A Survey on Design, Applications and Limitations of Computational Intelligence

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Abstract – Computational Intelligence (CI) is a branch of Artificial Intelligence (AI), which deals with the designing and enhancement of intelligent models with the ability to process and assess big data. The segment of CI has developed significantly over the past few decades due to the enhancement of AI and soft computing approaches, techniques, and tools, which envision the status of intelligence embedded in reality observation. This research contribution provides a critical survey of CI designs and its different applications. This research provides a description of the major methods, techniques and concepts in the field of CI, including smart system designs, CI types, and practical applications in different fields. The research also presents an analysis of limitations and challenges of CI, and provides insight into the results, effects and future research. The main purpose of this study is to provide a detailed understanding of CI applications and design; making is a vital resource for practitioners, and researchers in the field of AI.

Keywords – Computational Intelligence, Artificial Neural Networks, Evolutionary Algorithms, Fuzzy Systems, Intelligent Systems, Swarm Intelligence.

I. INTRODUCTION

Through the incorporation of smart technology (ideally wearable devices) into traditional medicine, including the diagnostic, surveillance, and management of diseases, Artificial Intelligence (AI) and Computational Intelligence (CI) play a vital role in the creation of smart medical systems. Computational intelligence-based healthcare systems and smart Internet of Things (IoT) rely on data collecting and machine learning as fundamental characteristics since miniaturized devices is the building blocks and paradigm shift to alter healthcare. Decisions, accuracy, and precision at various levels of IoT systems are all determined by computational intelligence approaches, which are in charge of data collecting, device and internet connectivity, data processing, and decision making independently of human intervention. Thus, very speedy processing with a desired maximum acceptable accuracy has always been vital to the fast evolution of IoT applications.

Over the last five years, advancements in soft computing and artificial intelligence have allowed researchers to better envision the significance of smart inherent in real-life observations, fueling explosive growth in the area of computational intelligence. As a result, Chang [1] has been able to define and describe real-life processes and behaviors that had been largely unexamined due to a lack of suitable methodologies for characterizing the inherent imprecision, uncertainties, and redundancies represented. Computational intelligence has allowed scientists to probe and uncover hitherto inaccessible levels of smarts in the systems they study. Signal processing, predictive control, smart manufacturing, robot navigation, sensor design and smart cities are just a few of the computational domains that have benefited from the expansion of Computational Intelligence.

The foundation of smart IoT-based healthcare systems and CI is the design and implementation of different machine learning and optimization approaches, ideally with maximum precision and precision ratio [2]. Next-generation artificial intelligence and Internet of Things-based applications are increasingly emphasizing the incorporation of new learning and evaluation approaches. These developments in AI-based methods may greatly improve sustainability without diminishing service standards. The widespread use of these gadgets for cutting-edge IoT applications, however, results in a deluge of data that may severely hamper computer performance. So, how can we use computational intelligence methods to boost the efficiency of ultra-fast computing in the Internet of Things?

Various computational intelligence and AI approaches are approaching a more maturity phase as a result of recent advances, especially in advanced learning and optimization; nonetheless, it is crucial to explore the trade-off between the use of emerging computational intelligence approaches and the needs of next-generation IoT and AI technologies. In addition, Internet of Things (IoT) [3] and Artificial Intelligence (AI) [4] enabled surveillance systems are still in their infancy in the healthcare industry; hence, scientists all over the world need to work hard to investigate the possibilities of computational intelligence, IoT, and AI in the healthcare area, taking into account many practical issues such as the prediction and treatment of various illnesses e.g. mental disorder (especially schizophrenia, dementia and depression), myocardial infarction and liver chronic infection.

Over the past few decades, the developments in AI have made it a significant resource for handling complex problems in different fields. CI is a major field of AI, which concentrates on the development of intelligent systems, which have the capacity to handle and make sense of big data. The purpose of this research contribution is to survey the CI field and its different potential applications. This research introduces the readers to basic ideas, applications and methods of CI in different real-life contexts. However, advanced fields such as unsupervised learning, reinforcement, and deep learning will not be reviewed in this paper. The rest of this paper is organized as follows: Section II presents an overview of CI in terms of definition, types and key characteristics. Section III focuses on CI systems design, focussing on simulation and modelling, problem formulation, algorithm selection, and hyper-parameter optimization. Section IV reviews the applications of CI in different fields. In Section V, the limitations and challenges of CI have been discussed. Lastly, Section VI draws final remarks to the research.

II. OVERVIEW OF COMPUTATIONAL INTELLIGENCE

Definition and Aspects

Soft computing or computational intelligence is an approach to computing that mimics the way humans learn. Computers improve in intelligence as they are taught using scientific and logical procedures. Computational intelligence, in contrast to AI, is concerned with a system's development rather than its perfection, and it does not rely on the binary values 0 and 1 for its learning, instead employing more nuanced methods. To create its machine learning algorithms, computational intelligence draws on several fields of study, including mathematics, logic, and computer science. The three fundamental components of computational intelligence are as shown in **Table 1**.

Table 1. Fundamental Components of Computational Intelligence

Fuzzy logic	In contrast to AI, computational intelligence (CI) allows for systems to evolve and learn while only having access to limited data and information. Information and processing in CI may be incomplete to varying degrees. Typically, this kind of reasoning is built by exposing a computer to pictures and training it to recognize differences in subject matter.
Artificial neural networks	All of these operations are modelled after the human brain. The system is trained by being shown a variety of photos and then having certain attributes described to it. Deep learning refers to a learning process with multiple levels, each one more intricate than the last.
Evolutionary computation	Swarm intelligence and natural selection are only two examples of how ideas from evolutionary theory might be used in IT. Scientists examine animal societies to better understand how groups may function well without a strong leader. Therefore, it is possible that computing systems will exhibit intelligence and the ability to make decisions without the need for a human leader.

