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COLLAPSING THE COMPLICATED/COMPLEX DISTINCTION: IT'S COMPLEXITY ALL THE WAY DOWN

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ABSTRACT

Several complexity theorists draw a sharp and ontologically robust distinction between (merely) complicated systems and (genuinely) complex systems. I argue that this distinction does not hold. Upon fine-grained analysis, ostensibly complicated systems turn out to be complex systems. The purported boundary between the complicated and the complex appears to be vague rather than sharp. Systems are complex by degrees.

KEY WORDS

complex systems, complexity theory, Stuart Kauffman, Sandra Mitchell, Edgar Morin

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INTRODUCTION

Is the world *complex* or are only parts of the world complex? One's answer to this question has significant implications in both science and philosophy. If the world is complex, then our models, predictions, and manipulations of it will always be partial and limited. This is because complexity, almost by definition, implies some recalcitrance to epistemic capture. However, if only parts of the world are complex – if some parts are merely *complicated* – then we can presumably come to model, predict, and manipulate the complicated parts precisely. Although the above question has these epistemic consequences, the answer itself relates to ontology. I will however limit my discussion to *systems* rather than make ontological claims about the world as a whole. So, the question at hand becomes "are systems complex or are some systems complex while others are complicated?" The same consequences follow, but specifically as they relate to systems.

We can take systems to be that which constitutes the subject matter of science. As Sandra Mitchell states, "[c]ontemporary science studies complex structures and behaviors at a variety of levels of organization ... using representations of different degrees of precision, from fine- to coarse-grained" [1; p.178]. On my account, a system is not a fundamental entity or structure. Fundamental entities or structures (assuming there are such things) are not standardly categorised as either complicated or complex. This dichotomy is applied to systems, and that will be my focus here. If some scientists are studying fundamental entities and structures (a matter that is open to debate), then my argument will not apply to whatever their subject matter is (quantum particles and forces or supersymmetric string perhaps).

Systems do though seem to be composed of or structured out of whatever *is* fundamental. Roughly, one might think of systems as 'clumps' (or what Edgar Morin calls a "tangle" [2; p.84]) of whatever is fundamental. Systems are the clumps of world stuff studied by scientists not engaged in fundamental ontological inquiry. This should be relatively uncontroversial. I am not aware of any thesis that posits systems as fundamental. I think most would agree that systems are what is usually called *emergent*. They emerge from some thing(s) and/or process(es) more fundamental. I will though not discuss emergence in any detail here (see however [2] and [3]). Emergence is a big philosophical topic that is beyond the scope of this article. Nonetheless, we can debate the nature of systems without considering exactly how they emerge. My direct concern is with whether systems are complicated or complex, and not with how they come about. My argument is that systems appear to be complex by degrees rather than divided into complicated and complex types.

Several writers contributing to the complexity literature draw a sharp and ontologically robust – i.e. joint-carving – distinction between (genuinely) complex systems and (merely) complicated systems.

> *Complex systems:* It is questionable whether 'complex system' can be defined by a single and neatly comprehensible term [1-3]. However, following Richardson and Cilliers, a complex system is roughly a "a system that is comprised of a large number of entities that display a high level of nonlinear interactivity" [4; p.8] (emphasis removed). Most importantly, complex systems are systems whose behaviour is irreducible to any comprehensible algorithm, set of rules, or simpler constituent parts. Complex systems are recalcitrant to exact modelling, prediction, or manipulation, and they cannot be understood completely. Our epistemic grasp on complex systems is necessarily partial and limited. We cannot know whether the parts of a complex system we isolate during modelling constitute the essential characteristics of that system.

> *Complicated systems:* Complicated systems are systems that may appear complex but are, in fact, simple. Their behaviour is reducible to some comprehensible algorithm, set of rules, or simpler constituent parts. Complicated systems can, in principle, be modelled, predicted, manipulated, and understood precisely.

I will call the purported distinction between complex systems and complicated systems *CCD*.

According to Paul Cilliers, when it comes to complicated systems, "if you work hard enough, with clever enough techniques, you can figure the system out" [5; p.7]. In contrast, "grappling" with complex systems "requires a more reflexive and transformative approach" [5; p.7]. For Cilliers, we should recognise and even embrace the indubitable partiality and limitedness involved in our inquiries into the nature of complex systems. According to Minka Woermann and colleagues [6], complicated systems are dealt with in the "restricted paradigm", while complex systems are dealt with in the "general paradigm".

> In the restricted paradigm, complex systems are epistemically complex but ontologically complicated. We might think that some system is genuinely complex, but, upon analysis, it turns out to be merely complicated.
>
> In the general paradigm, complex systems are both epistemically and ontologically complex. No matter what clever techniques we employ, we can never isolate the system in order to model, predict, and manipulate it completely.

Note that proponents of CCD are not merely making the epistemic claim that our theories or models draw a distinction between complicated systems and complex systems. Instead, they are making the metaphysical claim that systems have a dualistic constitution; two types of systems exist: complicated and complex ones. CCD is thus manifestly ontological. As such, my argument does not apply to those who think that a distinction between complicated systems and complex systems is an epistemic placeholder, heuristic convenience, or practical aid that we utilise while inquiring into and interacting with the world. We may successfully employ different theoretical structures or modelling methods in different domains of inquiry, but we should be cautious of extrapolating from an epistemic demarcation to a robust ontological one. Even those who peg their ontological commitments to our best current science, invariably remain fallibilists about such commitments given that the history of science is littered with discarded ontologies and given that science has evidently not reached any ideal end of inquiry [7-9] (I return to this topic in the section titled 'Ontological Foundationalism is Indefensible')[1].

Some may wonder in what sense a system can be regarded as epistemically complicated if all systems are supposed to be ontologically complex. How can we talk about complexity if we do not provide a clear definition of a complicated system? My focus here is on the ontological conception of CCD because proponents of CCD consider it to be first-and-foremost an ontological question whether a system is complicated versus complex. Proponents of CCD maintain that CCD holds both epistemically and ontologically, while I think that it only holds epistemically. I certainly do not intend to deny the *usefulness* of the complicated/complex dichotomy. That said, I am focusing on ontology since I have no disagreement with proponents of CCD when it comes to epistemology.

A full-fledged account of the epistemology of CCD would require its own paper length treatment. Briefly though, a pragmatist approach may be suitable for articulating in what sense CCD can be epistemic but not ontological. A system is epistemically complicated versus complex when treating it as one or the other results in successful novel predictions and/or useful applications (e.g. accurate weather forecasts or efficacious vaccines). What does it mean to *treat* a system as complicated versus complex? Roughly, a system is epistemically complicated if the theories or models we use when successfully predicting or manipulating the system depict (characterise or idealise) it as being reducible to some comprehensible algorithm, set of rules,

or simpler constituent parts. In contrast, a system is epistemically complex if the theories or models we use when successfully predicting or manipulating the system depict (characterise or idealise) it as being irreducible to some comprehensible algorithm, set of rules, or simpler constituent parts. This description leaves open systems' ontological status, which, as mentioned, is my focus in this article. As we will see, probing the ontological issue requires fine-grained investigation of whatever system is purported to be complicated versus complex.

In any event, my goal in this article is to call CCD into question and then suggest a way to make sense of the proceeding ontological repercussions. I argue that those who advocate for CCD face the following problem. CCD cannot be drawn at any discernible location. Some proponents of CCD attempt to draw the distinction at the boundary between living and non-living systems or between physical and non-physical systems. As we will see, both are prone to demonstrable counterexamples. I argue that CCD therefore constitutes a vague rather than sharp demarcation. If so, then systems are either complicated all the way down or complex all the way down. I argue for the latter, at least down to the quantum level.

Note also that I will focus on so-called physical systems (systems that are not abstract or normative), and I therefore side-line the question of whether mathematical and ethical systems might be complicated versus complex. I will also regrettably gloss over much of the important technical work being done in the study of complex systems. Being a philosophical investigation, rather than a scientific or computational one, this article engages with its subject matters at varying levels of abstraction across different domains of inquiry.

The outline of this article is as follows. In the first section, I introduce and explicate CCD. In the second section, I argue that CCD is vague rather than sharp. In the third section, I engage with three possible objections to my argument.

CCD: COMPLICATED VERSUS COMPLEX SYSTEMS

The purpose of this section is to introduce CCD and the various writers who advocate for it. I pay special attention to CCD's ontological nature, to the idea that it putatively carves nature at the joint/s.

According to Roberto Poli, complex systems contrast with complicated systems because complicated systems can be managed or controlled through the implementation of appropriate interventions, while complex systems need to be "systematically managed and any intervention merges into new problems as a result of the interventions dealing with them ... [T]he relevant systems cannot be controlled" [10; p.142].

Several post-structural complexity theorists – see notably Cilliers [11] and Woermann [12] – also subscribe to CCD. Cilliers and Woermann are particularly critical of what they call the "rule based" or "analytic approach" to the study of complex systems. The analytic approach, they claim, makes the mistake of treating complex systems as complicated systems. According to Woermann, those subscribing to the analytic approach aim, but fail, to "uncover the laws and rules of our complex realities and to develop mathematical formalisms to describe complex behaviour ..." [12; p.41]. Cilliers considers the work of Noam Chomsky, Jerry Fodor, Jürgen Habermas, and John Searle to be exemplary of the analytic approach. This is because they attempt to reduce complex semantic or linguistic systems to formal rules. According to Woermann [12; Ch.2], even general systems theory and cybernetics subscribe to the analytic approach. In the former, complex systems are reduced to the concept of "organisation"; in the latter to the metaphor of "the machine".

In their advocation of CCD, Cilliers and Woermann draw specifically on the work of Edgar Morin. Morin states that complexity obtains

> wherever one finds a tangle of actions, interactions, and feedback. And this tangle is such that, even with the aid of a computer, it would be *impossible* to grasp all of the processes involved [2; p.84] (emphasis added).

This contrasts to mere complicatedness where it would be *possible* to grasp all of the processes involved. For proponents of CCD, complexity is thus *in principle* irreducible to something simpler, while complicatedness is *in principle* reducible to something simpler (even if we might not currently possess the means to do so). In a slogan, a system is genuinely complex if the whole is greater than the sum of its parts, while a system is merely complicated if the whole is identical to or less than the sum of its parts [12-16].

An anonymous reviewer pointed out that, from the standpoint of the history of ideas, such a view is difficult to make sense of. Traditionally, any system is regarded as more than the mere sum of its parts because of its emergent properties. I agree with the reviewer that the view is difficult to make sense of. Hence, my compulsion to write this article. The view is though surprisingly widespread. When reading the complexity literature, it is not uncommon to come across the idea that some systems are more than the sum of their parts while others are identical to – nothing more than – the sum of their parts.

Stuart Kauffman's influential work on radical emergence is a notable example (see e.g. [16]). For Kauffman, biological systems have genuinely (i.e. ontologically or radically) emergent properties. Being alive is such a property. Biological systems are thus greater than the sum of their parts. In contrast, Kauffman considers physical systems – notably systems that obey Newton's laws – to be nothing more than a collection of constituents. Physical systems are thus not greater than the sum of their parts (not in the ontological sense we are concerned with). Kauffman's physical/biological distinction roughly maps onto the complicated/complex distinction we are concerned with. For Kauffman, biological properties, like being alive, are genuinely (ontologically or radically) emergent, while physical properties, like travelling through space along a parabolic trajectory, are not. I return to Kauffman's view in the section titled 'Physical versus Non-Physical Domains'.

According to Cilliers, examples of complicated systems include motor cars, jumbo jets, computers, and snowflakes. Examples of complex systems include living organisms, language, society, and the brain [11; Ch.1, 17; pp.41-42]. The former would then not possess ontologically significant emergent properties; they are nothing over and above the mechanical goings on of their constituent parts obeying simple laws. The latter would though possess ontologically significant emergent properties (what Kauffman [16] would call "radically emergent" properties); they are more than the sum of their parts.

Central to understanding CCD is the putative distinction between *closed* systems and *open* systems. Complicated systems, on the one hand, are closed; they are isolatable and therefore formally tractable. Complex systems, on the other hand, are open to their environment, including other complex systems; they are not formally tractable [11; pp.9-10] (see also [6, 10]). Importantly, proponents of CCD further consider the difference between closed and open systems – i.e. between complicated and complex systems – to be one of *type* and not of *degree*. There is then supposed to be a *sharp*, rather than a *vague* or *fuzzy*, demarcation between complicated and the complex systems. Preiser and Woermann [18] list various texts that "very convincingly" defend the idea that CCD is ontologically sharp. These include [10, 11, 19-22] (see also [6; pp.5-7]). What these texts have in common, according to Preiser and Woermann, is that they

> dispel the notion that the distinction is superficial (i.e. merely a matter of perspective or subjective interpretation). Instead, they argue that the distinction hinges on an order difference between complex and complicated phenomena [18; p.17].

On such accounts, a system is either closed or it is open, and not a bit of both. A system cannot be partly reducible and partly irreducible (whether to a comprehensible algorithm, set of rules, or simpler constituent parts).

Having introduced CCD, I now argue that it does not hold in a strict ontological sense. It does not denote a genuine metaphysical demarcation; it does not carve nature at the joint/s. I will not argue that a system can be both closed and open or that a system can be partly reducible and partly irreducible. Instead, I will argue that CCD cannot be unproblematically drawn at any specific location. If so, proponents of CCD should abandon their ontological dualism (even if they may wish to maintain a weaker epistemic, heuristic, or pragmatic kind of dualism).

CCD: A FALSE DICHOTOMY

In this section, I argue that the world is not divided into complicated versus complex systems. On fine-grained analysis, it is demonstrable that CCD is vague rather than sharp. Advocates for CCD are not always clear on what kinds of systems belong in the complicated versus the complex categories. In making my argument, I nonetheless focus on the two places where CCD is sometimes drawn. Firstly, the putative living/non-living demarcation, and, secondly, the putative physical/non-physical demarcation.

LIVING VERSUS NON-LIVING DOMAINS

For some, non-living systems are complicated systems, while living systems are complex systems [11; p.3, 12; p.185]. One obvious counterexample is the Earth's weather and climate systems. Such systems are non-living, and, if CCD maps onto the living/non-living distinction, then they should count as merely complicated. Earth's weather and climate systems are however widely considered to be complex systems because they are irreducible to simple rules, open to their environment, cannot be precisely modelled or predicted etc. [3].

Another example is computational systems. Michael Dillon [23] argues that modern computer software systems are complex systems even while they are (presumably) not alive. Such systems, he says, are "powerfully capable of self-adaptation and self-propagation... [The] distinction between the organic and the non-organic breaks down" [23; p.12]. Although most of us do not think of computer software programs as being alive (not yet anyway), they do display certain features normally associated with life. As Dillon points out, they seem to evolve (self-adaptat) and reproduce (self-propagate), at least in some minimal sense. Computer software programs are perhaps quasi-living (see also [16; epilogue, 3; pp.124-125]).

Moreover, if CCD equates to the living/non-living distinction, then there must be some way in which the merely complicated transmogrifies into the genuinely complex. There must be some ontological 'jump' from non-living to living that occurs in both ontogenetic and phylogenetic development. There is however no evidence from embryology or evolutionary biology for such a jump. Both ontogeny and phylogeny are gradual processes, even if there are periods of relative stasis versus relative rapidity [24, 25]. A living thing is not complicated one moment, then suddenly complex the next. There is no clear moment in the ontogenetic or phylogenetic history of living things where something like CCD could reside. In conclusion, it appears that CCD cannot be successfully mapped onto the putative living/non-living distinction.

As before, it may be useful or goal-attaining for scientists to *talk* of living versus non-living systems. We should however not mistake (even our best) theories or models of the world for the world itself. As mentioned in the introduction, to do so is to abandon the fallibilism rooted in the scientific method. It involves making the tacit claim that science cannot progress any further in its attempts to uncover the nature of the world (I return to this topic in the section titled 'Ontological Foundationalism is Indefensible'). Few would, I take it, want to bite this bullet.

PHYSICAL VERSUS NON-PHYSICAL DOMAINS

The idea that CCD can be drawn at the putative living/non-living demarcation seems fairly easily dismissible. It is however more common to draw CCD at the putative demarcation between what is physical versus non-physical. This is roughly equivalent to the putative material/non-material demarcation. According to Poli, CCD delineates the material from the psychological and the social: "the material stratum should be termed *simple* [approx. complicated], while the psychological stratum and the social stratum are *complex*" [26; p.12] (original emphasis).

As mentioned, Cilliers considers a motor car to be an exemplary complicated system. This is because a motor car is purportedly not more than the sum of its parts. It can be reduced to and understood in terms of something(s) simpler. However, when we look closely, a motor car is continuously interacting with its environment. Like all things, a motor car's composition and form changes over time. The body will rust, the tyres will degrade, and so on in a way that is unpredictable, non-linear, and ostensibly ungoverned by deterministic laws. There is ongoing micro-physical activity at the interface of any object and its environment that, ontologically speaking, renders that object *de facto* an open system. At the micro-level, chemicals are interacting, atoms are bonding, and various quantum events are ongoing. These include particle annihilation and creation (not to mention entanglement, decoherence and tunnelling). Mostly, the motor car slowly disintegrates, of course. Yet, there can also be moments of construction (or 'creativity') caused by chemical reactions and/or quantum effects. This can occur even while the system (like all systems) on-average obeys the 2nd law of thermodynamics. Events and processes usually associated with complexity (recall the definition in the introduction) can occur within an object, between an object and its environment, and between outwardly different objects.

The above suggests that a motor car is, in fact, a complex system (even if only minimally complex) that is evolving and adapting to its environment at the physical and chemical level [2, 27, 28]. What appear to be complicated systems at the macro-level, are then complex systems at the micro-level. James Ladyman and Karoline Wiesner make a similar point regarding the gravitational interconnectedness of so-called physical objects:

> A gas in a container at equilibrium can be treated as a closed system, as can systems of condensed matter, even though they are really interacting through gravitation with the rest of the universe because the effects of it on them are so small [3; p.29][2].

Systems can be epistemically closed (merely complicated), even while they are ontologically open (genuinely complex).

A motor car appears to be merely complicated at a certain level of course-graining. Yet, when we zoom in and inspect it in fine-grained detail, it reveals itself to be genuinely complex. Cilliers' claim that motor cars, jumbo jets, computers, and snowflakes are complicated systems while living organisms, language, society, and the brain are complex systems only holds at a certain level (or scale or degree of resolution) where certain kinds of theories and models apply. To make definitive ontological claims, we should though surely consider all levels of analysis. If we do not look closer, we may be missing something important. Cilliers appears to be cherry-picking his preferred level of analysis in a way that neatly supports CCD.

To press the point, consider H_2O. Even a supposedly simple (merely complicated) H_2O molecule has emergent qualities or properties – e.g. viscosity and solvency – that its H and O atoms do not have individually. An H_2O molecule can therefore be considered a complex system: it cannot be reduced to simpler constituents without losing some of what makes it H_2O in the first place. As Woermann notes, in such cases "systemic attributes cannot be reduced to the parts alone, but are the result of interconnections between the parts" [12; p.36] (see also [21]). The whole (the H_2O molecule) is greater that sum of its parts (the H and O atoms that bond to form H_2O) (see also [29; pp.84-86, 30; p.240])[3].

At times, Morin even thinks of so-called fundamental particles as complex systems. A fundamental particle, like an electron, he says, "is not a simple primary unit ... It oscillates between being and nonbeing, between wave and particle" [13; p.130] (see also [7]). Even a quark, claims Morin, can be thought of as a complex system given that, according to standard particle physics, it as a "fuzzy entity that cannot be isolated" [2; p.40]. In the "micro-physical world, what we see is a cloud of indeterminacies from which we can derive only a statistical orderliness" [2; p.87] (see also [28; epilogue]). If quantum processes apply to all objects – as standard quantum theory suggests [31] – then it may be that all objects exhibit features of complexity when examined at a suitably fine-grained resolution.

Now, we need not follow Morin in speculating about the metaphysical nature of electrons and quarks to collapse CCD. Whether electrons and quarks are complicated versus complex is a question we can leave to quantum physicists and philosophers of quantum physics. The debate around the ontology of quantum physics is ongoing (see [9, 32] for an overview). Questions related to non-locality, hidden variables, and the ontological status of the wave function are, for now, a matter of philosophical interpretation rather than textbook fact. Sound answers to these questions would bear on whether there is complicatedness versus complexity at the quantum level, but I do not think that there is sufficient clarity at this point to take a definitive stand either way.

To my knowledge, no proponents of CCD anyway advance the idea that complicated systems make up the ontology of quantum physics, while complex systems make up everything else (perhaps some string theorists would say this). In any event, even if the ontology of fundamental physics is complicated while everything else is complex, the version of CCD advanced by the writers mentioned in the first section still collapses. This suffices for our purposes. We might say that *systems are complex all the way down, at least down to the quantum level (about which we can remain agnostic for now)*.

We can nonetheless engage with an argument made by Kauffman for a sharp kind of physical/non-physical ontological dualism that roughly maps onto CCD. Kauffman's argument proceeds as follows: "the universe has made all the possible types of stable atoms" (the bosons and fermions that make up the ontology of particle physics) [16; p.2]. The universe has however made only a "tiny fraction [of] all possible complex things" (e.g. proteins, organisms, economic markets, and computer software systems); the universe can never make all possible complex things [16; p.3]. This suggests to Kauffman that the world consists in two distinct ontological domains: one made up of non-complex, physical, or *ergodic* systems and the other made up of complex, non-physical, or *non-ergodic* systems. An ergodic system "visits all its possible states over some 'reasonable' time period", while a non-ergodic system "does not visit all its possible states" [16; p.4] (see also [33; Ch.7, 34; Chs.2-3]).

Kauffman's dualism relates to a distinction between, on the one hand, the (non-complex/ergodic) ontology of general particle physics (which includes but is not identical to quantum physics), and, on the other hand, the (complex/non-ergodic) ontology studied in biology and other so-called higher-level sciences. Kauffman does not refer to ergodic systems as complicated systems. He does nonetheless think of them as obeying deterministic laws and as exhibiting precisely predictable behaviour. This is sufficiently similar to the way that advocates for CCD define 'complicated'.

In any event, Kauffman thinks that the ontology of physics is ergodic because, when investigating some system of interest, physicists work with a prestated phase space wherein the evolution of the system is logically entailed in the initial conditions and deterministic laws. The system's behaviour is, in principle, precisely knowable, predictable, and manipulable. Conversely, there is no prestatable phase space and there are no deterministic laws in biology; "ever-new functions constitute the ever-changing phase space of biological evolution" [34; p.70] (see also [14]).

The systems that make up the ontology of biology are continuously changing their states, says Kaufmann, and this contingency is not evident in the linear behaviour of systems composing the ontology of physics. This is what it means for biological systems (like economic and technological systems) to be non-ergodic. A non-ergodic system's behaviour is, in principle, only partially knowable, predictable, and manipulable.

Given the above, we can say that an ergodic system's behaviour is *necessarily* one way rather than another, while a non-ergodic system's behaviour is *contingently* one way rather than another. As with CCD, for Kauffman, the ergodic/non-ergodic dichotomy is not the result of contingencies in scientific methodologies; it is not epistemic. Instead, it is a qualitative ontological distinction that obtains 'out there' independent of whatever theories or models scientists employ during inquiry [33; Ch.2]. Regarding non-ergodic systems, "the parts exist for and by means of the whole" [16; p.8]; the whole is greater than the sum of its parts. Conversely, in ergodic systems, the whole is less than or equal to the sum of its parts.

Kauffman thinks of biological organisms as non-ergodic systems; they are complex systems composed of sustaining subsystems. He calls such systems "Kantian wholes". Kantian wholes are "autopoietic systems" that "build themselves" [34; Ch.4] (see also [14]). Although Kantian wholes have physical energy and particles as input, they are not themselves physical. They are "based on physics, but beyond physics" [16; p.127] (see also [22]).

As before, there are reasons to question Kauffman's strict ontological dualism. There appear to be vague cases that cannot be easily sorted into either the ergodic or non-ergodic category. Sandra Mitchell has argued along these lines. Contra CCD, she claims that the laws that apply in physics compared to biology are not qualitatively different; they vary "in degree – not in kind" [35; p.62]. Mitchell's argument is clear and on-point, and therefore worth quoting in full:

> many of the relationships connecting physical properties and events are more stable than are the relationships connecting biological properties and events. What stability denotes is the degree of invariance of a relationship between events or properties that are represented in scientific generalizations. The traditional view of laws required that stability be implacable. The relationship between mass, distance, and gravitational attraction would hold, come what may. But stability varies. Some structures are more stable than others, are less vulnerable to being disrupted by what occurs in their neighborhood, but few, if any, satisfy the strictest conditions of exceptionless universality. There is a difference between fundamental physics and the biological and social sciences – but it is not the difference of a domain of laws versus a domain of accidents [35; p.62].

Mitchell considers all scientific laws to be *ceteris paribus* laws. They only hold given whatever contextual suppositions and boundary conditions apply. Any scientific truth, says Mitchell, "describes events that could have been otherwise, whether it is about the physical constituents of our world or the biological ones" [35; p.57]. The so-called physical and the so-called biological are, in this sense, then modally indistinguishable. Thus,

> the 'laws' of physics and the 'laws' of biology are both strictly contingent; their truth depends not on logical form or definition, but on whether they accurately represent our world. There are differences, but they are differences in degree and origin, and not in logical kind ... The lawful relationship between free-falling bodies and the earth and parent and gamete frequency have different degrees of stability and scope, which affects the degree to which we can depend on them holding in many contexts ... The stability of the conditions upon which a causal relationship depends establishes a continuum, rather than a dichotomously partitioned space of the necessary and the contingent [35; pp.57-58] (see also [1]).

Although Mitchell is not engaging with Kauffman directly, her argument appears to be a powerful counter to his style of ontological dualism (see also [36-38]). Physicists and biologists may model and theorise about the world in different ways – they have different epistemic conceptions of things – but this does not entail that the world must *de facto* be constituted in those different ways. Mitchell's critique of the supposed demarcation between physics and biology suggests that they are not as different as Kauffman supposes.

Kauffman also appears to be working with an outdated conception of physics. In his writings, he repeatedly equates physics *simpliciter* with Newtonian physics. Contemporary physics is however not limited to Newtonian methods. It is a diverse field where different kinds of equations and models are applied in different contexts to generate ostensibly different ontologies, all of which do not obviously fit on the ergodic side of Kauffman's ergodic/non-ergodic divide. Kauffman writes, for example,

> [i]n physics, one always prestates the phase space of a system. For Newton, given his three laws of motion, the phase space is defined by the boundary conditions, for example, the boundaries provided by a billiard table. Given these, we can define what we call the phase space of all possible positions and momenta – every way the balls can move on the table. Then we write Newton's laws in the form of differential equations; and from the initial and boundary conditions, we solve for the trajectories of the balls by integrating the equations [16; p.126].

Notice how Kauffman conflates physics with Newtonian physics. Doing so excludes contemporary fields in the physics of information and in non-equilibrium and quantum thermodynamics. Here, the focus is on the structure, patterns, and the potentiality of physical things (systems in our case). The notion of work, for example, can be defined in term of its usefulness or its potential to generate energy. That is, work is defined relative to a context rather than in strictly mechanistic or linear terms, and the outcome of one's inquiry will likewise be relative to that context. This is oddly similar to how biology and other non-physical sciences are supposed to operate on Kauffman's account. Kauffman's artificially narrow definition of physics rigs the game in favour of his version of CCD.

In sum then, it seems that – as with the putative living/non-living demarcation – CCD cannot be drawn at the putative physical/non-physical demarcation. There may be other places where one could attempt draw CCD, but I suspect that fine-grained analysis would once again uncover vagueness rather than sharpness.

POSSIBLE OBJECTIONS

The above suggests that there is no clear location in space or time where CCD might reside, and that ontological analysis of various systems at various degrees of resolution invariably uncovers complexity (at least down to the quantum level). I now engage with three possible responses sceptics might make to my argument.

COMPLICATEDNESS RATHER THAN COMPLEXITY ALL THE WAY DOWN

If CCD collapses, some might want to say that there are complicated, rather than complex, systems all the way down. It would certainly be more convenient – inquiry would be simpler – if this were the case. We could then, in principle, come to understand all systems and not just some of them. To make such a claim is however to take on the massive burden of demonstrating how highly complex systems – like the brain (or the economy or the climate) – can be reduced to a simple algorithm, set of rules, or simpler constituent parts. Efforts to do so are ongoing, but there does not appear to be any clear end in sight. Stating that such a reduction is possible requires some formal proof, a proof that is currently absent (see [39, 40] for more on

reductionism in science and philosophy). Given my aforementioned arguments, it seems far more likely that there are complex systems all the way down (at least down to the quantum level).

Thinking along similar lines, Michael McGuire states that it is "plausible that [we] should allow for complexity to go 'all the way down'. That is, [we] ought to allow for infinite nesting of objects within objects, not metaphysical full stops" [41; p.189] (see also [35]). CCD implies metaphysical full stops, while I have suggested something like an infinite nesting of objects. Complex systems are, not only entwined with other complex systems, but they can also be imbedded in each other (something like Russian dolls)[4]. The brain, for example, is a complex system, but it has complex sub-systems imbedded in it, which, in turn, have complex sub-subsystems imbedded in them. Larry Swanson and colleagues [42] think of the brain as a "clustering hierarchy" or a "connectivity hub". Focusing specifically on the endbrain in rats, they claim that employing a multiresolution consensus clustering (MRCC) method

> provides a hierarchical description of community clustering (modules or subsystems) within the ... global network organization of axonal macroconnections between the 244 regions forming the endbrain ... [42; p.E6910].

The clusterings (modules or subsystems) within the global network organisation composing the endbrain are then composed of further clusterings etc. This suggests that the brain consists in a hierarchical nesting structure – "a hierarchy of subsystems" – in which

> there are 60 subsystems at the bottom of the hierarchy, and they combine in specific ways through 50 levels of the hierarchy branching pattern ... to form just four primary subsystems at the top level [42; p.E6919] (Swanson et al. [43] develop a similar hierarchical schema for the midbrain).

Swanson et al. find that the top-most clusterings in this hierarchy are highly complex, but get simpler down the levels (see also [44]). In other words, the brain consists in a hierarchy of complex systems nested inside further complex systems, and the degree of complexity diminishes down the hierarchy. Like many things, complexity naturally comes in degrees [27, 35; pp.55-57]. Swanson et al. do not discuss what occurs at the micro-biological or chemical levels. As argued above, we can though infer that there are further complex systems underpinning the bottom level of their endbrain hierarchy, and so on.

As we zoom in and out to differing degrees of course- versus fine-grained resolution, all systems seem to fit the definition of 'complex system' (at least down to the quantum level). These is a graded rather than strict demarcation between ostensibly complicated systems and complex systems, and CCD thereby collapses. One who does not consider all levels or scales when making ontological posits, will necessarily develop an oversimplified and parochial ontology that misses the complexity that reveals itself when we do.

CONTEXT DETERMINES WHETHER SOMETHING IS COMPLICATED VERSUS COMPLEX

A further possible response is that there is an inescapable contextuality inherent in our ontological investigations and proceeding ontological conclusions. We unavoidably adopt some context-relative *perspective* during ontological inquiry, where a perspective is a general outlook, attitude, or point-of-view incorporating a specific methodology or approach towards ontological inquiry (roughly what Kuhn [45] calls a "paradigm" or what van Fraassen [46] calls a "stance") (See the collection in [47] for the status of the current debate around perspectives and perspectivism). Thus, the ontologies we uncover are necessarily indexed to some contingent perspective. Ontological pluralism (or even relativism) follows (see e.g. [11, 12, 48-50]). The ontological pluralist might claim that some system is complicated versus complex relative to whatever perspective the ontologist adopts. Some system can be

complicated relative to perspective$_1$ but complex relative to perspective$_2$. This is a weaker version of CCD, a version that nonetheless contradicts my argument.

However, recall that one of my goals in this article is to investigate whether CCD denotes a genuine ontological demarcation in the world, and not merely an epistemic one. We must be careful not to mistake our theories or models of the world for the world itself. This is where the ontological pluralist seems to go wrong. To introduce perspectives into a discussion about ontology is to shift the focus from ontology to epistemology. We want to know whether CCD actually – i.e. ontologically – obtains in the world (in the way that proponents of CCD claim it does). Thus, it is unhelpful to say that it depends on what (epistemic) perspective one adopts. At least when it comes to CCD, the ontological pluralist seems to have missed the point.

To illustrate, let us return to the motor car example. An ontological pluralist would, I think, say that the motor car is *complicated* at the level of medium-sized dry goods but *complex* at the level of chemistry or physics. The motor car is complicated or complex depending on perspective. The problem with such a claim is that it suggests that the ontological constitution of the world (and not just our models of the world) changes – even changes radically – depending on the manner in which *we* investigate it. If I investigate a motor car from an arm's length, then it would *in itself* be complicated. Yet, if I use a high-powered microscope to zoom in and investigate the motor car up close, then it would *in itself* be complex. Then, if I zoom out to arm's length again, the motor car would return to *in itself* being complicated.

If this is the case, then one wonders what ontological constitution the motor car has when no one is looking, or when one ontologist investigates it from arms-length while another *simultaneously* investigates it up close. Might it perhaps enter a superposition of states, a kind of complicated/complex duality? Flippancies aside, the ontological pluralist's possible reply to my argument is grossly counter-intuitive. While it is standardly accepted that we do, to some degree, influence and possibly change some subject matter when we investigate it through empirical means (notably in quantum physics), few would, I take it, claim that the degree of resolution we employ while investigating some system can change that system *in itself* from complicated to complex and back to complicated again.

My quick dismissal of ontological pluralism should not be mistaken for misappropriated boldness. As a general philosophical thesis, ontological pluralism is often supported by thoughtful and weighty arguments (see notably [35, 51]). However, such arguments largely rely on calling into question the idea that ontology can be separated from epistemology (think Kuhn [45] and Hanson's [52] theory-ladenness of observation thesis). There may indeed be good reasons to do so (see [53]). However, this issue does not seem to apply here given that we have followed proponents of CCD in taking it as a strictly ontological question whether a system is complicated versus complex.

ONTOLOGICAL FOUNDATIONALISM IS INDEFENSIBLE

The third objection is one that was made by one of the anonymous reviewers. The reviewer agrees with my criticism of Cilliers and Kauffman when they mistake certain models of the world for the world itself. However, the reviewer thinks that the same kind of criticism can be levelled against me. The reviewer asks why my ontological view should be taken as definitive and absolute truth. My ontological foundationalism is indefensible because it does not take into account the fallibility and historical variability of the metaphysical presuppositions of science. The reviewer compares my view to Roy Bhaskar's (e.g. [54]) realism about fundamental laws of nature, and suggests that Alan Chalmers' [55] criticism of Bhaskar's view should apply to mine as well.

This is a good point, one that any attempt at ontological inquiry must deal with. However, my account does not involve anything as bold as Bhaskar's realism. It does not involve making

claims about what Chalmers refers to as "fundamental laws characterising the generative mechanisms of nature" (55; p.22). I agree with Chalmers when he states,

> real situations are typically too complex for a direct application of fundamental laws to be possible. The motions of a real liquid, the excitation and decay of a molecule, even the real motions of the planets in the solar system, are too complex to be precisely characterised by fundamental laws (55; p.21).

Also, I do not employ any "transcendental deductions" of the sort that Chalmers ascribes to Bhaskar. Rather, my claim is merely that, when we investigate different systems on a case-by-case basis, they appear to be complex rather than complicated (at least down to the quantum level). And, this suggests that the complicated/complex distinction does not hold. My view is thus far more modest than Bhaskar's.

My view is not a form of ontological foundationalism in which I make claims about the ultimate nature of reality. I do not intend to say that reality is fundamentally or intrinsically complex. To say that all systems (at least down to the quantum level) are complex is not to make a claim about the world's ultimate ontological constitution or its fundamental structure. Rather, it is to say that, whatever the world is made of or however the world is ultimately structured, when systems obtain, those systems appear to have a complex constitution. As mentioned in the introduction, my claim is limited to systems.

Regarding the fallibility and historical variability of the metaphysical presuppositions of science, I agree with the reviewer. I do not intend my account to be understood as the conclusive final word on ontology. In the spirit of fallibilism, my claims are open to revision pending disconfirmatory evidence. Once again, my view is modest in this regard.

Although my view is fallibilistic, it is not relativistic. I am not claiming that all systems (at least down to the quantum level) are only complex if we look at things a certain way (the way I do). Rather, my claim is that, given the current state of human knowledge and given the current state of science, fine-grained analysis of any given system will find that system to be complex (at least down to the quantum level). This should not depend on one's perspective or point-of-view. That said, I can only argue from my own point-of-view.

CONCLUSION

Some complexity theorists hold to a sharp and ontologically robust distinction between merely complicated systems and genuinely complex systems. I have called this distinction CCD. I inspected two places where CCD may obtain: the putative living/non-living demarcation and the putative physical/non-physical demarcation. I concluded that CCD does not reside at either, and that it is therefore a vague rather than a sharp distinction. I also analysed various systems (e.g. computational systems, a motor car, and an H_2O molecule). These systems turn out be complex, even if some may appear only complicated at first glance. I also engaged with three possible objections to my argument. I concluded that neither sustains CCD. There may be two ways of theorising about or modelling various systems: a complicated and a complex way. However, this epistemic dualism cannot be transposed onto the world to advance a robust form of ontological dualism.

REMARKS

[1]This is not to say that ontological claims in support of our current best science are necessarily false. It is rather to say that we should not commit to such claims wholeheartedly; we should remain ontological fallibilists. This appears to be the orthodox view amongst scientists and philosophers of science.

[2]Ladyman and Wiesner further suggest that the universe as a whole may be a complex system [3; p.1].

[3]Morin also considers a candle flame to be a complex system because it exhibits non-deterministic, non-linear behaviour [2; p.10] (see also [29; p.239]).
[4]This suggests that complexity may have a fractal nature [27].

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BEAUTY OF LIFE IN DYNAMICAL SYSTEMS: AN AESTHETIC VIEWPOINT OF LIFE

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ABSTRACT

Information plays a key role in life and complex biological systems. It is hypothesized that information processing capabilities distinguish life from other so-called non-living matter. Dynamical systems underlie and can be used to represent many complex life-like systems. Dynamical systems and information processing may be the hallmarks of life-like systems.

We combine dynamical systems with a computational framework to generate art. The framework can be used to generate aesthetically appealing forms of life-like systems. Our work suggests that we may need an "aesthetic sense" to recognize life we have never seen before.

This aesthetic view also allows us to appreciate the beauty of life-like systems, life-forms around us, and their intimate connections with dynamical systems. This perspective can give us a sense that every part of the Universe computes and that the entire Universe is alive and has intelligence. We hope this will give humanity a new sense of purpose, help us appreciate our place in the Universe and also give a renewed thrust to conservation efforts to save our planet.

KEY WORDS

life, dynamics, Belousov-Zhabotinsky, NetLogo

CLASSIFICATION

JEL: C65

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INTRODUCTION

Information plays a critical role in life and complex systems. Complex biological systems co-ordinate heterogeneous components in a decentralized fashion. How do these distributed and decentralized systems with billions of cells and components function? One key component is how these complex systems efficiently collect and process information.

It is hypothesized that information processing capabilities distinguish life from other so-called non-living matter [1]. Information processing is a key ingredient for life. Chemical reaction systems called reaction-diffusion systems have been studied for their complex properties for a long time. One example is the Belousov-Zhabotinsky (B-Z) reaction which is a chemical oscillator and displays complex properties reminiscent of life, Figure 1 [2, 3].

We hypothesize that carbon-based life forms are only one amongst a continuum of life-like systems that are possible in our Universe. Investigations into the role of computational substrates that allow information processing is important and could yield insights into:

1) novel non-carbon based computational substrates that may have "life-like" properties, and
2) how life may have actually originated from non-life on Earth.

Life may exist as a continuum between non-life and life and we may have to revise our notion of life and how common it is in the universe. Looking at life or life-like phenomena through the lens of information theory can yield a broader view of life. Information processing capabilities can distinguish life from other so-called non-living matter [1].

Information processing is one amongst many key ingredients for life. Chemical reaction systems called reaction-diffusion systems have been studied for their complex properties for a long time.

