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Neural & AI

Highlights

Development of Expert System

Formal Verification of Artificial Neural

Automated Lead Time Estimation

Diagnosis of Computer System Startup

Discovering Thoughts, Inventing Future

VOLUME 24 ISSUE 1 VERSION 1.0

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Neural & Artificial Intelligence

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Harnessing Innovation Together: How Technology is Shaping Healthcare's Future

Editorial by Dr. Björn Zoëga

Introduction- Healthcare is evolving in surprising ways, even for experienced professionals. New technologies worldwide are being used in unexpected ways beyond just speeding up diagnostics and predicting care needs through biotechnology. AI in healthcare is making transformative and disruptive advances.

Countries like the US, Switzerland, the UK, and China are already home to some of the largest biotech and pharmaceutical companies and research programs. In the UK, AI is helping radiologists identify lung cancer with greater accuracy, while Germany's genomic researchers are integrating AI to customize therapies based on the genetic profile of each tumor. Researchers in Switzerland have already developed CRISPR-based therapy to cure sickle cell disease and another hemoglobin-affecting genetic disorder (beta Thalassemia).

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HARNESSINGINNOVATIONTOGETHERHOWTECHNOLOGYISSHAPINGHEALTHCARESFUTURE

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Editorial

Harnessing Innovation Together: How Technology is Shaping Healthcare's Future

Dr. Björn Zoëga

I. Introduction

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Countries like the US, Switzerland, the UK, and China are already home to some of the largest biotech and pharmaceutical companies and research programs. In the UK, AI is helping radiologists identify lung cancer with greater accuracy, while Germany's genomic researchers are integrating AI to customize therapies based on the genetic profile of each tumor. Researchers in Switzerland have already developed CRISPR-based therapy to cure sickle cell disease and another hemoglobin-affecting genetic disorder (beta Thalassemia).

Yet, these developments are far from confined to any single country or institution; instead, we have a unique opportunity to learn from one another's experiences and build a collective understanding of how best to implement these advances. In this dynamic and interconnected space, innovation knows no boundaries in a universal mission to better human lives.

II. Embracing Emerging Potential

In Saudi Arabia, cutting-edge medical technology has fundamentally altered the practice of medicine. Biotech advancements, particularly in genomics, provide unprecedented insights into human biology. While these technologies are gaining ground globally, their impact is most significant when integrated into comprehensive healthcare strategies considering local needs and contexts. This is why Saudi Arabia's National Biotechnology Strategy has set clear strategic goals to advance self-sufficiency in vaccines, biomanufacturing, and genomics.

This strategy fosters a pro-innovation environment that enables us to leverage this high-growth sector to improve people's health and well-being. At King Faisal Specialist Hospital & Research Centre (KFSHRC), AI is used in early diagnosis and patient management. A KFSHRC-developed metagenomic protocol successfully diagnoses infectious diseases that traditional methods have failed to identify. Patients can now receive highly accurate results within 24 hours. In radiology, AI enhances the detection and treatment of diseases such as cancer and cardiovascular disorders, improving diagnostic accuracy by 25% (with an 18% drop in misdiagnosis rates).

Another example is Whole Genome Sequencing (WGS), which is prioritized for early detection and treatment of genetic disorders. Over 7,000 WGS tests were conducted in 2023. Utilizing CRISPR technologies, KFSHRC researchers have recently uncovered the crucial role of a protein (Phosphatelipase C Zeta) in the normal development of embryos during the early stages of pregnancy.

Meanwhile, robotics enhance surgical precision, reduce recovery times, and allow procedures that were once considered highly complex to be performed with excellent safety and efficiency. For example, in August 2023, KFSHRC performed the world's first fully robotic liver transplant.

These advancements-unattainable without leveraging the innovation-ready environment-will go a long way toward improving the future of human health not just for Saudi Arabia but for the entire world.

III. Navigating Ethical Challenges

Embracing the power of biotech and AI requires responsible integration. Advances such as CRISPR – now more widely used for diagnostics - call us to confront new ethical questions about patient consent, data security, and equitable access to care. Institutions worldwide strive to set moral standards, prioritizing the responsible use of these critical technologies and balancing innovation with patient safety and privacy.

Globally, organizations like the World Health Organization (WHO) and the Global Partnership on Artificial Intelligence (GPAI) are creating ethical frameworks that ensure these breakthroughs benefit all patients while maintaining safety and transparency. These global efforts highlight the importance of

Artificial Intelligence (GPAI) are creating ethical frameworks that ensure these breakthroughs benefit all patients while maintaining safety and transparency. These global efforts highlight the importance of developing universal moral standards. Institutions worldwide also contribute to these discussions by applying these principles in diverse contexts, sharing their experiences, and refining best practices. By sharing and developing ethical frameworks and protocols that can be adapted globally, we can contribute to a more effective, inclusive, and connected universal healthcare system.

IV. The Path Forward: Working Together

AI-driven drug discoveries, AI-powered robotic surgeries, and genomics are just a few instances of how technology is already transforming healthcare and enhancing treatment outcomes.

Yet, the path forward is not simply about deploying the latest technology. It is about how we can thoughtfully leverage these advancements in medical research and patient care to achieve a tangible impact. Whether through shared study, cross-border partnerships, or open forums for discussion, we have much to gain from working together.

For healthcare providers everywhere, the question is how we can learn from these diverse advances and apply them meaningfully in our contexts. By adopting a global outlook, we can better understand how these technological breakthroughs reshape patient care and fundamentally contribute to making it more precise, accessible, and effective for all.

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By Dr. Shivakumar Nagarajan, Ms. Divya T & Dr. Prasanna S

Abstract- The increasing complexity of modern business operations demands efficient and accurate lead time estimation to enhance decision-making processes. This study proposes a novel approach to automate lead time estimation using machine learning algorithms. Traditional lead time estimation methods often rely on manual calculations and historical averages, leading to inaccuracies and inefficiencies. In contrast, machine learning algorithms leverage historical data, contextual factors, and patterns to predict lead times dynamically. The automation of lead time estimation not only improves accuracy but also facilitates real-time decision-making. The system continuously learns from new data, adapting its predictions to changing business environments. A user-friendly interface is developed to allow easy input of relevant data and to visualize the lead time prediction.

Keywords: *particle swam optimization, k-means clustering algorithm, neural network, analogy-based estimation.*

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Abstract- The increasing complexity of modern business operations demands efficient and accurate lead time estimation to enhance decision-making processes. This study proposes a novel approach to automate lead time estimation using machine learning algorithms. Traditional lead time estimation methods often rely on manual calculations and historical averages, leading to inaccuracies and inefficiencies. In contrast, machine learning algorithms leverage historical data, contextual factors, and patterns to predict lead times dynamically. The automation of lead time estimation not only improves accuracy but also facilitates real-time decision-making. The system continuously learns from new data, adapting its predictions to changing business environments. A user-friendly interface is developed to allow easy input of relevant data and to visualize the lead time prediction. In this project design an automated time estimation is calculated for the usage of two algorithms and to get the accuracy for the maximum amount of iterations to be fitted by the PSO algorithm and then use the K-means clustering for the grouping the classes. From the PSO algorithm get the best features and then apply the Neural Network and Analogy Based Estimation for encrypt the data and then apply model to get the accuracy and time estimation from initialization to the end of the prediction and compare the two model for the accuracy and time comparison and also get the best features.

Keywords: particle swam optimization, k-means clustering algorithm, neural network, analogy-based estimation.