Types of Computational Intelligence

Artificial Neural Networks

Evolutionary neural networks found in animal brains serve as inspiration for artificial neural networks (ANNs) [5] (**Fig 1**), also known as neural networks (NNs) or neural nets. Artificial neurons establish the foundation of ANNs and are considered a network of interlinked nodes purposed to approximate the neurotransmitters functions in a biological brain system. Just like the neurotransmitters in the brain, every connection may act as a transmitter of the signal between different neurons. Artificial neuron can process inputs from different neurons and communicate them to its signals. Every neuron computes its output as non-linear proportions of the summation of its input and signals at the connection is an actual number. The edges are the interlinked segments of the graph [11].

The significance of edges shifts and neurons over time as a network learns. As the mass tends of shift, the strength of the signal at the nodes tends to decrease or increase [12]. It is potential that neurons have a threshold at which they tend to send signals in case the overall input surpasses that level [13]. Neurons are typically organized in layers. It's possible for inputs to undergo different transformations at various layers [14]. It is possible that signals will make more than one pass through the layers on their way from the input layer to the output layer [15].

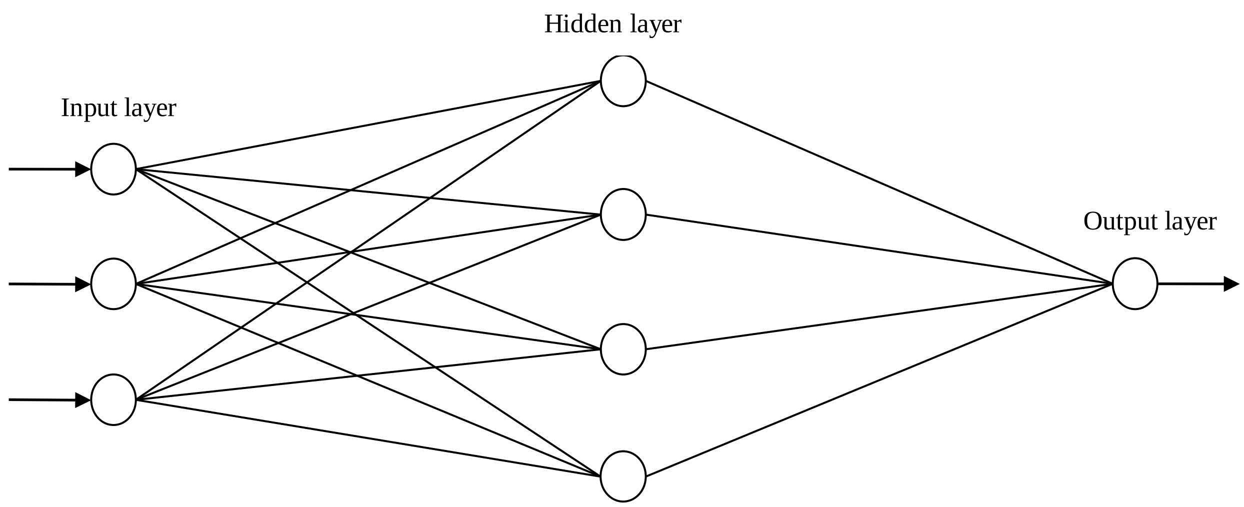

Fig 1. Representation of ANNs

Fuzzy Systems

The usage of fuzzy sets and fuzzy membership is essential to fuzzy operations. The potential states of an output are represented by linguistic variables, each of which is represented as a fuzzy set. The generic value's membership function in the fuzzy system is the variable such that the generic values and the intuitionistic fuzzy share membership in the universal set. Based on the IF-THEN principle, the output is determined by the extent to which that generic value belongs to the fuzzy set. Memberships are distributed on the basis of inputs, input rates of change, and assumed outcomes. One way to think about a membership degree is as a graphical way to illustrate a fuzzy collection. First, we introduce the fuzzy set A, which represents a subset of X, and then we consider the value 'x' such that $x€X$ for all intermission [0, 1]. The fA gives the weighting factor of x in the set A. Keep in mind that 'x' represents the membership degree. **Fig. 2** presents a visual illustration of fuzzy sets.