The science fiction writer Arthur C. Clarke once described a potential alternate form of life that arises on an ultra-cold planet [4]. He envisioned electrical currents and waves forming in a superconducting fluid of liquid Helium 3. The entire planet is barely above absolute zero, yet harbours an intelligence that uses these electrical currents to perform computation. Very little material transport occurs and most information processing happens using waves of electrical currents that propagate to form a planetary scale global "brain". This form of intelligent alien life stretches the boundary of what we currently call life. It may not be recognized as intelligent life, if we did encounter it, using the guidelines of carbon-based lifeforms we have observed on Earth.

TEACHING RESOURCES

This section presents teaching resources for high-school and undergraduate students. We assume that the students have a basic background and interest in science.

Our conception of life is shaped by what we see around us on Earth. What life forms might we expect to see on alien planets? Would they be carbon-based like us or can they be even more exotic? Answering questions like these means we have to come up with an objective definition of life.

Chemical reaction systems called reaction-diffusion systems have been studied for their complex properties for a long time. One example is the B-Z reaction which is a chemical oscillator and displays complex properties reminiscent of life, Figure 1 [1, 2]. The full model is available on the NetLOGO online platform [2, 5]. The parameters chosen for the simulation are also shown in Figure 1. The students can click on the setup button, play around with the sliders and set the parameters. They can then click on the go button. This will start the simulation. Simulation time is called ticks and is shown in the window in Figure 1.

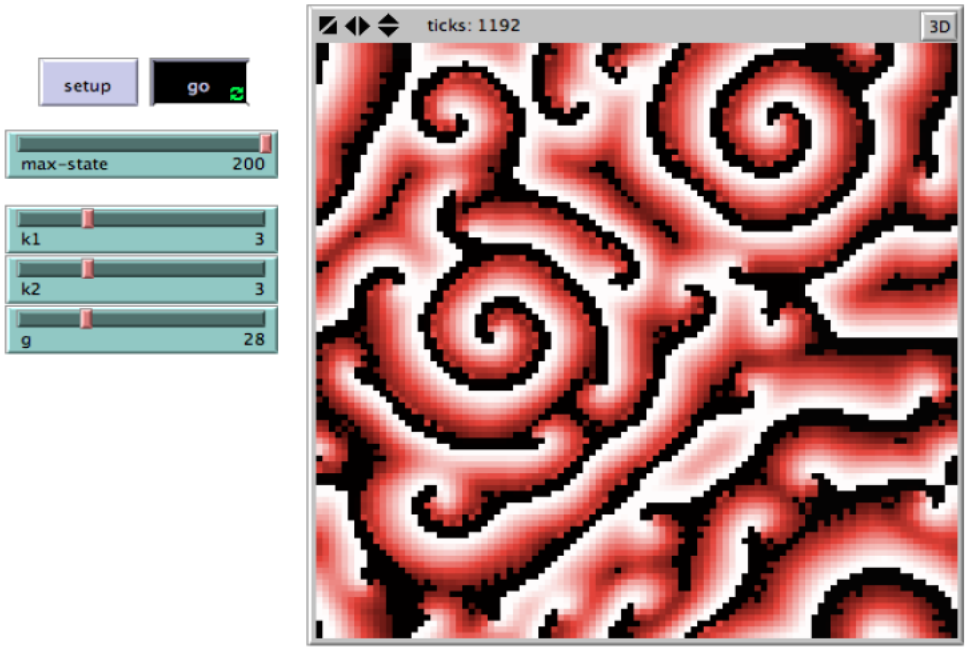

Figure 1. Screenshot from the NetLOGO simulation tool for the B-Z reaction showing wave like patterns that persist [6].

SOFTWARE RESOURCES FOR ACTIVITIES: INSTALLATION AND PREREQUISITES

We introduce some computational resources which can be used to create activities for students. These resources are available from the repository

https://github.com/neelsoumya/deep_dali.

This requires the Python programming language which can be installed from

https://www.python.org/downloads.

The dependencies can then be installed by typing the following at the command line:

pip install -r requirements.txt.

The NetLOGO language can then be installed from

https://ccl.northwestern.edu/netlogo/download.shtml.

Alternatively a version of NetLOGO that can be run from the web browser is available here:

http://netlogoweb.org.

As way of introduction, B-Z reaction displays complex properties and wave-like patterns reminiscent of life, Figure 2 [2, 3]. Students can generate this image by going to the following website which runs NetLOGO in the browser:

http://netlogoweb.org/launch#http://netlogoweb.org/assets/modelslib/Sample%20Models/Chemistry%20&%20Physics/Chemical%20Reactions/B-Z%20Reaction.nlogo.

They can click on the setup button and then the go button. This will start the simulation of the B-Z model. The simulation will yield myriad beautiful patterns. Once the students observe a pattern they like, they can pause the simulation by clicking on the go button. They can then take a screenshot of the pattern and save it on their computer (say as *simulation.jpg*). The image of this reaction-diffusion system can then be modified using a deep-learning algorithm (Google Deepdream) [7]. The deep learning algorithm modifies the image and creates a new image with dream-like qualities. A sample of such a modified image is depicted in Figure 3.

The deep learning ‘dreaming’ program is available at:

https://github.com/neelsoumya/deep_dali/blob/main/deep_dream.py.

The student can download the full code repository

https://github.com/neelsoumya/deep_dali.

The deep learning program can be executed by running the following at the command line:

python3 deep_dream.py simulation.jpg result_dream.

The new modified picture will be saved as *result_dream.jpg*. The image has a dream-like quality and emphasizes the beauty in life and in dynamical systems. It points to the computational origins of beauty in life itself. Our framework forms new representations of potential life-like systems. Artificial Intelligence (AI) coupled to dynamical systems can be used to form new representations of life-like systems that may possibly exist somewhere in our Universe. More examples on computational art for dynamical systems can be found in the following repository:

https://github.com/neelsoumya/deep_dali.

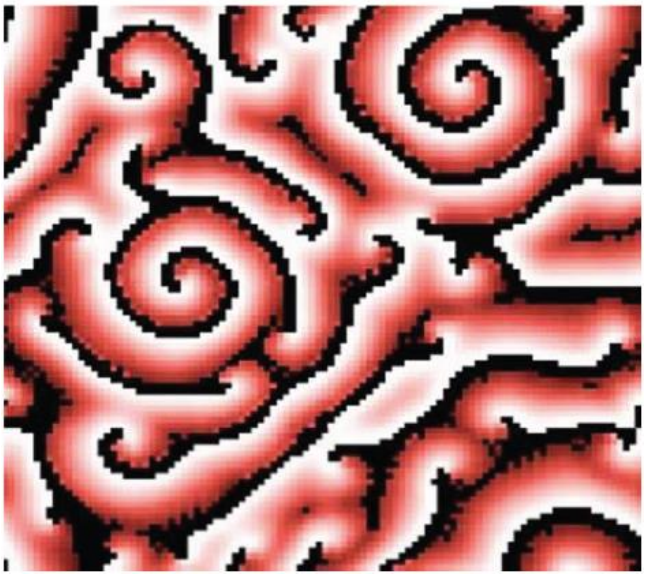

Figure 2. Screenshot from the NetLOGO simulation tool for the B-Z reaction showing wave like patterns that persist [2, 3].

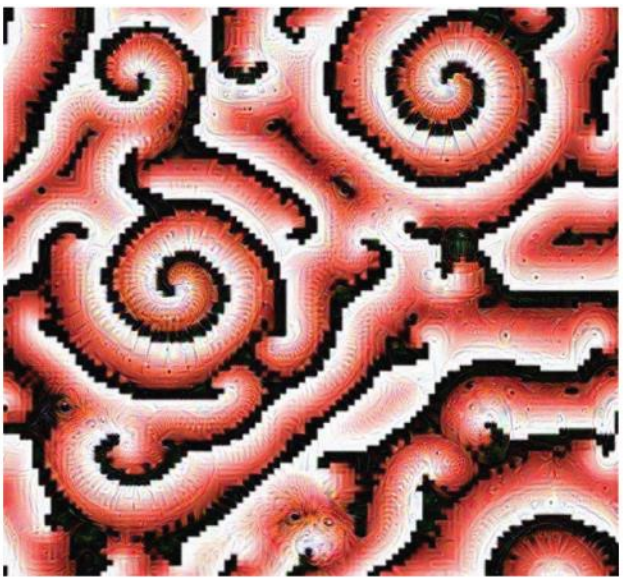

Figure 3. The image of a reaction-diffusion system modified using a deep-learning algorithm.

CORE ACTIVITIES

We outline some core activities in this section. Not all parameters in the B-Z reaction system will lead to patterns. An example is shown in Figure 4. After 446 time steps, one can observe no patterns at all. This suggests that life or life-like systems are very fragile. We note that since the simulation is stochastic, you will not get the same result every time, even if you run it with the same parameters.

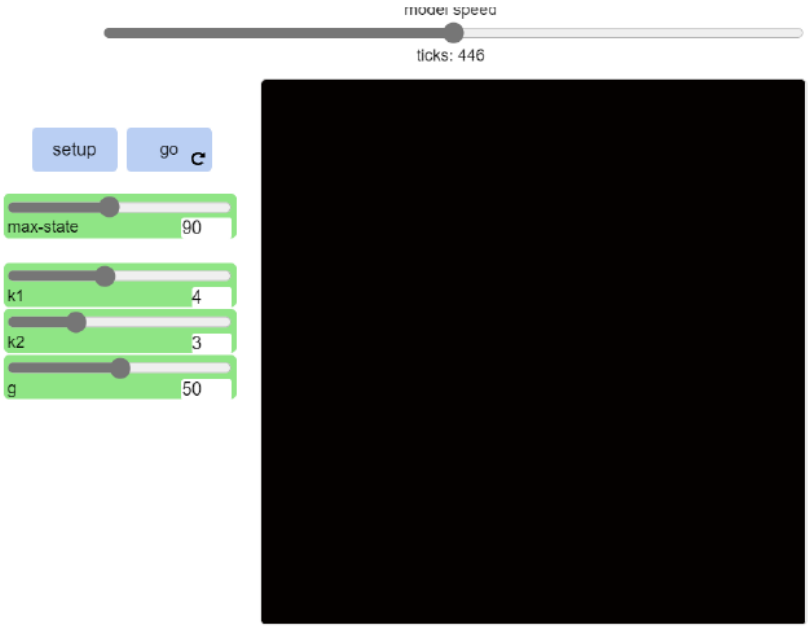

Figure 4. Screenshot from the NetLOGO simulation tool for the B-Z reaction showing no patterns after the simulator is run for 446 time steps [6].

We encourage students to play around with the parameters by moving the sliders. Some parameters can also lead to persistent but very simple patterns, Figure 5.

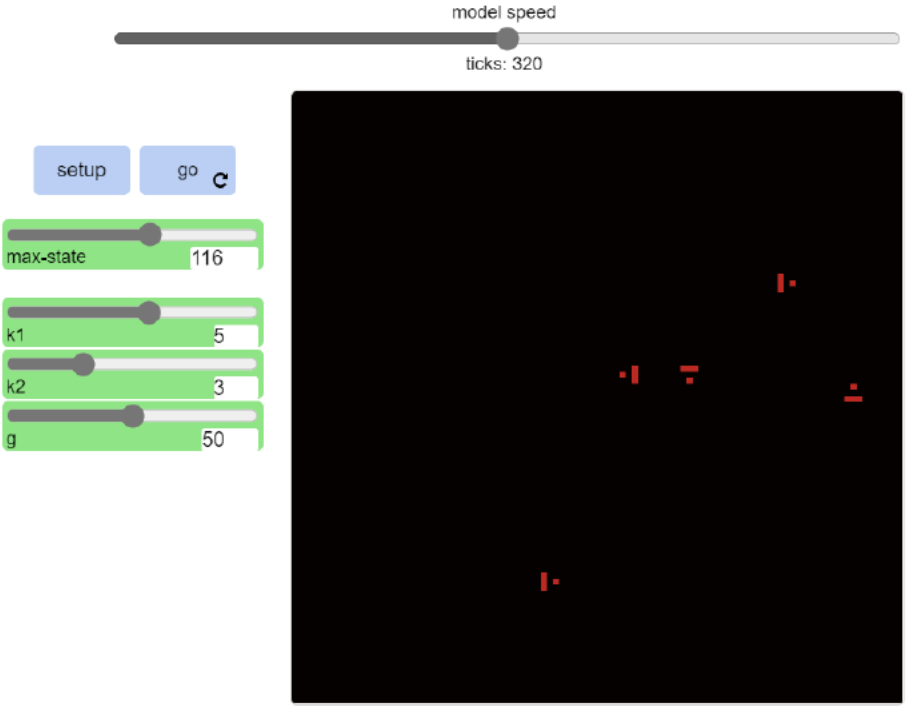

Figure 5. Screenshot from the NetLOGO simulation tool for the B-Z reaction showing a pattern that is very simple but still persists over time [6].

ACTIVITIES ON DYNAMICAL SYSTEMS

Another activity is thinking about creation and destruction of life as shown in a simple model of a forest fire. This can be simulated on the website https://sandspiel.club. A forest fire model is a very simple way to visualize and think about complex dynamics, and reflect on how life is about creation and destruction. We now outline the steps of how students can use this website to create simulations. Once the webpage is opened, students will see the screen shown in Figure 6.

Figure 6. Screenshot of the first step of a forest fire model simulated on https://sandspiel.club. This is the opening page and initial step.

The next step is to add seeds. This can be done by clicking on the button labelled Seed and then clicking on the grey simulation area shown in Figure 7.

Figure 7. Screenshot of the second step of a forest fire model simulated on https://sandspiel.club. The student has to click on the button labelled Seed and then click on the grey simulation area in the center of the screen.

The next step is to add some water, which can be done by clicking on the button labelled Water and then clicking on the grey simulation area in the center of the screen. Alternate between adding seeds and water and the plants will begin growing. A snapshot of this simulation is shown in Figure 8.

Figure 8. Screenshot of the third step of a forest fire model simulated on https://sandspiel.club. This shows the plants growing progressively as seed and water are added.

Once the plants have grown for some time, the student can add some fire by clicking on the button labelled Fire and then clicking on a plant in the grey simulation area. This would set fire to the plants and the fire would rapidly spread. A screenshot of a sample simulation is shown in Figure 9. This simulation depicts the creation and destruction of life.

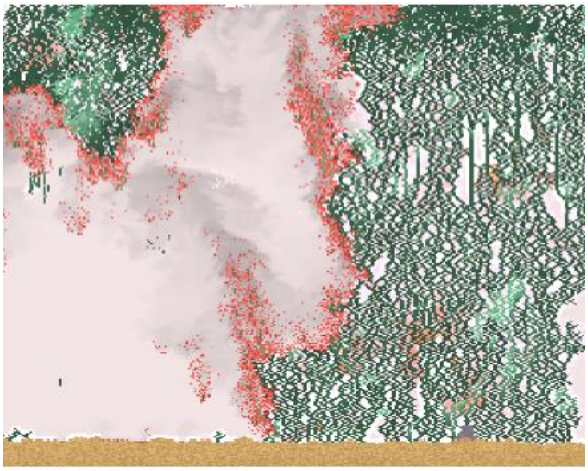

Figure 9. Screenshot of a forest fire model simulated on https://sandspiel.club. The simulation is meant to depict the creation and destruction of life.

Additional activities for students: Students can now think of other ways to grow plants. What would happen if you added some fungus and mite by clicking on the buttons labelled Fungus and Mite. What would happen if you added some oil (play around with the Oil button)? Team up with your best friend and play with these simulations on two different computers. Ask your friend to follow the same steps as you do. Can you try to replicate the simulation on your friend's computer? If not, why do you think the simulations are different on these two

computers, even though you followed the same steps? Students can then modify the picture (Fig, 9) using the deep learning 'dreaming' program. The program is available at:

https://github.com/neelsoumya/deep_dali/blob/main/deep_dream.py.

The student can download the full code repository

https://github.com/neelsoumya/deep_dali,

and then install python on a laptop. The dependencies can be installed by typing the following command at the command line:

pip install –r requirements.txt.

The deep learning program can be executed by running the following command:

python3 deep_dream.py life_creation_destruction.jpg result,

where life_creation_destruction.jpg is the name of the picture. The program will produce a modified picture named *result.jpg*. This picture is shown in Figure 10.

Yet another activity is described further in the text. The students can take a picture on their phone (for example, see Figure 11) and then modify it using the deep learning computer program. This picture can then be modified using the deep learning algorithm, Figure 12.

REFLECTION ACTIVITIES AND SUMMARY

Here we outline additional activities that can be arranged for school students who do not have sufficient background in science or mathematics.

ACTIVITIES

Students can start by listening to the short story Crusade by Arthur C. Clarke which discusses an alternate life form. An audio rendition is available here:

https://www.youtube.com/watch?v=Li0TnrRTmM8.

They can then listen to a short presentation on how this alternative view can tell us what can kind of life forms can exist in the Universe:

https://youtu.be/jDIt60LVyWY?t=76.

For school students who may not have enough scientific background, a very simple lay summary is given below. This can be read and then discussed by students in small groups. They can then draw a diagram of what kind of life they think we can expect to find elsewhere in the Universe.

LAY SUMMARY

What kind of life forms can we expect to find in distant planets? We always talk about life as we know it. But what about life as we do not know it? Hence the presentation outlined above is titled "Life as we do not know it".

Life forms on earth are carbon based. It thrives on air, water, minerals and carbon in temperate conditions. This form of life consumes energy for its sustenance. Is it possible to have life forms in extreme cold conditions say –270 ˚C, without any air or water? We propose that life-like activity is possible in such conditions.

This life-form, however may be very different and hence is the title "Life as we do not know it". In extreme cold conditions in some distant planet without air, water, sunshine, carbon and such other earthly materials, life-like activity is possible which consumes very little or no energy at all. Helium can exhibit life-like properties in extreme cold conditions in liquid form.

Figure 10. Screenshot of a forest fire model simulated on https://sandspiel.club modified with a deep learning dreaming program. The picture is meant to depict the creation and destruction of life.

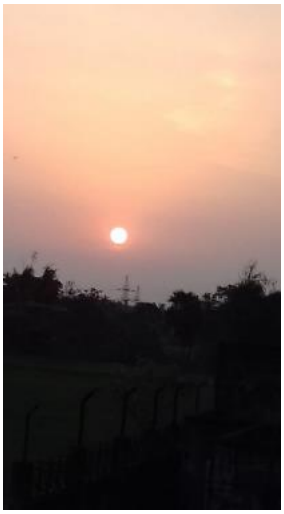

Figure 11. An example picture taken using a smartphone. This is a picture of a sunset in Kolkata.

Figure 12. An example of a picture take using a smartphone and modified using a deep learning dreaming program.

Life-forms essentially should have the following:

1) Memory
2) Basic "intelligence" to process information
3) "Sense" external stimulus and act.

These features can be presented in the form of a mathematical model. In any rate, life in other planets is still a mystery.

SUMMARY OF LEARNING ACTIVITIES

We summarise some of the learning activities in this section. These activities would be appropriate for high school students or those studying for an undergraduate degree.

1) Warm-up questions.
   a) How might one define life?
   b) How might we recognize life that is completely "alien" to us?
   c) Does life need to be carbon-based?
   d) How do movies bias our conception of alien life-forms (do they have to be little green men?)
   e) How would you recognize life if it does not fit the definition of life we have seen on Earth?
2) Demonstration of software. Download the NetLOGO software [1] and experiment with the B-Z model. For what parameters do you observe the emergence of "interesting" patterns?
   a) Is this life-like?
   b) Would you call this life if you saw it on another planet?
   c) Peer-discussion and take feedback.
3) Watch the short story *Crusade* by Arthur C. Clarke describing a potential alternate form of life that arises from electrical currents and waves in a superconducting fluid [4].
4) Read the paper on a computational theory of the value of information in life [3].
5) Look at the video of waves propagating in a cell visualized using a powerful microscope [8]. Do you see similarities to the waves seen in the B-Z model?
6) Discussion. What did you learn from these papers?
7) Register on SAGANet (http://www.SAGANet.org) to join a community of people interested in questions around origins of life and astrobiology. Contribute to a discussion forum on SAGANet.
8) Writing task and group presentation. Have a discussion on what is life and how might you recognize it, if you were to find it in another part of the Universe. Write up your ideas in 2 pages and make a 5 minute presentation to your class on this.

EVALUATION

Here we present a rubric for how the class performance can be evaluated by the instructor or peers. These evaluations are suitable for high school students or undergraduates.

1.) Delivery of presentation
   a) Was the presentation on topic?
   b) Were the main ideas clearly communicated?
2.) Organization and format of write-up
   a) Does the write-up have a good introduction?
   b) Is it properly formatted?
   c) Are there any grammatical errors?
   d) Does the write-up have a conclusion?
3.) Originality of content

a) Was the content original?
b) Did the students make an effort to develop new ideas?

4.) Analysis of literature review
a) Did the group assimilate the findings of the background reading into the write-up and presentation?

DISCUSSION

This work emphasizes the beauty of mathematics and dynamical systems especially in questions around origins of life. Our conception of life is shaped by what we see around us on Earth. What life forms might we expect to see on alien planets? Would they be carbon-based like us or can they be even more exotic? Answering questions like these means we must come up with an objective definition of life. It is hypothesized that an objective definition of life is that it should be capable of information processing and computing [1]. Our work also suggests that we may need an "aesthetic sense" to recognize life we have never seen before. Such aesthetic versions of life-like systems can be generated using the computational framework presented here. Life on other worlds may have been initiated and evolved very differently from what we are accustomed to seeing on Earth. For example, alien life may not even be carbon-based. We may need to look at life through a new lens to recognize life-like systems on other worlds. Our computational framework combines dynamical systems with deep learning to generate novel and aesthetically appealing forms of life-like systems. These potentially life-like systems can conceivably be present somewhere in our Universe. They can even broaden the search horizons beyond current searches for carbon-based lifeforms within the habitable zones of sun-like stellar systems. This aesthetic view also allows us to appreciate the beauty of life, life-forms around us, and their intimate connections with dynamical systems. This perspective can give us a sense that every part of the Universe computes and that the entire Universe is alive and has intelligence. We hope this will give humanity a new sense of purpose, help us appreciate our place in the Universe and also give a renewed thrust to conservation efforts to save our planet. Our work is also an example of how computational art can be created using empathetic Artificial Intelligence and dynamical systems. Such forms of art can be used to educate the general public about the benefits of AI and bridge the gap between lay audiences, artists and computer scientists. The general public, artists and computational scientists can come together to co-create computational life-like systems using AI. This will also allow us to value and appreciate life on Earth and how precious it is. Dynamical systems are general and powerful mathematical representations of our Universe. They can represent diverse complex systems ranging from intra-cellular regulatory networks to global scale models of how scientists collaborate with each other. We posit that dynamical systems underlie much of our Universe and we hypothesize that they form the basis of computation, life, intelligence and consciousness in our Universe [9].

CONCLUSION

In conclusion, we present teaching resources for school and university students. We hope our work will help popularize a computational view of life and educate students on how arts and mathematics can be unified. It will hopefully also instill an aesthetic sense of life in future scientists. We anticipate that our teaching resources may be especially useful in developing nations that are investing in science education. We hope our resources can be used to teach students in low and medium income countries. The only requirements are a laptop, desktop or smartphone with an internet connection. This work started with a science fiction story. We want to end with a question: what if someday we journey to the stars and we do find life. What if we fail to recognise it? What kind of metrics and objective criteria should we have for life or

life as we do not know it? Only by educating the next generation of students can we keep an open mind about life elsewhere in the Universe and try to creatively reimagine what kinds of life can exist. An aesthetic sense of life will help in this reimagination of life or life-like forms that can exist elsewhere in the Universe. It will also allow us to better appreciate life on Earth.

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A NEW SIMPLE METHOD FOR AN EFFICIENT ORGANIZATION OF THE LEARNING PROCESS

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ABSTRACT

The most appropriate learning results take place when the trained matter is unmistakably identified, understood and achieved by the student. An individual learning process should be developed by the trainee, in parallel, by self-inspiring and by involving his own capabilities through natural mind procedures. In addition to motivation and pertinent chances which operate as a learning means, practical suggestions gained by the authors through experience and specific studies were used to develop a new suitable method of study organization.

In this article, after an introduction in which some existing methods were reviewed related to learning and study planning, a novel simple method is presented, which has been successfully experimented for years. Such an approach has proven to be valid to achieve the main purposes, i.e. learning, passing exams successfully, remembering as long as possible the technical and cultural knowledge studied and applying efficaciously the acquired wealth of knowledge in the future professional life.

KEY WORDS

study organization, learning method, memory, neurobiology, connectome

CLASSIFICATION

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INTRODUCTION

The learning process involves all our senses and is an inner occurrence both on a mental level and as a human activity with significant effects on career and life. Proper motivation and substantial circumstances act as a learning means. Appropriate activities contribute to strengthening the learning process and making it easy. These activities should be advanced based on the aptitude of the student and multi grade environment [1].

A review is preliminarly presented of the main learning approaches currently available in scientific literature and provided to help the learning process on an individual, team or organisational level. The criterion with which these approaches were selected was to find method for study organizations (MSOs) that through successive phases were conceived to gradually lead the student to complete learning of the subject.

The so called discovery learning methods, e.g., are components of educational practice promoting the way to active learning that is process oriented and self-directed [2]. These methods are based on the idea that students create their own understanding and knowledge through experience and reflect on those experiences, thus interacting with their environment and being stimulated to think, hypothesize, raise questions, speculate and cooperate with others, developing confidence in problem solving [3]. A concise learning method exists, e.g., based on the use of mind mapping to integrate all class notes into mind maps, and also learning some success skills [4]. Such methods use an active, cognitive, inquiry-based constructive process, avoiding passive and dull memorization. This considers learning as a multi-phase process in which the student organizes and connects basic concepts through visual maps by critically thinking and asking key questions [5]. A learning approach is also included in the so called "mind map" thinking tool, which is a form of note-taking that can be adopted where linear notes would normally be taken, such as when carrying out research, studying or attending lectures [6].

Various experiments have been carried out in the world to analyse the learning process. Metacognitive skills or strategies were investigated, e.g., considering 400 university students randomly chosen from different schools and departments of the Gazi University, Turkey, in 2012. Their selection was performed according to their perceived self-confidence levels about learning. Those possessing higher self-confidence in their capabilities got better results using the strategies of note taking, summarizing, reflecting, reciting and reviewing what they learned, in combination with things they had already known, being able to approach complicated tasks as challenges to be mastered [7].

During the advancement of the school career, e.g. passing from high school to university studies, students need to manage their instruction ever more and involve rising energy into becoming self-managing learners. Essential study and organizational skills are needed to divide class and homework duties into subtasks and to use time proficiently to complete duties like storing classified papers and other texts for postponed retrieval, habitually reviewing class notes and course readings, and practicing efficient study techniques. Some concepts that can allow one to study more effectively and to become more organized have been reported in [8] and the following learning methods can be mentioned as further examples:

- *the case study method*, a learning technique in which the student conducts an in-depth examination of complex phenomena within some specific context and real situation (i.e., the case), analysing it and using real information as a methodological tool [9];
- *the Pomodoro study method*, a time management technique that involves using a timer to time short, intense work sessions, traditionally 25 minutes long [10, 11];

- *the Feynman learning technique*, in which the learning process happens through the act of teaching. The students choose a topic, then explain it in their own words as if teaching, then they improve their explanations and go through the process again until they have mastered the topic [12];
- *the PQ4R method*, adopted to read and to comprehend detailed scientific texts, with emphasis on understanding and retaining the content and not on the reading speed: the letters P, Q and 4×R mean the 6 different steps needed to work through the text [13];
- *the SQ3R method*, in which the student is expected to develop his understanding of the text by purposely engaging in the reading process before, during and after: the letters S, Q and 3×R mean in this case the 5 different steps needed when actively and effectively reading a specific text [14].

In recent years, digital learning materials and auxiliary resources have been developed such as slide decks, videos, simulations, worksheets and test banks, as well as all-inclusive, stand-alone online solutions, enabling students to complete assignments, to get automatic feedback and to engage with their classmates and instructor. Learning materials, anyhow, should be adequately contextualized: courses assembled by collecting materials coming from multiple sources. This is unlike a commercial or open textbook, may not have built-in summaries, timelines, background information or the explicit interpretation necessary to help students to fully comprehend the subject. To facilitate student learning, thus, the preparation of a contextual commentary is suggested, e.g., by adding the content in the form of recorded or written lectures, or by embedding it into discussions and other learning activities [15].

The best study program, however, is undoubtedly the one customized according to the needs of each student, even in the sector of higher level studies, due to the different course programs and skills of the specific student. Learning and memory, anyhow, have neurobiological bases that are favoured and developed by applying a new dedicated simple MSO, which has been meticulously developed and refined during university studies, and will be presented in the next section.

THE NEW SIMPLE METHOD FOR STUDY ORGANIZATION

This MSO is our original method, a valid learning tool which has been successfully experimented in Italy in various disciplines especially during graduate studies, i.e.: in the ‘80s, in Mechanical, Electronic and Civil Engineering at the University of Ancona and in Aerospace Engineering at the University of Rome; in the ‘90s, in Nuclear Engineering PhD studies at the University of Bologna. Such MSO has allowed all the dozens of students who have adopted it to pass university exams brilliantly and it can be generally applied to diverse higher and graduate studies. With respect to the previously existing methods, this MSO helps: solving the problem of correctly meeting the times available for studying and in particular the deadlines for exams; optimizing these preparation times and helping to acquire a deeper knowledge of the subject studied, fixing it in long-term memory; avoiding showing up unprepared for exams or obtaining unsatisfactory results. It is composed of five successive phases to be faced, by the student, with appointment and enthusiasm for the matters that must be learned.

PHASE 1

Know exactly what you must study. Collect, therefore, all the necessary material: personal notes from lectures given by the teacher of the course, books, diagrams, various drawings, additional notes and anything else recommended by the teacher, who should be consulted, especially to dispel all doubts.

You have to reach the sureness of having all the necessary material to tackle the study.

PHASE 2

Read and fully examine the material collected in Phase 1, only trying to understand. You should not read on if you do not clearly understand a concept, a formula, or even a word. Before you go on, you need to clarify the meaning of what has been read. The aim of this phase is only to understand everything that is written, without trying to remember or memorize.

PHASE 3

Write on a dedicated notebook the summary of the examined texts. This is the most important and responsible phase. The summary must be drafted very correct and as clearly as possible so to later study it directly. The same summary must collect fully all the considered concepts, ideas, issues, principles, rules, theorems and formulas, highlighting also the main purpose of the course so as to overcome any questioning as well as the final examination.

Even at this phase, so as not to bring the notebook texts that do not affect the required arguments, if in doubt you should consult the teacher of the course and, possibly, those who have recently passed the exam successfully. It is recommended to write down in a notebook also all schemes - technical, logical, etc. as well as drawings and graphics to be studied, trying to use different inks to improve comprehensibility.

It must succeed, hence, to no longer need the material collected in Phase 1, except when the same presents exercises to solve. Such exercises are to be addressed in parallel to the study as soon as one possesses a full knowledge of the topics to which they relate.

PHASE 4

Study the contents of the summary notebook prepared in Phase 3, in order to remember what you have already understood – and partly automatically stored in your mind – through the preparation of the same notebook.

It is advisable to carry out the study as follows: repeatedly and carefully reading medium voice sentence by sentence, as if you were facing the examiner; then, repeating in a middle voice what was just read several times enthusiastically, as if you were to ask a person who does not know the subject.

Write several times the mathematical formulas that may be present in the text, to learn along with their precise meaning and the units of measure of each symbol present. The same applies to the charts and drawings to be studied.

During this phase, list separately and very carefully all the concepts, formulas and generally all the parts that result that are difficult to understand or remember.

PHASE 5

Refresher. Re-read the whole notebook, pausing at each of the difficult points already mentioned during the study with reference to Phase 4, then re-studying them to dispel any doubt.

This phase is also required to form mentally and quickly a complete picture of all the topics covered.

The same phase can also be repeated more than once, to retain maximum clarity of the exposition of the subject, together with an appreciable readiness for the exam.

ADDITIONAL PRACTICAL SUGGESTIONS

Keep the best hours of the day for the study. Phases 2, 4 and 5, in particular, should not be addressed if tired, sated or nervous.

Study quietly, focusing solely on the above subject and avoiding any chance of diversion as background noises, loud and distracting music, conversation, smoking or a phone not on silent. The best sound for productivity is silence. A break can be taken every few hours to listen to music, e.g. for 15 minutes [16].

Organize a study schedule, postponing other types of commitment out of the involved time. Phases 2, 3 and 4, in this regard, can be divided according to a schedule of study, to be prepared in order to reserve a right margin of time, before the examination, to refresh and rest. See, e.g., Table 1.

Table 1. Example of simple subdivision of the study calendar.

	Wednesday Mar. 06	**Thursday Mar. 07**	**Friday Mar. 08**	**Saturday Mar. 09**	------
morning	Phase 2 Book XXX pages 251-300	Phase 2 Book XXX pages 351-400	*rest*	Phase 3 Book XXX pages 21-40	**……**
afternoon and evening	Phase 2 Book XXX pages 301-350	Phase 2 Book XXX pages 401-fine.	Phase 3 Book XXX pages 1-20	etc.	**……**

The calendar should be organized by everyone of the students according to their ability to study. The same calendar is useful especially when you have availability for studying on a specific period of days. Once established, the timing must be respected rigorously recovering any delays and anticipating the study where possible.

During the last phases of study, strictly avoid any occasion of hours of sleep loss, alcohol, smoking, considerable physical effort and sleeping pills or medicines. Secure, however, the right intervals of relaxation and refreshment.

It is advisable to study alone, though colleagues can be consulted if necessary, but after having already studied solo. Only then, from the comparison and verification with colleagues can one get the right benefit.

NEUROBIOLOGY OF LEARNING AND MEMORY IN THE MSO CONTEXT

This MSO encloses all the components that represent the neurobiological basis of learning and memory, see Figure 1.

The enthusiasm activates the emotional memory whose anatomical seat is in the amygdala, which is stimulated by impulses internal and external. The enthusiasm also “colours” the memory traces interpreting them according to the subjective language of emotions, recording sensory data through the connections with the thalamus, hypothalamus and hippocampus [17]. The structures most responsible for memory processes are the hippocampus and the amygdala, two subcortical structures in the temporal lobe, which are part of the limbic system. The hippocampus plays a primary role in the formation of short-term memory, but not of long-term memory. The amygdala, on the other hand, attributes a particularly affective and/or emotional meaning to information, consolidating it over time. The amygdala also makes it possible to associate a stimulus with a reward or a penalty [18].

Memory is initially stored as a transient change that can consolidate into a long-term memory trace. Consolidation largely depends on the emotional state. The interaction between these two structures, the hippocampus and the amygdala, is crucial in many forms of learning and memory. The hippocampus, as well as the amygdala, exhibits a type of synaptic plasticity known as long-term potentiation (LTP). Recent studies have shown that hippocampal LTP consolidation can be modulated by the emotional state and activation of the amygdala [19]. Calm, silence, solitude and concentration all reduce stress and lower blood cortisol levels.

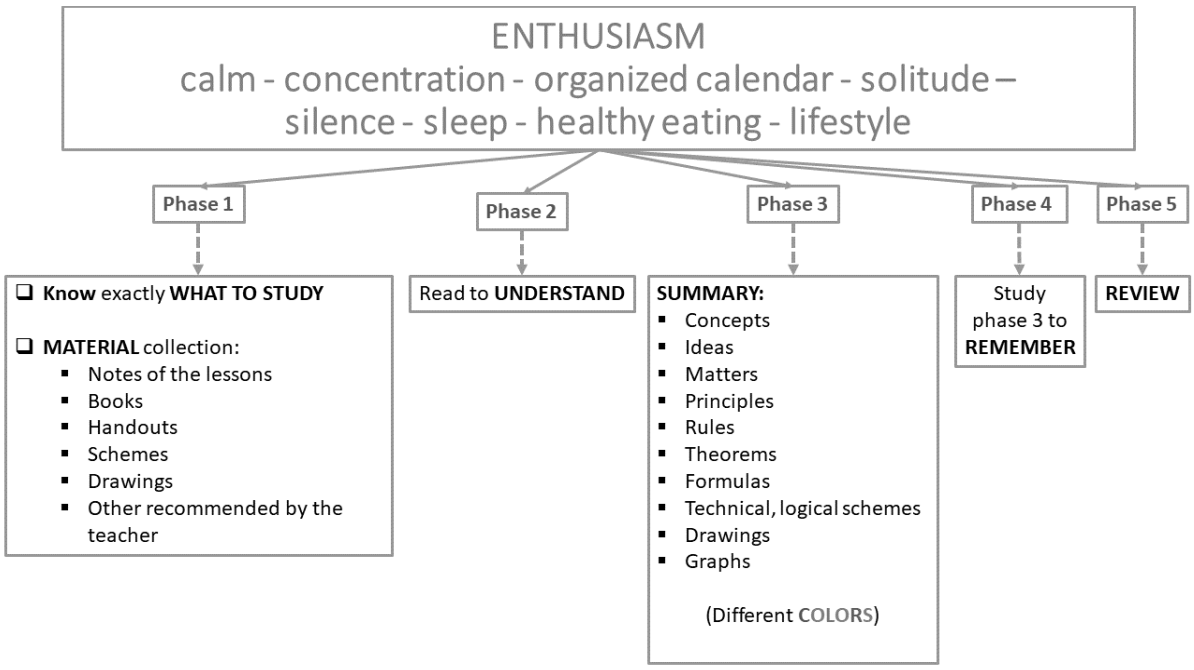

Figure 1. The 5-phase scheme of the MSO: 1 complete collection of the texts to be studied; 2 reading of the collected texts to understand their meaning; 3 drafting the summary of the examined texts in a notebook also containing diagrams, drawings and graphs; 4 study and memorization of the summary; 5 repeated review of the summary.

The hippocampal system is very sensitive to stress and memory can increase or decrease based on the subjectively perceived feeling of stress [20]. Acute stress prevents memory centres from recovering certain types of memories [21], while in chronic stress the high concentrations of cortisol are associated with an excessive release of excitatory neurotransmitters, resulting in a reduction in neuronal trophism and inhibition of neurogenesis [22].

The organized calendar of this MSO, together with a healthy diet, good sleep quality and a lifestyle based on moderate physical activity free from smoking, alcohol, etc., they favour a perfect psycho physical shape and optimal cognitive performance.

It is also important to choose the place to live and study in order to receive the correct environmental epigenetic stimuli [23, 24]. Moderate calorie reduction is recommended, as excess calories can reduce synaptic plasticity. It is suggested to prepare light meals based on seasonal foods rich in active ingredients such as:

- B vitamins, to protect brain function by reducing blood levels of homocysteine (*eggs, chicken, fish, vegetables*);
- C vitamin, is useful for brain tissue and to manage stress (*black currants, peppers, citrus fruits, broccoli*);
- E vitamin, is useful to protect synaptic membranes from oxidative stress and improve cognitive performance (*extra virgin olive oil, nuts, almonds, Brazil nuts, hazelnuts, flax seeds, olives, eggs, green leafy vegetables, unrefined whole grains, especially spelled and oats*);
- K vitamin, to improve cognitive function (*cabbage rich in glucosinolates able to maintain high levels of the neurotransmitter acetylcholine at the synaptic level for a healthy brain and clear memories*);
- Zinc, Magnesium and Tryptophan, precursor of Serotonin, to increase memory, thinking skills and good mood (*pumpkin seeds*);

- Omega 3, to preserve synaptic function and the plasticity of neurons (*walnuts, flax seeds, oily fish, pumpkin seeds*);
- Alpha lipoic acid, for antioxidant effects (*spinach, broccoli*);
- Lycopene, to prevent damage from free radicals (*tomato*);
- Tannins, Anthocyanins and Phenols, to increase short-term memory and promote the regeneration of retinal purpura (*blueberries, blackberries*);
- Spices, to improve memory and concentration (*sage, rosemary, turmeric, chilli pepper*) [25];
- Astaxanthin, to protect the retina and cell membranes. Furthermore, astaxanthin activates the FOXO3 gene also called the "longevity gene" [26]. A neurogenesis of the hippocampus has been observed in the elderly treated for 4 weeks with this substance (*crustaceans and salmon*).

Meals with a high saturated fat content (meat and cheeses) are not recommended, since they reduce the molecules useful for cognitive processing [23]. Proper hydration is important by drinking at least 1,5 litres of water a day.

Good sleep quality is of paramount importance for physical health, mental well-being, attention and creativity [27]. Sleep loss (total or partial) impairs performances such as working memory, alertness and cognitive performance, moreover inducing an all-round decline in attention [28]. Moreover, moderate physical activity reduces oxidative stress (i.e., excess free radicals) and nitrosative stress (i.e., excess of nitrogen monoxide), improves neuroendocrine self-regulation by counteracting neuronal degeneration [29], releases stress, increases endorphins, improves blood circulation and stimulates the "anti-aging" activity of sirtuins which promote neurogenesis [30].