I. Introduction

In the fast-paced world of software engineering, accurate estimation of lead time is a critical factor that can significantly impact project planning, resource allocation, and overall project success. Lead time refers to the time taken from the inception of a software development task to its completion, encompassing various stages such as design, coding, testing, and deployment. Traditional methods of lead time estimation often suffer from subjectivity, imprecision, and a lack of adaptability to changing project dynamics. However, the rise of data-driven approaches and machine learning techniques has opened new possibilities for automating and improving lead time estimation.

The dynamic field of software engineering encompasses the methodical design, development, testing, and maintenance of software systems. It involves using a methodical approach to software development, which includes defining requirements, coming up with solutions, writing code, and subjecting the finished result to rigorous testing. Together, software developers use a range of methodologies, including as Agile and DevOps, to continuously build and enhance software while reacting to shifting input and requirements. The methodology includes selecting appropriate programming languages and design patterns as well as managing version control, assuring security, and maintaining documentation. A combination of technical know-how, teamwork, project management, and a commitment to ethical considerations are required to produce reliable and efficient software solutions that address real-world problems the software industry

The K-Means clustering algorithm is one such powerful technique that is gaining prominence in the software engineering domain. K-Means is an unsupervised machine learning approach that uses similarity to divide data into separate clusters. Its capacity to detect hidden patterns and structures in datasets makes it a great candidate for lead time estimating automation. K-Means can accurately forecast lead times for new activities by exploiting prior project data to find intrinsic correlations between development tasks and their related lead times.

This paper presents an in-depth exploration of the K-Means clustering algorithm and its application to automate lead time estimation in software engineering projects. We will delve into the underlying principles of K-Means, its strengths, limitations, and how it can be fine-tuned to suit the unique characteristics of software development processes. Furthermore, we will discuss the challenges associated with implementing K-Means for lead time estimation and propose strategies to overcome them.

The objective of this research is to equip software development teams, project managers, and stakeholders with a data-driven, efficient, and reliable lead time estimation tool that can facilitate better decision-making, resource allocation, and project planning. By harnessing the power of K-Means clustering, we aim to enhance the accuracy and efficiency of lead time estimation, ultimately leading to improved project management and successful software development endeavours.

Software lead time estimation, a critical aspect of project management, employs various techniques to predict the time needed for software development projects. Among these techniques, analogy-based

Author α: Department of Computer science and Engineering, Thiagarajar college of Engineering. e-mail: shiva@tce.edu

methods, neural networks, and Particle Swarm Optimization (PSO) play distinctive roles.

Analogy-based methods leverage historical data from similar projects to estimate lead times. By comparing known project outcomes and characteristics to those of the current project, these methods extrapolate estimates. While intuitive and easily accessible, their accuracy relies heavily on the quality and relevance of historical data.

Neural networks, a machine learning approach, demonstrate their strength in lead time estimation by learning complex patterns from historical data. These interconnected layers of nodes process input parameters to generate accurate predictions. Their ability to capture nonlinear relationships and adapt to diverse project variables makes them robust tools, particularly when adequate data is available for training.

Particle Swarm Optimization, inspired by the social behaviour of birds flocking or fish schooling, employs optimization to estimate lead times. It simulates a population of particles traversing a solution space to find optimal estimates. Through iterative refinement, PSO converges towards accurate predictions by adjusting particle positions based on local and global information.

II. Related Works

In 2008, Kim[1] et al. published the first study on JIT-SDP, where they described a set of input features for JIT-SDP models. Other research looked into input features that could be useful for JIT-SDP, like the day of the week or the time of day a software change was produced, and input features to make it possible to identify software changes that are difficult to fix. According to Shihab[2]et al., the amount of lines of code contributed, the proportion of bug fixes to total file changes, the number of bug reports associated with a commit, and the developer experience are all reliable indications of software modifications that cause defects. Kamei[3] et al. carried out a substantial empirical investigation to look into a variety of factors extracted from commits and bug reports as input features for JIT-SDP models. They considered 14 features grouped into five dimensions of diffusion, size, purpose, history and experience, and showed such features to be good indicators of defect-inducing software changes for yielding high predictive performance on both open source and commercial projects. Many subsequent studies have adopted these features.

In 2022, Elvan Kula[4]; Eric Greuter[5]; Arie van Deursen[6]; Georgios Gousios[7] wrote late delivery of software projects and cost overruns have been common problems in the software industry for decades. Both problems are manifestations of deficiencies in effort estimation during project planning. With software projects being complex socio-technical systems, a large pool of factors can affect effort estimation and on-time delivery. To identify the most relevant factors and their interactions affecting schedule deviations in large-scale agile software development, we conducted a mixed-methods case study at ING: two rounds of surveys revealed a multitude of organizational, people, process, project and technical factors which were then quantified and statistically modelled using software repository data from 185 teams. We find that factors such as requirements refinement, task dependencies, organizational alignment and organizational politics are perceived to have the greatest impact on on-time delivery, whereas proxy measures such as project size, number of dependencies, historical delivery performance and team familiarity can help explain a large degree of schedule deviations. We also discover hierarchical interactions among factors: organizational factors are perceived to interact with people factors, which in turn impact technical factors. We compose our findings in the form of a conceptual framework representing influential factors and their relationships to on-time delivery. Our results can help practitioners identify and manage delay risks in agile settings, can inform the design of automated tools to predict schedule overruns and can contribute towards the development of a relational theory of software project management.

In 2021, Lei Zou[8], Zidong Wang[9], Qing-Long Han[10], Donghua Zhou[11] wrote the full information estimation (FIE) problem is addressed for discrete time-varying systems (TVSs) subject to the effects of a Round-Robin (RR) protocol. A shared communication network is adopted for data transmissions between sensor nodes and the state estimator. In order to avoid data collisions in signal transmission, only one sensor node could have access to the network and communicate with the state estimator per time instant. The so-called RR protocol, which is also known as the token ring protocol, is employed to orchestrate the access sequence of sensor nodes, under which the chosen sensor node communicating with the state estimator could be modelled by a periodic function. A novel recursive FIE scheme is developed by defining a modified cost function and using a so-called "backward-propagation-constraints." The modified cost function represents a special global estimation performance. The solution of the proposed FIE scheme is achieved by solving a minimization problem. Then, the recursive manner of such a solution is studied for the purpose of online applications. For the purpose of ensuring the estimation performance, sufficient conditions are obtained to derive the upper bound of the norm of the state estimation error (SEE). Finally, two illustrative examples are proposed to demonstrate the effectiveness of the developed estimation algorithm.

III. Proposed Methodology

a) Particle Swam Optimization (PSO)

PSO was developed by Eberhart[4] and Kennedy[5] in 1995. It is swarm intelligence meta-Heuristic inspired by the group behaviour of birds flocks or fish schools. It is simple, fast and easy to understand. Similarly, to Genetic Algorithm (GAs), it is a population-based method, that is, it represents the state of the algorithm by a population, which is iteratively modified until a termination criterion is satisfied. In PSO, the potential solution called particle which searches the whole space by previous best position (pbest) and best position of the swarm (gbest). The fitness function can be evaluated by the following equation.

$$f_n = \sum_{j=1}^{k} \sum_{i=1}^{n} || x_i^j - c_j ||^2 \tag{1}$$

Initially, position and velocity of the particles are expressed as follows

$$X_i = \text{LB} + \text{rand (UB-LB)} \tag{2}$$

$$V_i = \frac{LB + rand\ (UB - LB)}{\Delta t} \tag{3}$$

The velocity and positions values are updated during each iteration. Velocity update equation is given below

$$V_{i+1} = wV_i + c_1 \text{ rand} \frac{pbest_i - X_i}{\Delta t} + c_2 \text{ rand} \frac{pbest_i - X_i}{\Delta t} \tag{4}$$

Where, Xi is current position, Vi+1 is the velocity of next iteration, Vi is current velocity, Δt is the time interval, rand is a uniformly distributed random variable that can take any value between 0 and 1. $Pbest_i$ is the location of the particle that experiences the best fitness, $gbest_i$ is the location of the particle that experiences a global best fitness value, c1 and c2 are two positive acceleration constants responsible for degree of information, w represents inertia weight which is usually linearly decreasing during the iterations.