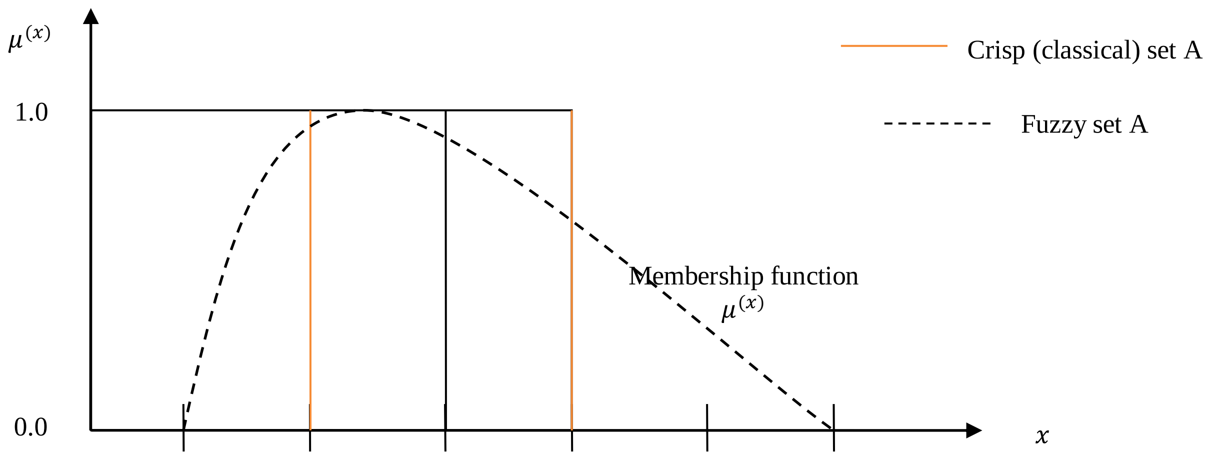

Fig 2. A visual illustration of the Fuzzy Sets

The y-axis signifies the membership strength, while x-axis signifies the scope of the universal set. It's possible for these membership functions to take the form of a triangle, a singleton, a trapezoid, or even a Gaussian.

Evolutionary Algorithms

Fig 3 is a cross-over through sub-tree transformation used to dual GPs (a) and (b) that are signified as binary trees. The tree represented by (a) is S-expression $(-(11\ x))$, the tree represented by (b) signifies $(+\ (1\ (*\ (x3))))$. The dotted line represents the position, where crossovers happen. Dual offspring are established in (c) that signifies $(-(11\ (*\ (x3))$ and (d) that signifies S-expression denoted by$(+\ (1\ x))$.By emulating Darwinian evolutions key features, evolutionary computing is a method for engineering and development in which systems are not built from scratch but instead "developed." One of the main approaches in "nature-inspired computer technology" is evolutionary computation. Soft computing and computational intelligence have been used to describe the branch of AI that takes inspiration from nature rather than symbols. This branch comprises swarm intelligence, neural networks, and fuzzy logic. Technically speaking, simulated annealing is a form of heuristic search, which is defined as a search method based on trial and error; in EC, the 'trials' are the potential solutions and the 'error' is the distance by which each trial deviates from the ideal solution.

Depending on the magnitude of the error, different trials are chosen to be used in the generation of new trials. First and foremost, if you want to further decrease the error rate, you should generate trials by tweaking the ones that had the minimum error rates from before. Evolutionary computing focuses primarily on the evolutionary algorithm. If there is an issue that requires solving, then the "search space" is the collection of all the potential problems to that issue.

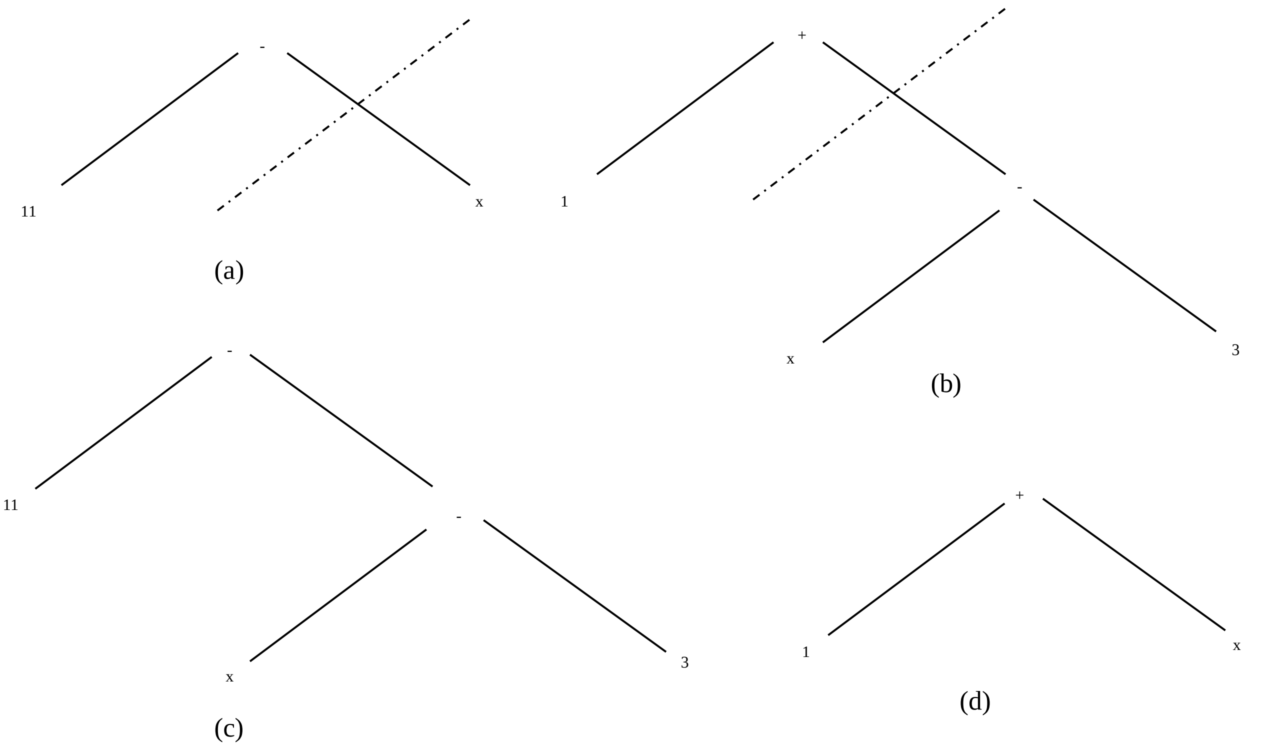

Fig 3. Cross-over through sub-tree Transformation used to dual GPs

Key Characteristics of Computational Intelligence

Computational intelligence (CI) is a subfield of AI that aims to mimic human cognition with the use of computer simulations. A few of CI's most distinguishing features are provided in **Table 2**.