The preparatory subdivision of the study into the 5 phases creates a construct on which to organize a rhythmic and rational guide for the study; furthermore, thanks to the information sent to the brain in the form of summaries, logical diagrams, drawings and graphs, it favours the formation of the brain maps of the connectome through a progressive reconfiguration of the neuronal circuits.

Neural networks normally require huge amounts of data to build their complex mappings (connectome) so memory augmented neural networks improve connectome maps [31]. The connectome is a dynamic mapping of neural networks that is strengthened and updated with experience and learning [32]; its study and coding began in 2009, by H.S. Seung, in the Department of Brain and Cognitive Sciences and the Department of Physics at the Massachusetts Institute of Technology.

The neuroimaging methods used, Resting-state functional connectivity fMRI [33], to analyse the mechanisms of grey matter and Diffusion imaging for the study of white matter – allow representing the axon bundles in different colours depending on the direction of the synaptic flow.

Prof. Seung has schematized the plastic reconfiguration of the connectome according to 4R:

R_1) Reweighing: neurons adapt (or reweigh) their connections by strengthening or weakening them through variations in the number of neurotransmitter vesicles in the synaptic terminations (see Figure 2);
R_2) Reconnection: neurons reconnect by creating or eliminating synapses;
R_3) Rewiring: neurons reform new circuits (rewire themselves) by making branches grow or retract;
R_4) Regeneration: creation and elimination of neuronal cells [34, 35].

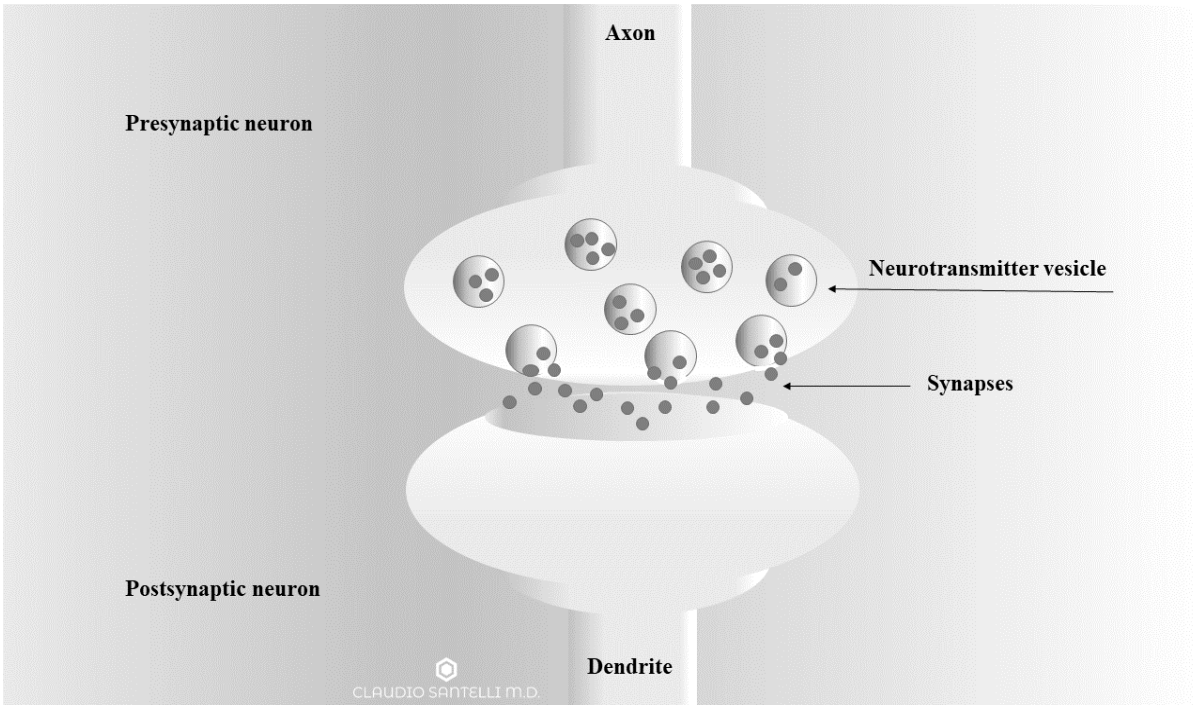

Figure 2. Synaptic connection between an axon of the presynaptic neuron and a dendrite of the postsynaptic neuron. The number of vesicles containing the neurotransmitter that is released in the synaptic space varies according to the cognitive stimuli received.

These neurophysiological models originally inspired the construction of the neural networks of artificial intelligence where, in neuromorphic chips that process algorithms and computational mathematical calculations, the "deep-learning" takes place in the latest generation computers and robots capable of processing functions and dynamics by learning from experience and examples [36].

The use, in this MSO, of graphics, colourful diagrams, drawings, symbols, etc., activates mirror neurons and advances eidetic memory based on visual perception. Mirror neurons allow one to understand the meaning of physical actions among peers and constitute the neural basis of learning by imitation and empathy [37]. The signals associated with the figures in the drawings, through the hypothalamic neurons, stimulate the brain to form memories of objects [38]. This aspect is also the basis of neuroaesthetics, a discipline founded in 1994 by S. Zeki, University College London. In 2004, together with H. Kawabata, by using the Functional Magnetic Resonance technique, he noticed an increase in metabolic activity in the orbitofrontal regions of a person's brain while observing artworks [39].

There are many anecdotes about famous cases of eidetic (visual or photographic) memory in adults. W.A. Mozart, e.g., was able to reproduce a symphony after having listened it only once (in this case, we refer to eidetic memory for sounds) [40].

Also the Italian humanist and philosopher, Pico Della Mirandola (born in Mirandola, February 24, 1463 and died in Florence, November 17, 1494), remained famous for the ability to make complex calculations without writing anything and for the many works he knew by heart [41].

CONCLUSIONS

The described MSO provides students with a solid basis for the implementation of practical training. Enthusiasm strengthens the emotional memory, while calm, silence, solitude and concentration avoid the distress and the consequent hormonal increase of cortisol.

The organized calendar together with a healthy diet, a good quality of sleep and a lifestyle based on moderate physical activity free from smoking, alcohol, etc. favour a perfect psycho-physical shape and optimal cognitive performance.

The subdivision of the study into a sequence of 5 phases creates a construct on which to organize a rational and preparatory learning guide. It also stimulates the formation of brain maps of the connectome through the progressive reconfiguration of neuronal circuits similar to the deep learning mechanism of Artificial Intelligence, which builds its own neuromorphic chips by mimicking the dynamic neuronal circuits of the connectome.

Graphics, colour schemes, drawings, symbols, etc., finally, activate mirror neurons and eidetic memory based on visual perception.

Researches related to anti-aging are currently oriented towards improving life's quality and health's duration. In addition to promoting healthy lifestyles, therefore, future research activities should be devoted to the study of senolytic products and supplements to improve executive functions and cognitive abilities of healthy individuals, e.g. attention, creativity, memory, mood and motivation.

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AUTONOMOUS VEHICLES: THEORETICAL AND PRACTICAL CHALLENGES FOR EFFICIENT AND INCLUSIVE TRANSPORT IN AFRICA

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ABSTRACT

Autonomous vehicles otherwise regarded as self-driving vehicles are poised to be the next generation of technological advancement in the transportation sector globally. They offer superior value for money with regard to the cost of operation, excellent safety records, and many other benefits. Cities around the globe have adopted it even as research and development efforts are ongoing. This study investigates the role autonomous vehicles could play in Africa, especially as it relates to transportation inclusivity. The study determined that there are lots of inclusivity issues beguiling African nations ranging from religious, financial, educational, and cultural issues and was able to highlight how the adoption of autonomous vehicles can aid to solve issues relating to stigmatization and social exclusion.

KEY WORDS

inclusion, autonomous vehicles, Africa, transportation

CLASSIFICATION

JEL: R42

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INTRODUCTION

As defined in [1], autonomy is described in the simplest terms as a person's ability to act on his or her values and interest. The key feature of autonomy is the self-awareness of action, which drives a person to act based on an established value of interest. Autonomous vehicles are vehicles that can operate themselves and perform necessary functions without human intervention. Examples of these autonomous vehicles are, flying electric cars which in itself is a personal air vehicle that provides door-to-door transportation by air and ground [2]. They can achieve this through the ability to sense their environment [3]. Human drivers have long been a key part of the transportation systems of communities, from horseback riding to bicycles, motorcycles, and cars. The inefficiency of a human driver was elaborated by [4], who determined that there are five critical issues to a human-operated vehicle namely; driver independence and mobility, driver acceptance and trust, failure management, third-party testing, and political support. The human factor has been identified as a contributor to poor safety issues relating to transport, [5] opined that eliminating the human factor and error from driving will increase safety, mobility, and cost efficiency.

Autonomous vehicles permits a vehicle to manage driving points that otherwise would have been managed by a human driver [6]. As a mode of mainstream transport, autonomous vehicles are still plagued by numerous challenges relating to human interference and behavior, cyber security issues [6] ethical issues, traffic management strategies, and liabilities [7]. This has limited the proliferation of the service around the world, most especially in the African Continent. Autonomous vehicles are self-driving or robotic vehicles incorporated with vehicular automation, which grants them the ability to sense their environment while navigating safely with little to no human input [8]. The allure of self-driving vehicles has been primarily driven by the need to transport humans and goods safely, however, issues relating to transportation in human and business-driven society can create situations where members of the population are disenfranchised from opportunities due to an inefficient and/or classist transportation systems. There also exists a need to elaborate on the social implications of adopting autonomous vehicles as an alternative transport medium. Authors in [9] described the sentiment of people living in the Hungarian capital, Budapest, with respect to the choices they would make when presented with a smart solution (autonomous vehicles as a mode of transport). This study rather thus investigates holistically, using readily available data sources from the internet, the existing challenges facing transport inclusivity amongst the diverse populations on the African continent.

TRANSPORTATION IN AFRICA

Transport systems in Africa cut across the use of the three major components of transportation as detailed in [10], the primary transportation infrastructure; such as buses, cars, traffic lights, road networks; the transport management system such as regulatory bodies, traffic rules and the integration of information and communication technology, such as the internet, telecommunication networks and the global positioning systems. The existence and usage of each identified mode of transport are spread across the entire continent as evidenced by [11], who also established a link between urbanization and transport accessibility by stating that current urban transportation is not up to the demand of the African population, where colonial impacts can still be found to impact transportation accessibility, due to low quality of vehicles and poor road safety. A majority of nations/cities within the African continent are connected by roads as seen in Figure 1.

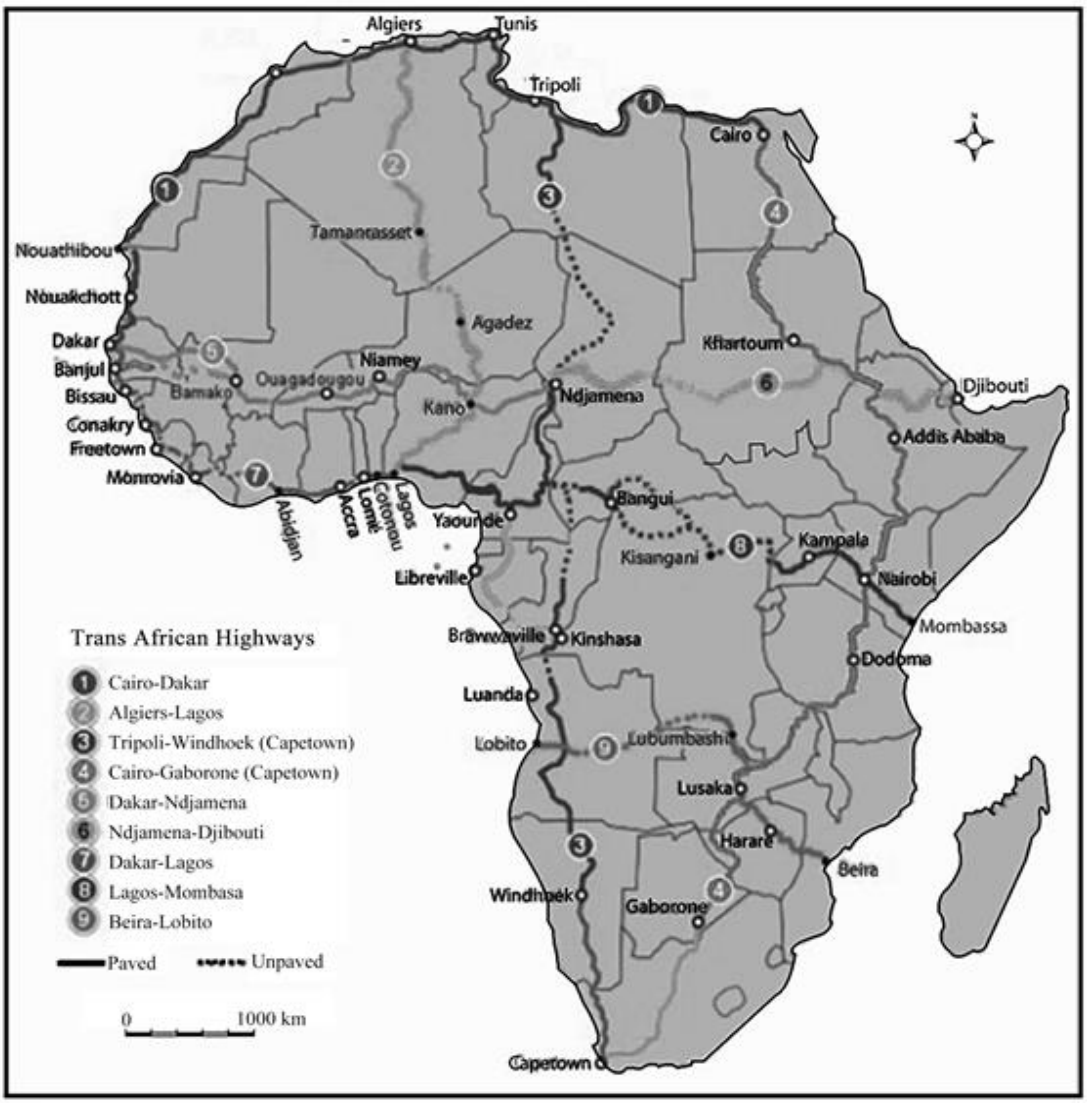


Figure 1. Trans African Highways [12].

The road connectivity ensures that cities within the African continent are interlinked, forming a basis for trade and cultural exchange access between Africans. Road transport is deemed to be the most dominant mode of motorized transport in Africa [13], accounting for 80 % of the goods traffic and 90 % of the passenger traffic on the continent. To further foster the development of road networks within the African continent, intervention efforts from banks as detailed in [14] showed that African Development Bank's (AfDB's) commitment to the transport sector increased more than six-fold from $150million in 2000 to over 1 billion dollars in 2011, where this level of financial commitment represented nearly a quarter of the bank's total portfolio at the time. This is a testament to the need to have increased mobility amongst Africans regionally.

Road accidents kill 1,2 million people globally every year, with 19 % of the deaths occurring in Africa, thus ensuring that Africa has the highest number of road accidents per capita [13]. The need to have robust transportation systems across Africa has been long identified and has thus enjoyed high investments in transport networks with funding currently at high levels, yet there are poor numbers of cars per 1000 people within the population in different countries within Africa as evidenced in Table 1 and Figure 2, where the highest number of cars per 1000 people was found to be highest in Liberia with 250 cars and least in Uganda with 13 cars, this number is dwarfed by the lowest number of 272 for Denmark as seen in Figure 3b).

Table 1. Passenger car availability for Africa [15].

Country	Cars per 1000 people
Liberia	250
South Africa	200
Tunisia	142
Morocco	91
Nigeria	85
Egypt	71
Ghana	45
Kenya	30
Tanzania	21
Uganda	13

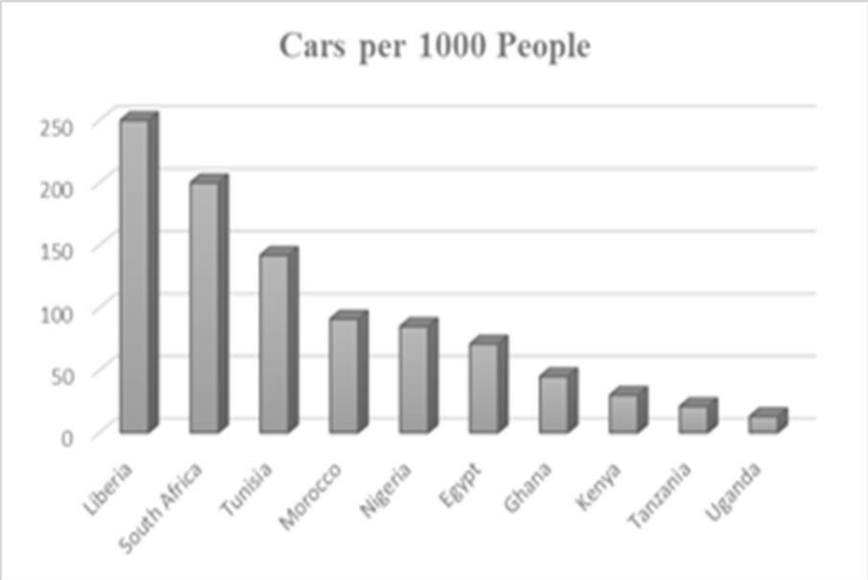
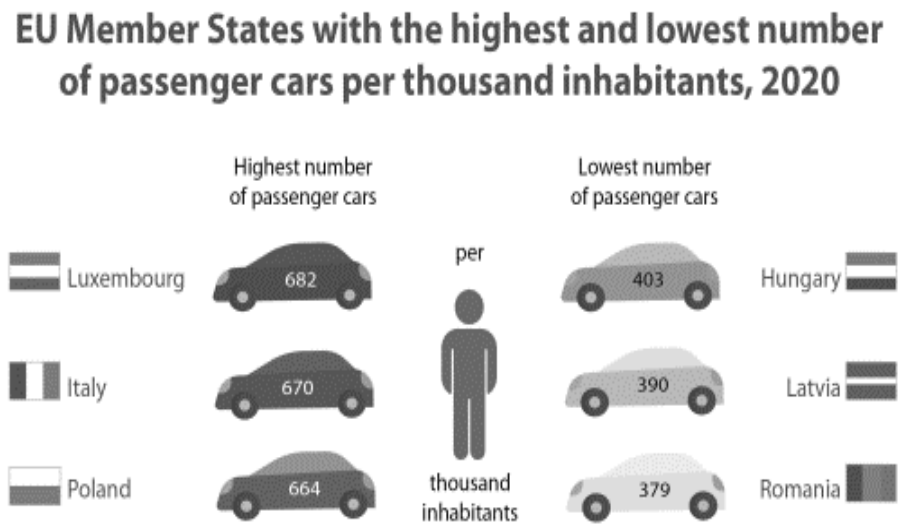


Figure 2. Passenger car availability for Africa [15].

The significance of having lower vehicles per population in Africa as opposed to European and Asian cities might have a negative impact concerning accessibility and ease of trade, but it also has a positive impact concerning pollution, as transport systems generally hurt the environment and human health thanks to their contribution to air pollution. Africa still has a low impact on health due to air pollution, compared to other developing and developed countries [13], even though it is estimated that the cost of air pollution in Africa is almost 2,5 % of its gross domestic product. Other challenges identified with transportation systems include; destruction of flora and fauna, destruction of forests and associated ecosystems, soil erosion, and congestion of cities amongst others.

Transportation policies on-road use in Africa as discussed in [16] were articulated around four blocks namely; responsibility; which pertained to the need to create a coherent organizational structure for network management, with relevant institutions having assigned roles and responsibilities, Ownership; which pertains to the need for constituent representation of road users through oversight boards, Sound business practices; which pertained to the establishment of commercially oriented management practices to derive value for money from road investments and spending, and sable and secure financing; which pertains to the need to establish an adequate

a)



b)

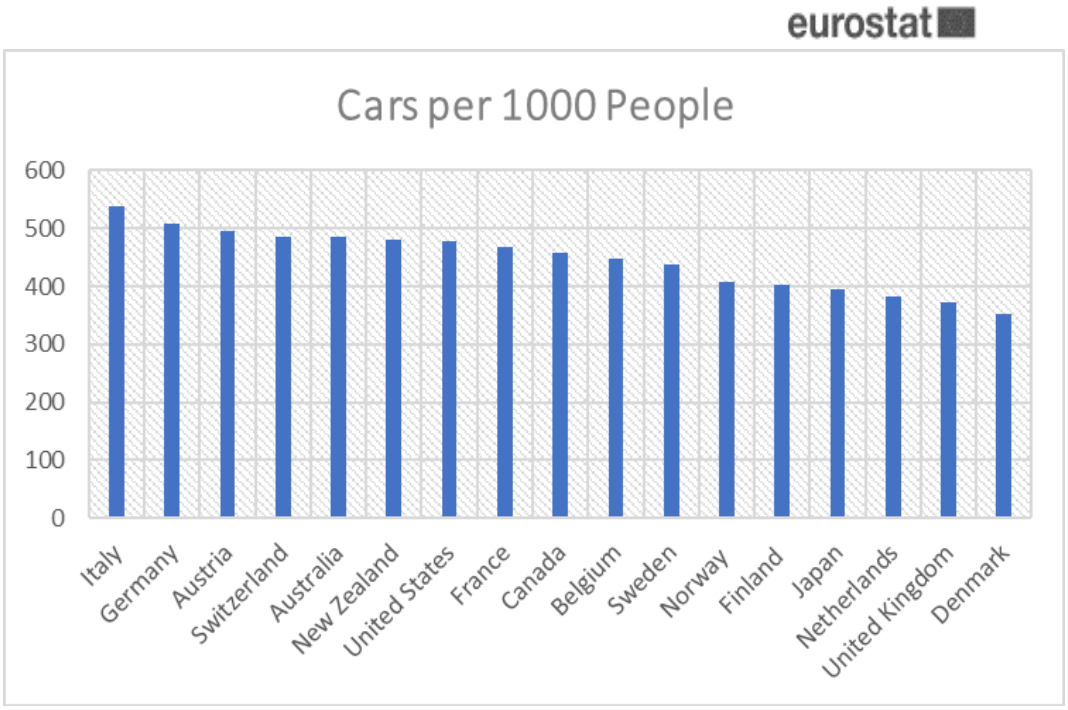


Figure 3. Passenger Car availability for Europe [17].

flow of funds from created road funding apparatus which are in themselves independent. The possibility of sustenance of the transport sector in Africa is highly dependent on highly scalable policies, made by forward-thinking policymakers with a resolve for consistent funding on not only the road networks, but all other transport networks within the region, to ensure that mobility and connectivity within the African continent are seamless is highly desirable.

Logistic performance as a strategic factor for indicating the competitiveness of economies was widely explored in [18]. Artificial intelligence and other related smart technologies, such as autonomous vehicles have a big role to play in achieving any economic competitiveness. The current transportation networks in Africa does not support high logistic performance and this in turn has a negative effect on African economies.

AUTONOMOUS VEHICLES FOR INCLUSIVITY

Inclusion or inclusivity can be described as the policy or practice that encourages equal access to resources and opportunities for all people, irrespective of their gender, social class, religious leaning, sexuality, or physical and mental disabilities. Safe and inclusive transport is described in [19] report as being key to participation in society as it provides access to life-enhancing and socioeconomic opportunities through the navigation of an environment, for a predetermined destination safely and reliably, while being considerate of individual needs is a key pillar for safety and inclusivity in transport systems. Ease of mobility is highly linked to social development and poverty reduction, as people can access opportunities for commerce and skill acquisition in locations other than their base location (country, cities, towns, etc.). Goal 11 of the United Nation's sustainable development goals encourages members to provide accessible, safe, and affordable transport for everyone, most especially for vulnerable people.

The world bank reports that 62 % of jobs in the informal sector have been lost post-COVID in regions like Togo, Benin, Burkina Faso, Cote d'Ivorie, Guinea, and Niger [20], where informal workers represented 80 % of that figure, for which 90 % of them were women. The increase in poverty amongst African nations was also established in [21], which reports that less than half of all African countries have experienced inclusive growth between 200 and 2020, with 17 out of 49 countries showing trends of poverty-reducing outcomes, however, inequality increased in 18 countries, and non-inclusive growth on other dimensions occurring in 14 African countries.

Autonomous vehicles offer an opportunity to create inclusive mobility [22], by designs that suit the requirements of those who need them most. Challenges against mobility which autonomous systems aim to provide solutions to are; street design and traffic complexities, children's independent mobility, elderly mobility, physically disabled people with mobility issues, cognitively disabled people, visually impaired people, etc. the mobility challenges issues faced by diverse groups of people can be looked at from various perspectives.

PHYSICAL INCLUSIVE CHALLENGES

Physical inclusive mobility challenges relate to people with physical limitations that affect their ability to move about safely. This can be considered from the perspective of children and seniors who are limited in size, strength, and cognition to be able to navigate unaided, to people with physical challenges who are not mobile, due to being unable to do so effectively and safely. Autonomous vehicles play a critical role for seniors and for those with a physical disability as discussed in [23], who estimated that poor mobility access amongst seniors and people with physical disabilities can be a huge barrier to independence and quality of life. The study submits that autonomous vehicle technology offers a great sense of independence and freedom to people living with physical disabilities. This ensures that the mobility people of this category do not have to depend on family members and caregivers alone, as door-to-door automated transportation services can now be deployed to meet their mobility needs. The existence of a gap in interventions for equitable mobility provisioning for disadvantaged groups was elaborated in [24], whose study investigated autonomous vehicle policies and how they affect equity amongst disadvantaged groups. Although it highlighted that autonomous vehicles had the potential to either improve or harm equity for disadvantaged groups, it agreed with the need to have policies that ensure equitable outcomes for under-represented populations. Generally, autonomous vehicles have to be able to provide succor for people with physical disabilities from pain points by providing a custom design that complies with the specific needs of people with different physical disabilities. In [24] it is suggested that such a provision could lead to a higher price in cost of the vehicles due to the customization needed to satisfy a wider audience.

COGNITIVE AND VISUALLY IMPAIRED INCLUSIVE CHALLENGES

Cognitive impairment implies people with some form of mental dissonance, while visual impairment relates to people with vision problems ranging from poor eyesight to its total lack thereof. Visual and cognitive impairment tend to go together if not always mutually exclusive. People within this category are also faced with similar issues as those with physical challenges concerning mobility. They ordinarily need help from family and caregivers for mobility, whereas, for the visually impaired, care can come from guide animals, walking canes, and other assistive technologies deployed to the blind and visually impaired. For effective mobility, autonomous vehicles can also serve as a platform for easy access to transport. The relationship between physical and mentally challenged individuals concerning how autonomous vehicles can serve a purpose was further discussed by [24], who proposed that shared automated vehicles could increase the accessibility levels for people with physical and sensory disabilities, so long as certain bottlenecks such as identification of appropriate boarding spots with minimal obstacles, price of the service can be handled. A further argument that justifies the need for an autonomous vehicle solution for the mentally and visually impaired is highlighted by [25] who determined that paratransit services utilizing public facilities for people with disabilities have proven to be expensive and difficult to coordinate. Therefore, a custom approach to mobility for the visually impaired using autonomous vehicles is an optimal solution for mitigating the observed challenges in that group.

ECONOMICALLY INCLUSIVE CHALLENGES

Economic issues can also cause a lack of inclusivity concerning transportation. People with low income have difficulties in accessing the capital cost of owning a vehicle [26], the cost of owning a vehicle goes beyond the purchase cost, but also to the maintenance cost and the availability of parts. Governments globally have invested a lot in mass transit transport systems to aid inclusivity amongst citizens, however, this has still not captured people with physical, cognitive, and visual impairments within the existing infrastructure. People with low means of income, even when not impaired by disability still find themselves excluded from mass transit systems due to the absence of adequate subsidies within the sector in some countries. This thus implies that more cost-effective solutions to mass transit would help with affordability, thus encouraging more people of low income to use transport systems. Autonomous vehicles offer a cost-effective solution for economic inclusion. The absence of the driver eliminates the cost of salaries, as evidenced in [27] who determined that the cost of the driver represented 88 % of the cost of running a transport taxi service in Zurich. The rigid schedule of operations required with human-operated transport services is also another factor autonomous vehicle can mitigate economically. People of low income are mainly janitors, factory workers, waiters, maids, nannies, small retail business owners, etc. The rigid schedule of operations of transport services mostly does not suit the time movements of people in this category, who have to resume at odd hours of the day and night to carry out their jobs, thus even if many of them could afford the fares of typical mass transit systems, they are simply unavailable during the time they need them. Transit systems using autonomous vehicles with a capacity to run 24 hours a day would solve that bottleneck. Though there are other associated costs to using a shared autonomous vehicle transit system, such as mobile smartphones, internet connectivity, credit/debit cards, bank account, etc as these are needed to implement such a system, these are technologies majority in the population are already using and are conversant with.

AUTONOMOUS VEHICLES AND INCLUSIVITY IN AFRICA

Africa is plagued with three urgent transport challenges according to [28], namely the highest rate of road fatalities in the world, an unprecedented rate of urbanization, and the highest

transport costs in the world. As much as Figure 1 depicts the interconnected road networks on the continent, it is still so fragmented that there is a dearth of transport infrastructure and inefficient transport services. [29] investigated the emission issues relating to transportation in Africa by elaborating on vehicle fuel economy and electromobility, where due to unavailability of proper funding and incomes, the majority within the population are only able to buy cars with outdated technologies and thus advocated for flipping of the script, where Africans learned to adopt cutting-edge vehicle technology. Cutting-edge technology in the transportation domain is currently autonomous vehicle technology, which offers low operational, financial, and emission costs for the transportation of man and goods across the continent. Inclusivity in the African continent can be investigated from the lens of its diversity, centered around culture, ethnicity, gender, and religion [30], where ethnicity was investigated as a major driver of diversity.

Gender issues within the African context also play a key role in diversity as it relates to inclusivity [31], where financial inclusivity for women was identified as one of the four key strategic pillars for gender transformative financing. Inclusivity within the African continent can also be viewed through the lens of urban development and access amongst the general population [32], who highlighted the need for a massive restructuring of the urban spaces, to ameliorate the negativities arising out of apartheid and colonial governments in southern Africa. A lot of related studies have investigated financial inclusivity within Africa, such as [33] which determined that financial inclusion had a significant and positive effect on entrepreneurship in Africa. [34] also argued that financial inclusion breeds growth within the African continent, however, but that education plays a key role in fostering financial inclusion.

Disability inclusion is opposed in African Societies due to cultural and religious issues [35], where some cultural beliefs attribute children and people with disabilities as being cursed by the gods or that such children are suffering disability aliments due to crimes their parents committed or crimes they committed in a past life. Thus, you see a high level of segregation and stigmatization. Parents are willing to leave their children at home, hiding them from the glaring eyes of the public and with some simply abandoning them after birth in hospitals.

Religious inclusion issues also abound in Africa, where women have been the major victims of this practice, due to religious beliefs, the movement of women can be limited to reduce their close contact with people of the opposite sex to whom she is not related to. There is also another religious and cultural practice that which ascribes a class status to a set of individuals and prevents them from interacting with others freely, an example is the Osu Caste System [36]. There are many more inclusion challenges faced by people in Africa, which go beyond those mentioned in this study. However, it still highlights the need for inclusivity within African communities and cultures.

Autonomous vehicles can play a critical role in driving inclusivity in Africa. Just as suggested in [26] that automated vehicles can influence the accessibility of vulnerable social groups in urban and rural areas, thus having a major impact on social exclusion. A major reason why there is a divide between rural and urban city inclusion amongst the African population can be attributed to the cost of transport in itself or the lack of transport infrastructure. Autonomous vehicles offer are more cost-effective solution to transportation as its lower cost of operation could drive down the transportation fares, thus allowing a lot more people in the rural areas to have access to urban centers. The role autonomous vehicles can play to ensure disability inclusion is immense, as it eliminates the human component, which in any case would be a human African driver, who might be culturally and religiously biased against the disabled person. The availability of autonomous vehicles within the African transportation system would improve the quality of life currently enjoyed by people living with disability, as they will have greater access to mobility as they have to engage only with a computerized vehicle

as opposed to a human-operated one. This advantage also applies to people in Africa affected by religious inclusion issues. Women of certain faiths are not allowed to use vehicles in the presence of other men or people who are prejudiced by others. Autonomous vehicles will also aid the mobility of women and people in this category as well by providing around a clock computer-operated transport service that is not prejudiced against them. There are lots of interventions ongoing to promote financial inclusion amongst African women, where investments in their education are currently ongoing to ensure they are educated enough to fully benefit from the interventions, autonomous vehicles can also aid in promoting the education of women and the poor, as it would provide a round the clock, affordable transport alternative to ensure that the divide between people and opportunities are ever being constricted.

CONCLUSION

This study attempts to establish a link between inclusion in African communities and the impact autonomous vehicles could have in fostering such inclusivity. Existing transport challenges within the continent were identified, with key mention of existing interventions currently underway to provide a solution. Autonomous vehicles are poised to be the transportation method of the future and although it has not yet permeated the African Space, there are lots of advantages to be gleaned if adopted, especially with respect to their impact on fostering inclusion. African transportation systems are in dire need of world-class, modern solutions that could aid its economic development and autonomous vehicles are one of such technologies that can drive social and financial change, thus bridging the gap between the rich and poor.

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A COMPARATIVE PERFORMANCE EVALUATION OF VARIOUS CLASSIFICATION MODELS FOR DETECTION AND CLASSIFICATION OF FLYING INSECTS

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ABSTRACT

Agriculture has long been a part of Indian culture. It is known as the Indian economy's backbone. Agriculture contributes to 17 % of the Indian GDP, but still, farmers confront several problems in growing their crops, one among them is insect pests. "Computational Entomology" is a branch of data mining that assists farmers in overcoming the challenges of damaging insect pests by utilizing appropriate sensors and methodologies for pest classification and application of the pesticides at the right time. The authors used various machine learning and deep learning algorithms to classify insects and examine the influence of classification performance on multiple classes of insects often found in Indian agricultural fields with varying numbers of data and classification models. The study found that proposed CNN based classification model performs better than other classification models in insect categorization, with a classification accuracy of 94,6 %**.** The research work done till now in the field of computational entomology deals with the insects grown in laboratory colonies or well-developed insects grown in the same geographic region and condition, but we have evaluated the performance of different classification models using random images available over the internet to select the well-suited classification model to classify flying insects**.** Applications with precise insect classification using machine learning and deep learning algorithms would have significant implications for entomological research. It is necessary to develop an automated insect classification techniques to provide a foundation for future research in the field of computational entomology.

KEY WORDS

computational entomology, insect pest, machine learning techniques, classification, deep learning techniques

CLASSIFICATION

JEL: C88

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INTRODUCTION

A key component of the Indian economy is agriculture due to India's geographical location, soil composition, climate, and other factors, all of which have played a role in making agriculture possible. The geographic position of our country has been highly conducive to the development of agricultural production. In agricultural production, insects are vital they aid in the reproduction of thousands of flowering plants, fruit trees and some crops [1, 2].The most beneficial insect to agriculture is bee, since it is responsible for all kinds of foods such as honey and almonds. The most harmful insect to agriculture is Bactrocera dorsalis(hendel), since it is responsible for destroying crops worth thousands of crores per year [3]. The insect borne diseases kill millions of people each year [4]. Meanwhile, beneficial insects pollinate most crop varieties, which constitutes our daily consumption [1]. The excessive use of chemical fertilizers to avoid harmful insects has led to the over-extraction of groundwater in the area. The research is needed to assess and design the best pest management strategies for the site. Despite the traditional Indian farmer's wisdom and scientific knowledge, modern technical opinion affirms its validity.

Unsurprisingly, computer science has a more significant impact in the field of entomology. Recent advances in sensor technology have changed this, spawning a new area known as "Computational Entomology".

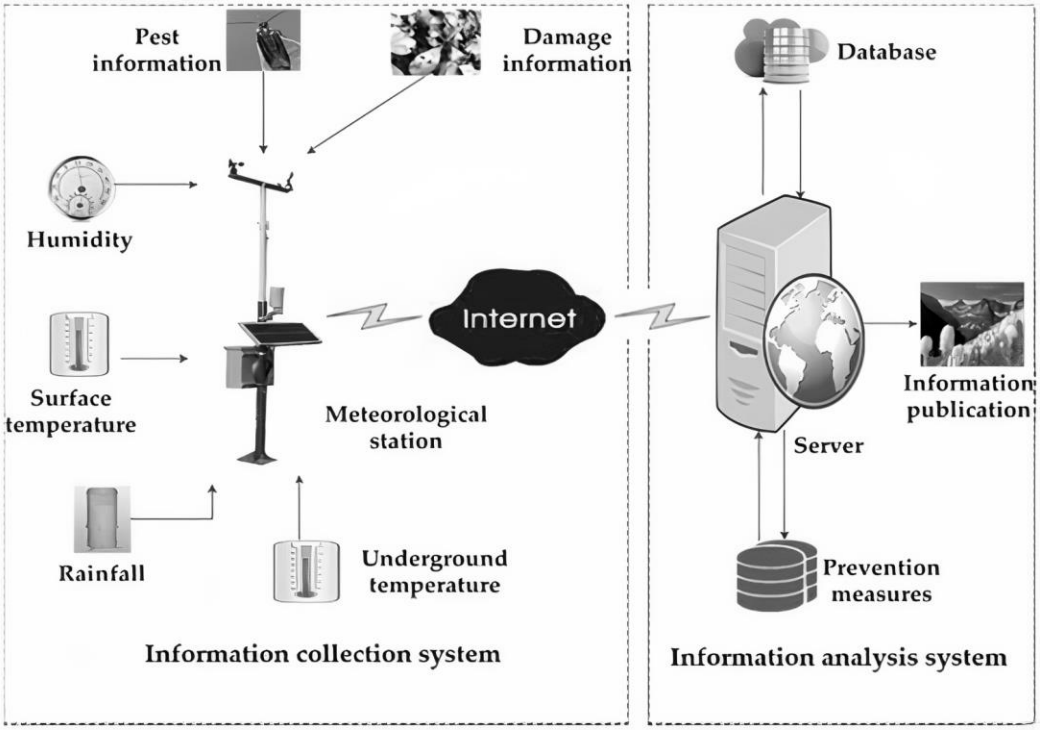

Figure 1. Computational Entomology.

As shown in Figure 1, recognizing harmful insect pests will help monitor the population dynamics of pests prior. The pest monitoring service platform will be an integrated platform the utilizes computer-based technologies, which can be categorized into two sections such as:

- Information Collection System
- Information Analysis System

INFORMATION COLLECTION SYSTEM

Technologies suitable for collecting data related to insects can be applied for data acquisition such as listed in subsubsections.

Internet of Things

Different types of sensors can be used for detection and classification based on different parameters. Acoustic sensors to detect the insect based on sound recorded, the recorded sound will be used as sound fingerprints for classification and bioacoustics recognition [5]. Image Sensors to detect the insect based on the captured image, using machine learning or deep learning models for classification [6-8]. Weather parameter sensors such as temperature and humidity sensors are used to measure the weather parameters to recognize the suitable environmental condition. Laser sensors/IR sensors can be used to identify insects based on wingbeat frequency, using signal processing techniques.

Computer Vision

Computer vision is used to detect the threat/damage, based on the image analysis using different algorithms such YOLO, SSD, SSP-net etc. [9-11]. The extent of threat or damage can be passed to the end-user to take necessary controlling measures.

INFORMATION ANALYSIS SYSTEM

Technologies suitable for analyzing the collected data related to insect pests can be applied to take necessary actions/decisions such as

Artificial Intelligence/ Machine Learning

The Artificial Intelligence (AI)/Machine Learning Algorithms can analyze the data. They check for patterns and will try to predict the behavior [6, 10]. The algorithm checks whether it is preparing to swarm. Once they are analyzed, the insights will be shared with the conservationists and Entomologists well in advance to take necessary actions.

Cloud

The data collected from the sensing device can be stored in the cloud, and the classification model can be deployed in the same cloud to get the data analysis results with very little delay. Once this data is shared to the cloud, we can monitor the continuous measurement of various parameters such as temperature and humidity, acoustics, weight, flight activity, etc.