Updating position is the last step in each iteration, it is updated using velocity vector. Position update equation is given below

$$X_{i+1} = X_i + V_{i+1} \Delta t \tag{5}$$

Where, X_{i+1} is the next position, X_i is the current position, V_{i+1} is the next velocity, Δt is the time interval.
Update the best fitness values at each generation, based on below equation

$$P_i(t+1) = \begin{cases} P_i(t) & f(X_i(t+1)) \leq f(X_i(t)) \\ X_i(t+1) & f(X_i(t+1)) > f(X_i(t)) \end{cases} \tag{6}$$

Where, f denotes the fitness function Eq. (1), Pi (t) stands for best fitness value and the coordination where the values are computed, Xi(t) is the current position, t denotes the generation step.

Update the velocity, position and fitness computations are repeated until the termination criteria is met.

b) K-Means Clustering Algorithm(KMC)

This K-means clustering is the best unsupervised learning algorithm. Using a certain number of clusters, it is simple and easy to classify a given data set. Initially, select the k centroids, then calculate the distance between each cluster centre and each object. Repeat the steps until no more changes are done. The objective function of k-means clustering is given as

$$f_n = \sum_{j=1}^{k} \sum_{i=1}^{n} || x_i^j - c_j ||^2 \tag{7}$$

Where, n is the number of data points, k is the number of clusters, $||x_i^j - c_j||^2$ is the distance between each cluster centre and each object. The steps of k-means clustering is shown below

1. Place K points into the space which denotes initial group centroids.
2. The group closer to the centroid is assigned with a cluster.
3. When all the objects are assigned to the groups, the positions of K centroids are reallocated.
4. Repeat Steps 2 and 3 until the centroids no longer move.

In this paper, combination of PSO and k-means clustering is used. PSO works efficiently for global search but its local search ability is poor. K-means clustering which produces local optimal solution due to initial partition but it does not work well for global search ability. Hence the proposed method overcome the limitation of K-means clustering, PSO offers global search methodology. Initially PSO is performed to find the location of cluster centroids. These locations of cluster centroids are given as input for the k-means clustering and provide optimal clustering solution. The steps for the proposed method is given below

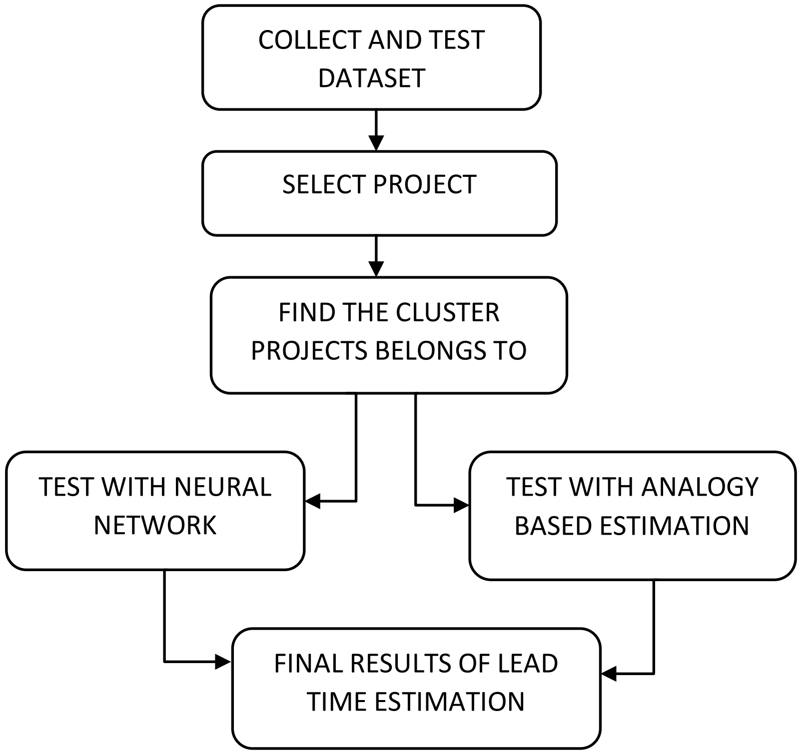
Step 1: Randomly generate particles and particles are grouped which creates population.

Step 2: Position and velocity of particles are initialized using Equation (2) and (3).

Step 3: Compute the fitness value using Eq. (6)

Step 4: Position, velocity, gbest and pbest values of the particles are updated using Equation (4) and (5).

Step 5: Repeat step (3) and (4) until one of following termination conditions is satisfied. 5(a). The maximum number of iterations is exceeded. 5(b). The average change in centroid vectors is less than a predefined value.



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Step 6: Input the number of clusters which is to be generated.

Step 7: Compute the cluster centroids using the best positions of k of PSO.

Step 8: Compute the distance between the particles and centroids.

Step 9: Cluster centroids of k-means clustering can be recomputed using Eq. (7).

Step 10: Repeat the steps (8) and (9) until the centroids no longer move.

The combination of PSO and k-means provides better clustering result compared to result of each individual technique. PSO is used to find the optimal solution, the output of PSO is given as input to the k-means to obtain the clustering result. Check if the number of projects in clusters is greater than or equal to 15. For analogy method the number of projects present in a cluster should be less than fifteen. There are two reasons for choosing based on 15 projects. First, each project in the dataset usually has at least 10 features to train the neural network properly. Second, when using combination of PSO and K-means clustering the minimum requirement is 15. Anything less than 15 will become useless for training Neural Network. Testing stage consists of following steps. The Euclidean distance between a particular project and cluster centre is measured. The it is done for all the projects, the one with minimum is chosen. If it is marked in the training stage as ABE, then ABE is used to estimate the lead time. Otherwise NN is applied to predict the lead time. Repeat the steps until all test projects are applied to the hybrid model. For each test project the MRE is calculated and the final result is computed based on MMRE and PRED.

IV. Analogy based Method

The most common example of analogy-based project estimation is case-based reasoning, where identical projects from the lesson learned are identified and used for estimation. They can be used in combination with collective expert opinion and formal models, Software lead time estimation by using an analogy-based tech commonly involves the following steps.

1. Measuring the values of identified metrics of the software project for which estimation is being performed (target project).
2. Finding a similar project from the repository.
3. Using the estimated effort values of the selected projects to use as an initial estimate for the target project.
4. Comparison of metric's value for the target project and selected project.
5. Adjustment of lead time estimates in view of the comparison performed in the previous step.