Table 2. CI's Most Distinguishing Features

Flexibility	The algorithms used in CI may change and improve as more data is collected.
Robustness	CI algorithms can deal with data that contains both noise and uncertainty.
Interactivity	Algorithms developed for CI may aid people in solving problems in order to improve efficiency and effectiveness.
Naturalness	Algorithms used in CI draw inspiration from human thought and perception to create their models and depictions.
Autonomy	Algorithms used in CI systems are able to make choices independently of humans.
Learning from examples	Algorithms used in CI may learn from data and become better over time.
Human-centeredness	Rather than trying to replace human intellect, CI algorithms are built to enhance it.

Fuzzy logic, evolutionary algorithms, neural networks, and expert systems are just a few of the many specializations that fall under the umbrella of CI. Computational intelligence, in its broadest sense, is a collection of computational approaches and methodologies that take their cues from the ways in which nature works to solve problems in the real world that are too complicated for computational reasoning, integrate uncertainties in the process, or are typically stochastic. Indeed, various real-life problems cannot be minimized to the binary language (values of distinction from 0 to 1) employed by computing systems. Because of this, problems of this nature can be solved by means of Computational Intelligence.

The methodologies used are analogous to the way humans reason; they make use of imperfect information to generate control actions that can be adjusted to changing circumstances. Therefore, CI makes use of a total of five distinct methods that work in tandem. Evolutionary computing that is based on the learning theory process, probabilistic, and natural selection approaches that aid coping with uncertainty imprecision; fuzzy logic that allows computers to interpret natural language; the artificial neural network that lets systems to gain experience of the data by acting like biological ones; Aside from these core tenets, today's most well-liked methods include image processing, evolutionary computation, data mining, NLP, and AI (sometimes mistaken with Computational Intelligence), as well as biologically inspired algorithms such as artificial immune systems and swarm intelligence. Even though CI and AI share some common goals, they are distinct disciplines with their own unique methods and approaches.

III. COMPUTATIONAL INTELLIGENCE SYSTEMS DESIGN

Simulation and Modeling

Fig 4 depicts a simulation approach developed by the authors to direct investigations and experimentation in a practical problem-solving scenario. The process was assessed by applying it to a practical example where the goal of the research was to investigate the time-related efficiency of a new design and development process in order to determine the time resource utilised by working groups in the process and to propose improved management techniques that would shorten product innovation cycle times. This section details each of the thirteen steps of the process seen in **Fig 4**.

Define research problem

Owners of the case studies provide more detail about their research interests, the issue in the actual world is defined, and goals for the study's findings are discussed.

Specify purpose

The simulation experiments have goals and criteria for success that have been laid forth.

Collect data & information

As data input for the experimental tests, the information and data necessary for the development of both conceptualization and computational models is described and gathered [6]. Because the required data must already exist in an adequate form and be approachable, this is generally an ongoing negotiation approach between the research program and case study owners. If not, case study owners may collaborate with the study's research team to create a simulated data collection.

Build up conceptual model

Survey information and data are organized and used to build and construct a conceptual model that represents the important linkages inherent in the study under investigation.

Select simulation method

To properly depict the specified study issue, a modeling and simulation approach is used. When deciding on a simulation approach, it is important to weigh both its applicability and its practicality.

Choose simulation tool

It is important to select the appropriate software platform on which to run the simulation model. The selection procedure takes into account the accessibility and versatility of the tools under consideration.

Develop simulation model

Using the chosen simulation approach and software, a computational model of the conceptual framework is built for use in testing its assumptions and performance in practice.

Conduct verification experiments

The simulation model is put through a battery of tests designed to verify that it produces accurate and predictable results when fed specific inputs under conditions known to the case study's owners.

Verify the simulation model

Verification experiments' simulation results are analyzed, and the simulation model and its output are checked using predefined verification techniques and metrics. It's possible to go back over steps 3, 4, 5, 6, 7, and 8 if required. The simulation model is refined and modernized for the next phase by considering and acting upon comments, feedback loops, and ideas from a variety of sources.

Conduct validation experiments

The updated simulation model is used in the experimentation that validates the model. The goal of the validation experiments is to determine whether or not the simulation model accurately represents and subsequently addresses the research problem, as defined by the research objectives.

Validate the simulation model

The validation results of the experiments are checked against predetermined validation criteria. A return to previous procedures is possible if required.