The main aim of presented work is to develop a good classification technique to classify harmful insects in the agriculture field. Deep learning and computer vision topics are related to a greater need for cost-effective pest management and pollinator monitoring. The Convolutional neural networks (CNNs) can be used to extract image features with deep learning models trained on real-world data, without the need for manual feature extraction, deep learning models can learn features by training on examples. Automatic detection and classification of insects using trained CNNs can be done automatically through video and time-lapse images, which can be used for monitoring [8, 12, 13]. A good classification algorithm will seek to minimize the difference between its prediction and the actual output. The excessive usage of pesticides to avoid the harmful pests in the agriculture sector increases the risk of cancer and other deadly diseases affecting human health worldwide. Computational entomology can address this issue by using advanced computer science technologies in entomology for the early detection and classification of harmful pests. The related work done in this field till now deals with the insects grown in laboratory colonies or well-developed insects grown in the same geographic region and condition [8, 11, 14].

Our article initially provides the pros and cons of various feature selection procedures and how to fix the parameters based on the region and genetics. Finally, we have evaluated the performance of different classification models using random images available over the internet

to select the well-suited classification model to classify flying insects. The insect image classification has been done using different Deep learning and Machine learning algorithms such as CNN, MobileNet, Decision tree, and Support Vector Machine (SVM) and to come up with a conclusion on well suited classification model for computational entomology. The organization of this article is as follows: Section-I deals with introduction on the importance of entomology research in the field of agriculture, Section-II provides the insights on research works done in the field of entomology using the various computational methods, Section-III with the methods used in the conduction of experiments such as selecting suitable data for insect classification, insect image data preprocessing for the classification, and classification using various machine learning and deep learning algorithms. Section-IV deals with results of insect classification, followed by a discussion on comparison between various classification techniques used in our study and conclusions.

RELATED WORKS IN THE FIELD OF COMPUTATIONAL ENTOMOLOGY

The research work done in the field of entomology using different computation technologies are as follows:

MORPHOLOGY BASED APPROACH

In this kind of approach, image classification uses various machine learning or deep learning algorithms for handcrafted features that domain experts design [5, 15, 16]. One good example is the discriminative local soft coding (DLsoft) based approach for classifying insects by a hybrid approach [17]; a hybrid system can test the fruit fly, Tephritidae, with different species. Here initially, the dataset is trained, and then it is stretched to form a testing set. An image of Tephritidae is used as a sample used for both datasets. The calculation of local soft codes and discriminants is done. Subsequently, the overall max-pooling of the vectors in the same image is calculated. A spatial pyramid pooled vector is presented in an image sample that uses machine language or deep learning algorithms for classification.

CHARACTERISTICS BASED APPROACH

In this kind of approach, the experimental set-up consists of low powered laser source or any other form of the light-emitting source, which is placed side-by-side [18, 19]. An electronic board consists of a latter. The laser undergoes a total internal reflection after pointing to the inner reflector. It scatters the light back to the source, while some hits the phototransistor. In this process, counting of insects and classification takes place by recording high amplitude “beeps” of the signal [14, 20, 21].

BIOLOGY BASED APPROACHES

Medical Entomology focuses on the public health importance of insects, including mosquitoes that can transmit arboviruses and parasites that can cause lymphatic filariasis. The projects on medical entomology addresses pathogen-vector interactions with the organismal and molecular levels that mainly depended on factors such as control vector competence [22]. In “Pesticide toxicology,” specific laboratory educates and trains scientists in insect toxicology and environmental toxicology/chemistry of agrochemicals. It also contributes to the development of science in computational entomology by using natural products such as insect repellent and insecticides. Insect toxicology focuses on the environmental effects of agrichemicals and environmental toxicology. Pesticide toxicology mainly investigates on ecological effects of conventional pesticides, protein toxins, veterinary antibiotics, and vaccines that transgenic plants produce.

MATERIALS AND METHODS

SELECTION OF FEATURES FOR INSECT CLASSIFICATION

The only two measurable parameters used for detecting and classifying flying insects are "Morphological Features" or "Characteristic Features".

Morphological Features (Shape, Color, Size, Texture)

The experimental set-up should have an image-capturing sensor/device with night vision inside the trap to detect the morphological features such as Shape, Color, Size, etc. Collected morphological features are processed and analyzed to detect the flying insect class [5, 8, 15, 16, 23, 24]. In this kind of data collection, any image capturing sensor based on cost and functional requirements, preferably a "raspberry pi camera" that supports all revisions of the Pi, "5 megapixel OV5647 sensor in an adjustable-focus module" based on the size of the targeted class of insect, can be used along with technologies such as machine learning and deep learning algorithms to classify the insect-based on the captured image [17].

The pros of morphological feature-based insect classification are support for advanced tools along with detection, insects' classification can be easily done with the most advanced tools such as TensorFlow and AutoML. Classification accuracy, insects with any genetic and geographic background can be classified with less erroneous classification. Advanced learning techniques can give good results over image-based datasets than sound or waveform datasets. The only con of morphological feature-based insect classification is that there is no cost-effectiveness compared to characteristic behavior analysis because of the equipment's required for the experimental set-up.

Characteristic Feature (Wingbeat frequency, Sound)

Any light emitting or sound acquiring sensor should be placed inside the trap; once the insect enters the trap, its wingbeats intercept the light/sound source in the trap will be recorded and analyzed to detect the flying insect class [15, 25-27]. In this kind of data collection, sensors such as Opto-Electric Sensor (custom-made), LED with Phototransistor, IR Reflexive Sensor, Ultrasonic Sensor, Laser Sensor or LiDAR, Microphone can be used along with technologies such as signal processing to analyze the recorded characteristic features [14, 20, 21, 28].

The pros of characteristic feature-based insect classification are that it is cost-effective low-cost sensors can be used for data collection. Consumes less power as the experimental set-up records only sound/light interception. The cons of characteristic feature-based insect classification are that insect aerodynamics (wingbeat) is dependent on geographical region, genetics, and morphology (muscle weight), so it may vary based on the region where the insect is grown. Very minimal data means that the waveforms/frequency/sound recorded using a sensing device is minimal, which leads to erroneous in classification. Every class of insect needs to be reared in laboratory colonies with standard environmental parameters. Erroneous classification in the detection of insect pests due to similarity in the frequency/sound recorded.

Based on the above analysis related to characteristic features (wingbeat, Sound) and morphological features (Shape, Size, Color), if the experiment is done on insects grown in entomological research laboratories, then we can use characteristic features for classification because the insects will grow in uniform environmental parameters. Also, if the experiment is done on insects grown in agriculture fields, it's better to make use of morphological features to get accurate classification results, but experiment set-up for morphological analysis costs more compared to characteristic behavior analysis.

INSECT IMAGE DATASET AND PREPROCESSING FOR CLASSIFICATION

The image acquired by any image capturing setup cannot be directly used for classification; the raw image must go through preprocessing procedures before it is fed into any classification model to get results.

Dataset Description

In our work, we have considered five classes of insect species commonly available in the farms of India as dataset, the utilized classes of the insect species are Auchenorrhyncha, Diptera, Heteroptera, Hymenoptera, and Lepidoptera. Here we are trying to predict what class of insect does the image belongs to. For the chosen classes of the insects, we have considered a total of 151 images for each of the selected individual classes, and then finally, we have a total of 755 insect images in the dataset. The images required for the dataset were taken from Kaggle – Arthropod taxonomy orders object detection data set, which consists of images recorded from the agriculture fields.

Image Augmentation

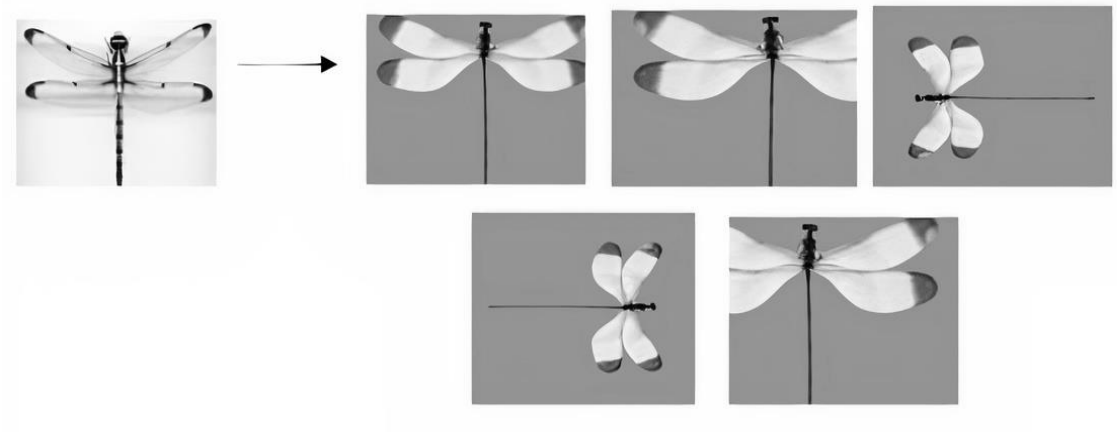

Figure 2. Augmentation of the original image using flipping, zooming, and rotation.

A total of 32 images from each of the five classes was downloaded from Kaggle and manually validated [29]. Data augmentation was used during the data preparation phase to increase the dataset size to 755 images. The original image set was split into two parts: training and testing. To learn effectively and avoid overfitting, classification models require a large corpus of training data. To increase the images in dataset, the dataset was artificially expanded by image augmentation using various processing methods or a combination of multiple processing methods, such as random rotation, shifts, and flips, as shown in Figure 2. The augmentation procedures used are as follows:

- Horizontal flipping
- Vertical flipping
- Zooming
- Rotate

Normalization and Feature Extraction

The selected raw images should be normalized, and the dimension of the image will be reduced as per the requirement so that it will be easy for preprocessing to extract the features and train them. The parameters which we have employed for the selected classes of the insect species in our project are as follows: Length of the insect, Size of the insect, Shape of the insect, Color of the insect and Texture of the insect species. We examined the performance across all data sets by

employing a pooling strategy known as global max-pooling (which uses the maximum value for each filter layer) [28]. Other dimensionality reduction strategies could have been used, but this max-pooling strategy dominates current Image classification applications.

INSECT IMAGE CLASSIFICATION USING MACHINE LEARNING TECNIQUES

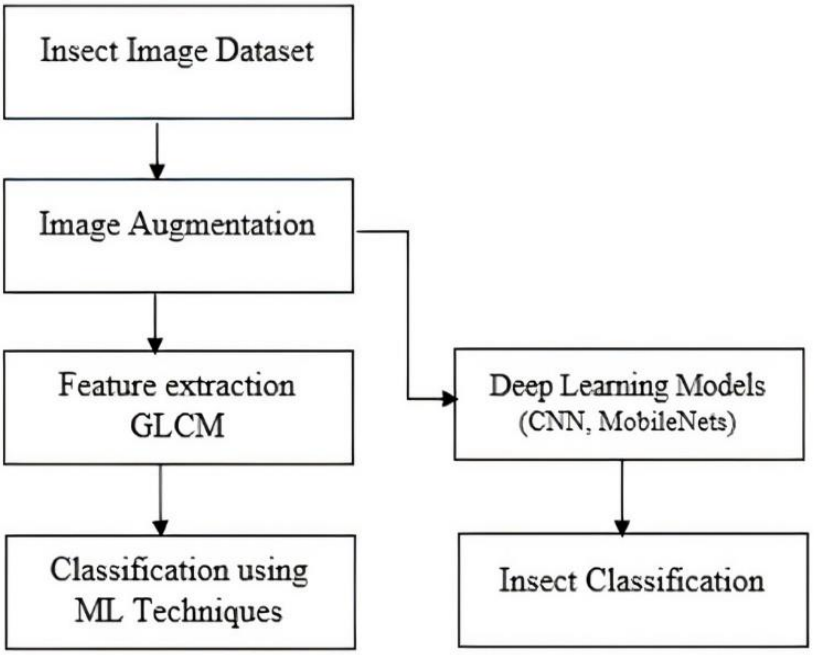

Figure 3. Insect image classifier framework.

Image classification on preprocessed images is applied as shown in Figure 3, classification models such as Support Vector Machine (SVM), MobileNet, Convolutional Neural Networks (CNN) is applied on preprocessed images.

Machine learning is a technique where a machine automatically learns to make accurate classifications or predictions based on past observations. Some good examples of classification using machine learning techniques are text categorization, fraud detection, natural language processing, bioinformatics, etc. [30]. here in our experiment same machine learning techniques, such as “Decision tree”, “Linear SVM”, “Quadratic SVM”, “Cubic SVM”, and “Fine Gaussian SVM”, are applied to the insect image dataset to check the classification accuracy. Unlike deep learning classification models for classification, the machine learning techniques require manual “feature extraction” to be applied on insect image datasets. Once after feature extraction, the extracted features from insect images will be fed into the machine learning algorithms for classification purposes mentioned in Table 1.

Gray-level co-occurrence matrix

Gray-level co-occurence matrix (GLCM) is a statistical method of examining an image’s texture that considers the spatial relationship of pixels in the gray-level co-occurrence matrix (GLCM) [31]. The GLCM functions characterize an image’s texture by calculating how often pairs of pixels with specific values and a specified spatial relationship occur in an image, creating a GLCM, and then extracting statistical measures from the matrix [31]. Here in our experiment GLCM is applied to five classes of insects such as Auchenorrhyncha, Diptera, Heteroptera, Hymenoptera, and Lepidoptera. The list of statistics considered in GLCM feature extraction are as follows:

$$\sum_{i,j=0}^{N-1} P_{i,j}(i-j)^2. \quad (1)$$

Table 1. Comparison of various machine learning algorithms used in the experimental study.

Classification Model	Interpretability	Model Flexibility
Decision Tree	Easy	It makes many leaves to provide fine distinctions between classes.
Linear SVM	Easy	Provides a simple linear separation between classes used for classification.
Quadratic SVM	Hard	The quadratic decision function can separate the data non-linearly.
Cubic SVM	Hard	Cubic refers to the way the Gram matrix $G(x_i,x_j)$ is created for classification.
Fine Gaussian SVM	Hard	Provides finely detailed distinctions between classes, with kernel range set to $(p/4)^{1/2}$

Equation (1) defines how the **contrast** is used to measure the local variations in the GLCM co-occurrence matrix.

$$\sum_{i,j=0}^{N-1} \frac{(i-\mu_i)(j-\mu_j)}{\sqrt{(\sigma_i)}(\sigma_j)}. \quad (2)$$

Equation (2) represents the **correlation** is used to measure the join probability among pair of pixels.

$$\sum_{i,j=0}^{N-1} P^2{}_{i,j}. \quad (3)$$

Equation (3) represents the **energy** is used to measure the uniformity using squared sum in GLCM.

$$\sum_i \sum_j \frac{1}{1+(i-j)^2} P_{i,j}. \quad (4)$$

Equation (4) represents the **homogeneity** is used to compare the elements between GLCM and GLCM diagonal.

INSECTS IMAGE CLASSIFICATION USING MOBILENETS

MobileNets are based on a streamlined architecture that builds lightweight deep neural networks using depth wise separable convolutions [32]. In this experimental study, we used the pretrained tool Teachable-Machine, a web-based tool for quickly and easily creating deep learning models. MobileNets is a classification model is composed of separable convolutions of two layers, such as "Depth wise convolutions" and "Pointwise convolutions". Depth wise convolutions for the input depth is written as follows:

$$\hat{G}_{k,l,m} = \sum_{i,j} \hat{K}_{i,j,n} * F_{k+i-1,\, l+j-1,\, m}. \quad (5)$$

In the equation (5), $\hat{K}$ indicates depth-wise convolutional kernel size is applied to the mth channel in F to produce filtered output feature map $\hat{G}$. Pointwise convolutions are the sum of depth-wise is written as follows:

$$\mathbf{D_K * D_K * M * D_F * D_F + M * N * D_F * D_F}. \quad (6)$$

MobileNet employs $3 \cdot 3$ depth-wise separable convolutions, which consume 8 to 9 times less computation energy than standard convolutions while sacrificing only a minor amount of accuracy [32]. The experiment was done with five classes of insects, such as Auchenorrhyncha, Diptera, Heteroptera, Hymenoptera and Lepidoptera.

MobileNets based Image Classification Model

The MobileNets makes use of the transfer learning-based algorithm to classify the given insect images as shown:

Algorithm: MobileNets Classification Model

Input - set of insect images with the class label **Output** - classification of detected insects

Step-1: Give different class labels for training data
Step-2: Load the label to the dictionary
Step-3: Provide Training images from any source or a path you choose
Step-4: Load and format your image for use with TM2 model
Step-5: Image is reformatted to a square
Step-6: Return output inference
Step-7: Load the model to any edge device
Step-8: Record image from any source, Resize and flip the image so it's a square and matches training
Step-9: Classify and display the result.

INSECT IMAGE CLASSIFICATION USING CNN

Convolutional neural networks (CNNs) can be used to extract image features with deep learning models trained on real-world data. Without the need for manual feature extraction, deep learning models can learn features by training on examples. They reduce the number of network units. This means that there are fewer parameters to learn, which reduces the likelihood of overfitting because the model is less complex and produces more accurate results [6]. there are two essential processes involved in the training of any neural network: "Forward Propagation – Receive input data, process the information, and generate output" and "Backward Propagation – Calculate error and update the parameters of the network".

Algorithm: CNN based classifier

Input - set of insect images with the class label
Output - classification of detected insects
Step-1: Load the input images from the insect dataset.
Step-2: Define filter matrix $\mathbf{Z_1 = X * f}$ for image convolution.
Step-3: Apply "Activation function" on the result

$$\mathbf{A = sigmoid(Z_1)}$$

Step-4: Initialize weight and bias matrix and apply a linear transformation $\mathbf{Z_2 = W^T.A + b}$
Step-5: Apply sigmoid function to get final output

$$\mathbf{O = sigmoid(Z_2)}$$

Step-6: Change in $\mathbf{Z_2}$ with respect to Weight W

$$\mathbf{Z_2 = W^T.A^1 + b} \text{ Where } \mathbf{A^1 = \partial Z_2/\partial W}$$

Using trained CNNs, automatic detection and classification of insects can be done automatically through video and time-lapse images, which can be used for monitoring. Due to the automated detection process of pests and pollinators employed by utilizing the CNN image classification model, farmers can detect pests at an early stage and take necessary steps to avoid crop loss.

In our experiment, we have considered five classes of insect species for the datasets. We have considered 151 images for each of the selected individual classes, and then finally, we have a total of 755 images in the dataset of insect species. The image dataset for our project has been taken from Kaggle, an online community for finding and publishing datasets. The characteristic parameters which we have employed for the selected classes of the insect species in our experiment are as follows: Length of the insect, Breadth of the insect, Height of the insect, Size of the insect, Shape of the insect, Color of the insect and finally the texture of the insect species. The selected species of the insects are then fed into the convolution neural network where they would undergo through the several layers of the network and are then filtered accordingly based on the parameters that we have defined and finally, we get the desired result, in other words, the specific class of the insect that was after.

RESULTS AND DISCUSSIONS

The classification results obtained by applying the methods discussed in the previous section on the insect images mentioned in Table 2.

Table 2. Different classes of insect species data set considered in the experimental study.

Insect Class	Number of Insects
Auchenorrhyncha	151
Diptera	151
Heteroptera	151
Hymenoptera	151
Lepidoptera	151

CLASSIFICATION RESULTS OF MACHINE LEARNING TECHNIQUES

The experiment was conducted on five classes of insects such as Auchenorrhyncha, Diptera, Heteroptera, Hymenoptera and Lepidoptera. The results are represented using a confusion matrix.

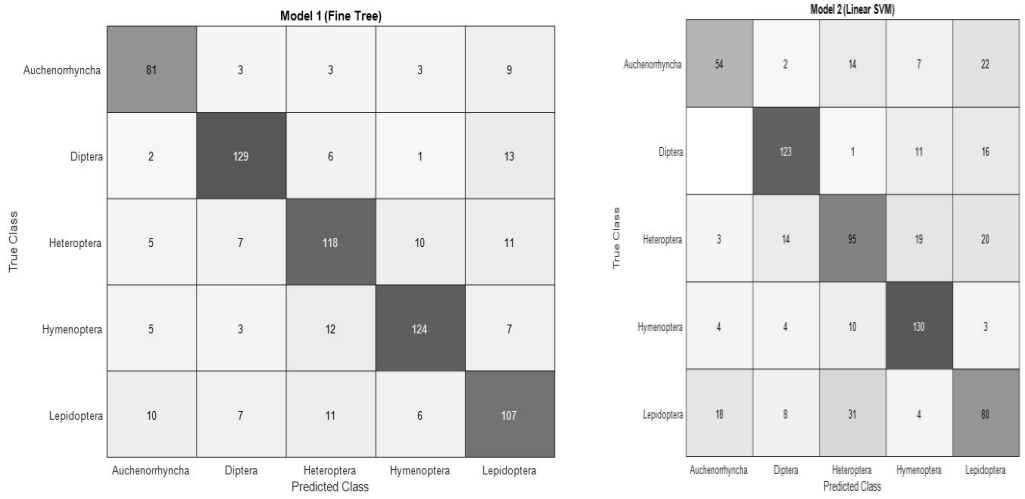

Figure 4. (left) Output-based confusion matrix after applying decision tree technique on the insect image dataset, (right) output-based confusion matrix after applying linear SVM technique on the insect image dataset.

CLASSIFICATION RESULTS OF MOBILENET'S

The MobileNets classification model is applied on insect images captured in smartphone for classification, as shown in Figure 7.

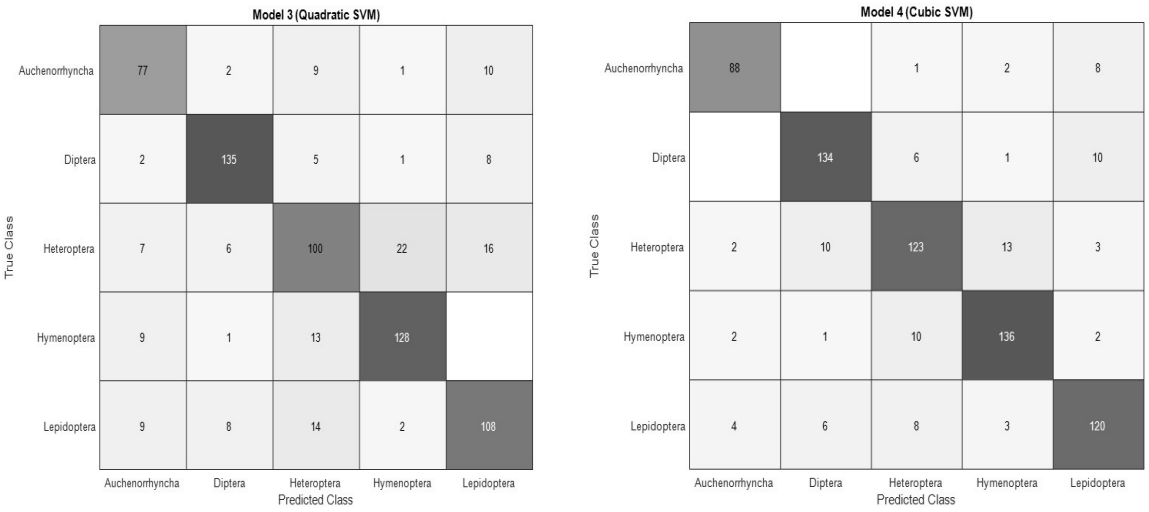

Figure 5. (left) Output-based confusion matrix after applying quadratic SVM technique on the insect image dataset, (right) output-based confusion matrix after applying cubic SVM technique on the insect image dataset.

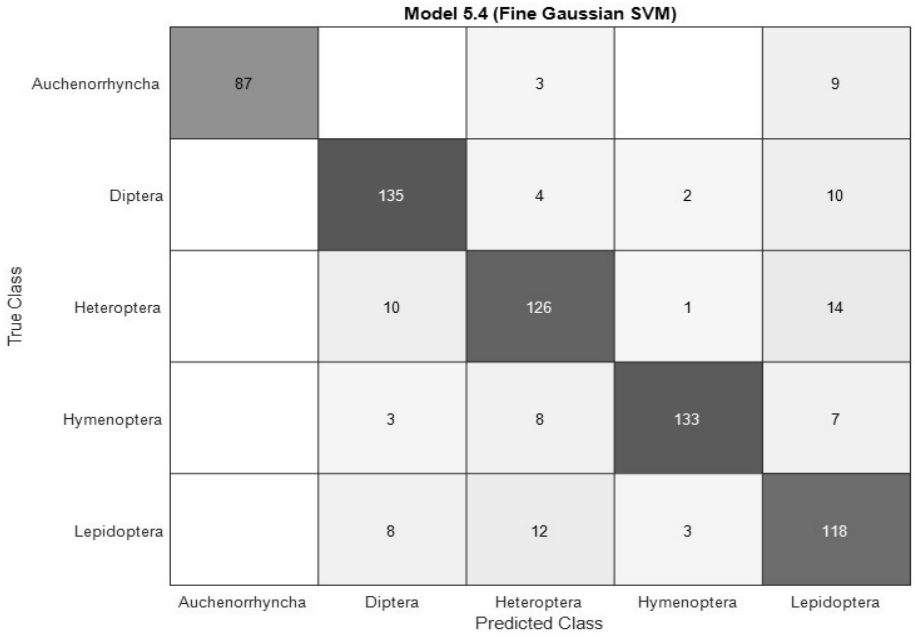

Figure 6. Output-based confusion matrix after applying fine gaussian SVM technique on the insect image dataset.

The classification model was tested using 150 images consisting of all five insects considered in the experimental study. Out of 150 images considered for validation, the MobileNet-based classifier classifies 135 images to their valid class, so the MobileNet based classification model gives more accurate classification results up to 90 % compared to machine learning models discussed in the previous section.

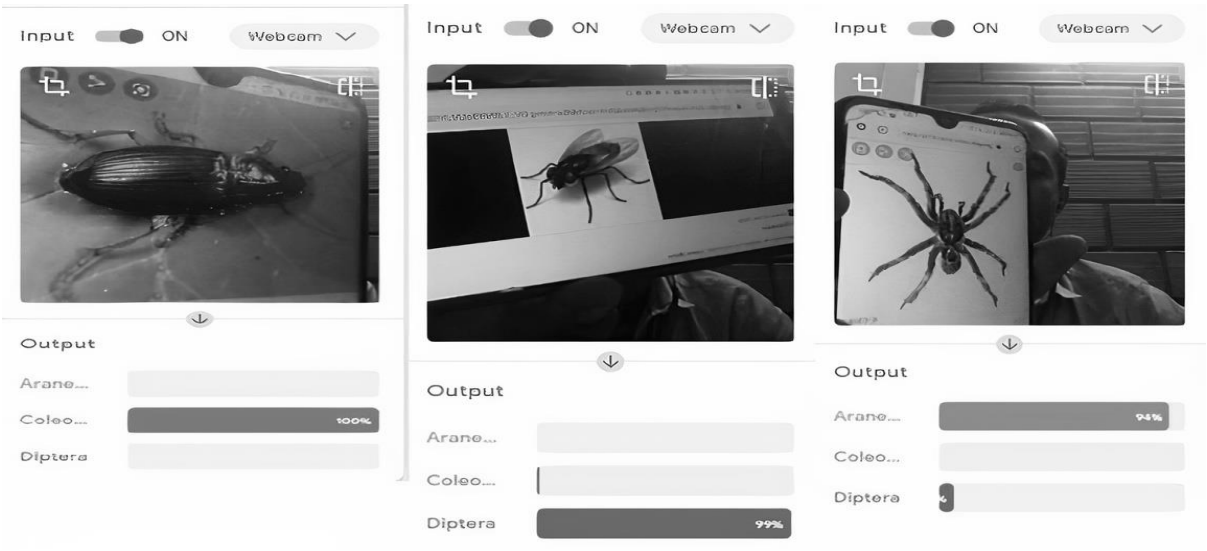

Figure 7. Simulation of insect classification in edge devices using MobileNet-Transfer learning technique: (left) classification of Coleoptera class insects; (middle) classification of Diptera class insects; (right) classification of Arena class insects.

CLASSIFICATION RESULTS OF CNN

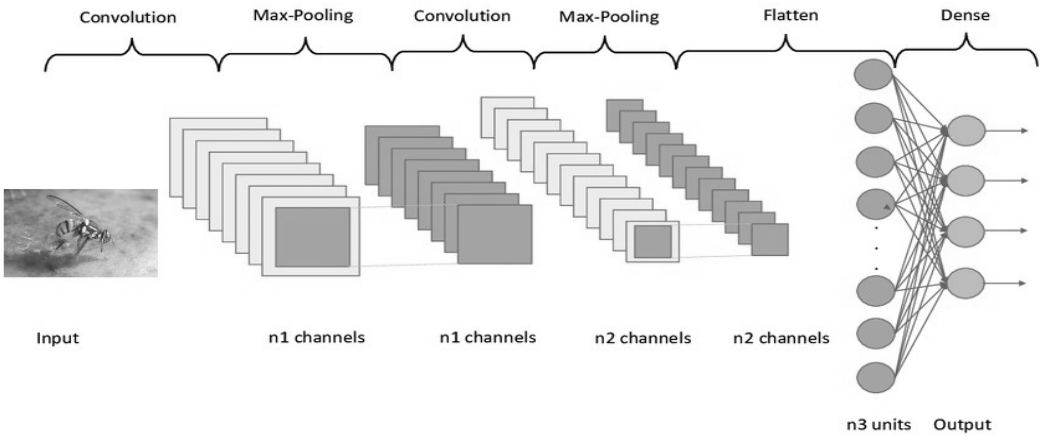

Figure 8. Layer wise output from proposed CNN model for insect classification.

The algorithm takes images as the input and assigns importance to various parameters in the image and differentiates one image from another. The processing of images undergoes through different types of layers present in the Convolution Neural Network, which are Convolution Layer, Max Pooling Layer, ReLU layer, Flattening Layer, and Softmax Layer as shown in Figure 8. An image is selected from the dataset and is set for preprocessing. The image is used for Normalization. Here the dimension of the image is reduced as per the requirement so that it will be easy for preprocessing to extract the features and train them. The images are trained iteratively in terms of epochs.

An epoch represents the number of passes the machine learning algorithm has made through the entire training dataset. Typically, datasets are organized into batches. The dataset's internal model parameters are updated with each epoch as shown in Figure 9.

In the testing process, the selected image will be compared with the 755 trained images from 5 different classes of insects and matches with a particular class of insect. Here, re-training is not required once training is done.

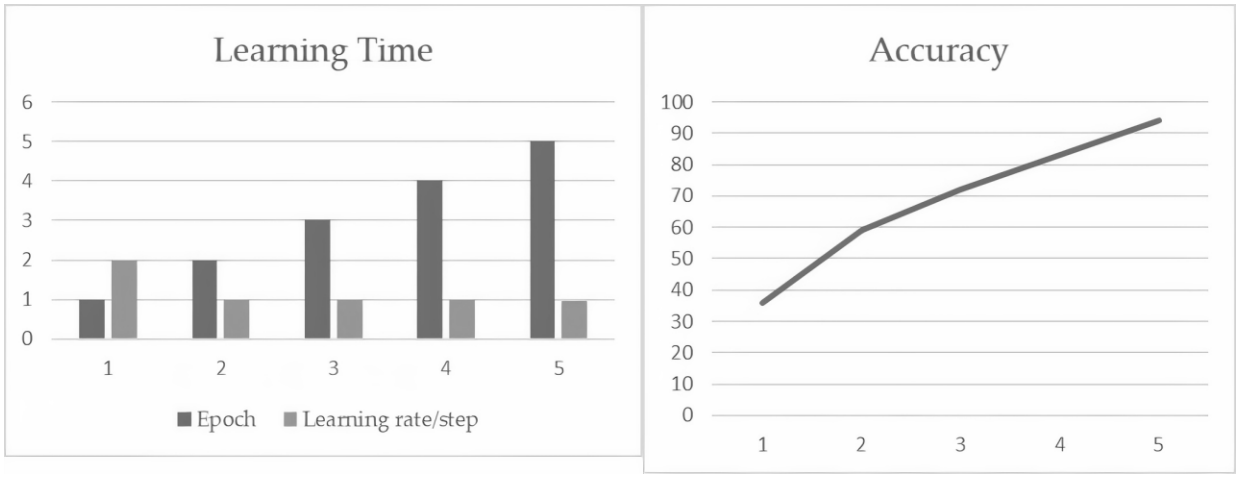

Figure 9. (left) epoch wise Learning rate, (right) accuracy achieved in each Epoch by Deep Learning based Classification model.

As shown in Figure 10, The classification model was tested using 150 images consisting of all five insects considered in the experimental study. Out of 150 images considered for validation, the CNN-based classifier classifies 142 images to their valid class, with a classification accuracy of 94,6 %.

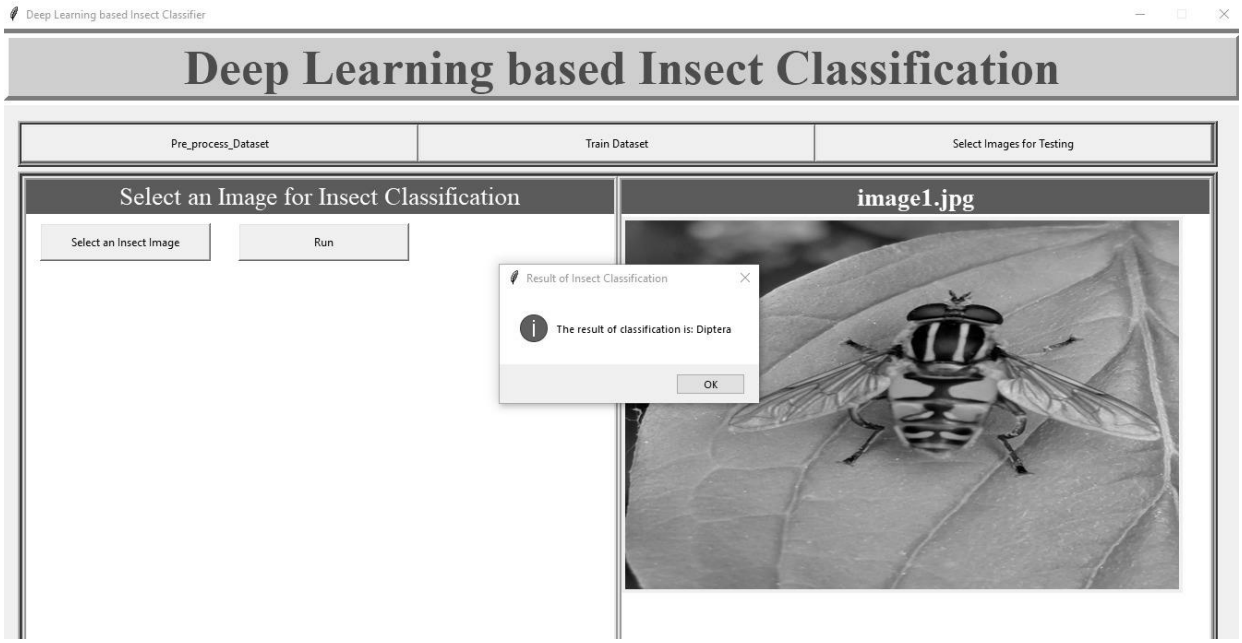

Figure 10. Sample output of proposed CNN based insect classifier on Diptera class insect.

The misclassification was only when classifying the Diptera class of insects due to their resemblance in morphological features with other classes of insects used in our experimental study. The classification model's accuracy is calculated by using the following equation (7):

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FN+FP}. \quad (7)$$

The denominators TP, TN, FN, and FP represent "True-positive", "True-negative", "False-negative", and "False-positive", respectively, indicating the total number of classifications done by the model. The numerators TP and TN represent "True-positive" and "True-negative", respectively, indicating the total number of correct classifications done by the model.

The experiment for insect image classification was conducted using Machine learning techniques and Deep Learning techniques on commonly found insects in indian region to analyze the performance of various classification models on insect image classification as shown in Figure 11.

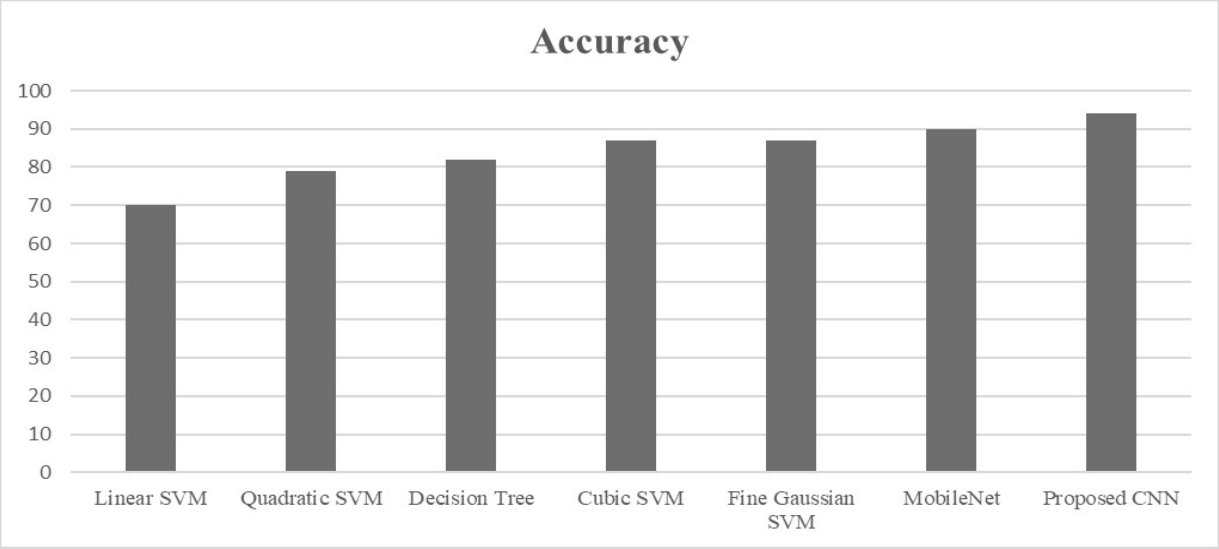

Figure 11. Comparison on Classification accuracy of various models used in the experimental study.

CONCLUSION

In this article, the insects generally present in the agriculture fields of India such as Auchenorrhyncha, Diptera, Heteroptera, Hymenoptera and Lepidoptera were classified and detected by applying various machine learning and deep learning algorithms, and the results were compared. All the insect images obtained from the agriculture field-based dataset were rescaled, preprocessed, and augmented to improve the accuracy of classification models. In the agricultural field, achieving the highest accuracy in real-time is a major challenge in the presence and absence of sunlight, dirt such as fallen leaves and flowers, etc. The classification accuracy of various machine learning and deep learning algorithms is compared, including Fine Tree, Linear SVM, Cubic SVM, Fine Gaussian SVM, MobileNet Model, and CNN model. The results demonstrated that the deep learning-based CNN model has the highest classification accuracy of 94.6 percent when compared to all other classification models tested in the study. The pest detection algorithm (CNN) based on Deep Learning outperforms other learning techniques in detecting insects with class labels for larger insect datasets. The proposed classification methods will be more beneficial to farmers in terms of early detection and classification of insects in agricultural fields and making necessary decisions in advance to improve crop quality while using fewer pesticides to control harmful insect pests and reduce the threat to the environment and pollinators.

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AUGMENTED REALITY APPLICATION DEVELOPMENT USING UNITY AND VUFORIA

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ABSTRACT

This article presents a method to develop an application based on Augmented Reality technology in a Unity development environment. The article presents two test scenarios that give an insight into the possibilities of augmented reality applications. The first scenario is a presentation of a simple game based on a graphic marker and its generated content in the form of a maze. By physically moving the marker in front of the camera, the maze and the ball inside is moved. The second scenario includes a simulation environment of a collaborative robot in the form of an augmented reality application that offers the possibility of planning the robot's trajectories. The possibilities of this technology are endless and cover a large segment of application development from educational to industrial applications. Marker based Augmented Reality using predefined visual markers embedded within the system, physical world objects are detected for superimposition of virtual elements. The test application was designed using a combination of Vuforia, Unity 3D platforms, and the mobile phone used was an Android based Xiaomi Redmi 10 pro phone. This article focuses on the implementation challenges faced whilst designing Augmented Reality applications on mobile platforms.