V. Neural Network

Neural networks are a type of machine learning model inspired by the structure and function of the human brain. They are mathematical models composed of interconnected nodes, or neurons, that process information through a series of weighted connections. These connections allow neural networks to learn patterns and make predictions based on the input data. The artificial neural network is a powerful tool in the field of machine learning, as it can adapt and learn from data in a way that resembles human brain processing (Singh & Shrimali, 2019). It is important to understand the structure and functionality of neural networks in order to effectively utilize them for various applications in machine learning. Additionally, neural networks have layers, including an input layer, hidden layer(s), and an output layer. These layers help to organize and process the data, allowing for more accurate predictions or estimations. Furthermore, neural networks have been successfully applied in various fields including image recognition, natural language processing, and financial forecasting. By understanding the structure and functionality of neural networks, researchers and practitioners can effectively utilize these powerful machine learning models for various applications. In today's rapidly changing world, the significance of accurate weather forecasts cannot be overstated. In the context of neural networks, understanding their structure and functionality is crucial for effectively utilizing them in machine learning applications. Additionally, the widespread applications of neural networks in the control field, such as system identification and controller design, highlight their versatility and potential for solving complex problems. Overall, understanding the structure and functionality of neural networks is essential for harnessing their potential in machine learning applications and solving a variety of complex problems. In today's rapidly changing world, the significance of accurate weather forecasts cannot be overstated. Neural networks, with their ability to learn from data and make predictions, have wide-ranging applications in machine learning.

VI. Exprimental Design

a) Evaluation Criteria

The research community realizes that MMRE, Pred(x) can be influenced by the presence of outliers, therefore, we used the following performance metrics to assess and compare the accuracy.

b) Magnitude of Relative Error

The error ratio between actual and predicted effort for each project instance in the dataset is computed using MRE. To calculate the fitness function, first the MRE is calculated for every project i.

$$\text{MRE} = \left| \frac{Actual\ \ effort - Estimated\ \ Effort}{Actual\ \ Effort} \right| \tag{8}$$

c) Mean Magnitude of Relative Error

MMRE measure is used for assessing software estimation technique performance. The values of MRE is calculated for each software project instance. MMRE computes the average over N number of project instances in the data-set.

$$\text{MMRE} = \frac{1}{N}\sum_{i=1}^{N} MRE \tag{9}$$

d) Percentage of Prediction

PRED(x) represents the percentage of MRE that is less than or equal to the value x/100 among all projects.

$$\text{PRED(X)} = \frac{100}{N}\begin{cases} 1 & if\ MRE \leq \frac{X}{100} \\ 0 & otherwise \end{cases} \tag{10}$$

where A is the number of projects with MRE less than or equal to X. N is the number of projects in test set. Usually the ideal value of X is 25% in software development effort estimation and compared with various methods.

Table No. 1: Time Estimation Table

Algorithm	Time Estimation
Neural Network	3.73
ABE algorithm	0.78

Table No. 2: Accuracy Table

Algorithm	Accuracy
Neural Network	95.79
ABE algorithm	97.68

Table No. 3: Loss comparison Table

Algorithm	Loss
Neural Network	4.21
ABE algorithm	2.32

e) Lead Time Estimation

Lead time estimation is the process of predicting the amount of time it will take to complete a specific task, project, or deliver a product or service. It is a critical aspect of project management and supply chain management and is used in various industries, including manufacturing, logistics, and software development. Accurate lead time estimation helps organizations plan and allocate resources effectively, manage customer expectations, and avoid delays and disruptions in their operations.

f) Leave-One-Out

In this method a project is selected from the dataset as the target project. The ABE method is applied to estimate the effort of the target project by using all the remaining projects in dataset. Then the target project combined with the dataset and another project is selected as a target project. This procedure repeated until all the projects in dataset are estimated.

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Finally, the MRE and MMRE values are computed for each project

g) Dataset Description

Software to detect network intrusions protects a computer network from unauthorized users, including perhaps insiders. The intrusion detector learning task is to build a predictive model (i.e. a classifier) capable of distinguishing between "bad" connections, called intrusions or attacks, and "good" normal connections.

The 1998 DARPA Intrusion Detection Evaluation Program was prepared and managed by MIT Lincoln Labs. The objective was to survey and evaluate research in intrusion detection. A standard set of data to be audited, which includes a wide variety of intrusions simulated in a military network environment, was provided. The 1999 KDD intrusion detection contest uses a version of this dataset.

Lincoln Labs set up an environment to acquire nine weeks of raw TCP dump data for a local-area network (LAN) simulating a typical U.S. Air Force LAN. They operated the LAN as if it were a true Air Force environment, but peppered it with multiple attacks.

The raw training data was about four gigabytes of compressed binary TCP dump data from seven weeks of network traffic. This was processed into about five million connection records. Similarly, the two weeks of test data yielded around two million connection records.

A connection is a sequence of TCP packets starting and ending at some well- defined times, between which data flows to and from a source IP address to a target IP address under some well-defined protocol. Each connection is labelled as either normal, or as an attack, with exactly one specific attack type. Each connection record consists of about 100 bytes.
Attacks fall into four main categories:

- *DOS:* denial-of-service, e.g. sync flood;
- *R2L:* unauthorized access from a remote machine, e.g. guessing password;
- *U2R:* unauthorized access to local super user (root) privileges, e.g., various "buffer overflow" attacks;
- *Probing:* surveillance and other probing, e.g., port scanning.

It is important to note that the test data is not from the same probability distribution as the training data, and it includes specific attack types not in the training data. This makes the task more realistic. Some intrusion experts believe that most novel attacks are variants of known attacks and the "signature" of known attacks can be sufficient to catch novel variants. The datasets contain a total of 24 training attack types, with an additional 14 types in the test data only.

h) Numerical Results

In this paper, for training stage two clusters are considered. When Applying the PSO and k-means clustering to the intrusion detector learning dataset, the best situation is with two clusters. When it is more than two some clusters with one or two projects appeared not perfect for estimation. On the other hand, splitting projects in clusters size less than two decreases the performance of NN training.

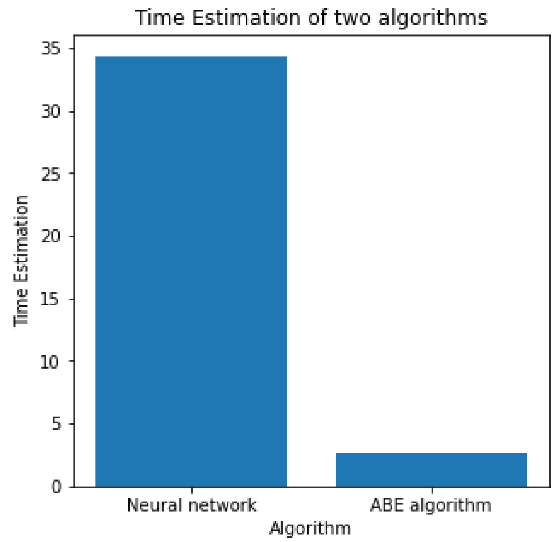

Fig. 1: Time Estimation of NN and ABE algorithm

Results on all Data. Initially, the selected features from PSO is 19 are grouped into five clusters by k-Means clustering algorithm. Based on the number of projects in a cluster either ABE or NN is identified displayed the clusters formed from PSO and K-Means clustering algorithm. The identified method for cluster. Identifying a cluster for a project is done according to the maximum degree of membership function. First clusters are NN and second cluster are marked as ABE.