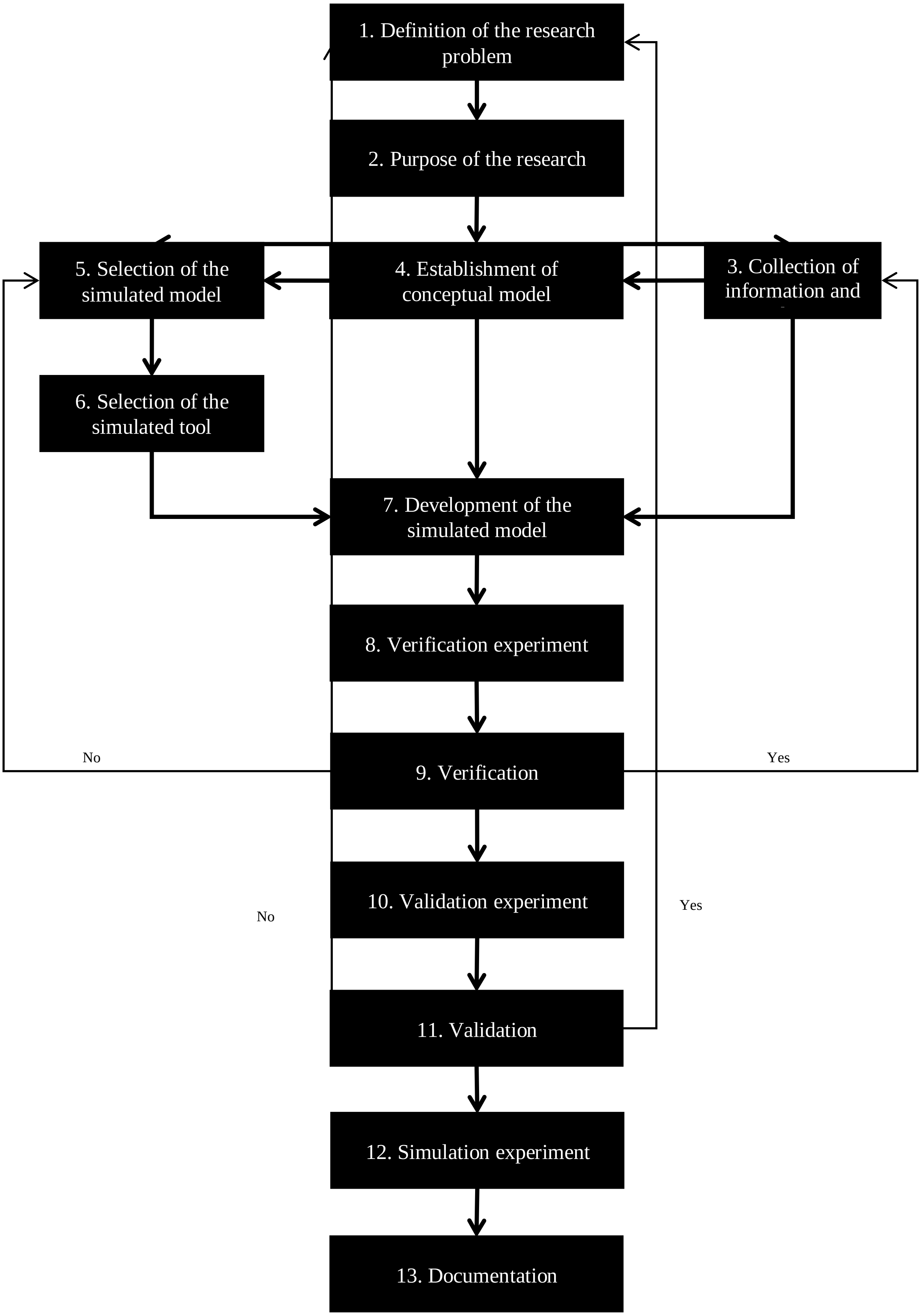

Fig 4. Simulation and Modeling Process

Simulation experiments
Attempts at simulating actual operational conditions are made through the use of simulation experiments. We evaluate and discuss the outcomes of our simulations. In order to solve the outlined issues, possible managerial solutions are evaluated.

Documentation
Documentation and instructions for using the simulation model and doing simulation experiments are created This includes things like how to run the model, what values to use for inputs, and how to interpret the results. This is important so that the simulation model can be easily understood and modified by other users or customers. Furthermore, it boosts users' assurance when employing the model to address real-world issues. As part of the case study used to determine the efficacy of this method, an instruction manual for running the simulation model was drafted.

Problem Formulation
Up until recently, the primary focus of problem-solving theory was on the identification of problem spaces and the subsequent identification and pursuit of optimal solutions within those spaces. In this light, the ability to solve problems (i.e. intelligence) could be comprehended as the property of appropriate heuristics that allow the search to be done in an effective manner. This point-of-view considers that search spaces are well-structured and explicit, i.e. that there are finite sets of operators (or issue states to be produced) at every point of decision, and the most effective one may be chosen using heuristics. This approach is normally employed in 'game' contexts (such as chess) and 'toy' issues (such as Hanoi problem tower wherever the potential 'moves' are established by predetermined protocols. We all know that children (and adults) use games and toys to learn about the world through play, i.e. by simulating actions so that their consequences can be investigated without having to deal with the complexities and dangers of the real world.

Through the process of building computer models of how to play games or manipulate toys, we have gained a great deal of insight into problem-solving and intelligence. This, however, does not mean that we can use this information to create models of how to deal with the real world. An increasing number of researchers in the field of artificial intelligence now recognize the importance of creating autonomous agents (such as robots) that can engage in naturalistic interaction with the world around them in order to gain insight into practical intelligence. However, a theory of problem-solving in complex, unstructured environments should be developed at the same time in order to experiment with such systems effectively. In this paper, we propose the broad strokes of a study designed to produce such a theory.