KEY WORDS

augmented reality, image recognition, Unity 3D, Vuforia

CLASSIFICATION

JEL: L86

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INTRODUCTION

Augmented reality (AR) is a kind of virtual (apparent) extension of reality, when, for example, virtual elements can be projected into the real environment by looking around with a mobile phone camera or using glasses created for this purpose [1]. The horizon of meaning and appearance of augmented reality is very wide, but all of its forms have common features. The most important of these is that virtual objects are integrated into the context of the material world in real time. The process, which is definitely a part of some kind of mediatized communication, is inseparable from the technology that creates augmented reality, as it requires optics that detect the outside world (and other sensors), as well as a display that meets the requirement of natural fidelity. With the help of applications, information about the material world becomes interactive and digitized, thus becoming storable and easier to access, while being superimposed on the real world as an information layer. Augmented reality is therefore device-dependent, technically determined and convergent: it appears in the context of smartphones, films and books, and even medical visual diagnostics. This work explores the use of Unity 3D, the integrated game development tool for multiple platforms. It uses the extension of the software development kit developed by Qualcomm for mobile devices. People can experience AR, which is also known as hybrid reality in the Unity 3D environment. The application of AR technology in Unity 3D can be reflected through the design of a game and the basic use of reality enhancement can be explored.

RELATED WORK

The research discussed by Sarosa et. al. is about developing the AR system that will improve the learning process of character education by helping the teacher to provide the new interactive tools for teaching the students [2]. Desiertot et. al. aims to apply the augmented reality (AR) technology in storytelling to enhance and give a more motivating and fun reading experience to children. The primary objective of this study is to develop a bilingual AR children storybook mobile application called GoonAR [3]. Nazar et. al. are developing and measuring the usability of the Augmented Reality App used for learning Chemistry, focusing on the concept of molecular geometry. AGILE model of development was employed to step by step development, starting from the analysis of the curriculum and need assessment, followed by design, development, deployment and evaluation [4]. The work done by Koca et. al. developed an augmented reality-based education application for preschool children using Unity 3D Platform and Vuforia SDK. In the application developed for Android phones, when users display the card of one of the different animal pictures defined in the Vuforia database in the phone camera, they see the 3D character defined for that photo and hear the character's voice [5]. Subhashini et. al. presented a remarkable arrangement that utilizes augmented reality to make the learning measure more interactive and fascinating. The application when focused on text or image shows significant 3-dimensional (3D) model or video on the smart phone screen [6].

RESULTS AND DISCUSSION

AR applications can be developed using a variety of tools and frameworks, including Unity and Vuforia. Unity is a popular game engine and development platform that can be used to create AR applications. It provides a wide range of features, including a powerful editor, a scripting API, and a large community of developers. Unity supports a variety of platforms, including iOS, Android, and Windows, and can be used to create AR applications for smartphones, tablets, and head-mounted displays (HMDs) such as the Hololens [7]. Vuforia is an AR development platform that can be integrated with Unity to create AR applications [8]. It provides a variety of features, including image and object recognition, and support for 3D models and animations. Vuforia also includes an SDK (Software Development Kit) for Unity,

which allows developers to easily integrate AR functionality into their Unity projects [9]. The data stream of the AR SDK is divided into four separated modules: camera input, object database, object tracking and matching and display output as depicted in Figure 1.

As shown in Figure 1 the first step is to design and import the target image in any image editing software. This can be a logo or a digital ID in the form of a QR code [10]. The next step is to design the AR experience elements such as the 3D object with or without animation using any CAD software for 3D modelling. Table 1 shows a smartphone specification used for AR application testing.

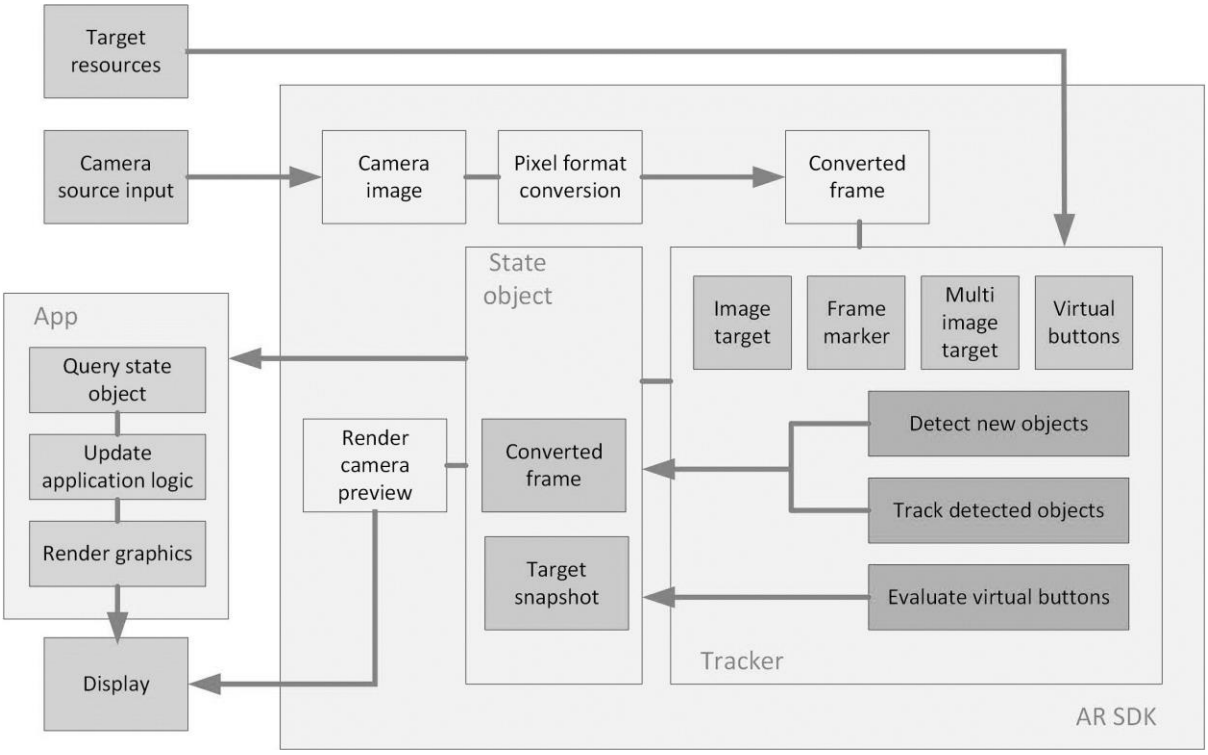

Figure 1. AR subsystem data flow diagram.

Table 1. Smartphone specification used for testing.

Chipset	Qualcomm SM7125 Snapdragon 720G (8 nm)
Processor	Octa-core (2x2.3 GHz Kryo 465 Gold & 6x1.8 GHz Kryo 465 Silver)
Memory	6GB RAM
GPU	Adreno 618
Internal Storage	128GB
Main Camera	Quad 64 MP, f/1.9, 26mm (wide), 1/1.72", 0.8µm, PDAF 8 MP, f/2.2, 119˚ (ultrawide), 1/4.0", 1.12µm 5 MP, f/2.4, (macro), AF 2 MP, f/2.4, (depth)

TEST SCENARIO 1 – LABYRINTH GAME

The aim of this test scenario is to create an augmented reality game in which the user have to deliver a ball through a maze to the exit, as if the virtual ball were affected by gravity. This labyrinth is actually a 2D image printed on an A4 sheet, which can be transformed into a 3D model with the help of AR, Figures 2-4. To create the project, the Unity 3D development environment with the Vuforia plugin can be used [11]. The former is responsible for creating the 3D environment, program functions and models, while the latter is responsible for placing

it in real space. First of all, the installation of all components is needed, including Vuforia. An AR Camera and an image target needs to be dragged, which can be placed under this as Parent.

Vuforia Online's target manager must be used to create the image target, which will be the maze image file itself. After the image import, these components can be placed in the space. It should be placed neither too close nor too far away. Then a Plane can be created, which can be placed in the plane of the image target, or a little below it. The black walls can be built in the space from cubes (first the horizontal ones, then the vertical ones), and then the ball can be placed also. An 'Ice' material can be added to everything to ensure sliding between the virtual surfaces and color the ball red and the walls black. A gravity parameter can be defined for the Ball. After that, an empty Cube can be placed, it will be the spawn point of the ball. A script can be also added to the ball so that if it falls below the plane of the Plane, it will automatically return to the spawn point.

The ready-made Plane can be assigned and the ball to the public variables of the Script. All the Android plug-ins can be easily downloaded and can already build the application in .apk form.

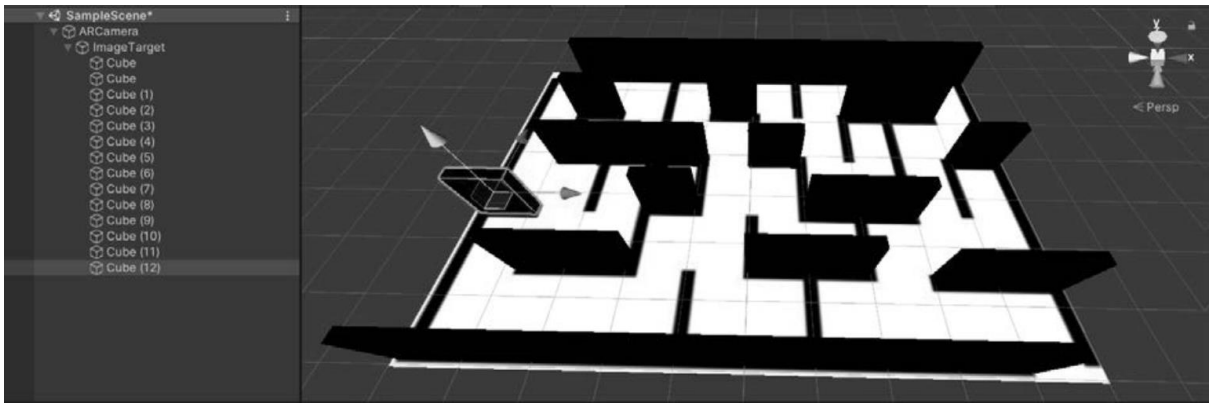

Figure 2. Placement of horizontal walls.

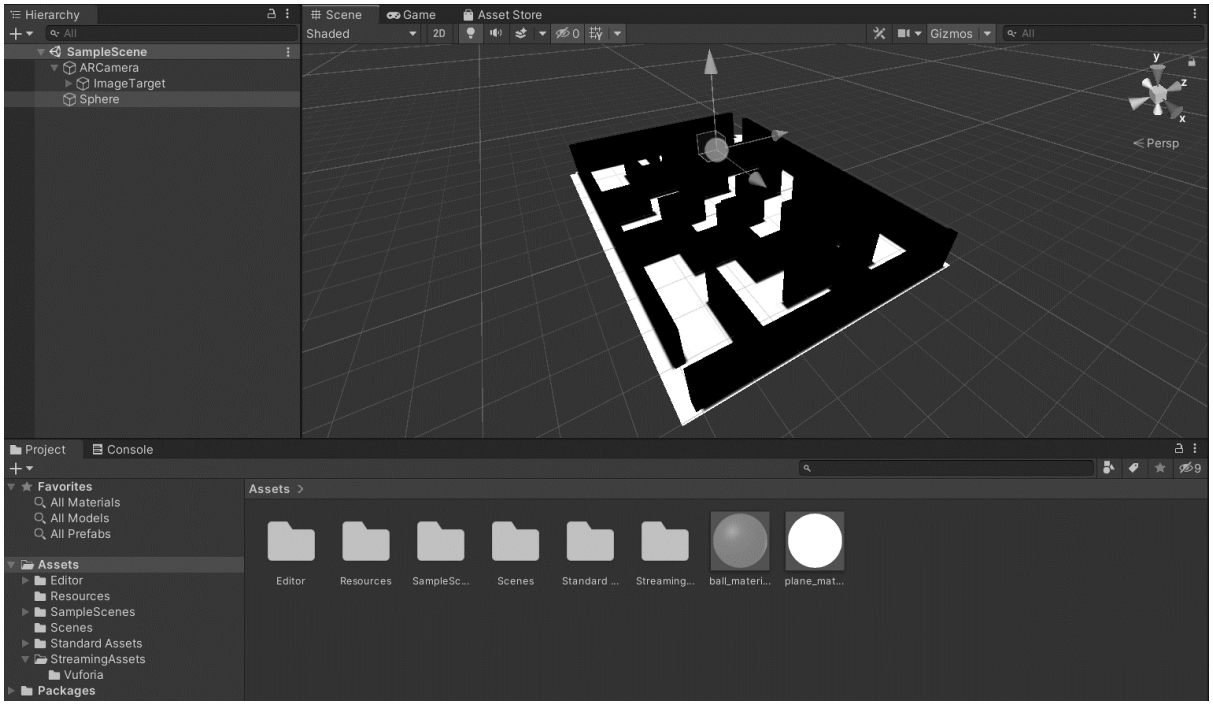

Figure 3. Ball positioning.

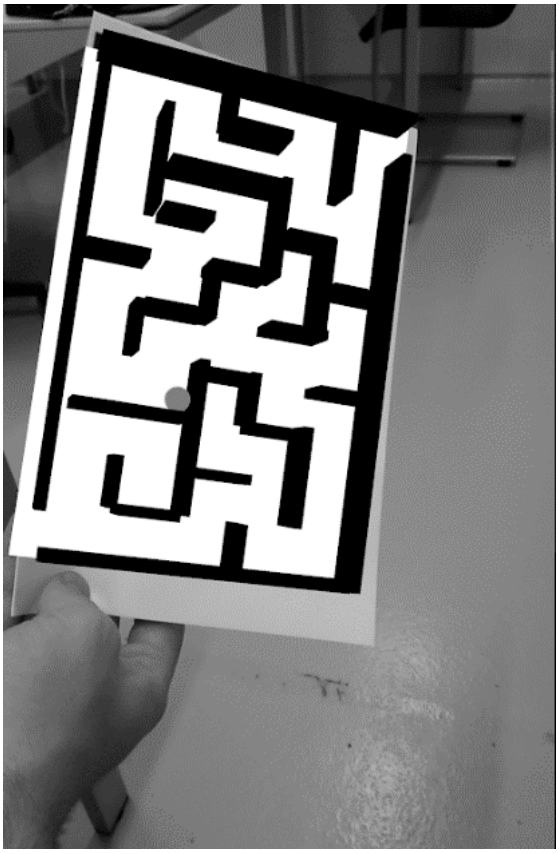

Figure 4. Completed application on Android.

The Unity video game engine has won several awards since its release. In 2010, it won the Technology Innovation Award in the software category, which is presented every year by the American newspaper The Wall Street Journal. In 2006, at the Apple Design Awards, the game engine won second place in the category recognizing the best graphics software that can be run on Mac OS X systems [12]. One of its biggest advantages is that it is completely free for personal use, at the hobby level. As a result, there is a large user community and thus a lot of help and documentation can be found. Due to its multiplatform support, programs can be developed even for the following systems: Windows, iOS, Android, OSX, Linux, Nintendo switch, Xbox, Playstation and other supported platforms.

TEST SCENARIO 2 – AR ROBOT CONTROL

The UR5 robot arm by Universal Robots is a popular industrial robot that can be used in a variety of applications, including manufacturing, assembly, and material handling. One way to enhance the capabilities of the UR5 is by using it in conjunction with trajectory planning and simulation software, Figures 5-7. Trajectory planning software can be used to create optimal and safe paths for the UR5 to follow during its operation [10]. The software can take into account the robot's kinematic constraints, such as joint limits, and can also take into account the environment and other objects that the robot may come into contact with. Simulation software can be used to test and validate the trajectory plans created by the trajectory planning software. The simulation software can simulate the UR5's motion, and can also simulate the behavior of the environment and other objects that the robot may come into contact with. This allows users to test and validate the trajectory plans in a virtual environment before they are implemented on the real robot. Additionally, the simulation software can be used to test and optimize the performance of the UR5, such as cycle time, payload, and repeatability, under different scenarios and conditions. This can help to identify any issues or constraints that may

arise during the operation of the robot and allows users to make adjustments before deployment [5]. The UR5 robot model and the corresponding script are taken from github. The downloaded file can be extracted and then imported into the newly created Unity project. It included the model of the robot with the individual segments, as well as their control using a slider. A Reset button can be added as well and a Scale option to the project. Scale can be used to set the size of the robot to a maximum of 4 times the initial value. The control UR5Controller.cs is written in C#.

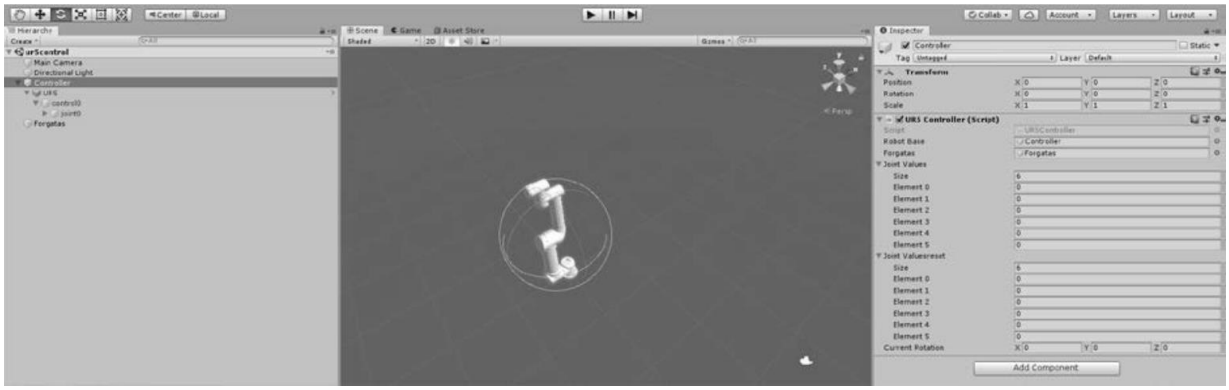

Figure 5. UR5 in Unity environment.

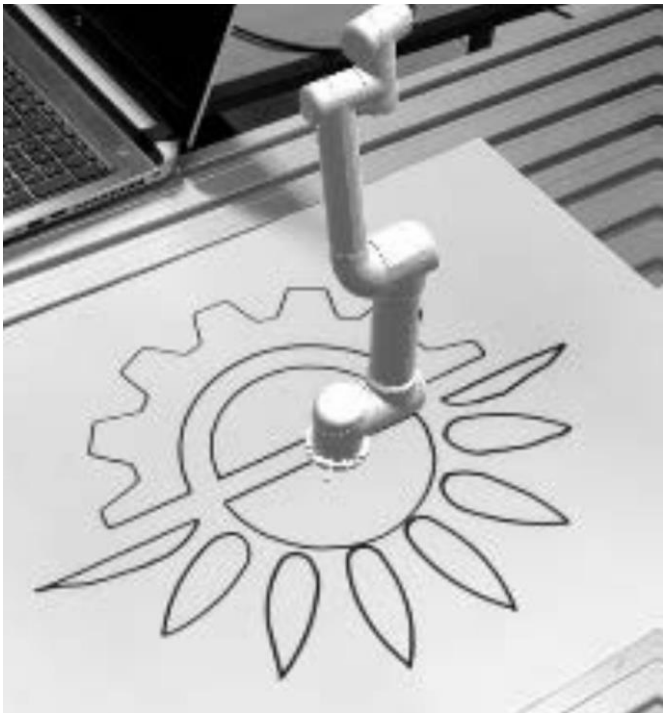

Figure 6. AR application in action.

It can be seen that the individual segments form a parent-child relationship on the Hierarchy tab. At the top level is the Controller. To this, a script can be assigned, in which the inputs are defined on the Inspector tab, these are the public variable game objects in the script. In addition, a Rotation empty object can be created, which contains only one coordinate system, so that the robot returns to its starting position at reset.

Universal Robots UR5 collaborative robotic arms can be used in virtually any industry and any process, and can be used by any worker. The goal of Universal Robots is to make collaborative robot technology accessible to all businesses, regardless of their size.

The difficulty of industrial robot trajectory planning is that in the case of a general six-jointed industrial robot, the state space is also six-dimensional. Randomized pathfinding algorithms

Figure 7. Physical UR5 in action.

are best able to cope with this challenge. Among these, the Rapidly-exploring Random Trees (RRT) and Probabilistic Roadmaps (PRM) procedures are the most significant. The former executes all trajectory planning requests without preprocessing according to the current cell state (so-called single-query procedure), while the latter does this with the help of a previously prepared collision-free map (multi-query approach). To implement the algorithms, a self-maintained environment is created from the ground up in the form of AR application, which contains the necessary geometric and kinematic models, collision detection and trajectory planning algorithms, as well as the visualization of the UR5 used for planning and the calculated robot movements. Tracks designed using the completed program library are tested in a simulated environment and in real life with the help of UR5 collaborative industrial robots, and the experiences gathered in this way are also displayed. As a case study, the automation of two real industrial applications, a pick-and-place and an assembly operation, which fully utilize the implemented feature, was tested. In summary, trajectory planning and simulation software can be used to enhance the capabilities of the UR5 robot arm by Universal Robots. They can be used to create optimal and safe paths for the robot to follow, test and validate these paths in a virtual environment, and optimize the robot's performance before deployment, which can improve the safety, efficiency, and overall performance of the robot.

CONCLUSIONS

Virtualization systems allow manufacturers to study the virtual elements of the system, enabling them to analyse and design where real-world changes are needed. Virtual reality reduces unnecessary design by giving the engineer the opportunity to test changes before the final solution is created. Virtual reality training programs can simulate realistic and risky scenarios in a manufacturing environment (such as chemical spills, dangerous machinery, and

noisy environments) without putting workers in actual danger. If the inevitable does happen, employees will have usable experience and are more likely to respond appropriately to the situation. Perhaps one of the most significant indicators of the industrial potential of augmented and virtual reality can be seen in the change in recruitment by major engineering companies. Lately, companies have been extremely open and actively recruiting people with degrees in game design. These young engineers are adept at virtual reality and Android and mobile devices, helping to make Industry 4.0 and Internet of Things solutions tangible. As a future work development of a virtual manufacturing assembly simulation system for industry 4.0 platform is considered.

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A FUZZY APPROACH IN THE STUDY OF AMOUNT OF PESTICIDE USE IN AGRICULTURAL SUSTAINABILITY

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ABSTRACT

The level of progress of human civilization what it is now has been possible for, among other issues, the ever increasing use of pesticides in agriculture. The use of pesticides has made it easy to meet the target of one of the basic need i.e. food of such a huge population. Without the use of pesticides we may have to starve to death due to a severe food crisis. But too much use of pesticide is harmful. A pesticide may not be so harmful if it can be used in proper dose i.e. the correct quantity is very important in the exposure (use) of any pesticide. Here arises the need of fuzzy logic that helps framing an appropriate model for proper use of pesticides that can overcome the food crisis. In this article, in order to determine the correct use of pesticides compatible with agricultural sustainability we introduce fuzzy set theory and fuzzy logic to develop fuzzy rule based systems in our fuzzy model. Using five important sustainable indicators in agricultural sustainable development due to pesticides, we introduce here a fuzzy rule based system for the hypothetical fuzzified values of three of the indicators and obtain a fuzzy conclusion. Membership functions are used in the trapezoidal or triangular form to represent the fuzzy numbers associated to each indicators. We get a numerical crisp value for hypothetical data input after the defuzzification process. The discussion about fuzzy model developed in this article provides an approach to build up an way to agricultural sustainable development regarding pesticides.

KEY WORDS

fuzzy logic, fuzzy set theory, indicators of sustainability, linguistic variable, sustainable development

CLASSIFICATION

JEL: C65, Q18, Q19

MSC2020: 00A71, 03E72

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INTRODUCTION

We all know that the sustainability or sustainable development is that which aims at the fulfillment of the needs of the present situation or generation without violating the needs of the future generation. Agriculture sustainability or Agricultural sustainable development is that by which we meet towards one of the basic need (i.e. food) among the present generation without affecting the environmental or ecological, economical and social issues. Sustainability in agriculture must include the policies of healthy ecosystem which contain the indicators such as human health, ecological or environmental safety, production target and food security.

In the period between 1950 to 2000, the world population grew from 2,5 billion to 6,1 billion which means that the population on earth increased more than double in amount in the past 50 years (1950-2000). The United Nations (UN) estimates that, by the year 2050, the population will be around 9,7 billion on earth increasing 30 % more population than in recent year 2020. Currently, the annual growth rate of the world population is about 1,2 % i.e. around 77 million people per year. Most of the population growth occurred in developing countries and it would be continued in upcoming years also.

As a result, for the increasing demand of food production with the increase of population, the use of agrochemicals (pesticides) has been increasing day-by-day in agriculture. Different agricultural poisons i.e. pesticides are used and they may be categorized into insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant- growth-regulators and others based on their activities and target groups (organisms). The global pesticide market divided according to the type of pesticide used as follows: 40 % herbicides, 33 % insecticides, 10 % fungicides and 17 % other types of pesticides. In tropical countries like India, the pesticide market for crop protection is skewed towards insecticides which is about 60 % and obviously the major applications are found in rice and cotton crops. The application of herbicides and fungicides are found to be about 16 % and 18 %, respectively. The major application area of fungicides are in fruits, vegetables, and rice whether the most of the application of herbicides are found to be in rice and wheat crops.

According to World Health Organisation (WHO), around 20 thousand people die annually due to the consumption of pesticides in food and about 25 million workers connected to agriculture are suffering for pesticide poisoning every year in developing countries. Though the issues related to pesticides are always highlighted in the media as well as in research journals, the indiscriminate and excessive use of synthetic toxic agrochemicals leads to many serious consequences like environment pollution, emergence of new pests, development of insect resistance, destabilization in biodiversity, destruction of ben- eficial organism, adverse health impact on society etc.

The report of Bruntland Commission also known as ‘World Commission on Environment and Development’(WCED) after releasing “Our Common Future” in October 1987 enlighted on food security on world population growth, where the commission observed that there are many people in the world who do not get enough food, lacking of nutrients. It also states that, due to overuse of the soil and agrochemicals (pesticides), the pollution in both of water resources and foods increases as the production in the industrialized countries. On the other hand, in many developing nations, farmers especially small farmers are not provided improved technologies and subsidies or incentives by the government for sufficient food production. According to the commission, after the World War-II, pesticides have played a huge role in the increase of food production in spite of receiving clear warnings for over-reliance on chemicals. Pesticides control many pests, weeds, fungi etc and enhance food productivity but its overuse threatens the human health and the lives of the other species such as depletion of commercial fisheries, bird species are endangered and the insects that prey on pests wiped out. A study in 1983 in

developing countries estimated that for pesticide poisoning approximately 10 thousand people died each year and about four hundred thousand people suffered acutely. The effect of pesticides are not limited to the regions where it is used but it travels through the food chain. The effect is less harmful if the level of use of agricultural chemicals is quite low in that areas.

There are more than 1000 pesticides used around the world to ensure food is not damaged or destroyed by pests. Each pesticides has different properties and toxicological effects. Many of the older, cheaper (off-patent) pesticides, such as dichloro-diphenyl-trichloro-ethane (DDT), aldrin, dieldrin, endrin, parathion and lindane can remain for years in soil and water. These chemicals have been banned by countries who signed 2001 Stockholm Convention – an international treaty that aims to eliminate or restrict the production and use of persistent organic pollutants. The toxicity of a pesticide depends on it's function and other factors.

The Food and Agriculture Organization (FAO) of the United Nations estimates that, in developing countries, 80 % of the necessary increases in food production keep pace with population growth are projected to come from increases in yields and the number of times per year crops can be grown on the same land. Only 20 % of new food production is expected to come from expansion of forming land. Pesticides can prevent large crop losses and will therefore continue to play a role in agriculture. However, the effects on humans and the environment of exposure to pesticides are a continuing concern. The use of pesticides to produce food, both to feed local populations and for export, should comply with good agricultural practices regardless of the economic status of a country. Farmers should limit the amount of pesticide used to the minimum necessary to product their crops.

Since the publication of Rachel Carson's landmark book "Silent Spring"(1962), which reveals the horrifying impacts of pesticides like DDT, scientists are continually discovering new and disturbing ways that pesticides threaten our environment and our health. The world learned about dangerous pesticides from Rachel Carson's "Silent Spring" in 1962. Even when the link between the disappearance of birds and the chemical pesticide DDT was made, it was not banned in the United States until 1972. Thereafter, other countries discontinued the use of DDT, as well. Even after Carson had proven that DDT weakened bird eggshells and poisoned lakes leading to fish kills, pesticide manufacturers claimed the small amounts of the chemical apparent in the environment possibly be responsible. In the book, Carson mentioned problems that could arise from the indiscriminate use of pesticides. This book inspired widespread concern about the impact of pesticides on the human health and the environment.

The notion of impact of pesticides in agriculture was introduced by Aktar et al in 2009 [1]. In 2003 Andriantiatsaholiniaina et al. [2] concerns about strategies for sustainable development and introduced a model named by SAFE model in their paper. Also introducing fuzzy set theory, Cornelissen et al. [3] discussed about sustainable development, and Stojanovic introduced a mathematical model using fuzzy set about tourism sustainable development [4].

In this article a mathematical model has been prepared using Fuzzy set theory and Fuzzy logic for an "Agricultural sustainabilty" problem. Sustainability implies an ongoing dynamic development, driven by human expectations about future opportunities, and is based on present ecological, economical and social issues and informations [5]. Agricultural sustainability is the sustainability to agricultural production systems, concerning about ecological, economical and social issues, which can meet of the need for sufficient, safe, and inexpensive food products to achieving agricultural production without possible undesirable side effects [6-8].

As described in previous paragraphs, it is clear that pesticides are needed to meet the food demand of the huge population of the world. At the same time, excessive use of pesticides can cause serious hazards to public health and also it is harmful for the environment. Thus to maintain the agricultural sustainability it is important to determine the safe level of use of

pesticides. In this article a completely theoretical model has been developed based on Fuzzy set theory and Fuzzy logic to achieve this goal.

METHODOLOGY

BASICS OF CLASSICAL AND FUZZY SET THEORY

Classical set i.e. crisp set theory is based on two valued logic. Let us consider the universal set U that consists of elements x (*i.e.* $x \in U$) so that if A is a subset of U (*i.e.* $A \subset U$), then each element x is either a member of A ($x \in A$) or not a member of A ($x \notin A$). In classical set theory, the words 'subset' and 'event' are synonymous, i.e., $x \in A$ means that for element x event A has occurred. A characteristic function μ_A defines an clear distinction between members of A and nonmembers of A. To each x characteristic function μ_A assigns one of two values: $\mu_A(x) = 1$ if and only if $x \in A$, or $\mu_A(x) = 0$ if and only if $x \notin A$.

Let us consider the universal set U_{SI} for the sustainability indicator **(SI)** "Use of Pesticide", where x is the amount of pesticide used (kg/hect) and let **T** be the subset "Tolerable" ($T \subset U_{SI}$). Further, we can consider for sustainability of using pesticides in agriculture of human growth and development as tolerable a maximum (threshold) amount of use of pesticide x_t. If $x \leq x_t$, then the amount of use of pesticide is tolerable, so $\mu_T(x) = 1$. If $x > x_t$, then the amount of use of pesticide is intolerable, so $\mu_T(x) = 0$ (Figure 1a). Thus Classical set (crisp set) theory provides a hard threshold x_t to determine an unambiguous distinction between tolerable amount of using pesticides ($x \leq x_t$) and intolerable amounts ($x > x_t$). A hard threshold is often unrealistic in practice, however, because two nearly indistinguishable measurements x of SI on either side of x_t will be placed in complementary subsets.

On the other hand, fuzzy set theory is based on multivalued logic. Similar to crisp set theory, $\tilde{T}$ is a fuzzy subset of U ($\tilde{T} \subset U$) and a membership function $\mu_{\tilde{T}}$ defines the partial membership or degree of membership in a fuzzy set.

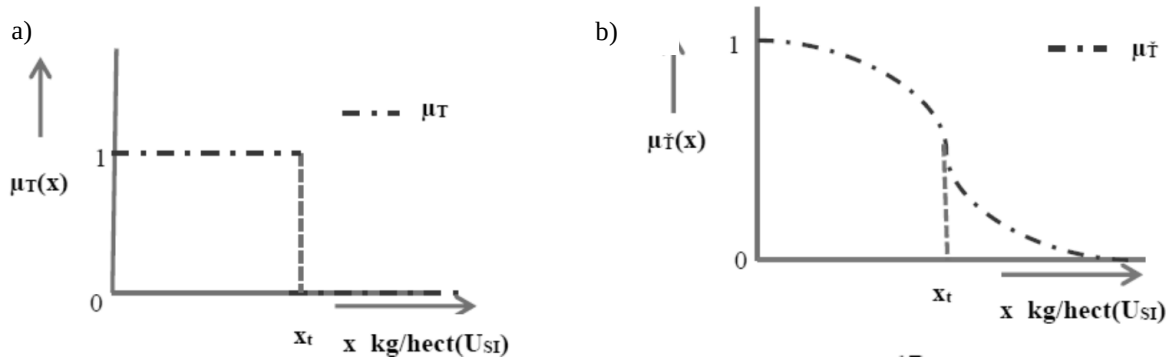

Figure 1. U_{SI} is the universal set for the sustainability indicator (SI) "Pesticide Use" and x is the amount of pesticide used (kg/hect): $x \in U_{SI}$. a) T is the classical subset "Tolerable" ($T \subset U_{SI}$) and characteristic function μ_T defines a hard threshold x_t between tolerable amounts of pesticide used ($x \leq x_t$) and intolerable amounts ($x > x_t$): μ_T assigns to each x one of two values: $\mu_T(x) = 1$ if and only if $x \leq x_t$ or $\mu_T(x) = 0$ if and only if $x > x_t$. b) $\tilde{T}$ is the fuzzy subset "Tolerable" ($\tilde{T} \subset U_{SI}$) and membership function $\mu_{\tilde{T}}$ defines a soft threshold x_t between tolerable amounts of pesticide used and intolerable amounts: $\mu_{\tilde{T}}$ assigns to each x a value $\mu_{\tilde{T}}(x)$ decreasing from 1 to 0 with increasing x.

Thus, membership function $\mu_{\tilde{T}}$ assigns to each x a value from 0 to 1, indicating the degree of membership $\mu_{\tilde{T}}(x)$ of x in $\tilde{T}$. Membership functions, therefore, are functions that maps x from U into the interval [0, 1], Figure 1b.

Consider that the poisons (pesticides) used in agriculture and the universal set for "Pesticide use" U_{SI}. Let $\tilde{T}$ be the fuzzy subset "Tolerable" ($\tilde{T} \subset U_{SI}$). Membership function $\mu_{\tilde{T}}$ is assumed to have a nonlinear form, with degree of membership $\mu_{\tilde{T}}(x)$ for agricultural sustainability in using pesticides decreasing from 1 to 0 with increasing x (amount of pesticides kg/hect), Figure 1b). Hence, fuzzy set theory provides a soft threshold to assess an intermediate value $\mu_{\tilde{T}}(x)$ between tolerable amounts of using pesticides and intolerable amounts. A membership function $\mu_{\tilde{T}}$ defines a soft threshold, which enables a smooth and practical assessment of measurements x of sustainability indicator (SI).

UNCERTAINTY IN AGRICULTURAL SUSTAINABLE DEVELOPMENT

On construction of a mathematical theory on agricultural sustainability model, we must consider the type of uncertainty related to Sustainable Development (SD). Because SD of agriculture will be assessed using selected sustainability indicators (SI), this selection determines how much we know about SD, i.e. how much information is available; and how much we do not know about SD, i.e. how much information is missing. Certainty about SD requires complete and consistent information. To reduce the description of SD to a manageable level and to obtain feasible model, it is necessary to reduce the amount of information.

In this context we can quote the following: "Further, an increasing number of pest control is an issue of conflict because pests are our major competitors on earth. But from our experience gathered so far, it remains a fact that war against pests is neither necessary nor effective. Pesticides themselves beget more virulent pests, they do not control them. Pests are controlled when there is an ecological balance between diverse components of the farming system. One possible alternative could be application of non-toxic environmental friendly formulations and solutions to combat pests. Bio-pesticides, typically microbial biological pest control agents, are the appropriate substitutes for toxic chemical pesticides. Use of bio-pesticides as a component of Integrated Pest Management (IPM) program can considerably decrease the use of chemical pesticides. Ecological or organic farming is also considered as environmentally suitable, economically viable and socially adaptable through which agricultural sustainable development can be attained" (Jaydev Jana, The Statesman, Kolkata, India, 4th December, 2019).

Due to incomplete and inconsistent information, SD has no well-defined meaning. The type of uncertainty regarding an assessment of the contribution of SI to SD, therefore, essentially concerns the meaning of SD. In mathematical terms, this type of uncertainty is known as fuzzy uncertainty.

LINGUISTIC VARIABLES IN FUZZY MODEL

For any fuzzy model, membership functions play fundamental role for which we use such functions to operate "linguistic variables" [9, 10]. In fuzzy set theory, a linguistic variable $\tilde{T}$ may be characterized by: (i) name of $\tilde{T}$, (ii) base variable x of $\tilde{T}$, (iii) linguistic value $\tilde{T}_i$ of $\tilde{T}$ (i = 1, 2, ..., m) and (iv) membership function $\mu_{\tilde{T}}$ of $\tilde{T}_i$. Characteristics of a linguistic variable are shown in Figure 2.

Consider that the amount of pesticide used x, which is a measurement of the SI "Pesticide Use", defines U_{SI}; hence x is the base variable of $\tilde{T}$. If the contribution of "Pesticide Use" to SD is

expressed in terms of "Tolerance" of base variable x, then the name of $\tilde{T}$ is "Tolerability".Three linguistic values $\tilde{T}_i(\tilde{T}_1, \tilde{T}_2, \tilde{T}_3)$ define the contribution of x to SD in linguistic terms: $\tilde{T}_1$ = "Tolerable", $\tilde{T}_1$ = "Moderately Tolerable" and $\tilde{T}_3$ = "Intolerable".

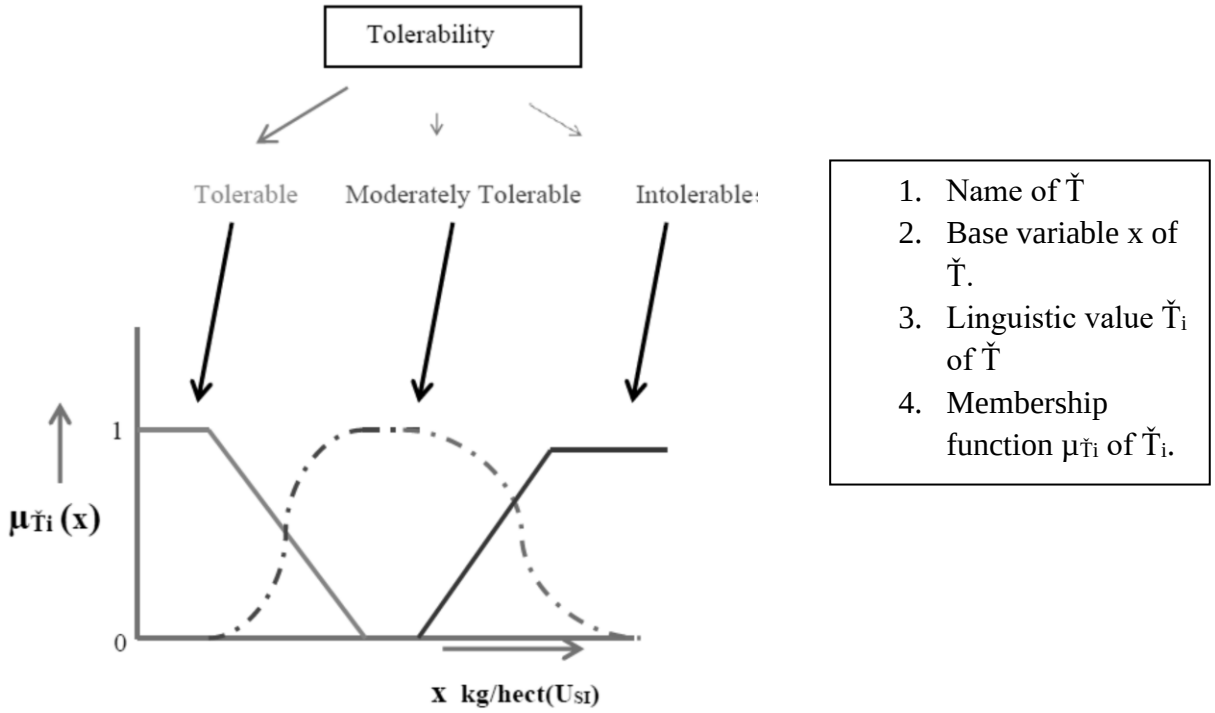

Figure 2. Linguistic variable $\tilde{T}$ is characterized by: (i) name of $\tilde{T}$, (ii) base variable x of $\tilde{T}$, (iii) linguistic value $\tilde{T}_i$ of $\tilde{T}$ and (iv) membership function $\mu_{\tilde{T}}$ of $\tilde{T}_i$.