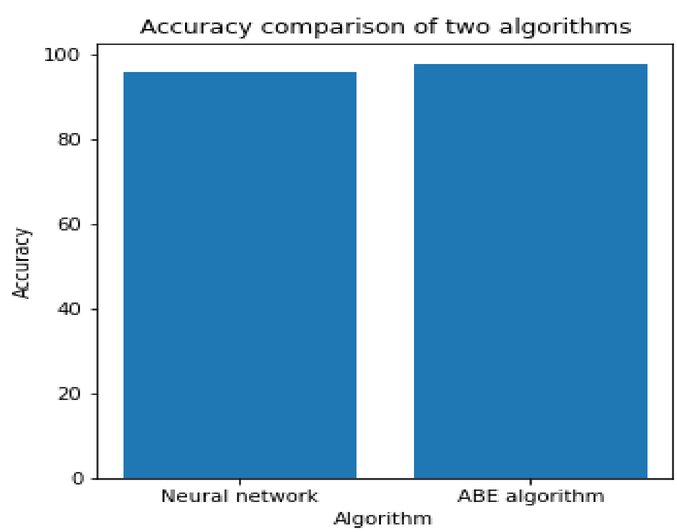

Fig. 2: Accuracy comparison of NN and ABE algorithm

VII. Result

Finally, from the Fig-1 and Fig-2, by comparing the Neural Network and Analogy Based Estimation, the accuracy of NN: *95.79%* and time taken for Neural Network: *34.34 seconds.* Accuracy of ABE: *97.68%* and time taken by Analogue Based Estimation: *2.66921 seconds.*

The performance of *ABE is better than NN*, with less time taken and improved accuracy.

VIII. Conclusion

This paper proposes a hybrid scheme for clustering based on PSO and K-means algorithm. K-means algorithm paves way to predetermine the number of clusters by the end users which results in an improper clustering. Hence PSO algorithm is integrated with K-means algorithm to improve the better clustering result. This result is more efficient when applied to neural networks and ABE.

IX. Future Work

To perform the model compiling for the minimum accuracy. Time taken to done for the pre-processing the dataset is very low, when compared with the other techniques. Our future work is to implement other techniques for effort estimation for this method.

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Optimizing the Running Time of a Trigger Search Algorithm based on the Principles of Formal Verification of Artificial Neural Networks

By Aleksey Tonkikh & Ekaterina Stroeva
Moscow State University

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GJCST-D Classification: *LCC Code: QA76.87*

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Aleksey Tonkikh [α] & Ekaterina Stroeva [σ]

Abstract- The article examines the problem of scalability of the algorithm for searching for a trigger in images, which is based on the operating principle of the Deep Poly formal verification algorithm. The existing implementation had a number of shortcomings. According to them, the requirements for the optimized version of the algorithm were formulated, which were brought to practical implementation. Achieved 4 times acceleration compared to the original implementation.

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I. Introduction

This paper discusses a trigger search algorithm that is based on one of the algorithms for the formal verification of neural networks, which is an urgent task, since many technology companies are faced with the problem of attacks using trigger overlays on images when training neural networks, as well as with the need to check the robustness of neural networks, which can be done mainly using formal verification algorithms.

In turn, one of the main problems of formal verification algorithms is the long operating time. This article proposes some methods to reduce the running time of the algorithm [1], which is used to detect the presence of a trigger in images from the MNIST dataset [2].

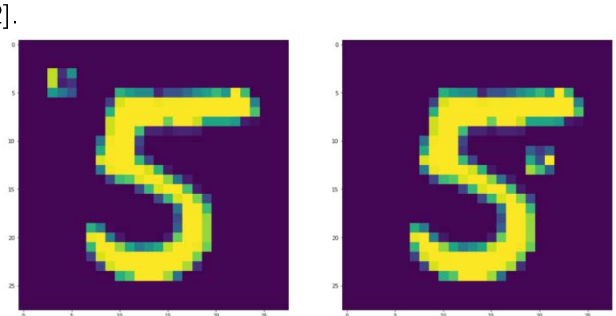

Fig.1: Example of a trigger and its location

Basic Definitions and Notations:

N —neural network;

I— an image that is analyzed in terms of the presence of a trigger;

X — set of images I, which is checked by the algorithm;

n — number of pixels in the image;

x_i — the value of the neuron before the one that is currently being analyzed;

x_j — calculated current value of the neuron;

$x_i \in [l_i, u_i]$ — range of values for each neuron;

$\phi_{pre} = [h_p, w_p] \leq j \leq [h_p + h_s, w_p + w_s] \wedge 0 \leq x[j] \leq 1$— preconditions for pixels that may contain trigger;

(c_s, h_s, w_s) — trigger parameters: number of channels, height and width, respectively;

(h_p, w_p) — upper left coordinate of the trigger;

t_s — output value of the neural network for the image with a trigger superimposed on it;

θ — specified success probability value;

K— the number of images in the sample checked for the absence of a trigger, or the number of elements in the set X.

A trigger is a rectangular sticker on an image that has the same number of channels and changes the classification (it is assumed that the trigger is the same for all images of a certain set and is located in the same place), for example, a3×3 square with pixels of different colors in Fig.1.

Formal definition: for a neural network solving the problem of classifying images of size (c, h, w), the trigger is some image $S$of size(c_s, h_s, w_s) such that $c_s = c, h_s \leq h, w_s \leq w$.

We can say that in the picture I there is a trigger of size(c_s, h_s, w_s), the upper left corner of which is located at the place (h_p, w_p)(subject to the obvious conditions $h_p + h_s \leq h, w_p + w_s \leq w$), if

$$I_s[c_i, h_i, w_i] = \begin{cases} S[c_i, h_i - h_p, w_i - w_p], \textit{if } (h_p \leq h_i < h_p + h_s) \wedge \\ \wedge\, (w_p \leq w_i < w_p + w_s); \\ I[c_i, h_i, w_i], \textit{otherwise.} \end{cases}$$

In other words, the trigger changes certain pixels of the image to given ones.

Formal Statement of the Problem

There is no patch (trigger) S such that when applied to a certain set of images $I \in X$, the neural

Author α σ: Moscow State University. e-mails: alexej-t@mail.ru, katestroeva@gmail.com

network Nchanges the output class to the target class t_s, on imagesI_s with the trigger S:

$$\exists S(c_s, h_s, w_s): \forall I_s \in X: N(I_s) = t_s.$$

Initial conditions:

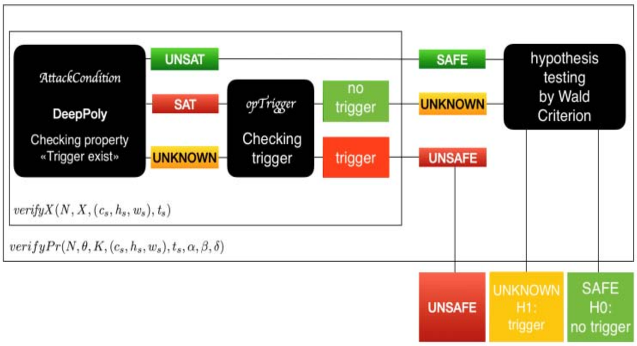

Fig. 2: Flowchart of the algorithm for searching for a trigger

1. *Dataset:* MNIST — 10,000 images in $1 \times 28 \times 28$ format; neural networks: fully connected and convolutional with activation functions ReLU, Sigmoid, Tanh with the number of parameters up to 100,000;
2. *Trigger Parameters:* $1 \times 3 \times 3$, any pixel values in the area;
3. *Security Property:* no trigger;
4. *Verification Algorithm:* DeepPoly.