Algorithm Selection
Algorithm selection represents a meta-algorithmic strategy employed to select algorithms from portfolio on a case-by-case aspect; it is also identified as per-case offline algorithm selection. The idea is inspired by the realization that many real-world problems call for algorithms with varying degrees of efficiency. That is, some algorithms excel in specific contexts while failing miserably in others, and vice versa. If we know which algorithm to use and under what conditions, we can boost performance generally. Selecting algorithms strive for this very effect. To use algorithm selection methods, it is sufficient that a group of related algorithms already exists (or may be built).

The Boolean satisfiability problem is a famous example of the use of algorithm selection. In this case, the algorithms constitute a (complementary) collection of SAT solvers, the examples are Boolean formulae, and the cost measure might be anything from the average runtime to the number of unresolved cases. The objective is to find a high-quality SAT solver for each instance. Many other -hard problems can also benefit from the use of algorithm selection (e.g. mixed integer programming, AI planning, CSP, TSP, QBF, MAXSAT, and solution set programming). Winners of SAT competitions include SATzilla, 3S, and CSHC. Algorithm selection is more commonly referred to as meta-learning in the field of machine learning. The algorithms of machine learning (such as DNN, SVM, and Random Forest) established a portfolio, instances such as cost metrics and data sets could be anything from the error rate to the size of the dataset [7]. Predicting which algorithms of machine learning will generate smaller errors on a particular set of data is the major purpose.

Hyperparameter Optimization
The goal of hyperparameter optimization, also known as hyperparameter tuning, is to find the optimal values for the model's hyperparameters for a particular data set [8]. Generalization performance in machine learning models can be greatly improved by tuning hyperparameters. The term "generalization" is used to describe the model's efficacy both on the training data and on novel data. Overfitting, underfitting, and optimal depth all prevent a model from generalizing successfully.

Overfitting
The system may do inadequately on the testing data because it focuses so intently on the correlations in the training data. This indicates the model can only be used on the training data and will not work with untrained data.

Underfitting
The model's results are subpar whether using training data or test data. An example of a hyperparameter is the highest amount of branches a decision tree can take before stopping to make a prognostication (the tree's depth) in a decision-tree model. If the model's depth is too great, it will produce many subcategories that are unique to the data used for training (overfitting). A shallow model will improperly group data into a few useless classifications (underfitting).

Optimal depth
Tuning the depths hyper-parameters through iteratively running the model at varying depths allows for a more optimal result.

IV. APPLICATIONS OF COMPUTATIONAL INTELLIGENCE

Ambient Intelligence (AmI)
Prediction strategies using computational intelligence methodologies for predicting user behavior in ambient intelligence ecosystems were studied by Revathy, Aurchana, Logeshwari, Priya, and Kalaiselvi [9]. From their research, it was found that predictive ambient intelligence environments are the next generation of smart buildings. Both environmental changes and occupant behavior patterns can be analyzed by the emerging environment. To make predictions, ambient intelligence settings compile information gathered by a network of sensors. Environmental changes and occupant responses to those changes are just two examples of the types of information that can be gleaned from the data collected. Data like this is used in a learning-based approach to create a smart space that can anticipate when people will be present in various parts of the building and what amenities and amenities they will be interested in using at various times. This foresightful function, for instance, can boost the effectiveness of energy-saving strategies in a smart environment, while also improving the comfort of the building's occupants and their own personal safety.

Text mining and Information Extraction (IE)
Due to the proliferation of the internet and World Wide Web, there has been a meteoric rise in the quantity and variety of digital data, the vast majority of which consists of text. For instance, it has been calculated that around 1,000,000 new websites are launched each day. Information overload is a problem that we face every day. It is vital to be able to analyze such data, derive structured information, and transform it into knowledge that robots can understand and manipulate to allow intelligent cognition and decision making. This calls for the use of sentiment analysis and IE techniques and tools, which automate the analysis of textual material and the extraction of structured information by drawing on a broad variety of computational intelligence methods including machine learning and optimisation. Text mining and IE provide a structured visual representation of human knowledge that allows additional computational intelligence applications, e.g., those dealing with ambient intelligence.

Computational Optimisation
The emphasis here is on research and development of heuristic search and optimization approaches. Simulated annealing, genetic algorithms, Tabu search, ant colony optimization, and the hybrid approach Memetic Algorithms are also examples of such techniques. Finding the best input vector for a system requires searching for the best possible input vector and optimizing the system's response to that input vector, which is a common theme in many technical and scientific challenges. In addition to the possibility of incomplete and noisy measurements, it is not always possible to determine the system's transfer function and derivatives. This makes using conventional techniques to such issues challenging. It has been demonstrated that computational optimisation techniques can provide significant benefits in such situations, especially when compared to more traditional methods. Heuristic search and algorithmic optimisation techniques are applicable to problems in all of engineering and science where an optimization model of a product or component, or an optimal input or reaction to a framework, is required.

Biologically-inspired Speaker Verification
When compared to other biometric technologies, voice recognition is still in its infancy. Current speaker verification algorithms are severely hindered by issues like background noise, inter-speaker feature variation, and platform-specific differences in speech processing. The speech-enabled networks research group at NTU has created unique supervised, unsupervised, and hybrid neural structures that have the ability to automatically handle these problems as part of their development process. Researchers are now looking at Spiking Neural Communication networks as a more biologically believable speaker verification tool because of its close resemblance to human auditory system models.