A linguistic value is a fuzzy subset $\tilde{T}_i$ of the universal set U_{SI} ($\tilde{T}_i \subset U_{SI}$). A membership function $\mu_{\tilde{T}}$ defines to each linguistic value $\tilde{T}_i$ by determining to what degree $\mu_{\tilde{T}i}(x)$ a base variable x is "Tolerable", $\mu_{\tilde{T}1}(x)$; "Moderately Tolerable", $\mu_{\tilde{T}2}(x)$; or "Intolerable", $\mu_{\tilde{T}3}(x)$.

In the sustainability framework, human expectations about SD are expressed as ecological, economical and social issues, for which SI provides numerical data. Use of linguistic variables in fuzzy models enable one to link expectations about SD, expressed in linguistic propositions, to numerical data, expressed in measurements of SI. Use of "Tolerance", for example, enables one to link the proposition "Pesticide Use is Tolerable" to the amount of pesticide used (x kg per hectare).

FUZZY MODEL TO ASSESS AGRICULTURAL SUSTAINABLE DEVELOPMENT

SYMBOLS

Here are two techniques in the fuzzy model used to assess SD: one applying **fuzzy set aggregation** and another which applying **approximate reasoning**. Input in fuzzy model has n sustainability indicators SI_j (j = 1, 2, ..., n) and base variables x_j. In each SI_j there is a membership function μ_{ij} associated with a linguistic value $\tilde{T}_i$ by functioning x_j into the interval [0, 1]. Each x_j with μ_{ij} results in n degrees of membership $\mu_{ij}(x_j)$. Numerical assessment of SD, μ_{SD} is the output of the fuzzy model; i.e. the value of μ_{SD} lies in the interval [0, 1].

FUZZY SET AGGREGATION IN FUZZY MODEL

Steps in fuzzy aggregation

Aggregation operations for the assessment of SD is shown in Figure 3. Five steps are involved: 1st step defines model input, sustainability indicator SI_j and base variable x_j; 2nd step defines linguistic variable $\tilde{T}$ and linguistic value $\tilde{T}_i$; 3rd step constructs membership function μ_{ij}; 4th step computes degree of mem- bership $\mu_{ij}(x_j)$; and 5th step selects a fuzzy set aggregation for $\mu_{ij}(x_j)$ so as to assess model output μ_{SD}.

Computation in fuzzy aggregation

The computations of aggregation for the SD gives a meaningful numerical assessment μ_{SD} which requires careful selection of an aggregation.

Let us assume that 2nd step defines linguistic variable "Tolerability"($\tilde{T}$) and linguistic value "Tolerable"($\tilde{T}_1$). An inclusive (conservative) attitude toward SD means that μ_{SD} is the smallest degree of membership among $\mu_{11}(x_1)$, $\mu_{12}(x_2)$, ..., $\mu_{1n}(x_n)$. In fuzzy set theory, the standard fuzzy intersection makes computation of SD by applying the minimum operator:

$$\mu_{SD} = \min\{\mu_{11}(x_1), \mu_{12}(x_2),..., \mu_{1n}(x_n)\},$$

where 'min' denotes the minimum operator. Consequently, if one degree of membership $\mu_{1j}(x_j)$ is 0, then assessment μ_{SD} is 0.

On the other hand, an exclusive (liberal) attitude toward SD means that μ_{SD} is the largest degree of membership among $\mu_{11}(x_1)$, $\mu_{12}(x_2)$, ..., $\mu_{1n}(x_n)$. In fuzzy set theory,the standard fuzzy union makes computation of SD by applying the maximum operator:

$$\mu_{SD} = \max\{\mu_{11}(x_1), \mu_{12}(x_2), ..., \mu_{1n}(x_n)\},$$

where 'max' denotes the maximum operator. Consequently, if one degree of membership $\mu_{1j}(x_j)$ is 1, then assessment μ_{SD} is 1.

In agricultural sustainability, ecological, economical and social (EES) are the main three pillars. Averaging operations allow a degree of compromise among the n degrees of membership $\mu_{11}(x_1)$, $\mu_{12}(x_2)$, ..., $\mu_{1n}(x_n)$ and determine a value for μ_{SD} between $\min\{\mu_{11}(x_1), \mu_{12}(x_2), ..., \mu_{1n}(x_n)\}$ and $\max\{\mu_{11}(x_1), \mu_{12}(x_2), ..., \mu_{1n}(x_n)\}$. Again in addition, the relative importance (weightage) of each sustainability indicator SI_j may be considered in proportion to its importance.

If ω_j denotes the relative importance (weightage) of SI_j, then a generalized formula of weighted averaging operation is

$$\mu_{SD} = \sum_{j=1}^{n} \omega_j \mu_{1j} x_j, \quad (1)$$

with $\sum_{j=1}^{n} \omega_j = 1$.

In the special case when the relative importance of each SI_j is equal, equation (1) reduces to

$$\mu_{SD} = \frac{1}{n} \sum_{j=1}^{n} \mu_{1j} x_j. \quad (2)$$

Using poisons (Pesticides) in agriculture, assume SD is to be assessed based on five SIs:

- SI_1 is "Effect on **Human health**" (x_1 kg/ hect),
- SI_2 is "Impact on **Environment**" (x_2 kg/ hect),
- SI_3 is "**Production quantity**" (x_3 kg/ hect),
- SI_4 is "**Food quality**" (x_4 kg/ hect),
- SI_5 is "Effect on **Animals and Birds**" (x_5 kg/ hect).

Further assume that associating x_j with μ_{1j} results in degrees of membership $\mu_{11}(x_1) = 0{,}3$; $\mu_{12}(x_2) = 0{,}4$, $\mu_{13}(x_3) = 0{,}6$, $\mu_{14}(x_4) = 0{,}2$ and $\mu_{15}(x_5) = 0{,}5$.

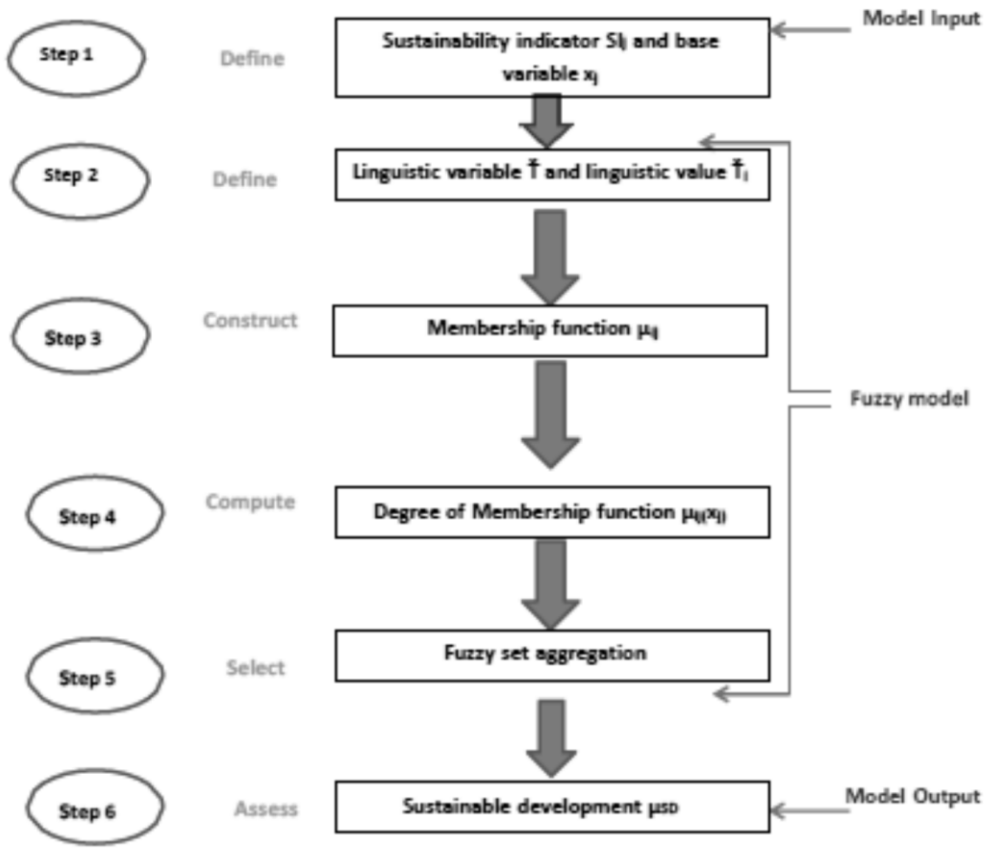

Figure 3. The scheme of a fuzzy model applying fuzzy set aggregation to assess the contribution of SI to SD.

Equation (1) determines the degree of membership μ_{SD} for some specific relativeness of weightage.

NORMALIZATION OF DATA

Normalization is generally used to a scale so that the value of the raw data falls in such a standard (smaller) range, such as from –1 to 1, or from 0 to 1, etc. Normalization is generally required when we are dealing with re-scaling of raw data on different scales especially when values are on larger scale. So normalization brings all the data on same scale. We use here so called 'Max-Min Normalization'(Min-Max scaling) technique so that normalized data of each basic indicator are on a scale between zero (lowest level of sustainability) and one (highest level of sustainability) for fuzzy computations. It may be done as follows.

Let c be the indicator value for the system whose sustainability we want to assess. The normalized value, x_c, is calculated as given in Figure 4.

Between a minimum value $\underline{c}$ and a maximum value $\overline{c}$ of each basic indicator c, we assign a target, which may be a single value or an interval on the real line of the form $[t_c, T_c]$ representing a range of desireable values for the indicator.

SOME SUSTAINABLE INDICATORS AND FUZZY NUMBERS

Indicators of health influence and effect of pesticides on human health

Pesticides are incredibly harmful to human health. Pesticides have been proven to cause reproductive and development effects, cancer, kidney and liver damage, endocrine disruption etc. People are exposed to pesticides when they breathe air where pesticides have been sprayed,

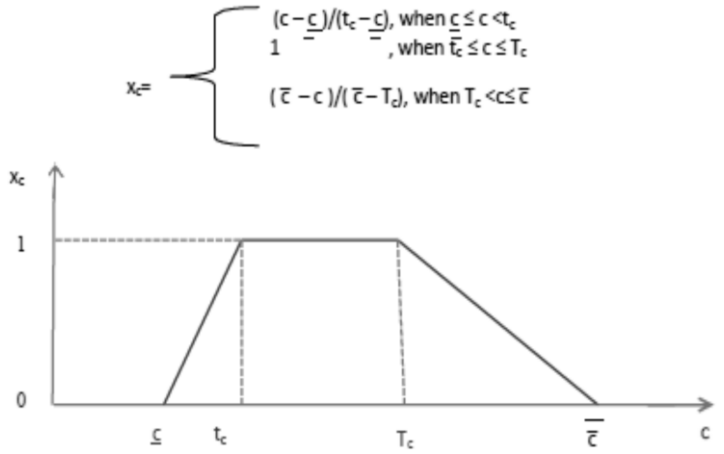

Figure 4. Normalized value of indicator *c*. It is clear that x_c is a trapezoidal function.

drink contaminated water or come into contact with areas where pesticides have been used, such as lawns, parks, lakes and more. Its adverse effects on health depends upon the degree of toxicity, amount of water intake each day and the individual's health. Adverse effects on human health can also be caused by impurities in pesticides.

Children, whose bodies are still developing, are particularly vulnerable. They take inpesticides at home in daycare and at school in the playgrounds, as kids are more likely tocrawl on the ground and put their contaminated hands in their mouths. Research shows that children are even exposed to pesticides in utero. One of these pesticides, chlorpyrifos, has been found to cause irreversible brain damage in infants when they are exposed to theinsecticides during this period. Children ages 5-10 nationwide have significantly higher level of pesticide residues in their bodies than all other age categories.

People and families working on and living near industrial farms are some of the mostat risk populations of these health problems. Farm workers/ Farmers/ Agricultural workers often suffer from short-term effects such as blindness, coma, asthma and death as wellas long-term effects like infertility, birth defects and cancer.

Let us apply, regarding this criteria, fuzzy logic on effect of pesticides on human health indicator using following symbols and terminology.

Suppose *H* is a set of all fuzzy sets which we will use to describe as an human healthindicator related to the amount of a particular pesticide used in agriculture. Notation is as follows:

- H_1 is fuzzy number which indicates that the effect of that pesticide on Human health is "sustainable". For sustainability we may assume that the value of base variable of the membership function may be assumed to be less than 0,4;
- $H_{1/2}$ is fuzzy number which indicates that the effect is not sustainable i.e."moderately sustainable". In this case the value of base variable of membership function may range between 0,4 and 0,6, and
- H_0 is fuzzy number which indicates that the situation is "unsustainable". In this case the value of base variable of membership function must be greater than 0,6.

Therefore, set H contains H_1, $H_{1/2}$, H_0 and $H = \{H_1, H_{1/2}, H_0\}$. Sets H_1, $H_{1/2}$, H_0 indicate the state of sustainability of Human health in using pesticides in agriculture. Based on this indicator we must gain those sets using membership function in trapezoidal form displaying fuzzy numbers, Figure 5.

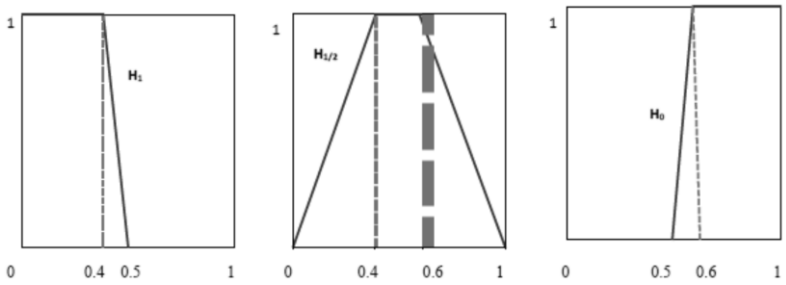

Figure 5. Membership functions of fuzzy sets H_1, $H_{1/2}$ and H_0.

Indicators of environment issues and environmental impact of pesticides

The arrival of humans in an area, to live or to conduct agriculture, necessarily has environmental impacts. The use of agricultural chemicals such as pesticides magnify thoseimpacts. Pesticides, in addition to their potential negative effects on human health, poseadverse effects also on the environment (soil, water and air contamination, toxic effects on non-target organism). In particular, inappropriate use of pesticides has been linked with : (i) adverse effect on non-target organism (e.g. reduction of beneficial species population), (ii) effect of soil fertility extensive use of pesticides, (iii) water contamination from mobile pesticides or from pesticide drift, (iv) air pollution from volatile pesticides, (v) injury on non-target plants from herbicide drift, (vi) injury to rotational crops from herbicide residues remained in the field, (vii) crop injury due to high application rates, wrong application timing or unfavourable environmental conditions at and after pesticideapplication. The extensive use of pesticides in agricultural production can degrade and damage the community of micro-organism living in the soil, particularly when these chemicals are overused or misused as chemical compounds built up in the soil. The full impact of pesticides on soil micro-organism is still not entirely understood;many studies have found deleterious effects of pesticides on soil micro-organisms and biochemical processes. The effect of pesticides on soil micro-organism is impacted by the persistence, concentration and toxicity of the applied pesticide, in addition to various environmental factors. In general, long-term pesticide application can disturb the biochemical process of nutrient cycling.

Pesticide impacts on aquatic systems are often studied using a hydrology transport model to study movement and fate of chemicals in rivers and streams. Pesticide residues also been found in rain and groundwater where as it is shown that pesticideconcentrations exceeded those allowable for drinking water in some samples of river water and groundwater. Water containing pesticides, when used for drinking purposes, canbe harmful, ranging from mild headache and skin allergy to cancer of internal organs.

Pesticide can contribute to air pollution. Pesticides that are applied to crops can volatilize and may be blown by winds intonearby areas, potentially posing a threat to wildlife. Pesticide use accounts for about 6 % of total tropospheric ozone levels.

Let us denote as E a set of all fuzzy sets that describe the impact of pesticide on environment, and:

- E_1 represents fuzzy set that points that the impact of pesticide on Environment is “sustainable”. For sustainability the value of base variable of the membership function can be assumed to be less than 0,3;
- $E_{1/2}$ represents fuzzy set that points that the impact on environment is “tolerable” and in this case the value of base variable of the membership function may be in between 0,3 and 0,7;
- E_0 represents fuzzy sets that points that the impact on environment is “unsustainable” and in this case the value of base variable of the membership function should be larger than 0,7.

Obviously, E contains E_1, $E_{1/2}$ and E_0 i.e. $E = \{E_1, E_{1/2}, E_0\}$, where E_1, $E_{1/2}$, E_0 represents the state of impact of pesticide on environment. Membership functions of E_1, $E_{1/2}$ and E_0 are given in Figure 6.

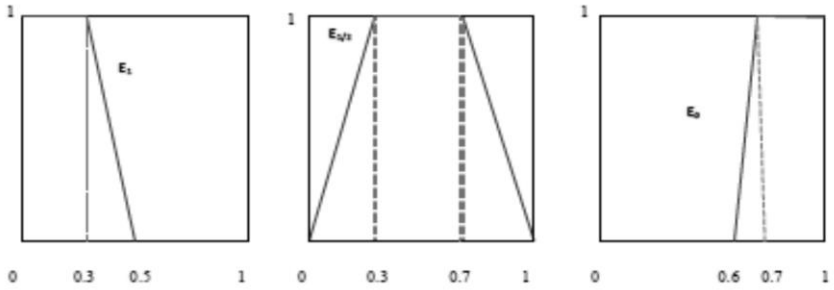

Figure 6. Membership functions of fuzzy sets E_1, $E_{1/2}$ and E_0.

Indicators of quantitative issues of pesticides on production quantity

The production of pesticides started in India in 1952 with the establishment of a plant for the production of Benzene Hexachloride (BHC) near Calcutta (now Kolkata), and India was the second largest manufacturer of pesticides in Asia after China and ranked twelfth in world [11]. There has been a steady growth in the production of technical grade pesticides in India, from 5 000 metric tons in 1958 to 102 240 metric tons in 1998. In 1996 to 1997 the demand for pesticides in terms of value was estimated to be around Rs. 22 billion (USD 0,5 billion), which was about 2 % of the global market [1].

The increased threat of higher crop losses to pests has to be counteracted by improved crop protection whatever method it will be (biologically, mechanically, chemically, IPM (Integrated Pest Management) and training of farmers). The use of pesticides has increased dramatically since the early 1960s; in the same period also, the average yield of wheat, rice and maize, the major sources for human nutrition, has more than doubled. Without pesticides, food production would drop and food prices would soar. With lower production and higher prices, farmers would be less competitive in global markets for major commodities. Where overall crop productivity is low, crop protection is largely limited to some weed control, and actual losses to pests may account for more than 50% of the attainable production [12].

From the time when synthetic pesticides were developed after second World War, there have been major increases in agricultural productivity accompanied by an increase in efficiency, with fewer farmers on fewer farms producing more food for more people. A major factor in the changing productivity patterns, either directly or indirectly, has been the use of pesticides. Ensuring the safety and quality of foods and the increase in crop loss was accompanied by a growth in the rate of pesticide use.

Let us suppose that:

- P_1 represents fuzzy set that points that the effect of using pesticide on production amount is "sustainable". For sustainability we may assume that the value of base variable of the membership function may lie between 0,3 to 0,8;
- P_0 represents fuzzy set that points that the effect of using pesticide on production amount is "unsustainable". For unsustainability we must have the value of base variable of the membership function must be greater than 0,8.

Obviously $P = \{P_1, P_0\}$. Corresponding membership functions are given in Figure 7.

Indicators of qualitative issues of pesticides on food quality

In the first world countries, it has been observed that diet chart containing fresh fruits and vegetables far outweigh potential risks from eating very low residues of pesticides in crops [13]. Increasing evidence (Dietary Guidelines, 2005) shows that eating fruits and vegetables regularly reduces the risk of many cancers, high blood pressure, heart disease, diabetes, stroke and other chronic diseases [1].

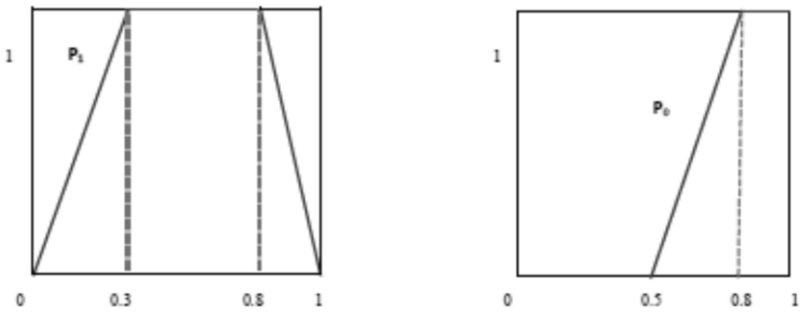

Figure 7. Membership functions of fuzzy sets P_1 and P_0.

The current model of agriculture is designed to maximize profit by increasing production yields and quality of agricultural products, while reducing costs for both producers and consumers. In this regard, the use of pesticides has paid an enormous importance allowing controlling insects or fungal infestations or growth of weeds, either to handle immediate infestations or to anticipate long lasting problems. Pesticides can also be usedto help protect seeds, or prolong the life of crops after they have been harvested.

However despite their many merits and due to their inherent nature, pesticides are some of most toxic, environmentally stable and mobile substances in the environment. Their excessive use (misuse) especially in the developing countries, their volatility, long distance transports eventually results in widespread environmental contamination. In addition, many older, non-patented, more toxic, environmentally persistent and inexpensivechemicals are used extensively in developing nations, creating serious acute health problems and local and global environmental impacts [14]. As a consequence of their extensive applications, most of the applied pesticides find their way as 'residue' in the environment into the terrestrial and aquatic food chains, where they undergo concentration and exert potential, long term, adverse health effects. Nevertheless, the perceptionon the risks that pesticides in food pose to human health relative to other dietary risks varies between consumers and scientists. Pesticides itself slowly start dissipating after these are sprayed. The rate at which pesticides are moved or dissipated varies with the nature of pesticide molecule, type and portion of food material and environmental factors [15]. From an effective point of view, food safety monitoring programs must consider all these possiblesituations. Therefore, the result of the processing studies should be as follows:

- to provide information on the transfer of residues from the raw agricultural commodity to the processed products, in order to calculate reduction or concentration factors;
- to enable a more realistic estimate of the dietary intake of pesticide residues;
- to establish MRLs (Maximum Residue Limits) for residues in processed products where necessary, according to the requirements of national regulatory authorities or international standards.

Production of safe and healthy food is a key priority in the worldwide. Recommendations are also given on those research challenges facing the study of the effects of fermentation on pesticide residues, as well as the effects of residues on food quality andsafely.

Let us express this statements in fuzzy sets. Let F be the set of all fuzzy sets which describe the effect of pesticides on the quality of food or crops.

- F_1 represent fuzzy set which shows that the impact of pesticide on the quality of food or crops is "sustainable". For sustainability we may assume that the value of basevariable of the membership function may be less than 0,4;
- F_0 represents the fuzzy set which shows that the impact of pesticide on the quality of food or crops is "unsustainable". For unsustainability the value of base variable of themembership function then should be greater than 0,7.

Obviously $F = \{F_1, F_0\}$. Membership functions of F_1 and F_0 are given in Figure 8.

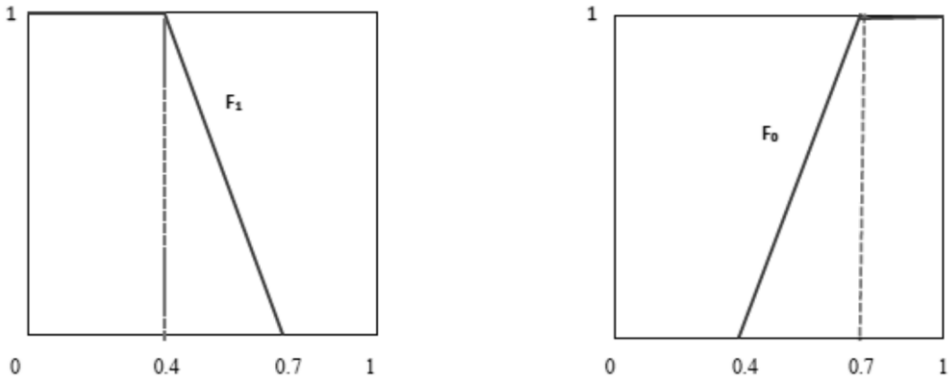

Figure 8. Membership functions of fuzzy sets F_1 and F_0.

Indicators of bio-diversities of pesticides on wildlife

Wildlife may come into contact with pesticides in many ways. They can be exposed if they touch treated areas, eat treated plants, or drink contaminated water. Hidden nests or young may also be directly exposed to pesticides during an application. Pesticides that destroy habitat or food can also affect wildlife. Birds of prey were primarily affected; exceptions apparently are the result of lesser exposure because of different food habits. Many species of fish-eating birds are also affected.

We may be familiar with colony collapse disorder and the effect it has on bee populations. Pesticides are non-discriminatory chemicals, meaning they impact both good bugs and bad ones alike.

Atrazine, the most widely used pesticide in the United States, has been shown to cause sexual abnormalities in frogs. Atrazine is not water soluble, meaning when it rains, it can easily wash off crop fields and into surrounding watersheds without breaking down. Frog exposed to atrazine have exhibited multiple ovaries and testes or even frogs with both sets of gendered sex organs. This pesticide has been banned in Europe and has been linked to human cancers and reproductive disorders.

Birds that come into contact with toxic pesticides (like neonicotinoids) have shown a decrease in breeding success, physical malformations, an impaired ability to avoid predators or migrate, and in some cases, pesticides can lead to death.

Let us say that set W represents set of all fuzzy sets that describe the impact of pesticides on Animals and Birds (Wildlife), so:

- W_1 is fuzzy set that represents the impact of pesticides is “sustainable” and the value of base variable of the membership function may less than 0,4;
- $W_{1/2}$ is fuzzy set that represents the impact of pesticides is “tolerable” and the value of base variable of the membership function may be lie between 0,4 and 0,6;
- W_0 is fuzzy set that represent the impact of pesticides is “unsustainable” and the value of base variable of the membership function should be greater than 0,6.

Obviously $W = \{W_1, W_{1/2}, W_0\}$, and fuzzy sets of its membership functions are given in Figure 9.

APPROXIMATE REASONING IN FUZZY MODEL

Steps in approximate reasoning

The computations of approximate reasoning for the assessment of SD is given in Figure 10. Six steps are involved: 1st step defines model input, sustainability indicator SI_j and the base

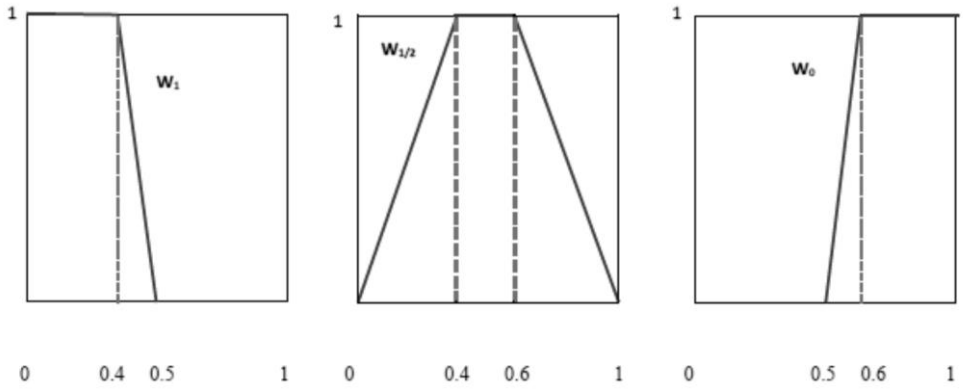

Figure 9. Membership functions of fuzzy sets W_1, $W_{1/2}$ and W_0.

variable x_j; 2nd step defines linguistic variable $\tilde{T}$ for input and m linguistic values $\tilde{T}_i$, and also defines linguistic variable $\tilde{O}$ for output and q linguistic values $\tilde{O}_p$ (p = 1, 2, ..., q) regarding assessment μ_{SD}; 3rd step constructs membership function μ_{ij} and $\mu_{\tilde{O}}$; 4th step computes degree of membership $\mu_{ij}(x_j)$; 5th step determines a fuzzy conclusion $\tilde{C}$; and 6th step draws a numerical assessment μ_{SD}.

In approximate reasoning, 4th step is known as fuzzification, 5th step as fuzzy inference and 6th step as defuzzification.

Fuzzy rule base

Approximate reasoning is the process of inferring a conclusion for a problem that cannot be observed directly (i.e. SD), but in the problem there are some things that can be observed directly (i.e. SI). In a fuzzy model applying approximate reasoning, the reasoning process is based on a series of r fuzzy rules $\boldsymbol{R}_k$ (k = 1, 2, ..., r), which together is referred to as the fuzzy rule base of the model. A fuzzy rule introduces us the contribution of SI_j to SD by using of linguistic IF-THEN fuzzy rule base propositions.

A proposition contains an antecedent (premise), the IF-part, and a consequent (conclusion), the THEN-part [16]. The premise can contain one and more facts "SI_j $\boldsymbol{is}$ $\tilde{T}_i$". The conclusion contains a single fact "$\boldsymbol{SD\ is\ \tilde{O}_p}$", where linguistic value $\tilde{O}_p$ defines a fuzzy assessment regarding SD ($\tilde{O}_p \subset U_{SD}$). Thus fuzzy rule $\boldsymbol{R}_k$ is the conditional statement

IF "SI_j is $\tilde{T}_i$" THEN "SD is $\tilde{O}_p$".

For instance, if SI_1 is "Pesticide impact on **Human health**", $\tilde{T}_1$ is linguistic value "Tolerable", SD is "Sustainable Development", $\tilde{O}$ is linguistic variable, "Output" or "Achievement", and $\tilde{O}_1$ is linguistic value "Very Good", then fuzzy rule R_k reads:

IF *Pesticide impact on Human health is Tolerable*

THEN *Sustainable Development is Very Good.*

Recall assessing the SD of Pesticide Use in Agriculture: SI_1 is "Effect on Human health" (x_1 kg/hect), SI_2 is "Impact on Environment" (x_2 kg/hect), SI_3 is "Production quantity" (x_3 kg/hect), SI_4 is "Food quality" (x_4 kg/hect), and SI_5 is "Effect on Animals and Birds" (x_5 kg/hect). Further linguistic value (Tolerability) $\tilde{T}_1$ is "Tolerable", and $\tilde{T}_2$ is "Intolerable", and linguistic value (Output) $\tilde{O}_1$ is "Very Good", $\tilde{O}_2$ is "Good", $\tilde{O}_3$ is "Average", $\tilde{O}_4$ is "Bad", and $\tilde{O}_5$ is "Very Bad".

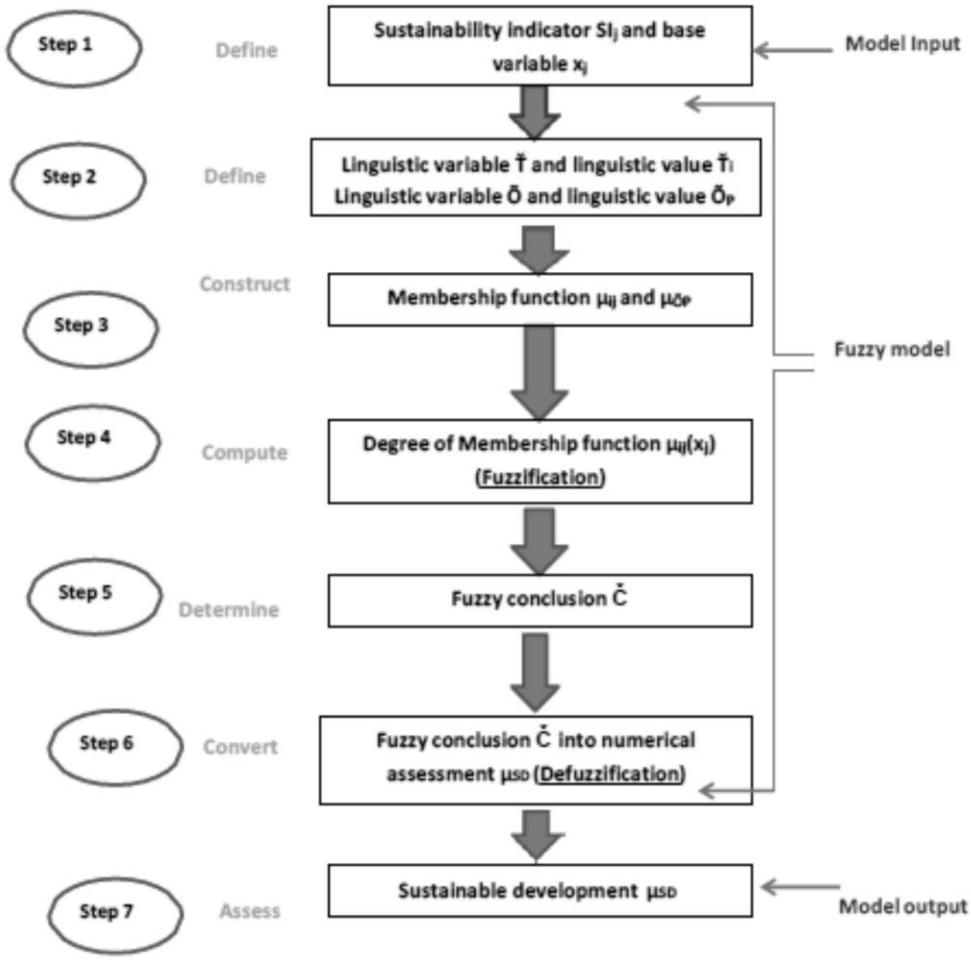

Figure 10. The scheme of a fuzzy model applying approximate reasoning to access the contribution of SI to SD.

A fuzzy rule base comprising five fuzzy rules could read

R_1: IF SI_1 *is* $\tilde{T}1$ AND SI_2 *is* $\tilde{T}1$ AND SI_3 *is* $\tilde{T}1$ THEN *SD is* $\tilde{O}1$;
R_2: IF SI_1 *is* $\tilde{T}1$ AND SI_2 *is* $\tilde{T}1$ AND SI_3 *is* $\tilde{T}2$ THEN *SD is* $\tilde{O}2$;
R_3: IF SI_1 *is* $\tilde{T}1$ AND SI_2 *is* $\tilde{T}2$ AND SI_3 *is* $\tilde{T}1$ THEN *SD is* $\tilde{O}3$;
R_4: IF SI_1 *is* $\tilde{T}2$ AND SI_2 *is* $\tilde{T}1$ AND SI_3 *is* $\tilde{T}1$ THEN *SD is* $\tilde{O}4$;
R_5: IF SI_1 *is* $\tilde{T}2$ AND SI_2 *is* $\tilde{T}2$ AND SI_3 *is* $\tilde{T}2$ THEN *SD is* $\tilde{O}5$.

Rule R_1, for example, reads "IF Pesticide effect on Human health is Tolerable AND Pesticides impact on Environment is Tolerable AND Pesticides on Production quantity isTolerable THEN Sustainable Development (SD) is Very Good"; where 'AND' denotes a logical connective [17]. 4th Step (Fuzzification), 5th Step (Fuzzy inference), and 6th Step (Defuzzification) will be illustrated based on the stated fuzzy rule base.

FUZZIFICATION

Fuzzification of model input refers to computing the degree of membership $\mu_{ij}(x_j)$. In the example of assessing SD of using Pesticides in Agriculture, the fuzzification for the hypothetical values (taken earlier) in computaion of SI_1 results in $\mu_{11}(x_1)$= 0,3; of SI_2, $\mu_{12}(x_2)$ = 0,4; of SI_3, $\mu_{13}(x_3)$ = 0,6. Further, $\tilde{T}2$ ("Intolerable") is the fuzzy complement of $\tilde{T}1$ ("Tolerable"), so that $\mu_{2j}(x_j) = 1 - \mu_{1j}(x_j)$ [17]: $\mu_{21}(x_1)$ = 0,7, $\mu_{22}(x_2)$ = 0,6, $\mu_{23}(x_3)$ = 0,4, Figure 11.

FUZZY INFERENCE

Fuzzy inference is a two step process : the implication process and the aggregation process [18]. The implication process defines a fuzzy conclusion $\tilde{C}_k$ for each rule R_k. The aggregation process then defines an overall fuzzy conclusion $\tilde{C}$ for the entire fuzzy rule base. We use here **Mamdani** fuzzy controllers for fuzzy inference.

The implication process first defines a value τ_k for the antecedent (premise) of the proposition in fuzzy rule R_k. If the antecedent (premise) contains a single fact "SI_j is $\tilde{T}_i$", then τ_k is defined by the degree of membership $\mu_{ij}(x_j)$. If the antecedent (premise) contains more than one fact, however, then τ_k is defined by a logical connective [9, 10].

Let us consider here Mamdani fuzzy controller in our fuzzy inference system to assess the SD of using Pesticides in Agriculture. For fuzzy rule R_k, the logical connective "AND" defines a fuzzy intersection operator to compute τ_k based on degrees of membership. Applying the min-operator for fuzzy rule R_1, for example, results $\tau_1 = \min\{0,3; 0,4; 0,6\} = 0,3$, Figure 11.

The implication process then defines how τ_k implies a fuzzy conclusion $\tilde{C}_k$ based on the fact "SD is $\tilde{O}_p$". The operator defined to implement the implication process in fuzzy rule R_k modifies membership function $\mu_{\tilde{O}p}$ (construction of membership function μ_{ij} and $\mu_{\tilde{O}p}$) to the degree specified by τ_k. Applying the min-operator for fuzzy rule R_1, for example modifies the membership function $\mu_{\tilde{O}1}$ by truncation at $\tau_1 = 0,3$. The fuzzy conclusion $\tilde{C}_1$ is the area under the truncated membership function, Figure 11.

The aggregation process defines an overall fuzzy conclusion $\tilde{C}$ by selecting an operator to aggregate the $\tilde{C}_k$. In a fuzzy rule base, rules are connected by the logical connective "ELSE". In the example, the fuzzy rule then reads

R_1: IF SI_1 is $\tilde{T}_1$ AND SI_2 is $\tilde{T}_1$ AND SI_3 is $\tilde{T}_1$ THEN SD is $\tilde{O}_1$,
ELSE R_2: IF SI_1 is $\tilde{T}_1$ AND SI_2 is $\tilde{T}_1$ AND SI_3 is $\tilde{T}_2$ THEN SD is $\tilde{O}_2$,
ELSE R_3: IF SI_1 is $\tilde{T}_1$ AND SI_2 is $\tilde{T}_2$ AND SI_3 is $\tilde{T}_1$ THEN SD is $\tilde{O}_3$,
ELSE R_4: IF SI_1 is $\tilde{T}_2$ AND SI_2 is $\tilde{T}_1$ AND SI_3 is $\tilde{T}_1$ THEN SD is $\tilde{O}_4$,
ELSE R_5: IF SI_1 is $\tilde{T}_2$ AND SI_2 is $\tilde{T}_2$ AND SI_3 is $\tilde{T}_2$ THEN SD is $\tilde{O}_5$.

Each fuzzy rule stated expresses a situation regarding the contribution of three SI to SD. In approximate reasoning, rules R_1 to R_5 are true to a certain degree, as expressed by τ_1 to τ_5, which means that all rules contribute partly to the overall fuzzy conclusion $\tilde{C}$. The logical connective "ELSE" is defined, therefore, by the max-operator to enable a fuzzy union of $\tilde{C}$k [18]. The fuzzy conclusion $\tilde{C}$ is the area under the curve, Figure 11.

DEFUZZIFICATION

Conversion of the fuzzy conclusion C˜ from an area under the curve to a numerical assessment μ_{SD} i.e. to a crisp value is known as Defuzzification. Various methods of defuzzification are available such as Maximum membership principle (Height method), Centre of gravity method (one of the Centroid methods), Weighted average method (for symmetric membership function), Mean-max method (Middle of maxima), etc. [16, 17, 19-21].