II. Algorithm for Searching for a Trigger in an Image

The algorithm [1] is based on the DeepPoly verifier [3]. Its main goal is to search for a trigger that consistently fools the classifier for a certain number of images. The output value of the artificial neural network changes to a predetermined value. The search is performed over the entire image and for all possible values of each trigger pixel (a 3×3 trigger is considered and tested, although other values are possible). The Wald Criterion [4] is also used to evaluate hypotheses about the occurrence of a trigger.

Step by step, the entire algorithm works as follows:

1. Fix the position of the trigger. In the future, it is in this fixed area that there will bechecking for the presence of a trigger;
2. We go through the set of images and build variations of images:
   a) Calculate for an artificial neural network and a given image a set of constraints. Constraints are calculated in the body of the attack Condition function;
   b) We pass these restrictions to the SAT solver, and look at the answer: if the formula is degenerate, then there is no trigger for the image, therefore, the neural network is resistant to triggers;
   c) Otherwise we add these restrictions to the previous ones;
3. If the SAT solver finds a counterexample, then, consequently, there is a trigger. We find it by gradually parsing the solution to a Boolean function, which is performed in the opTrigger function;
4. If the SAT solver confirmed that the set of constraints does not have a solution, then the neural network works correctly;
5. If the SAT solver could not confirm the degeneracy of the constraints, and a trigger was not found, then more research needs to be done.

The relationships between the Attack Condition, opTrigger functions and all of the listed methods are presented in the block diagram in Fig. 2.

a) Description of how the Verify Pr Function Works

The algorithm is represented by the function verify Pr, which takes as input data the neural network N, the number of pictures K in the sample being tested, all trigger indicators (c_s, h_s, w_s), $t_s$probabilistic parameters α, β, δ of Wald criterion (SPRT) [4] and provides information about the presence or absence of a trigger with a given probability (Fig. 3).

Algorithm 1: $verifyPr(N, \theta, K, (c_s, h_s, w_s), t_s, \alpha, \beta, \delta)$

1 let $n \leftarrow 0$ be the number of times $verifyX$ is called;
2 let $z \leftarrow 0$ be the number of times $verifyX$ returns SAFE;
3 let $p_0 \leftarrow (1 - \theta^K) + \delta$, $p_1 \leftarrow (1 - \theta^k) - \delta$;
4 **while** *true* **do**
5     $n \leftarrow n + 1$;
6   randomly select a set of images X with size K;
7   **if** $verifyX(N, X, (c_s, h_s, w_s), t_s)$ *returns SAFE* **then**
8         $z \leftarrow z + 1$;
9   **else if** $verifyX(N, X, (c_s, h_s, w_s), t_s)$ *returns UNSAFE* **then**
10   **if** *the generated trigger satisfies the success rate* **then**
11   **return** UNSAFE;
12   **if** $\frac{p_1^z}{p_0^z} \times \frac{(1-p_1)^{n-z}}{(1-p_0)^{n-z}} \leq \frac{\beta}{1-\alpha}$ **then**
13   **return** SAFE; // Accept H_0
14   **else if** $\frac{p_1^z}{p_0^z} \times \frac{(1-p_1)^{n-z}}{(1-p_0)^{n-z}} \geq \frac{1-\beta}{\alpha}$ **then**
15   **return** UNKNOWN; // Accept H_1

Fig. 3: Pseudocode for the verify Prfunction [1]

[lines 1-2] Two variables are introduced: n— the number of calls to the verify X function, z— the number of SAFE responses returned by the verify X function.

[line 3] Set the probabilities $p_0, p_1$for using SPRT.

[line 4] A loop is started that runs until the SPRT conditions are met, as soon as the test monitors the fulfillment of one of the conditions, the result is given which hypothesis should be accepted [lines 12-15].

[line 5] A counter is started for the number of calls to the verify X function.

[line 6] Selecting K images randomly and composing them into a verifiable set X, which is fed to the input of the verifyX function.

[lines 7-11] Application of the verifyX function, which will be described in the following pseudocode (Fig. 4). The SAFE output means that you need to increase the z variable by 1 and go to a new iteration of SPRT, the UNSAFE output checks that the flip-flop does not satisfy all the specified statistical parameters and moves on to SPRT.

b) Description of how the Verify X Function Works

The verify X function takes as input the neural network N, the tested set of images X, the dimensions (c_s, h_s, w_s) and position (h_p, w_p) of the trigger, the target label for the trigger t_s.

```
Algorithm 2: verifyX(N, X, (c_s, h_s, w_s), t_s)
1  let hasUnknown ← false;
2  foreach trigger position (h_p, w_p) do
3      let φ ← φ_pre;
4      foreach image I ∈ X do
5          let φ_I ← attackCondition(N, I, φ_pre, (c_s, h_s, w_s), (h_p, w_p), t_s);
6          if φ_I is UNSAT then
7              φ ← false;
8              break;
9          else
10             φ ← φ ∧ φ_I;
11     if solving φ results in SAT or UNKNOWN then
12         if opTrigger(N, X, φ, (c_s, h_s, w_s), (h_p, w_p), t_s) returns a trigger then
13             return UNSAFE;
14         else
15             hasUnknown ← true;
16 return hasUnknown ? UNKNOWN : SAFE;
```

Fig. 4: Pseudo code for the verify X function [1]

At the output, the verify X function produces the response SAFE if there is no trigger in the selected set X or UNSAFE if there is a trigger (Fig. 2).

[line 1] The has Unknown variable is created, which is responsible for the case of uncertainty (it is impossible to get an answer about the presence or absence of a trigger), by default its value is set to False.

[line 2] The cycle is started to cycle through all possible trigger locations on the image being checked.

[line 3] The neural network is specified by a set of conjunctions ϕ, that is, in a form accessible to the SAT solver. During initialization, a set of initial constraints $\phi_{pre} = \wedge_{j \in P(w_p, h_p)} lw_j \le x_j \le up_j$ for the value ofpixels x_j located at positions $j \in P(w_p, h_p)$ in which thelocation is assumed at this step is entered into this variable trigger. Here$lw_j$and $up_j$are normalized boundaries for the trigger value, lying in the interval $[0; 1]$.

[line 4] For each image $I \in X$, a cycle is started to check each image for the presence of a trigger.

[line 5] The main function for checking the presence of a trigger attack Condition uses the DeepPoly formal verification algorithm for neural networks, which checks the property "there is a trigger on the image", returns an image represented in the form of conjunctions ϕ_I, and a SAT response if the property is satisfied (trigger found), UNSAT - property not satisfied (trigger not found).

[lines 6-10] If the attack Condition function returned UNSAT in the previous step, then the neural network is not executable, the variable ϕ is assigned the value False, exiting the loop. If a trigger is found, then its representation $\phi_I$is added to the neural network function.

[lines 11-15] The resulting representation of the neural network ϕ is fed into the SAT solver, and if the output is SAT or UNKNOWN, then the opTrigger function is run.

i. *The function opTigger*

First checks whether the resulting rectangle S of size (c_s, h_s, w_s) at position $(h_p, w_p)$is a trigger that successfully attacks every image I in the test set X. Because If the accumulated error of abstract interpretation resulting from the application of the DeepPoly algorithm is too large, the resulting model may be a false trigger. If it is a real trigger, then it returns model S and the output is UNSAFE.