Temporal Issues in designing Fuzzy Systems
In recent years, fuzzy techniques have established themselves as one of the most appropriate and effective approaches to the design and development of complex systems in settings characterized by a high degree of unpredictability and inaccuracy. In today's world, this technique is utilized to model systems across a wide variety of application areas, from manufacturing machinery to financial decision support platforms. It's true that fuzzy logic has many applications, but one

of its limitations is that it lacks the temporal concept that is essential in many systems characterized by discontinuous nonlinear behavior. In particular, traditional conceptions of fuzzy control are incapable of modeling

Variable-Structure systems are defined as those that evolve in either their configuration (knowledge base) or behavior (rule base) over time. These limitations are addressed by this study by incorporating a theory from formal languages called timed automata into the original fuzzy systems concept. This innovative synergistic technique accomplishes two goals at once: 1) expressing a system in a qualitative and linguistic fashion, and 2) offering a revolutionary switching control idea able to maximize system performances and resilience. This method has wide-ranging practical implications, from cyber security to municipal waste management.

Recurrent Neural Networks for Modelling Temporal Phenomena

Everyday climate patterns, night/day time shifts, the shifting of the seasons, our periodical heart beats, and our general rhythms of daily existence all demonstrate the dynamic and temporal aspect of the world around us. Virtually every action we take in the real world, from summoning an elevator to using a dispenser to turning on a light, involves some kind of time-dependent procedure, and almost all of these actions include a transition between states. The utilization of natural language by humans presents a typical temporal difficulty since the structure and content of a sentence are conveyed in a linear string of words. Complex systems for computer vision [10] may benefit from the use of temporally based Neural Networks in order to better recognize certain inflexible and dynamic patterns present in the natural world, such as human actions and behaviors.

Middleware, Domain Specific Languages and Trust

In pervasive computing environments, it can be difficult to get devices and services from different manufacturers to communicate with one another and understand one another. Using lightweight service formulation middleware's created to permit collaboration and communication to enable the re-configuration and recognition of services is a hot topic in the field of research. This can be combined with DSLs to hide the environment's unpredictability and facilitate the creation of services. DSLs were previously explored in the context of smart home energy management and were utilised to program similar pervasive ecosystems. Work into rule-based provenance trust systems is presently being investigated because trust becomes an issue when there are numerous services available in a pervasive setting.

Image Processing and Computer Vision

Digital and analog image processing are the two approaches employed in image processing. The amount for processing images, tangible reproductions and prints of images is identified as analog image processing. Contrarily, image processing uses sophisticated algorithms to manipulate digital images in order to produce data. Images acts as an input for the analysis of image activities. It is fundamental to remember, nonetheless, that analog image segmentation typically requires an image input. In addition, digital image processing may also incorporate pictures or data related to an image, such as bounding boxes or characteristics. The following are ideal uses for image processing.

a) Image visualization refers to the depiction of processed dataset as visual outputs for effective cognition. This task is majorly accomplished for an object, which is not easier to detect in images.
b) Enhancing the image quality by utilizing image restoration and sharpening
c) Image search is linked with retrieving image sources from an analysis done by engines of image searches.
d) To accomplish classification to differentiate various objects and identifying the locations of images.

FundamentalPhasesin Digital Image Processing

Image Acquisition

Image acquisition often entails the capture of an image by a sensor, such a camera. If there is an output that isn't digital, an analog to digital converter is used to change it. Pre-processing, such as picture scaling, is also a part of this process.

Image Enhancement

Image enhancement is the method of modifying images to provide pertinent outcomes for predetermined activities to be carried out (see **Fig 5**). The goal of this procedure is to enhance the quality of the first image, which was acquired by conducting activities like background subtraction, contrast correction, luminance, and sharpening on the photographs.

Fig 5. Deblurring an image using an Image-Enhancing Method

Image Restoration

Computational and stochastic techniques may be used to restore the quality of a damaged picture. The elimination of blurring in a picture is a perfect illustration of this principle as depicted in **Fig 6**.

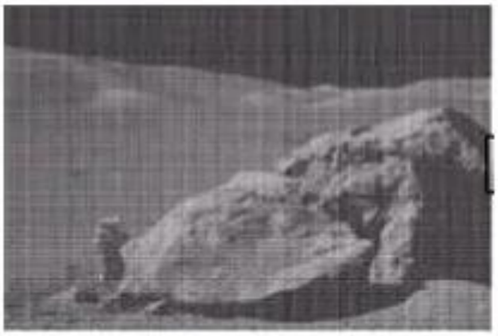

Fig 6(a). Degraded Image Quality

Fig 6(b). Image Restoration

Morphological processing

The geometry of an item in an image is described by the removal of superfluous details. Morphological processes such as dilatation and erosion are often used to generate various visual characteristics (see **Fig 7**).