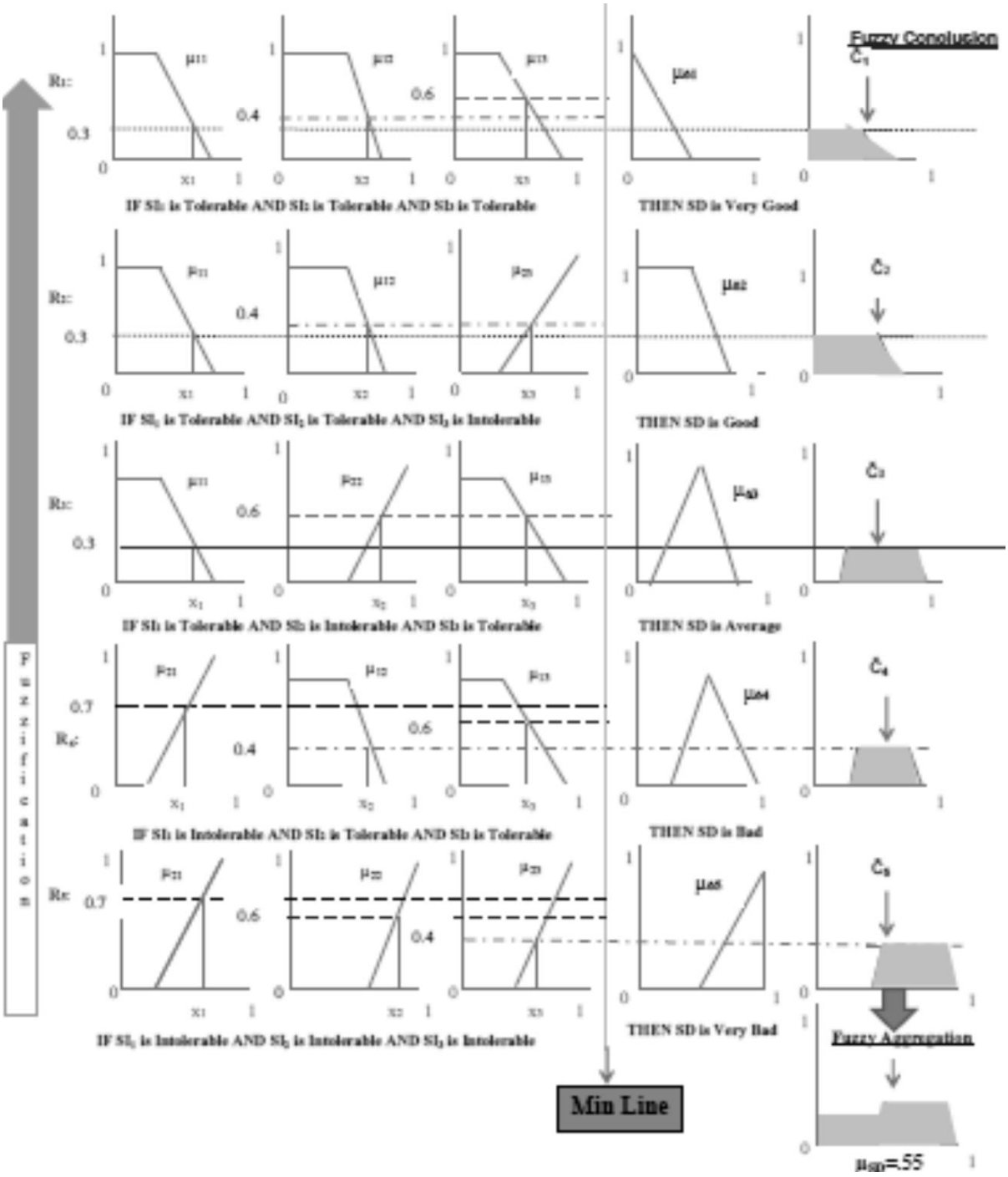

Figure 11. Approximate reasoning of a fuzzy model is represented graphically here to assess the SD amount of Pesticide Use. Five fuzzy IF-THEN rules are presented for three SI (i.e. Human health, Environment, Production quantity) to SD for the stated fuzzy rule base system. Approximate reasoning starts with fuzzification of model input x_1, x_2, x_3 (in kg/hect). Fuzzy inference is a two-step process containing the implication process and the aggregation process, determines an overall fuzzy conclusion $\tilde{C}$ based on fuzzy conclusions $\tilde{C}_1$ through $\tilde{C}_5$ for the five rules.

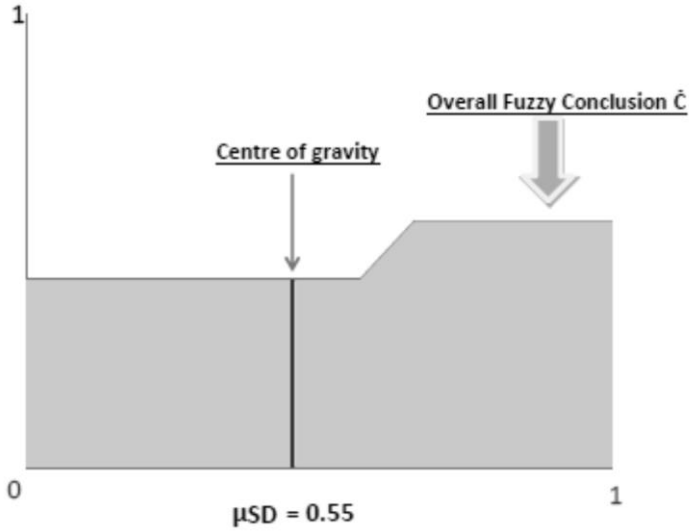

Figure 12. In the stated fuzzy model, defuzzification of the overall fuzzy conclusion $\tilde{C}$ applying approximate reasoning to assess SD of amount of Pesticide Use in Agriculture is graphically presented. The Centre of gravity method divides the area under the curve $\tilde{C}$ into two equal subareas and hence determines μ_{SD}.

CONCLUSIONS

In this article a preliminary study has been done to employ fuzzy logic to build a model for the use of pesticides leading towards sustainable development of agriculture. Here rules are defined for measuring the intensity of the sustainable development of agriculture using individual indicators, and any uncertainty in such process has been minimised. Using linguistic variables and rules, the model gives quantitative measures of human economical, ecological and social sustainability which are then combined into overall sustainability.

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EXAMINING THE RELATIONSHIP BETWEEN SENSORY BRANDING, BRAND AWARENESS AND PREFERENCE AFTER A BLIND TASTING TEST: AN APPLICATION ON TEA BRANDS

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ABSTRACT

The aim of this research is to explore whether there is a relationship between sensory branding and brand awareness and blind taste. A questionnaire and an experiment were used together on 101 volunteers who were familiar with tea brands in the University of Düzce, Turkey. The questionnaire was applied to the participants to measure their sensory branding and brand awareness perceptions. In addition, for the blind taste test, the experiment was conducted. Frequency, Spearman's Rank Correlation, Cochran Q, McNemar, Mann Whitney U Test, and Logistic Regression tests were used to test the hypotheses. According to the results of the analysis, there were low and moderate relationships between sensory branding and brand awareness in tea brands. In addition, according to the results of the Cochran Q and McNemar tests, there was a difference between the tea brands based on the participants' blind taste test responses. Moreover, it was determined that the sensory brand perception of the participants did not differ according to the blind taste test results. Similarly, the findings of the blind taste test revealed that the participants' brand awareness perceptions did not differ. Furthermore, according to the logistic regression analysis findings, sensory branding and brand awareness did not have any effect on the blind taste test. According to the findings of this research, even though the product contents were same, brand studies created awareness in the consumer.

KEY WORDS

sensory branding, brand awareness, blind tasting test, branded taste, tea brands

CLASSIFICATION

JEL: C93, M31

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INTRODUCTION

In today's competitive environment, the contents, prices and features of the products are very similar to each other. This leads to impersonal brand experiences [1]. However, with the communication studies, the products are shown to the consumer as if they are different [2]. In today's world of communication, humans are almost bombarded with messages. Today, when a consumer reaches the age of 65, he or she has spent 6 years of his life watching advertisements for eight hours a day, seven days a week [3]. It has even been claimed that children can have beliefs about brands until the age of two, and can distinguish the names, logos, and emblems of brands between the ages of two and six [4]. Consumers can receive messages every day, every hour, and every minute as a result of globalization and the internet's entry into our life. In order to gain competitive advantage in the globalizing world and not to lose the existing market, businesses need to take place in the virtual world [5]. Businesses are boosting the strategies they apply for the senses of color, shape, sound, taste, smell, and touch in order to influence consumers. It has become important to stay in the mind in this chaos. In other words, those who can direct the perception of the consumer can be successful. As Aristotle said, "perception is reality".

The mainstay of the sensory branding approach, which became widespread especially in the 2000s, was the possibility of settling in the memory through the senses and the senses causing various emotions [6]. Sensory branding can be defined as marketing that engages consumers' senses and influences their perceptions, judgments, and behaviors [7]. Many products are tested by smell, hearing, touch, sight, and taste. As a consequence of these trials, the quality of the products is evaluated and a link to previous experiences is established [3]. More than one sense organ is used to test some products. Especially in the food industry, there are studies that will activate other senses along with taste. Both corporations and academia are involved in these investigations. Starbucks, for example, was able to achieve success by combining visual, aural, and tactile senses with its atmosphere, along with taste [8]. When compared to other industries, the food industry has the advantage of utilizing the sense of taste. This intuition may be lacking in other industries.

Special structures called "Taste Buds" in the tongue enable us to taste. It takes about 0,2-0,5 seconds to feel the taste of something on the tongue [9]. The sense of taste varies according to culture, lifestyle, and habits [10]. The social culture to which people belong has a strong influence on individual taste preferences [1]. Mexicans, for example, prefer spicy foods, while Indians prefer spicy foods more. Sweet foods are more popular in Turkey and the Middle East. Alcohol consumption is a socially acceptable practice among Croats [11]. Drinking tea is also a socially accepted behavior in Turkey. In fact, tea originating from the Far East is preferred without sugar, while in Turkey, tea can be preferred with sugar. McDonalds and Burger King can build menus that reflect the tastes of different countries. In this context, it can be said that the positive or negative evaluation of tastes by consumers occurs as a result of socially learned behaviors, not genetic inheritance [12].

Tea, the world's most consumed beverage after water [13, 14], was investigated in this study. Tea has a 5 000-year history, and it is produced in over 45 nations throughout the world [15]. According to the world tea report, Turkey ranks first in annual tea consumption per capita with 3,5 kg. Middle Eastern countries have very high rates of black tea use. In this regard, it is critical to investigate the sensory feelings that tea creates on people.

The main purpose of this study is to explore the relationship between sensory branding, brand awareness and blind taste testing. For this purpose, an application was carried out on tea brands. Despite the fact that the number of studies on sensory branding is growing day by

day, they are not yet sufficient [16]. Since studies in this field are few, this study is important in terms of contributing to the literature. Furthermore, this research is useful in understanding the value of sensory brand in developing tea company brand strategies and conducting communication studies in this area.

SENSORY BRANDING

The use of the five senses by a brand to develop brand identity and position the brand on an individual level is known as sensory branding [1]. Sensory branding is to leave a permanent mark on the consumer with the works that appeal to the five senses (taste, sound, sight, hearing, touch). Human senses are used to distinguish one brand from another [17]. Communication researchers attempt to develop a link between these senses and the product. With sensory branding studies, it is tried to create a perception in the subconscious of consumers [16]. Consumers get more personal, emotional, and cultural experiences with sensory branding [1].

Sight is still one of the most remarkable senses among the five senses [3]. The sense of sight is especially crucial today when comparing products with similar content and qualities. Perception with the sense of sight takes 45 milliseconds [18]. On the other hand, smell is known to be the slowest sense of human beings [19]. Smell is 10 times slower than sight. But once the smell is noticed, it becomes permanent. The smell is still remembered after all these years [20]. The experience of flavor by humans is known as the sense of taste. Each taste bud on the tongue can distinguish between 50 and 100 different flavors. There are four tastes that humans distinguish: sweet, sour, bitter, and salty. Recently, another flavor called umami has been discovered [21]. It is the flavor that appears when the Glutamate component in meals is heated.

All tastes are associated with other senses such as sight, hearing, smell, and touch [22]. Some senses are thought to be more effective when used jointly. The sense of taste is the one that interacts with the sense of sight the most [1]. However, it will be most effective to address the consumer by using all the senses together. It does not make any sense when we think of an auditory horror movie without a visual and a visual horror movie without an auditory [3]. Likewise, the senses of sight and taste can be more effective together.

Companies appeal to the five senses to generate powerful memories in the minds of consumers in order to establish a strong relationship between consumers and brands [22]. This is possible with sensory branding. Coca Cola, Starbucks, McDonald's, Nutella, and Nescafe are the leading brands that make sensory branding. When the studies conducted with these brands are examined, it has been seen that sensory branding has an effect on brand loyalty [23]. In this case, it can be said that companies that make sensory branding can create brand awareness. In other words, the more attention is paid to sensory branding, the greater the brand awareness is [22].

Kellogg's, which has been researching the relationship between crispness and taste for years, signed a contract with a Danish laboratory and patented a special crackling sound. In the result of his research, he discovered that the cracking sound is related with freshness. This shows that there is a sense of freshness in the crunch-taste interaction [3].

BRAND AWARENESS

Brand awareness can be defined as anything from a vague recognition of the brand to the assumption that the product is the only one of its kind [24]. There are two sub-variables of brand awareness. These are recognition and recall [25]. Brand recall can be expressed as the consumer's ability to use past information when a clue about the brand or something reminiscent

of that brand is encountered [26]. For example, in the Middle Eastern countries, especially in Turkey, there is a culture of offering tea when people come together. Tea is commonly consumed with breakfast and immediately after meals in Turkey. It is part of both physiological and social demands in this scenario. A well-brewed and good-tasting tea can be associated with a tea brand by combining past experiences. In another example, Coca Cola is an example to remember when a consumer is thirsty or needs a drink alongside a meal. When consumers perceive a good or service with their five senses, the trust in that product also increases [27].

It is essential to focus on the internal process in consumer purchasing behavior in order to establish a strong brand. Many of the internal processes are linked to different senses of the body [22]. These senses are sight, smell, touch, sound, and taste [22]. Each tea brand produced in Turkey has its own brand image, personality, and different perceptions due to these characteristics [28]. In fact, tea produced in Turkey is mostly produced in the same region. However, it can be perceived differently with the packaging and communication studies carried out by the private sector. In this case, tea brands with similar content, properties and taste can be perceived differently. This situation is similar to gas stations. In fact, the fuel coming out of the same refinery can be perceived differently by different stations. Tea brands were evaluated in terms of quality and fulfilling the expectations in a study on tea brands in Turkey [28], Ofçay came first, followed by Lipton and Doguş tea. In terms of diversity and suitability for health, the ranking has changed as Lipton/Dogus tea and Ofçay.

Brand awareness and packaging studies are as important as sensory branding [29]. According to a study, product packaging has an impact on taste perception. The consumer can look at the packaging and generalize the taste of the product [30]. In a study conducted on children to measure the effect of packaging on their sense of taste, when asked which of the two products they would prefer, 51,2 % of the participants stated that they would prefer the animated beverage, while 48,7 % stated that they would prefer the non-animated product. Animation designed products have become the reason for preference at the point of purchase by establishing an emotional connection due to the cartoon characters. Non-animated designed products, on the other hand, provided a sense of trust due to their transparency and became a naturally defined taste [31].

In a study on McDonald's foods (n = 63), no significant difference emerged between the predictions about which foods belong to the brand. However, it turned out that children exposed to McDonald's advertisements were more likely to predict the taste of food [4]. According to the results of another study conducted on students (n = 317) about the Burger King brand, it was concluded that there is a positive and significant relationship between sensory branding and brand awareness [24].

It is thought that sensory branding is related to brand awareness, based on research findings in the literature. Based on the findings of this study, the following hypothesis was developed.

H_1: *There is a relationship between sensory branding and brand awareness.*

BLIND TASTE TEST AND RELATED LITERATURE

The blind taste test is an experiment that gives information about the sensory (sight, hearing, taste, smell, and touch) quality of the product [29]. This test can also be investigated with the concept of pleasantness in the literature [32, 33].

In a study on university students (n = 30), coffee taste was tested. The participants were asked to drink any coffee they liked, identify the brand of coffee they were drinking, and describe their feelings in the first ten seconds. In addition, the participants said that they would prefer

the leading coffee brand Nescafe before doing the coffee taste test. As a result of the blind taste test, the predictions were not correct when asked which brand of coffee they drank [10].

In another study, students (n = 57) were exposed to a blind taste test relating to cold tea [12]. The hypothesis that the individuals should be able to recognize and choose the brand they previously preferred in taste tests was evaluated in the study. As a result of the pre-test and post-test, they were expected to find the brand they preferred. The subjects participating in the study could not distinguish the cold tea that they said they liked in the taste test. In this case, it can be said that other senses other than taste are effective.

Moreover, the association between blind taste testing and branded taste with purchase intent was investigated (n = 107) in a study. According to the findings, people who are familiar with the product have more purchase intentions than those who are unfamiliar with the product. There were no differences between blind tasting and branded tasting tests for people who were unfamiliar with the product [29].

In another study, a blind taste test was used to examine whether there was a difference between tap water and bottled water. According to the blind taste test results (n = 578), while there is a significant difference in brand awareness (quality, trust, health, risk, etc.); participants could not discriminate in the blind taste test [34].

Furthermore, in a study on packaged dairy products (n = 138), different results emerged in the branded tasting and blind tasting test. In the branded blind tasting test, the participants stated that there were significant differences between brands. Although it was stated that organic milk consumption was higher (61,7 %), organic milk received the lowest score in the blind taste test [35].

The tastes of national and retail brands were compared in a study (n = 119), and it was discovered that the taste of national brands was preferred more [36]. In a study on Pepsi and Coca Cola, it was found that participants (n = 67) in blind taste tests stated that Pepsi tasted better, but in the branded taste test, they said that Coca Cola tasted better [37].

The main hypotheses and sub-hypotheses formed from the purpose and problem of the research are as follows.

H_2: *There is a difference between tea brands according to the blind taste test result.*

H_3: *Sensory branding perception differs according to blind taste test results.*

H_4: *Brand awareness perception differs according to the blind taste test results.*

H_5: *Sensory branding perception and brand awareness perception have no effect on the blind taste test.*

RESEARCH METHOD

This research proposes a model to explore the relationship between sensory branding, brand awareness and blind taste testing. The hypotheses proposed to be tested are shown in Figure 1. The model hypothesizes a relationship between sensory branding and brand awareness. It also suggests that there is a difference between brands of tea based on the blind taste test. Moreover, it offers that sensory branding perception and brand awareness perception differ according to the blind taste test. Last but not least, it offers that perception of sensory branding and perception of brand awareness have an impact on the blind taste test.

POPULATION AND SAMPLING

The population of the research consists of people over the age of 18 who were generally familiar with and consume the tea brands that are the subject of the research. Private sector

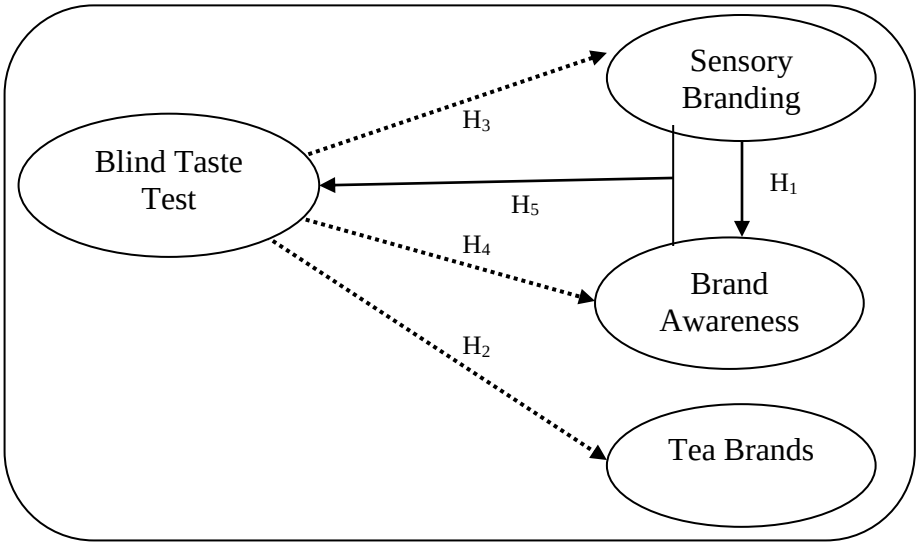

Figure 1. Research model.

tea brands, which are the most preferred producers in Turkey, have been taken into account. These private brands are Lipton, Doğuş and Ofçay [28]. In the related study, these brands were coded as T1, T2 and T3 brands to ensure confidentiality. Quota sampling method, which is one of the non-random sampling methods, was used in order to choose the participants. In this context, it is important that the distribution of participants is close to each other in terms of comparison, as tea brands representing different sensory branding and brand awareness components. For this reason, the participants were included in the research by classifying them according to their tea brand preference and determining the quota. Thus, in the study, a quota was designed to ensure that at least 20 persons from each of the relevant tea brands were targeted. Both a questionnaire and an experiment were conducted with 101 participants on a voluntary basis. Due to the nature of the research, it was not possible to collect a large number of data, since measurements were made not only with the survey method, but also with the experimental method. In terms of the reliability of the research, it is stated that data should be collected at least 5 times the number of items used [38, 39]. There are 16 items in total belonging to the two main variables of the study. Since data were collected approximately seven times the total number of items in this study, it is thought that the amount of data is sufficient for the reliability of the research results.

ETHICAL STATEMENT

The authors of the study declare that they continue to work in accordance with scientific study ethics and the Helsinki declaration in the study. Accordingly, the research was reviewed by the Scientific Research and Publication Ethics Committee of Duzce University and was given permission (Date: 27/12/2019, Number: 2019/118). In addition, the participants of this study participated in the research on a voluntary basis. Moreover, in this study, the most preferred private sector tea brands Lipton, Doğuş and Ofçay in Turkey were chosen as sample products. In the related study, these brands were coded as T1, T2 and T3 brands in order to keep the names of the relevant brands confidential. The purpose for keeping these brand names confidential is to prevent the research's findings from having a favorable or negative impact on these tea brands.

MEASUREMENT AND DATA COLLECTION PROCESS

The research consists of two measurements. In the first measurement, a questionnaire was applied to the participants. In the measurement of sensory branding perception, the study of

Uddin [22] was used. In this scale, there are 5 items created to measure sensory branding perception by considering all five senses. The scale related to brand awareness was created by adapting the study of Yoo, Donthu and Lee [40] study and the expressions in Aaker's definition [25]. In this scale, there are 11 items. A five-point Likert scale was used to determine the characteristics related to sensory branding and brand awareness variables (1 – strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, and 5 – strongly agree).

In the second part, a blind taste test was conducted. It is stated that the senses act together and have an effect onto the consumer [3]. In this direction, taste and image together create a different effect on the mind of the consumer. In this study, the difference between taste and appearance is examined by using a blind taste test. In the Blind Tasting test, the participants were asked to taste the teas without using any brand symbols (hiding them).

After this experiment, a number of questions were asked in terms of the taste of the teas. These questions are in the form of which tea belongs to which brand, which taste is the best, and the classification of teas with similar tastes and undesirable tastes. The blind taste test was conducted using 4 oz paper cups and 2/3 of the cups filled. Tea brands are written invisible on the bottom of the glasses. After the participant's blind taste test, the answer given to the question of which brand the tea he drank was written on the side of the glass. Glasses in which the participant's name was written were kept until the end of the research. Participants with flu and colds were not included in the experiment.

STATISTICAL ANALYSIS

Data were analyzed through IBM SPSS Statistics 26 program. In the data analysis process, firstly, preliminary analyzes were made by frequency analysis to determine the demographic characteristics of the sample and normality test to examine the normality assumption of the data. The normality of the data was examined using the kurtosis and skewness scores and their cutoff values [41, 42]. After it was determined that the data were not normally distributed as a result of the skewness and kurtosis values examined, it was decided to use non-parametric methods to test the research hypotheses. Accordingly, Spearman's Rank Correlation, Mann Whitney U Test, Cochran Q Test, McNemar test and Logistic Regression were used to test the hypotheses.

FINDINGS

DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

When the participants included in the study were examined in terms of gender, it was seen that the male and female ratios were close to each other as given in Table 1 (56 % to 44 %, respectively). When evaluated in terms of income, around a quarter of the participants fell into the lowest income group, while about half of them were at the highest of the income group. Various demographic data of the participants about tea and tea brands were reported before evaluating the research hypotheses about tea brands. Thus, it was aimed to estimate the inclusiveness of the research. In this frame, when the answers given by the participants to the question of how often they drink tea, as given in Table 1, were examined, it was discovered that the majority of the participants consume at least 3-4 cups of tea per day. The participants who drink tea were more or less similar, according to the tea drinking frequency categories defined, and the rate of those who consume 9 cups or more of tea was slightly lower than the other groups (15 %). When the tea brands examined in the study were evaluated according to most preferred ones, it was observed that 24 % prefer T1, 34 % favor T2, and 43 % choose T3.

Table 1. Demographic Characteristics of Participants.

		n	%
Gender	Male	57	56,4
	Female	44	43,6
Income	3501-5000 (₺) (low)	24	23,8
	5001-6500 (₺) (modarate)	29	28,7
	6501 (₺) and over (high)	48	47,5
Tea drinking frequency	3-4 cups	23	22,8
	5-6 cups	31	30,7
	7-8 cups	32	31,7
	9 cups and over	15	14,9
Most preferred tea	T1	24	23,8
	T2	34	33,7
	T3	43	42,6
Preferred type of tea	teabag	21	20,8
	bulk tea	80	79,2

Participants should be familiar with tea brands in general to ensure the research's reliability and validity. Table 2 shows the participants' level of familiarity with various tea brands for this purpose. Table 2 shows that, while only 2% of people are unfamiliar with tea brands, the majority are more familiar than the average.

Table 2. Familiarity of Participants to Tea Brands.

	Extremely Unfamiliar	Very Much Unfamiliar	Moderately Unfamiliar	Slightly Unfamiliar	Neither Familiar nor Nonfamiliar	Slightly Familiar	Moderately Familiar	Very Much Familiar	Extremely Familiar	**Total**
n	2	5	7	12	15	12	16	11	21	101
%	2	5	6,9	11,9	14,9	11,9	15,8	10,9	20,8	100,0

In the research, it was also asked whether the tea brands made sensory branding. The concept of sensory branding was explained at the beginning of the question before this question was asked, considering that there may be some among the participants who do not know what sensory branding is. Table 3 summarizes the results. When asked about sensory branding, more than half of the participants stated that all tea brands do sensory branding.

Table 3 also includes the findings of the participants' blind tasting tests. Accordingly, the rate of correctly knowing the brand of the tea they drink was moderate (57 %, 51 % and 68 % for

Table 3. Sensory Branding Perception of Tea Brands and Blind Taste Test Findings.

Status of Making Sensory Branding				**Blind Taste Test**			
		n	%			*n*	%
T1	Yes	56	55,4	**T1**	True	58	57,4
	No	45	44,6		False	43	42,6
T2	Yes	52	51,5	**T2**	True	51	50,5
	No	49	48,5		False	50	49,5
T3	Yes	52	51,5	**T3**	True	69	68,3
	No	49	48,5		False	32	31,7

T1, T2 and T3, respectively). This shows that the rate of those who misunderstand is too high to be ignored in all three types of tea brands.

The answers given by the participants to the best and worst tea tastes after the blind taste test were presented in Table 4. As can be seen in Table 4, It was discovered that the participant chose all tea brands in a ratio that was close to each other in terms of the best taste. In the same table, there were answers given by the participants about which tea taste was the worst. Accordingly, the ranking of the tea brands in terms of worst taste was stated as T1, T2 and T3.

Table 4. Best Taste and Worst Taste (After Blind Taste Test).

Tea Brands	Best Taste		Worst Taste	
	n	%	*n*	%
T1	30	29,7	51	50,5
T2	38	37,6	32	31,7
T3	33	32,7	18	17,8

Normality tests were employed to assess whether the data had a normal distribution before starting with the analyses that would be used to evaluate the hypotheses. As a result, it was decided whether parametric or non-parametric testing would be utilized. In this way, skewness and kurtosis values of data were assessed as +2 and –2 in study to determine data normality [41]. Thus, it was determined that the skewness and kurtosis values of all items did not change between –2 and +2. As a result, non-parametric tests were used.

SPEARMAN'S RANK CORRELATION ANALYSIS

In order to assess the H_1 hypothesis of the research, Spearman's Rank Correlation analysis was utilized to test if there is a link between sensory branding and brand awareness perception. Table 5 displays the results observed.

Table 5. Spearman's Rho Correlation Test.

	T1 Sensory B.	T1 Brand Aw.	T2 Sensory B.	T2 Brand Aw.	T3 Sensory B.	T3 Brand Aw.
T1 Sensory B.	1,00					
T1 Brand Aw.	0,318**	1,00				
T2 Sensory B.	0,440**	–0,085	1,00			
T2 Brand Aw.	–0,057	0,210*	0,339**	1,00		
T3 Sensory B.	0,232*	–0,147	0,455**	–0,018	1,00	
T3 Brand Aw.	0,070	0,185	0,063	0,326**	0,234*	1,00

*correlation is significant at the 0,01 level

**correlation is significant at the 0,05 level

When Table 5 was examined, according to the Spearman's Rho Correlation test result, it was seen that there was a moderate positive relationship between sensory branding and brand awareness for T1 (r = 0,318, p < 0,01). It was seen that there was a moderate positive relationship between sensory branding and brand awareness for T2 (r = 0,339, p < 0,01). For T3, on the other hand, it was presented that there was a weak positive relationship between sensory branding and brand awareness (r = 0,234, p < 0,05). Thus, the H_1 hypothesis of the research, "there is a relationship between sensory branding perception and brand awareness perception", was accepted as a result of the Spearman Correlation Tests.

COCHRAN Q TEST

The Cochran Q test was used to test the study's H_2 hypothesis that there is a difference between tea brands based on the blind tasting responses of the participants. Thus, the

compatibility of the decisions made by the participants for each tea item was examined with this test. In other words, with this test, it was determined to what extent the observation values of one participant were similar to the observation values of other participants. Table 6 displays the results of Cochran Q test.

Table 6. Cochran Q Test.

Tea Brands	*n*	Blind Test Results		df	Cohran's Q	Sig.
		True	False			
T1	101	58	43	2	6,861	0,032
T2	101	51	50			
T3	101	69	32			

According to the results of the Cochran Q test given in Table 6, the hypothesis that there was no difference in the perceptions of the participants about the brand of tea they drank as a result of the blind taste test was rejected (Q = 6,861; p = 0,032 < 0,05). As a result, there was a difference between the the participants about blind taste test. The result of the McNemar test performed to find the source of the difference was given in Table 7 (McNemar's test was used to compare pairs of the groups with defects and the results were presented in Table 7).

Table 7. Pairwise comparison of the groups using McNemar's test (n = 101).

Test	T1-T2	T1-T3	T2-T3
Chi-square	0,706	2,326	5,780
Asymptotic significant	0,401	0,127	0,016

As can be seen in Table 7, the source of the difference in the blind taste test results was the perceptions of the participants about T2 and T3 teas. (Only T2-T3 pairwise comparisons were statistically significant (p < 0,05)). In other words, the blind taste test results differ only in terms of T2 and T3 teas. As a result of the findings, the H_2 hypothesis of the research, "there is a difference between tea brands based on the blind tasting responses of the participants", was accepted.

MANN WHITNEY U TEST

Mann Whitney U Test was used to test the third hypothesis of the study, "sensory branding perception differs according to the blind taste test" and the H_4, "brand awareness perception differs according to the blind taste test". Table 8 displays the results. As can be seen in Table 8, the sensory branding perception of the participants does not differ according to the results

Table 8. Mann Whitney U Test for Sensory Branding Perception Considering Blind Taste Test.

Variables	Blind Test Results	*n*	Mean Rank	Sum of Ranks	*U*	*p*
T1 Sensory Branding	True	58	55,74	3233	972	0,058
	False	43	44,60	191		
T2 Sensory Branding	True	51	54,35	2772	1104	0,244
	False	50	47,58	2379		
T3 Sensory Branding	True	69	50,75	3502	1087	0,901
	False	32	51,53	1649		
T1 Brand Awareness	True	58	54,43	3157	1048	0,171
	False	43	46,37	1994		
T2 Brand Awareness	True	51	51,41	2622	1254	0,886
	False	50	50,58	2529		
T3 Brand Awareness	True	69	53,84	3715	908	.152
	False	32	44,88	1436,		

of the blind taste test for T1 (U = 972, p > 0,058). In other words, the difference between the participants' sensory branding averages and whether the tea brand is accurately recognized or not is not significant. Accordingly, the sensory branding scores of the participants did not depend on whether it was correctly known that the tea they drink was T1 brand. This finding was supported by the fact that the sensory branding mean rank of those who correctly knew that the tea they drink was T1 brand and those who misunderstood was close to each other.

In addition, the sensory branding perception of the participants did not differ according to the blind taste test results for T2 and T3 brands in Table 8 (respectively, U = 1104, p > 0,244; U = 1087, p > 0,901). In other words, the difference between the sensory branding scores of the participants and whether the tea brand was known correctly was not significant in terms of T2 and T3 tea. Accordingly, the sensory branding scores of the participants did not depend on whether it was correctly known that the tea they drink were T2 and T3 tea brand. This finding was supported by the fact that the sensory branding mean rank of those who correctly knew that the tea they drink was T2 and T3 brand, and those who misinterpreted, were near to each other. In this context, the difference between the sensory branding scores of T2 and T3 tea brands and whether the tea brand was known correctly or not was similar to the T1 tea findings. In the light of all these findings, the H_3 hypothesis of the research, "The sensory branding perception of the participants differs according to the results of the blind taste test", was rejected.

Furthermore, as shown in Table 8 for the fourth hypothesis findings, the participants' brand awareness perceptions do not alter based on the outcomes of the blind taste test for T1 tea (U = 1048, p > 0,171). In other words, there was no significant difference between the participants' brand awareness avarages and whether the tea they consume was known as T1. Accordingly, the brand awareness scores of the participants did not depend on whether it was correctly known that the tea they drink was the T1 brand. This finding was also supported by the close mean rank of brand awareness of those who knew the right thing and those who knew wrong about the tea they drink. Similarly, the brand awareness perception of the participants did not differ according to the blind taste test results for T2 and T3 tea brands (respectively; U = 1254, p > 0,886; U = 908, p > 0,152). In other words, the difference between the brand awareness averages of the participants and whether the brand of tea they drink was T2 and T3 tea was not significant. Accordingly, the brand awareness averages of the participants did not depend on whether it was correctly known that the tea they drink was T2 and T3 brand.

This finding was also supported by the fact that the brand awareness rank averages of those who correctly knew that the tea they drink were T2 and T3 brands, and those who misunderstood, were close to each other. In the light of all these findings, the H_4 hypothesis of the research, "The brand awareness perception of the participants differs according to the results of the blind taste test", was rejected.

LOGISTIC REGRESSION

Logistic Regression analysis was used to test the H_5 hypothesis of the research, "sensory branding perception and brand awareness perception have no effect on blind taste testing". First, the results of the Logistic Regression Analysis for T1 were given in Table 9. Hosmer and Lemeshow tests were used to test the fit of the created Logistic Regression Model to the data. If the significance level of this test is greater than 0,05, it indicates that the model is suitable for the data. In the study, this statistic was found as p = 0,574 (χ^2 =6,65, df=8). Therefore, it can be said that the model created is suitable for the data. The coefficients of the two independent variables were determined as β_1 = –0,446, β_2 = –0.366, but both independent variables were insignificant (p > 0,05).

Table 9. Coeffient of LR of Model for Brand T1.

							95 % C.I.for Exp(B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
T1 Sensory B.	–0,446	0,248	3,234	1	0,072	0,640	0,394	1,041
T1 Brand Aw.	–0,366	0,371	0,975	1	0,323	0,693	0,335	1,434
Constant	2,189	1,210	3,271	1	0,071	8,922		

In this case, the Logistic Regression Model can be expressed as follows:

$$\mathrm{Ln}Y = 2{,}189 - 0{,}446 \cdot X_1 - 0{,}366 \cdot X_2.$$

The coefficients were not interpreted since the derived model's results were meaningless. The proper classification rate of the data from which the model was derived, on the other hand, is shown in Table 10.

Table 10. Correct Classification Ratio of the Model for Brand T1.

		Predicted		
		Blind Test Results		Correct Percentage
Observed		True	False	
Blind Test Results	True	50	8	86,2
	False	27	16	37,2
Overall Percentage				65,3

The correct classification ratio of the models was created by taking the cut-off value of 0,5 and was shown in Table 4. The correct classification rate of the model was determined as 65,3 %. Therefore, as a result, using the independent variables that explain the model, it could be predicted with 65,3 % accuracy whether the participants would be assigned to the correct or incorrect groups based on the type of tea they consume. This value was greater than 51,1 % $((58/101)^2 + (43/101)^2 = 0{,}511)$, indicating that the success was attributed to coincidence. Therefore, it could be considered that the model performs a successful classification.

The results of the LR analysis for T2, another tea brand, were given in Table 11. The fit of the constructed Logistic Regression Model to the data was tested using the Hosmer and Lemeshow tests. This statistic was determined as $p = 0{,}369$ ($\chi^2 = 8{,}79$, df=8) in the research, indicating that the model generated was appropriate for the data. The coefficients of the two independent variables were determined as –0,330 and 0,008, respectively. However, neither independent variable was significant ($p > 0{,}05$).

Table 11. Coeffient of LR of Model for Brand T2

							95 % C.I.for Exp(B)	
	B	Lower	Lower	df	Sig.	Exp(B)	Lower	Upper
T2 Sensory B.	–0,330	0,237	1,936	1	0,164	0,719	0,452	1,144
T2 Brand Aw.	0,008	0,338	0,001	1	0,982	1,008	0,519	1,955
Constant	0,973	1,036	0,883	1	0,347	2,647		

In this situation, the LR model can be represented as follows:

$$\mathrm{Ln}Y = 0{,}973 - 0{,}330 \cdot X_1 + 0{,}008 \cdot X_2.$$

The coefficients were not interpreted since the derived model's results were meaningless. The correct classification rate of the data from which the model was created, can be seen in Table 12.

Table 12. Correct Classification Ratio of the Model for Brand T2.

Observed			Predicted		
			Blind Test Results		Correct Percentage
			True	False	
Blind Test Results	True		22	29	43,1
	False		25	25	50,0
Overall Percentage					46,5

The correct classification ratio of the models was created by taking the cut-off value of 0,5 and was given in Table 12. As can be seen, the correct classification rate of the model was obtained as 46,5. As a result, using the independent variables that explain the model, it was possible to estimate with 46,5 % whether the participants would be assigned to the correct or incorrect groups based on the type of tea they consume. This value was less than 50,0 % $(51/101)^2 + (50/101)^2 = 0{,}50$) indicating luck-based success. Therefore, it could not be said that the model made a very successful classification.

On the other hand, the results of the LR created for T3 brand were shown in Table 13. The fit of the constructed Logistic Regression Model to the data was tested using the Hosmer and Lemeshow tests. In the study, this statistic was obtained as $p = 0{,}984$ ($\chi^2 = 1{,}882$, df = 8), so it could be said that the model created was suitable for the data. The coefficients of the two independent variables were determined as $\beta_1 = -0{,}085$, $\beta_2 = -0{,}522$, but both independent variables were insignificant ($p > 0{,}05$).

Table 13. Coeffient of LR of Model for Brand T3.

							95% C.I.for Exp (B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
T3 Sensory B.	0,085	0,229	0,138	1	0,710	1,089	0,695	1,706
T3 Brand Aw.	–0,522	0,361	2,096	1	0,148	0,593	0,293	1,203
Constant	0,634	1,200	0,279	1	0,597	1,885		

Then, the LR Model can be expressed as follows:

$$\mathrm{Ln}Y = 0{,}634 + 0{,}085 \cdot X_1 - 0{,}522 \cdot X_2.$$

Since the results of the model were meaningless, the coefficients were not interpreted. On the other hand, the correct classification rate of the data from which the model was obtained is given in Table 14.

Table 14. Correct Classification Ratio of the Model for Brand T3.