The opTrigger function creates a trigger based on the available data, using an approach based on optimizing the loss function:

$$loss(N, I, S, (h_p, w_p), t_s) = \begin{cases} 0, & if\, n_s > n_0; \\ n_0 - n_s - \epsilon, & \text{otherwise.} \end{cases}$$

$n_s = N(I_s)[t_s]$ — outputfor target label t_s; $n_0 = max_{j \neq t_s} N(I_s)[j]$ — next after the largest value of the output vector; ϵ is a small constant, about 10^{-9}.

The loss function returns 0 if the attack on I by the trigger is successful. Otherwise, it returns a quantitative measure of how far the simulated attack is from being successful.

For the entire tested set X we obtain a joint loss function

$$loss(N, X, S, (h_p, w_p), t_s) = \sum_{I \in X} loss(N, I, S, (h_p, w_p), t_s)$$

An optimization problem is then solved to find an attack that successfully changes the classification of all images in X:$argmin_S loss(N, X, S, (h_p, w_p), t_s)$.

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ii. *The Attack Condition Function*

Takes all parameters as input and outputs the result

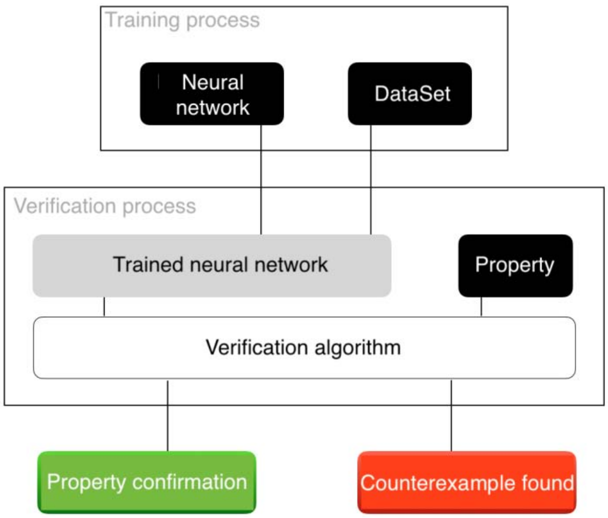

Fig. 5: Pseudocode for the Attack Condition function

there is a trigger or not a trigger (Fig. 5). Inserts restrictions on the trigger in the form of conjunctions and adds ϕ to the network structure.

The main idea of checking for a trigger: the area of pixels in which the trigger will be placed is selected, each such pixel is assigned a symbolic value included in the interval $[0;1]$ [lines 1-8]. Next, using the DeepPolyReLU function, we track the moment at which the checked pixel value from the segment $[0;1]$ will change the output vector of values, that is, the classification will change, we obtain the pixel value at which the trigger will be located on this pixel [lines 9-21].

If for all values of the checked pixel from the segment $[0;1]$there is no change in the value of the target label (the output segment for the target label at all points is greater than the output segments for all other values) [line 25], then there will be no trigger, we return UNSAT [line 26], if it is not clear whether the target label has changed or not (the output segment for the target label intersects with some output segment for some of the other values), then the situation requires moredeep analysis, UNKNOWN is returned [lines 29 and 37]. If the output label has definitely changed, then the trigger is found, SAT is returned [line 35].

The DeepPoly algorithm [3], like all formal verification algorithms [5], checks properties (Fig. 6). In the context of the verifyX function, the "no trigger" property is checked.

Algorithm 1 attackCondition$(N, I, (c_s, h_s, w_s), (h_p, w_p), t_s)$

```
1:  let constraints ← [[0,0]] * (h * w);
2:  for j ← 0,...,h * w do
3:      if j ∈ φ_pre then
4:          constraints[j] ← ([0,1]);
5:      else
6:          constraints[j] ← ([I[j], I[j]]);
7:      end if
8:  end for

9:  foreach layer ∈ N do
10:     if layer is ReLU then
11:         for i ← 0,...,len(constraints) do
12:             constraints[i] ← DeepPolyReLU(constraints[i][0], constraints[i][1]);
13:         end for
14:     else
15:         NewConstraints ← [[0,0]] * (layer.CountNeurons);
16:         for i ← 0...len(layer.CountNeurons) do
17:             NewConstraints[i] ← AffineCompute(constraints, layer.weights[i], layer.biases[i]);
18:             constraints ← NewConstraints;
19:         end for
20:     end if
21: end for

22: let flag ← True
23: for i ← 0,...,len(constraints) do
24:     if i ≠ t_s then
25:         if constraints[t_s][1] < constraints[i][0] then
26:             return UNSAT;
27:         else
28:             if constraints[t_s][0] < constraints[i][1] then
29:                 flag ← False;
30:             end if
31:         end if
32:     end if
33: end for

34: if flag then
35:     return SAT;
36: else
37:     return UNKNOWN;
38: end if
```

Fig. 6: General scheme of operation of algorithms for formal verification of neural networks

c) *Deep Poly ReLU function*

Analyzes approximate values for the output of the ReLU activation function (Fig. 7).

Algorithm 2 DeepPolyReLU(l, u)

```
if 0 ∈ [l_i, u_i] then
    let S_1 ← (u_i − l_i) * u_i/2;
    let S_2 ← (u_i − l_i) * (−l_i)/2;

    if S_1 < S_2 then
        return [0, u_i];
    else
        return [l_i, u_i];
    end if

else

    if u_i < 0 then
        return [0, 0];
    else
        return [l_i, u_i];
    end if
end if
```

Fig. 7: Pseudo code for the Deep Poly ReLU function

d) *Basic Moments*

- Linear constraints on each neuron are represented as a linear combination of only input data x_1, x_2(and not through the constraints of previous neurons), then the constraints for each neuron at each step will be better, the segment will expand less.
- If the ReLU input receives a segment with a half-living ends, then it turns into itself, without changes. If the segment contains a point zero, then as constraints we use $0 \leq x_j \leq \lambda x_i + \mu$ (the equation of

the straight line defining the upper boundary of the triangle passing through the points $(l_i; 0)$, $(u_i; u_i)$, l_i and u_i — boundaries of the interval in the previous step). If the entire segment is negative, then it simply goes to zero.

- The main difference from other algorithms is exactly one lower constraint. This makes it possible to narrow the boundaries of the intervals and facilitate computing power (Fig. 8). It is also argued that approximation by such triangles is better than zonotopes — they are easier to calculate, and also often have a smaller area. With a similar formulation of the problem, the zonotope in this case will be a parallelogram, the lower side of which contains the point $(0; 0)$.

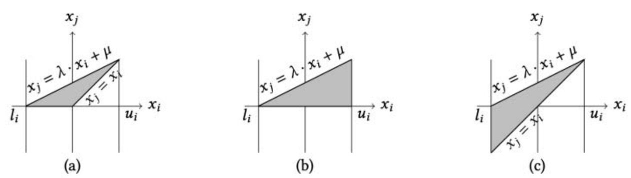

Fig. 8: Approximation of the ReLU function in the DeepPoly algorithm [3]

The AttackCondition function takes all parameters as input and outputs the result — there is a trigger or there is no trigger. Inserts restrictions on the trigger in the form of conjunctions and adds ϕ to the network structure.

These results are then used in the VerifyPr function, which gives a probabilistic assessment of the presence of a trigger.

e) The Affine Compute Function

Takes as input values from the previous layer, performs standard affine transformations — multiplying by weights and adding a bias vector, and at the output produces an interval within which all possible values supplied to the input of the ReLU function lie (Fig. 9).