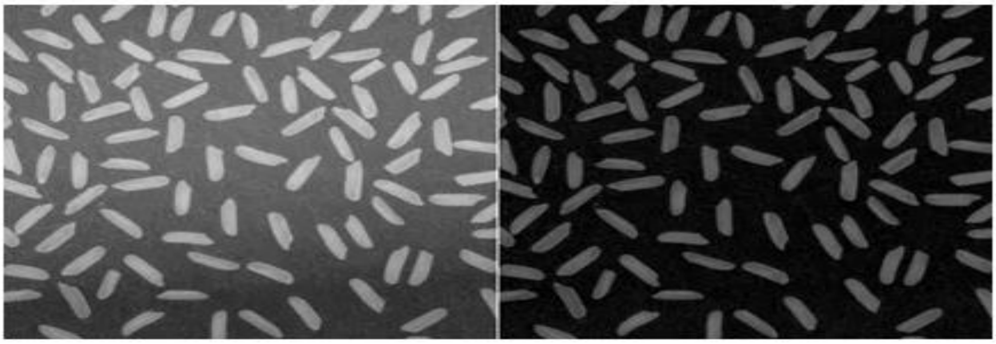

Fig 7. Morphological Results of Operation (imtophat transform)

Segmentation

Image classification is one of the required steps within picture processing that includes the splitting of the image into several parts (as seen in **Fig 8**). This approach helps to find items in an image and determine the limits of the objects. A crucial factor to notice is that the segmentation's reliability will lead to greater classification and identification accuracy.

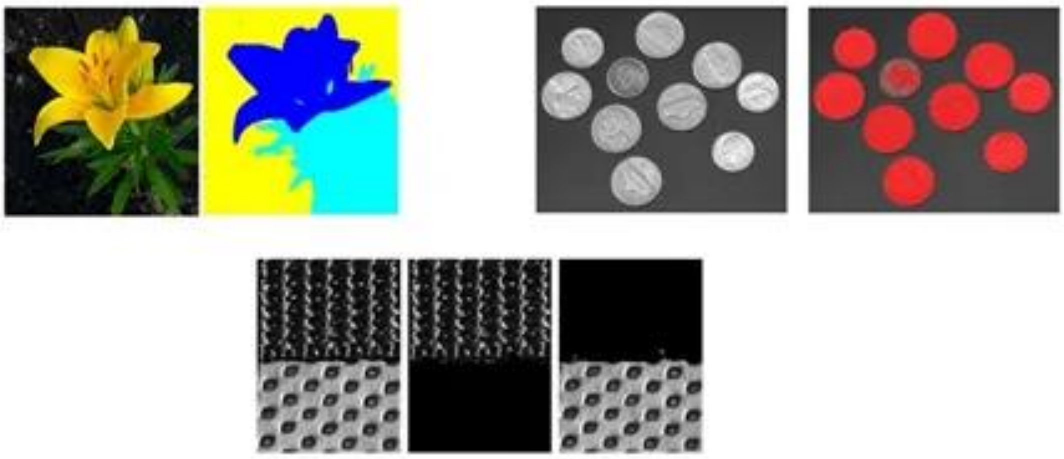

Fig 8. Segmentation of regions according to Color Values, Shapes, and Textures.

V. CHALLENGES AND LIMITATIONS OF COMPUTATIONAL INTELLIGENCE

Given that different forms of computational intelligence are best suited to different tasks; it stands to reason that as contemporary industry continues to advance, performance testing and fault diagnostic processing techniques will be combined with two or more intelligent ways to improve diagnosis performance. Take NFSs as an example; they combine the best features of fuzzy logic, and neural networks. Due to the difficulty in setting the correct values for the neural network's structural parameters, EAs are used to optimize these values in order to make the most accurate fault classification and prediction possible. The following obstacles must be overcome in order for computational intelligence to progress:

a) Inadequate mathematical rigor underpins most computational intelligence methods. Even if the theory behind neural networks is sound, the arithmetic behind EAs is far from flawless. Examining theoretical questions like instance, stability, effectiveness, and convergence is still in its infancy. As a result, researchers can apply computational intelligence to monitoring systems and fault diagnosis in a more informed and effective manner if they have a comprehensive understanding of the computation framework.
b) It is challenging to use computational intelligence approaches in engineering practice, hence additional simulated or validated signals are employed to confirm their efficacy. To better create reliable and practically applicable techniques for condition-based maintenance and fault detection, computational intelligence approaches should be studied and developed further.
c) The iterative nature of computational intelligence and its advanced techniques means that the corresponding algorithms are time-consuming. Future studies should therefore center on creating efficient online monitoring systems and fault detection systems powered by computational intelligence.

A zero-fault and predictable production system may be implemented using new techniques based on computational intelligence thanks to the growth of industrial big data, intelligent manufacturing, and Internet of Things. The gathered information is combined to establish a massive data platform, which can conduct real-time monitoring, fault prediction, fault alarm, asset management, auxiliary research and development, and intelligent service, as well as fulfill certain particular needs, finally producing a more useful value.

VI. CONCLUSION

This research contribution provides a critical analysis of the field of Computational Intelligence (CI) and its applications and design. The research highlights the various forms of CI, integrating artificial neural networks, swarm intelligence, fuzzy systems, and evolutionary algorithms. The design of intelligent systems was also evaluated, including the choice of effective CI methodologies, the development of algorithms, and the application of smart systems. Additionally, the research provides a survey of practical application of CI is different fields such as transportation, healthcare, and finance. The research also identifies the limitations and challenges of CI, including the requirement for future development and refinement of approach, and the limitations of prevailing algorithms. The results of this research have various implications for the field of CI. The advancement of novel and enhanced CI approaches that can address the limitations and challenges of prevailing algorithms is a key domain necessitating future research. In addition, the research highlights the significance of CI and its capacity for developing the capabilities of smart systems. The results and recommendations of this research provide guidance for students, practitioners, and research in the field of artificial intelligence, and provide a foundational framework for future research in the CI field.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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Ethics Approval and Consent to Participate

The research has consent for Ethical Approval and Consent to participate.

Competing Interests

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