Observed		Predicted		
		Blind Test Results		Correct Percentage
		True	True	
Blind Test Results	True	68	1	98,6
	False	31	1	3,1
Overall Percentage				68,3

The correct classification ratio of the models was created by taking the cut-off value of 0,5 and was represented in Table 14. The model's correct classification value was observed as 68,3 %. Therefore, using the independent variables that explain the model, it was possible to predict with 68.3 percent accuracy whether the participants would be assigned to the correct or incorrect groups based on the type of tea they consume. This value is greater than 56,7 % $(69/101)^2 + (32/101)^2 = 0{,}567$), indicating that the success was attributed to chance. Therefore, it could be said that the model performs a successful classification.

In this direction, when the LR findings were evaluated as a whole, it was revealed that sensory branding perception and brand awareness perception of tea brand did not affect the blind taste test. Therefore, H_5 hypothesis of the study, "sensory branding perception and brand awareness perception have an effect on blind taste testing", was accepted.

CONCLUSION

When the findings of this study are evaluated, it becomes clear that the participants' views on tea brands differ in terms of sensory branding, brand awareness, and blind taste testing. According to the study's findings, the participants were quite familiar with the drinking of tea and mostly used bulk tea. This conclusion is consistent with data from Turkish tea statistics.

In the blind tasting test, participants were asked to choose the best and worst tea. T2, T3 and T1 were selected respectively in the best taste selection, while T1, T2 and T3 were selected in the worst taste selection. This result was different from the results of Deveci et al. [28]. It seems that in the blind tasting test, no difference is detected in the ranking of the best and worst tea.

The correlation test indicated that there is a positive relationship between sensory branding and brand awareness. As a result, sensory branding is critical in today's competitive environment for positioning in the minds of consumers. These findings are similar to those of Kytö [29], Yilmaz et al. [31], Robinson et al. [4], Erenkol [24], Tosun and Elmasolu [23]. Sensory branding, rather than standard branding, can be used to raise awareness for tea firms in this direction. More effective results can be obtained with the five senses. It has been understood that the brands studied have recently had very little work on sensory branding. The participants were undecided about whether the tea brands used sensory branding.

After the blind taste test, there was no difference between T1 tea and other teas, but a significant difference emerged between T2 tea and T3 tea. While no significant difference was found after the blind taste test in the literature [10, 12, 34, 36, 37], there was a partial difference in this study. This result was reported by Kytö [29] and Robinson et al. [4] which shows similar results with this study.

The Mann Whitney-U test was used to determine the difference between sensory branding, brand awareness, and drinking tea after the blind taste test. There was no difference according to the results. In other words, although the participants were aware of the tea brands, they could not find out which brand the tea was drunk after the blind taste test. This result is generally accepted in the literature.

The effects of sensory branding and brand awareness on the blind taste test were tested with logistic regression. After analyzing the data, it was discovered that sensory branding and brand awareness had no effect on the blind taste test. As a result, it is possible to conclude that completing brand work is critical for distinguishing similar or identical products.

Given the fierce rivalry in the tea sector, conducting brand research is essential. In this direction, it is recommended that tea companies place a greater emphasis on brand communication studies.

LIMITATIONS

This study has limitations in terms of time, place and product. First of all, this study is a cross-sectional study limited to 2021. During this period, tea brands may not have done enough communication work. In this direction, the periods when tea brands have and have not done communication work can be examined separately. The second limitation is that it was limited to Düzce province. Consumers with tea drinking culture in various regions of Turkey or other countries might be researched comparatively. The relationship between

sensory branding, awareness of difference and blind taste test of international-national brands can be examined. It is possible to investigate the relationship between sensory branding, brand awareness, and blind taste testing of manufacturer and retailer brands. The third limitation is the brewing method that is used in the test, and the type of tea considering only black tea was used. Future studies can also be carried out using different types of tea and different brewing methods.

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CRITICAL COMPARISON ON SAFETY MANAGEMENT SYSTEMS, IDENTIFYING OPPORTUNITIES FOR COMPANIES MANUFACTURING AND USING HAZARDOUS SUBSTANCES

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ABSTRACT

In the life of companies operating with hazardous substances, the daily task is to maintain the safety on a high level and to introduce actions to increase safety performance. The companies covered by the Disaster Prevention Act have a special task, to operate a safety management system that also satisfies industrial safety aspects. To make this as efficient as possible, good practices from other safety management systems can be built into the currently used management system at the company. Perhaps the most frequently operated safety management systems for organizations producing and processing hazardous substances are the Occupational Health and Safety Management according to the ISO 45001 standard and the Process Safety Management systems. A comparison of the latter with what is required by law points to several points that may designate areas for improvement in the certified safety management system. In this way, they provide a basis for the development of a new system, that complying with the prescribed requirements, helps to maintain a high level of safety, to prevent the occurrence of accidents, and to work with safety-conscious employees and suppliers.

KEY WORDS

industrial safety, OHSM, PSM, safety management system

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INTRODUCTION

Appropriately designed and operated management systems can provide a framework for the activities of enterprises operating with dangerous substances. In practice, businesses develop their own operating scheme according to the requirements of a safety management system. According to the relevant standard and legal provisions, the safety management systems formulate the operational requirements and focus on the given system elements differently, but the primary goal of all of them is the safe operation and the reduction of safety risks. It is important to examine and compare these management systems so that the applied safety management system can be improved with effective and good practices used by other systems.

The term of 'safety' as 'an ability for a system to perform its intended purpose, whilst preventing harm to persons'. Safety, or the lack of safety, is an emergent property of an operational system. Thus, safety can be thought of as the combined result of the decisions and action of all persons with an ability to interact with the operational system. 'Safety management' is a label that we use to describe practices that can direct, monitor and intervene in core operations for the purpose of generating or maintaining safety. 'Risk' is a term that is linked to safety and we use it to refer to the level of uncertainty that the operational system will generate safety as an emergent property, and the severity of the potential consequences to people of a lack of safety. Finally, the term 'safety professional' is used to describe roles within an organization that exist with the primary purpose of safety management, and that does not have a core operational purpose for the organization [1]. An integral part of safety management is communication, which must be managed by business organizations on an appropriate platform. Data security and their preservation are just as important as the operation of dangerous technologies, which can be provided with various smart solutions and cloud-based data management. The cloud technology in information and communication technology (ICT) is a young and cutting-edge area. This is due to the fact that from the individual mobile to a full realization of virtual data centers it is possible to provide service over the network [2].

SAFETY RISK REDUCTION SYSTEMS

In the following sections, it is presented the three best-known systems by which companies operating with hazardous substances can increase safety.

OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEM BASED ON ISO 45001: 2018

ISO 45001: 2018 standard [3] was first issued in March 2018 replacing OHSAS 18001standard [4]. The purpose of applying the *Occupational Health and Safety* (OHS) *Management System* is to enable the organization to provide safe and healthy workplaces, to prevent work-related injury and damage to health, and to continually improve its OHS performance. The standard is applicable to any organization that intends to develop, implement, and maintain an OHS Management System (OHSMS) to improve occupational health and safety, eliminate hazards, and minimize OHS risks [3].

The main elements of OHSMS during the operation with hazardous substances

First of all, it is necessary to define the range of stakeholders and to identify the external and internal factors affecting the organization [3]. This is a basic requirement of all management systems and a condition for developing well-functioning processes. When defining an organization's environment, it is especially important to reveal the relationship between each factor and the activity with hazardous sustances. If we do this with sufficient thoroughness, it will be, so to speak, carried out *risk assessments*. In this way, the organization can explore

hazards, establish procedures, and *define responsibilities*. By operating with hazardous substances, it is important to provide the public with the opportunity to be consulted, and to emphasize awareness and the pursuit of safe operation. In connection with notifications made by the population, a thorough investigation must always be carried out and the notifier must be informed of the outcome and the method of the process in an official way. As an internal factor in terms of organizational structure and responsibilities, it can be thorough if it is created appropriate regulations (e.g., organizational and operational regulation) and always be recorded changes in them.

It is necessary to emphasize the *role of the top management*, the *leadership commitment* in the case of everyday activities as well. Good opportunities for this are the forums with employees and consultations with the individual departments. Careful consideration of the employee responsibilities and tasks as defined by the top management is also important. Responsibilities may need to be reviewed and modified when investigating incidents and technological problems that occur during the activity. In connection with hazardous substances, the risk assessment and handling is a fundamental task of the organization. The safety data sheets of substances and preparations must be used in compiling the documentation. Workers should also have access to these safety data sheets. In order to describe each activity (technological and operational instructions), it is important to consult the individual organizational units. The Organization for Health, Safety and the Environment (HSE) has a key role to play in this, as it usually collects the information (accidents, incidents, occupational diseases, quasi-accidents) on the basis of which development aims can be defined. At the same time, top management and human resource management must by now play a role in communicating these aims and the achieved results.

Training is one of the basic pillar of the safe operation of an organization dealing with hazardous substances. Besides of the entry-level training specified in the Hungarian Occupational Safety and Health Act [5], trainings related to hazardous substances, changes and experience of events must be repeated regularly. With proper internal communication, employees' confidence can be strengthened, their interest can be sustained and their professional development can be successful. In addition to negative events (accident, incident, off-spec quality product), it is advisable to communicate the positives (economic progress, development results, successful audits) also.

An organization dealing with hazardous substances should communicate with external stakeholders (population, authority, business partners) by a person with sufficient competence. The top management of an organization must be committed to the management system it operates. During the management review, top management should see opportunities for directions to the improvement.

The approach applied to the OHS management system in the ISO 45001: 2018 standard which is based on the PDCA (Plan-Do-Check-Act) concept. The PDCA concept is a repetitive process with feedback applied by the organization to achieve continuous improvement. One way to pursue technological safety is to use technologies that are automated or achieved by automating existing technological elements. This should be the part of the continuous improvement and thus reduce the problems generated by human omissions. Automated systems generate and transmit data. This communication must be properly designed, as it can potentially control or inhibit different processes of hazardous technologies. Access to these must also be precisely regulated. Technological data must be analyzed and stored so that they can be used during any technological event to determine causes and take preventive actions. Cloud technologies may be suitable for this in the future, provided, of course, that they meet all the important requirements of the company regulations.

The analysis of cloud building technologies shows that the most important characteristics of the cloud include reliability, component variability, flexibility and the measurability of the services. Among the components, the following must be defined: Client Infrastructure, Application, Service, Runtime Cloud, Storage, Infrastructure, Management, Security, and Internet. The technical requirements of the components can be grouped according to the following topics: availability (existence), virtualization of necessary resources (structural and energy knowledge), virtualization of implemented services (validation), flexibility (control and change management) [2].

PROCESS SAFETY MANAGEMENT SYSTEM

Process safety management (PSM) is the proactive identification, evaluation and mitigation or prevention of chemical releases that could occur as a result of failures in processes, procedures, or equipment. The Process Safety Management Guidelines for Compliance [6] targets hazardous chemicals that can cause a catastrophic incident. The purpose of the guideline as a whole is to assist employers in their efforts to prevent or reduce chemical releases that could lead to disaster in the workplace and possibly in the sorrounding community.

As PSM is specifically used in connection with operations related to hazardous substances, it is already different from OHSMS in that it is also used for non-hazardous technological activities. It is important to emphasize that in this system it becomes even clearer that the automation of the technological processes and the exploration of non-process-controlled system components – which require manual control – is needed to be monitored, thus increasing the role of the technological safety and the role of human resources in monitoring, data processing and data transmission. This virtual communication can be implemented with various smart solutions that are sufficiently reliable.

The main elements of Process Safety Management

Employers should compile written process safety information that identifies the hazards of extremely hazardous chemicals in progress, process technology, and information on ongoing equipment. By providing these information, it is possible to design the elements and the entire process of PSM, Figure 1. The compilation of the process safety information provides the basis for identifying and understanding the process hazards that are required to develop a process hazard analysis, change management, and event investigation [7].

The guideline places great emphasis on involving employees in developing and executing the PSM programs, especially in the area of hazard identification and assessment [8].

The process hazard analysis shall use as many methods as possible, which shall cover the hazards of the process, the identification of any previous incidents that may have catastrophic consequences in the workplace, engineering and administrative controls applicable to the hazards and their interrelationships, inadequate controls or the consequences of the lack of controls, the location of the facility, human factors, possible safety and health effects on workers [7].

Employers should develop a written action plan to implement the employee participation required by the PSM and prepare and execute written operational procedures that should include process safety information. Steps for each operational phase: initial start-up, normal operation, temporary operations, emergency shutdown, including conditions for the need for an emergency shutdown, and assignment of shutdown responsibility to qualified operators to ensure that the emergency shutdown occurs safely and in a timely manner. It is also important to correctly define the operating limit values, which can be used to ensure the analysis of the consequences of the deviations, as well as the definition of the steps necessary to correct or avoid the deviation. Operating procedures should be easily accessible to employees working on or maintaining the

Figure 1. The 15 main elements of the PSM.

process. Operating procedures should be reviewed as often as possible to ensure that they reflect current operating practices, including changes in chemicals, technology, equipment and facilities. They must be certified annually to ensure that they are up-to-date and accurate. It is also important to involve employees in the preparation of process risk analyzes [7].

Employers should provide basic training for all employees, including contractors, who are currently involved in the operation of a process or a newly assigned process by reviewing the process and operating procedures. This should be repeated at least every three years or more often if necessary so that employees understand and follow the current operating procedures of the process [8].

Specific provisions of the PSM include training for contractors and their employees who are at or near a particular process. When selecting a contractor, the employer must obtain and evaluate the contractor's security performance and program. It is the employer's responsibility to ensure that employees are trained and aware of the hazards of potential release of flammable, explosive or toxic substances, as well as the emergency plan, to comply with the safety rules of the facility, to know the specific hazards of their work [7].

PSM requires the employer to perform a pre-start-up safety review before new facilities and modified facilities starting operation. The safety review should confirm that the construction and equipment are in accordance with the design specifications, safety, operational, maintenance and emergency procedures are in place and appropriate, the process hazard analysis has been carried out for new facilities, and the training of all employees involved in the operation of the process has been completed [7].

The employer must establish and implement a written procedure while maintaining the continuing integrity of the technological equipment. The frequency of inspection and testing of process equipment shall be in accordance with the manufacturers' recommendations and good engineering practice. They should be performed more frequently if deemed necessary based on previous operational experience. All inspections and tests of process equipment must be documented [7].

Employers should provide and implement written mechanical integrity procedures and programs to perform appropriate maintenance and equipment inspections and tests at appropriate frequencies to detect equipment deficiencies before they fail. Employees involved in maintaining the integrity of process equipment should be trained in the procedures relevant to their job responsibilities [8].

A permit shall be issued for flammable activities, documenting that the fire prevention and protection requirements of OSHA (1910.252 (a)) [9] have been met prior to the commencement of fire protection work, indicating the date (s) permitted and identifying the equipment on which the flammable activity is carried out [7].

A key part of the process safety management program is to thoroughly investigate incidents by identifying a chain of incidents and causes so that corrective actions can be developed and implemented. Accordingly, the PSM requires the investigation of all cases that have resulted or could have resulted in the catastrophic release of an extremely hazardous chemical in the workplace. An investigation into such an incident should begin as soon as possible. The investigation should be carried out by a team involving a person familiar with the process, if necessary an expert, as well as other persons with appropriate knowledge and experience in order to thoroughly investigate and analyze the case [7].

If an incident occurs despite the best planning, it is essential that workers are able to take appropriate action. For this reason, a plant-wide emergency action plan must be developed and implemented in accordance with the provisions of other OSHA regulations (29 CFR 1910.38 (a)) [10]. In addition, the emergency action plan should include procedures for dealing with small releases of hazardous chemicals [7].

To ensure effective management of process safety, employers must demonstrate that compliance with the provisions of the PSM has been assessed at least every three years as part of an audit. This demonstrates that the procedures and practices developed in accordance with the standard are properly followed. The conformity check must be performed by at least one person familiar with the process and must report on the findings of the check and the correction of deficiencies. Planning is essential to the success of the audit process. The selection of members of an effective audit team is critical to the success of the program. Team members should be selected based on their experience, knowledge, and qualifications, and should be familiar with processes and control techniques, practices, and procedures. The size of the team depends on the size and complexity of the process under study. Effective control includes review of relevant documentation and process safety information, inspection of facilities, and interviews with all levels of plant personnel. The audit team should document, through systematic analysis, areas where corrective action is required and where the process safety management system is effective. It provides a record of audit procedures and findings and serves as a basis for operational data for future audits. It will help identify changes or trends in future audits. The employer shall ensure that any identified deficiencies are remedied, record the corrective actions to be taken, and properly document the responsible audit person or team. To monitor the process of corrective action, the employer should consider using a tracking system [6].

Once the hazards have been identified and assessed, controls (physical and behavioral) are also introduced to manage the hazards to an acceptable level of risk. These controls are often reflected in technical changes to systems and equipment, management systems and procedures. Non-physical controls, such as procedures and business processes, are documented by security management systems, supplemented by training programs [1].

Employers should make available all information necessary to comply with the PSM, even if it contains any trade secrets. However, the provisions of the PSM do not prevent an employer from entering into confidentiality agreements [7].

SAFETY MANAGEMENT SYSTEM REQUIRED BY HUNGARIAN DISASTER MANAGEMENT LEGISLATION

The purpose of the operation of the Safety Management System (SMS) is to implement the operator's safety policy for the prevention of major accidents and the reduction of risks. The SMS is a "quality management" system based on the fulfillment of a legal obligation, by the operation of which adequate safety against major accidents can be achieved and maintained [11].

For the operators of plants dealing with hazardous substances (hereinafter: plants), the IVth Chapter of the Hungarian Act CXXVIII of 2011 on Disaster Protection and Amendments to Certain Related Acts [12] requires the operation of a safety management system (SMS) or a management system (MS), depending on the status of the plant. This safety management system shall in all cases follow the SEVESO III [13] principles, including the required risk analysis, should be prepared with this in mind. In many cases, the development trends of automation and communication in smart cities can be included as an improvement factor in the management of risks, for example when it comes to the investigation of the terrorist threat. The risks to the safe operation of a chemical manufacturing and processing organisation must be excluded or minimized. These risks can be managed with secure communication solutions, secure data storage and movement, and a high degree of automation of production processes.

The main elements of the Safety Management System

The operator must define the exact responsibilities and roles of the personnel at all levels of risk management, set out the ability and competence requirements for the personnel, define the roles, responsibilities, tasks, competencies and interdependencies of the managing and executive personnel. "Security management" is responsible for constantly updating the system documentation, keeping it up to date, something about the organizational management of the safety management system [14].

The operator must establish and apply procedures for identifying and assessing hazards arising from the activity and from the handling and processing of hazardous substances and preparations. It is also necessary to define accident prevention and reduction measures. The assessment of the theoretical knowledge and practical experience required to design and implement the above procedures should be part of the management system. Hazard identification and assessment shall cover hazards during design, installation, commissioning, operation, development, hazards in normal and abnormal modes, accidents and potential hazards, external events, human factors and safety management. System failures, decommissioning, modifications and shutdowns, hazards of preventive activities, natural hazards, transportation, material handling activities, effects of surrounding activities, intentional or unauthorized actions. The hazard identification and assessment should also include the identification and assessment of major-accident hazards arising from activities carried out in the subcontracting system. Information on the results of hazard identification and assessment procedures, operational hazards and management shall be kept up to date and made available.

The operator must develop the standards of the safety management system, technological descriptions and instructions for safe operation with the involvement of the executive staff. The system of standards must also take into account normal operating technologies, shutdowns, start-ups, equipment maintenance and technological hazards, as well as possible malfunctions. The instructions must be given to the staff partially or completely involved and periodically ascertained as to their implementation, up-to-dateness and applicability [14].

Best practice should be included in the safety objectives. It is essential to monitor and control the condition of critical equipment. For this, it is necessary to develop a strategy and methodology in order to ensure safety against serious accidents involving dangerous substances. The operator must pay due attention to follow-up measures and any countermeasures that may be necessary. Practical implementation options include setting technical safety sustainability objectives and designating related procedures to regulate activities related to the periodic inspection, technical safety review, calibration and maintenance of physical equipment, and providing the necessary resources to perform these tasks [11].

The operator must pay attention to changes in equipment, storage facilities and production. The safety aspects of these changes must be taken into account in advance when planning and implementing the changes. In managing changes, particular attention should be paid to the definition of responsibilities and tasks, the documentation of the proposed change, the determination of the security implications of the proposed change, the definition and application of additional post-change review procedures [14].

The operator must draw up a protection plan to deal with the assessed hazards. The procedures necessary for the preparation, implementation, application, review, exercise, control and updating of the security plan shall be laid down and shall be included in the safety management system. The operator must ensure that those involved, including subcontractors, are familiar with the content of the plan and receive appropriate training and preparation on the relevant tasks [14].

The operator must develop methods to continuously monitor the achievement of the objectives set for the prevention of major accidents involving dangerous substances. The implementation of the tasks related to the objectives should be continuously evaluated. An information report on major accidents or incidents involving dangerous substances shall be provided, in particular on factors which indicate a failure of the safety system. An assessment should be made of the deficiencies identified, conclusions drawn and action taken on the basis of these to address the tasks required for prevention or remediation. The operator must operate monitoring systems to continuously assess the achievement of the safety objectives set. This includes, on the one hand, monitoring the implementation of plans and objectives and the implementation of risk management measures before the accident occurs (active monitoring), and, on the other hand, reporting and investigating failures in the event of a breakdown or accident (reactive monitoring). Compliance with the safety management system can be verified by conducting audits. The audit must be carried out by a person independent of the plant concerned. Based on the audit results, the need for improvements in the elements of the safety management system can be determined. A review of management can be used to determine whether the operator is achieving the objectives he has set with the safety management system [14].

In relation to compliance with SEVESO III, the operator shall introduce the indicators used in the safety performance assessment procedures and incorporate the changes identified as necessary during the inspection. In order to implement the new regulatory elements in practice, the PDCA cycle will play a particularly important role. The application of the PDCA cycle ensures, among other things, that measures identified as a result of management reviews, internal audits are implemented, and that lessons learned from unforeseen events are incorporated by operators into the operational SMS [11].

In order to maintain and continuously improve the safety level of the plant, it is essential to apply a systematic management system that guides the operator step by step throughout the development cycle, involving each element of the SMS in the process in the appropriate order and time. The PDCA cycle is based on four main elements: Plan, Do, Check, and Act. The application process of the four elements as a self-recurring loop allows for the continuous improvement of the tested system throughout the entire life cycle of the plant [11].

The application and implementation of the SMS can be simplified if it is based on a professionally high-level, sufficiently thorough safety report. In addition, in Hungary, companies subject to the SEVESO Decree also operate a certified OHSMS system, which also includes the provisions of the SMS.

COMPARISON OF THE THREE MANAGEMENT SYSTEMS – METHODS TO INCREASE EFFICIENCY

Critical comparisons are prepared for the three described management systems, namely OHS, PSM and SMS management systems, Table 1. The aspects of the comparisons are as listed.

Basic features of operation

It takes into account the environment and organization of the enterprise, as well as the basic information necessary for operation – management commitment, employee responsibility: an economic organization, especially when operating with hazardous substances, must declare that safe operation is important for managers and that all resources are provided for this. Employees must be aware of the dangers of their activities, their effects and all the responsibilities that affect them.

Planned activities to increase operational safety

The start and execution of technological activities must be preceded by a well-prepared planning process in which all possible risks are assessed and operated with these in mind.

Documents for operational safety

The precise course of hazardous technological processes is set out in instructions in which all tasks and responsibilities are clarified, not least the control points to which special attention must be paid.

Operation different from normal and normal conditions

In addition to the normal operating processes recorded in the procedures and instructions, the company must be prepared for changes in the process, possible accidents and their management.

Evaluation of operation, identification of deficiencies

Operation can be best measured with performance indicators, which focus on those elements of operation that provide information on the safety and continuity of the process. Based on these, deficiencies can be identified that are not perceptible at a given moment, but with their help it is also possible to take preventive measures.

Continuous improvement with risk assessment

A basic requirement of any management system, in which the assessment of risks related to processes and activities can help. Based on these, new development directions in terms of security can also be determined.

Data management

Although the PSM system most clearly highlights business secrets, the protection and secure management of data is an important aspect of any management system, for which the abovementioned smart solutions are also available, so the exact scope and authority can be determined.

Smart solutions

Management systems, safe operation can be improved by using them, so the pursuit of smart communication and automated methods should be emphasized.

Table 1. Comparison of safety systems.

	ISO 45001:2018 (OHS)	**Process Safety Management System (PSM)**	**Safety Management System /by law/ (SMS)**
Basic features of operation	organization's environment	Process safety information	Organization and personnel
Leadership commitment, employee responsibility	Leadership and employee participation	Leadership commitment Employee training Employee participation	
Planned activities to increase operational safety	Planning	Process hazard analysis Pre-startup safety review Critical process equipment	Identification and assessment of major-accident hazards
Documents for operational safety	Support	Operating procedures	Operational control
Normal and abnormal operation	Operation	Contractors (subcontractors) Flammable activity Emergency Response Incident investigation	Protection planning
Evaluation of operation, identification of deficiencies	Performance evaluation, Audits, Management review	Audits and controls	Performance monitoring, audit
Continuous improvement with risk assessment	Development Management of change	Management of change	Management of change
Methodology	Application of PDCA		SMS operating according to the PDCA cycle
Data Management		Trade secret	
Smart solutions	In the case of a security management system, it is not emphasized, but the methods used by different smart cities (automation, cloud-based data management) are possible for development.		

When comparing the three systems (Table 1), the following can be stated:

- each system seeks to avoid and prevent disasters such as those at Flixborough (United Kingdom, 1974), Seveso (Italy, 1976) and Bhopal (India, 1984);

- the PSM e.g. in the USA, SMS /by law/ in Hungary is a legal obligation under the Disaster Management Act, while OHSMS may be expected from external stakeholders;
- PSM and SMS aim at the prevention of disasters related to the avoidance and improper handling of hazardous substances, OHSMS focuses on hazards that can lead to health problems [15];
- OHSMS formulates in general terms that it can be applied to all activities, the PSM mainly gives directions to organizations operating with hydrocarbons, the SMS gives the system of activities with hazardous substances (harmful to human health, environment, flammable, explosive);
- all three systems can significantly reduce the likelihood of accidental events. To prevent accidental events, it is essential to know how control systems work. Effective management systems reduce the dangers of employees not performing their activities at the same level, and ensure that important tasks are performed. Management systems should be as simple and efficient as possible and should not involve unnecessary tasks, as cumbersome systems encourage employees to circumvent the rules;
- in the case of all three systems, it is important to determine the causes of malfunctions and to investigate the events that have taken place. An emphasized and detailed description of the range of events to be investigated has been made in the PSM standard and the guidelines related to the SMS. It is important to note, however, that none of the systems emphasizes those cases, technological events that do not have serious consequences, the release of hazardous substances, but it is important to consider and, if necessary, to investigate them. Such an event is, for example, an increase in the operating parameter in a technological equipment to an extent that is not yet critical, but has caused the shutdown of certain technological elements. If the possible causes are discovered in these cases as well, we can exclude these points as possible sources of danger later with preventive measures.

For any sector where hazardous substances are used, manufactured (chemical, pharmaceutical, cosmetics) it can be useful to improve the various elements of the safety management systems used, to increase efficiency, to start emergencies, to bit normal operation, focusing on new elements and methods.

AN EFFICIENCY-ENHANCING METHOD

An important element of any system is the traceability of the measures and the follow-up of the measures taken. If a workflow is not effective, it is necessary to consider what steps need to be taken to improve the workflow or improve the management system. In order for the measures taken to be actually carried out, the Direction, Competence, Opportunity, Motivation (DCOM) model [16] can be introduced for the development of the system.

The DCOM model examines what management needs to do for management systems to work effectively. It focuses on:

- *Direction*: norms, expectations, roles.

  In the field of direction, the audit examines the elements of the safety management system that: (i) includes written procedures that ensure the consistency of the tasks to be performed, reflect safe practices already in place, are available at all times, and provide appropriate guidance to employees and management on expectations; (ii) clearly defines who has what everyone's task and who is responsible for what; (iii) comply with legal requirements and operate as originally planned, and (iv) reflect management's clear expectations through the involvement of management in various operational and control activities.

- *Competence*: education, understanding of processes.

  This part of the study assesses how well employees perform their work, how aware they are of the dangers of the activity they are doing, and the requirements for bit-safe of safe work.

- *Opportunity*: the time, tools and resources needed to do the job well.

  When examining the possibilities, they check whether sufficient time and resources have been provided for the long-term support and development of management systems.

- *Motivation*: measurement, control and feedback processes that monitor the efficiency of the system, examination and evaluation of employee performance.

  The test protocol should be designed to incorporate the aforementioned principles of DCOM. During the assessment of motivation, it is necessary to establish whether the employees and the management are sufficiently motivated for the high-quality implementation, operation and continuous development of the management system. It must be checked whether (i) the effectiveness of the systems is monitored with measurements and other feedback on management systems; ii. the quality and efficiency of management systems and related support processes are periodically checked; iii. are there tracking systems in place to monitor the performance of tasks; (iv) whether the activities and behavior of employees have predetermined consequences.

FOCUSING ON IMPORTANT SYSTEM COMPONENTS

Proper handling of and compliance with statutory documents during activities with hazardous materials can significantly increase a company's performance. By following the operating and technological instructions and educating them properly, safe work can be ensured. The safe operation of machinery and equipment can be achieved if an appropriate maintenance plan is prepared and the maintenance is carried out on time. By thoroughly investigating unexpected events, the number of critical points can be continuously reduced through corrective and more preventive activities.

WHERE and WHAT is the danger: We need to define the basic characteristics of the operation, what activity, what hazards.

WHO AND WHY RESPONSIBLE: The importance of senior management commitment should be emphasized, as well as the definition of the responsibilities of each employee related to the activity, it is necessary to evaluate the performance of individual units (eg as the bonus system)

WHAT TO DO AND WHEN: Planning is needed, so a process hazard analysis needs to be performed, how safety reviews need to be defined, major accident hazards need to be identified, the range of documents that contribute to operational safety needs to be defined, ~~and~~ as well as the main elements of the documents.

HOW TO DEVELOP: Incident investigation, that is, the investigation of events that are not normal operation. Ongoing evaluation is also needed in this area. Without continuous improvement, the safety of operation cannot be increased. In connection with individual development proposals, appropriations and actions must be formulated depending on the danger of the organization's activities.

WHAT METHOD WE APPLY: Effective application of PDCA is an important element of all 3 systems, a methodology that can be applied to all systems, can be used for all components. Guidance should be given on the depth and documentation environment in which each organization should perform its tasks. By definition, the more hazardous substances there are, the more hazardous activities there are, the more thorough and detailed regulation is needed.

SOME ASPECTS OF SYSTEM DEVELOPMENT AND OPERATION

1) The impact of leadership behavior on the organization.
   All leaders need to be aware that the leadership style, attitude, ethical values, and willingness to take risks that they choose and certify will determine their organizational culture. Based

on practical experience, it is not always the focus because it can be taken for granted. If leadership commitment is not emphasized and there are no verifiable action processes behind it, none of the systems can be operated effectively and improved.

2) No design without planning.
   An essential condition for achieving the goals is sound planning, coupled with an appropriate performance appraisal system. This creates an opportunity to involve employees already in the definition of goals, which lays the foundation for easier identification with goals, motivation of employees to contribute to the achievement of goals.

3) Each objective / task must be assigned to a responsible person and a deadline.
   In the absence of a definition of the person responsible for implementing the objectives and the deadline for implementation, the achievement of the objectives is left to chance. It is important that the responsible person is provided with all the authority and resources necessary to achieve the goals. It is important to highlight this point because it is clear that all tasks are performed by someone, but one must also be aware of the responsibilities involved, so the selection of responsible persons plays a major role in the continuity of operation and development.

4) Responsibility of the delegation.
   It is important to keep in mind that when delegating tasks, responsibility is only partially transferred. The ultimate responsibility and accountability for the adequacy of the delegation, for the performance of the task remains. Therefore, in each case, it should be considered whether the delegated person / entity has the appropriate competence to perform the task. The delegate is also responsible for monitoring and controlling the fulfillment of the delegated tasks.

5) Find a balance between management and micro management.
   Careful consideration needs to be given to how the performance of a particular task can be managed in a way that does not require interference in processes to an extent that already hinders work and impairs efficiency, while providing an acceptable level of certainty to achieve goals. By incorporating or refocusing the above aspects, as well as the principles of DCOM, in the processes, we will focus more on assessing the participation of managers and accountability, so that our colleagues can focus even more on the factors that guarantee the sustainability of the management system.

Figure 2 follows the PDCA principle of management systems in production practice, but the implementation aspects and the implementation of DCOM principles further emphasize the possibility of creating continuous production and technological safety. These focuses should be emphasized in the regulation of operations, which should be made clear to all internal and external stakeholders.

OTHER ASPECTS THAT DESERVE MORE EMPHASIS

By placing even greater emphasis on the following aspects in the operated safety management system, the safety performance of the company can be further enhanced. These, although present, do not receive adequate attention in our applied systems.

1) Vulnerability analysis

   The vulnerability of each sub-area can be determined in different ways.
   In the case of organizations and individuals, existing documents should be reviewed, and personal interviews should be used to ascertain how well employees know the regulations, and the current level of employee safety awareness should be assessed.

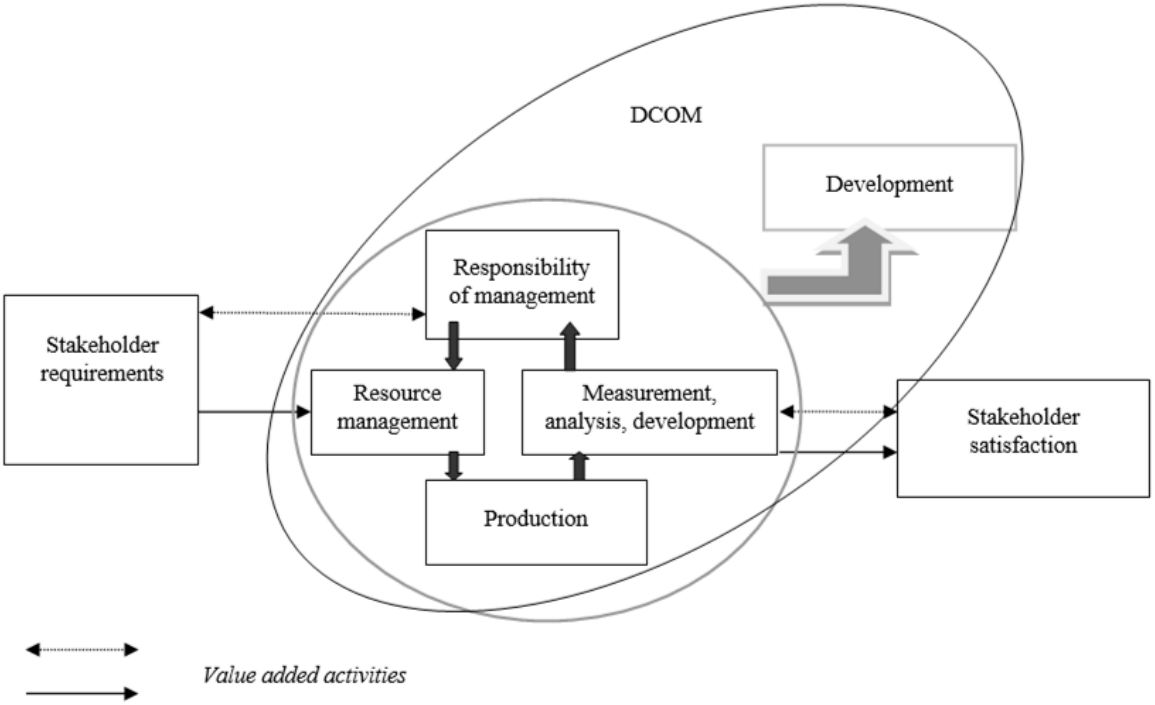

Figure 2. Management system in new focus.

Vulnerabilities are considered to be:

- the missing documents,
- existing rules but not implemented in practice,
- rules of inadequate quality,
- any rules for the implementation of which there are no personal conditions, and
- any case of conflict between the instruction to be executed and the responsible person assigned.

2) Development of a measuring and indicator system

The day-to-day operations of an organization dealing with hazardous substances cannot be completed without reporting. A production process requires a number of measuring devices, by examining the information and data provided by them, energy savings, quality improvement and a higher degree of safety can be achieved. Controls on processes and individual departments are also a factor in increasing safety, as non-conformities detected during audits can in many cases result in not only corrective but also preventive action.

The need for measurement stems comes from the consideration that if an organization does not define indicators of its safety performance, it cannot observe changes in them, so it does not know when and in what direction to intervene to achieve its goals. When designing a measurement system, as each area is different, measurement and indicator numbers must be defined for each area. The organization's measurement system should be designed so that measurements can be repeated and the results obtained are comparable. A prerequisite for the development of a measurement system is that the organization defines the goals and measurement methods with which safe operation can be monitored. Knowing these, you will already be able to measure your processes, the efficiency and effectiveness of your activities.

Basics of a general measurement system with a focus on safety:

- Deficiencies revealed during official inspections and audits
- Implementation of the improvements indicated in the development plan

- Number, type, severity of security incidents
- The number of technological incidents in which liability needs to be investigated, can have any technology safety implications, their likelihood, their potential severity to the technology
- Complaints

3) Psychosocial hazards

Most of the applied management systems do not pay enough attention to psychosocial hazards, even though this is one of the most common problems nowadays, as it is known that economic and technological development worldwide has changed the pressures on workers and the workplace requirements.

Traditionally, occupational safety and health has focused mainly on physical and chemical hazards in the workplace It has become increasingly clear that not all hazards are physical in nature. Psychosocial factors, i.e., psychological, economic, and social impacts on workers, have an impact on both physical and mental health and well-being. It is important to recognize that workplace psychosocial factors can significantly affect the health and well-being of workers. These factors related to the planning, organization, and management of work processes can lead to increased work-related stress and deterioration in work performance and physical and mental health. Research over the past few decades has identified working conditions ("psychosocial risk factors") that can cause stress to workers, regardless of their individual characteristics, job, or cultural background [17].

The Hungarian Occupational Safety and Health Act names psychosocial risk and provides for its management. The Ordinance on Medical Examination of Suitability specifies the pathogenic factors and certain groups of workers exposed to such effects. The latter list does not fully correspond to the definitions in the standards. The Hungarian legal system also allows for the reporting of occupational diseases caused by psychosocial factors. However, justifying exposure is often a significant challenge.

4) Incident investigation, startup of technologies, conditions of safe operation

At several companies engaged in hazardous activities, the important system elements – named by the PSM system or is mentioned in the SMS guidelines – are often not sufficiently focused on. Although the guidelines for the application of the standards may cover these, the practical experience and the circumstances of the occurrence of an accident show that it is worth dealing with this separately. For a large company, these are clear, but in the case of many small and medium-sized enterprises, their application can be problematic due to the compliance burden on them. Such named elements include incident investigation and effective use of its results, pre-startup review of the technology or technological component, the handling of contractors, and mechanical integrity. Enterprises engaged in hazardous activities are well aware of the importance of these elements from their operational practice, therefore sufficient emphasis must be placed on them in the construction, operation and development of the safety management system.

CONCLUSION

By comparing of the Occupational Health and Safety Management System, the Process Safety Management System and the Safety Management System – prescibed by law – important focal points can be can be identified. The emphasis on the proposed focal points in safety management systems operated by hazardous companies, highlights and takes over the elements that are part of all three systems. Important parts become visible, according to which new aspects can be added to the operated safety management system. As a result, the efficiency gains and the shaping of a safer workplace atmosphere become more achievable. With the

introduction of the new focused system, the documentation system will become more uniform and transparent, it can be an economic advantage for companies, as the continuity of operation will become more accessible by ensuring technological security. Monitoring would become more uniform, and responsibilities and authorities could be clarified. Parallels, overlaps, repetitive tasks will be reduced, thus reducing the administrative burden, thus giving attention to an area that may not have received enough attention so far.

By tailoring these focal points, the DCOM method and the solutions used by the different smart cities, a management system can be developed that is free of any over-regulation, focuses on the elements responsible for operational safety and continuity and uses the elements of all three management systems that the specific characteristics of the given activity and corporate structure. This, of course, requires staff familiar with all three systems, who will make development suggestions with local experts after assessing the processes. These can be well applied, effectively operated and reviewed if everyone is aware of the results available, has the leadership commitment that is highlighted in each forum and provides the necessary tools.

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