Algorithm 3 AffineCompute(constraints, w, bias)

```
let l_j ← bias;
let u_j ← bias;
for i ← 0, ..., len(constraints) do
    l_j ← l_j + w[i] * constraints[i][0];
    u_j ← u_j + w[i] * constraints[i][1];
end for
return [l_j, u_j];
```

Fig. 9: Pseudocode for the AffineCompute function

f) SPRT (Sequential Probability Ratio Test) or Wald Criterion

Designations:

θ is the probability of a trigger appearing, common to all K pictures: for a given neural network N, trigger S, target label t_s, it is postulated that S has a probability of success θ if and only if there is a position (h_p, w_p) such that the probability of occurrence $L(N(I_s)) = argmax_i(y_{output}) = t_s$ for any I in the chosen test set is θ.

No trigger:

$$\forall I \in X \exists s, I_s = I(s): L(N(I_s)) > t_s,$$

where α, β, δ are confidence levels.

Testable hypotheses:

H_0: The probability of no attack on a set of Krandomlyselected images is greater than$1 - \theta^K$.

H_1: The probability of no attack on a set $K$of randomly selected images is no greater than $1 - \theta^K$.

Next, the researcher sets the values of the parameters α and β, this is the probability of an error of the first and second kind, respectively (Fig. 10).

Truth	Decision: *accept H_0, reject H_1*	*reject H_0, accept H_1*
$p \geq \theta$: H_0 true, H_1 false	correct (>1 − α)	type I error (≤α)
$p < \theta$: H_0 false, H_1 true	type II error (≤β)	correct (>1 − β)

Fig.10: Errors of type 1 and 2

Parameter δ is the "gap" between the null and alternative hypothesis. If the value falls in a region where the estimated probability of not having the attack will be greater than $p_0 = (1 - \theta^K) + \delta$, then we accept the null hypothesis, if less than $p_1 = (1 - \theta^K) - \delta$, then we reject the null hypothesis , if between them, then we move on to a new iteration of the algorithm. This is precisely the procedure of sequential analysis, which consists in sequential testing of the indicated inequalities for probabilities, and in this way it differs from simple testing of hypotheses.

The article [1] sets the following parameter values $K = 5{,}10{,}100, \theta = 0.8{,}0.9{,}1, \alpha = \beta = \delta = 0.01.$

III. Experimental Part

a) Scalability Study

A scalability study showed that for neural networks with about 10,000 parameters, searching for triggers for all 10 labels takes about several minutes. In article [1] and the implementation, a search for triggers for the conv_small_relu neural network was proposed (the architecture is shown in Fig. 11). Such a neural network contains 89,000 parameters. Finding triggers for all 10 tags takes about 10 hours.

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 16, 13, 13]             272
              ReLU-2           [-1, 16, 13, 13]               0
            Conv2d-3             [-1, 32, 5, 5]           8,224
              ReLU-4             [-1, 32, 5, 5]               0
           Flatten-5                  [-1, 800]               0
            Linear-6                  [-1, 100]          80,100
              ReLU-7                  [-1, 100]               0
            Linear-8                   [-1, 10]           1,010
================================================================
Total params: 89,606
Trainable params: 89,606
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.00
Forward/backward pass size (MB): 0.06
Params size (MB): 0.34
Estimated Total Size (MB): 0.41
----------------------------------------------------------------
```

Fig. 11: Neural networkconv_small_relu architecture

Similar architectures with fewer and more parameters were tested. For neural networks with about 105,000 parameters, verification for one target label takes about 20 hours (for 10 labels it takes approximately 200 hours). From this we conclude that the duration of verification increases exponentially with increasing number of parameters.

b) Improved Work Speed

During the analysis of the repository, the bottleneck was identified — the back_substitute function of the utils.py module, which is responsible for the integration of interval arithmetic. Profiling of this program shows that about **70%** of the execution time is occupied by this function (Fig. 12). The calculation graph shows similar results (Fig. 13).

Name	Call Count	Time (ms)		Own Time (ms) ▼	
back_substitute	24430640	22239630	92.9%	17060946	71.3%
<method 'reduce' of 'numpy.ufunc' objec	171164012	1590864	6.6%	1590864	6.6%
<method 'nonzero' of 'numpy.ndarray' ol	156399360	1305071	5.5%	1305071	5.5%
f_wrapped	776610376	6201004	25.9%	1178936	4.9%
find_top_boxed_args	776610376	564045	2.4%	419477	1.8%
<built-in method numpy.core._multiarray	588557196	4058328	17.0%	234355	1.0%
roll	47374080	281605	1.2%	181411	0.8%
<lambda>	1580220125	171697	0.7%	171697	0.7%
_wrapreduction	171162011	1832933	7.7%	167766	0.7%
sum	171160960	1999585	8.4%	140632	0.6%
f_wrapped	238679620	251373	1.1%	105127	0.4%
delete	27040	100982	0.4%	100528	0.4%
array	143931460	506997	2.1%	96540	0.4%
apply_poly	13520	11371319	47.5%	95687	0.4%
<built-in method numpy.array>	143947586	78817	0.3%	78817	0.3%
<built-in method numpy.zeros>	29865701	70790	0.3%	70790	0.3%
sum	171160960	2143509	9.0%	70448	0.3%
<dictcomp>	171162011	62815	0.3%	62815	0.3%
append	47374080	1042424	4.4%	61034	0.3%

Fig.12: Table of execution times of all algorithm functions

To optimize the selected bottleneck, various approaches to code optimization and library replacement were tested, as well as deployment on GPUs using the PyTorch library.

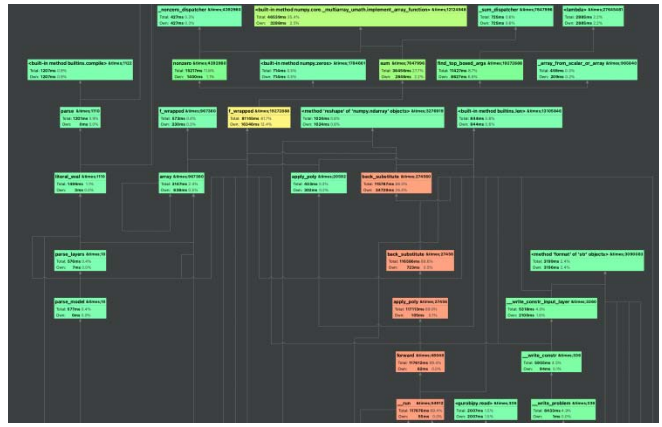

Fig.13. Calculation graph of all algorithm functions

It was not possible to obtain a significant increase in performance using the GPU, since the method uses a large number of not very complex calculations. As a result, calculations slowed down 10 times. This happened because GPUs are adapted for calculating large matrices, while the CPU copes better with the proposed task. The use of other libraries and code optimization led to a 20 percent improvement in the execution speed of the back_substitute function. The overall running time of the algorithm was also improved by approximately **10%** (Fig. 14).

```
No backdoor
No false alarm
No stamp
Running time = 496m 6s
         4363399642 function calls (4172002925 primitive calls) in 29766.186 seconds

   Ordered by: internal time

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
 24430640 24456.822    0.001 28484.934    0.001 utils.py:147(back_substitute)
```

```
No backdoor
No false alarm
No stamp
Running time = 534m 51s
         8737689942 function calls (8591859206 primitive calls) in 32091.220 seconds

   Ordered by: internal time

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
 24430640 23547.410    0.001 29343.768    0.001 utils.py:147(back_substitute)
```

Fig.14: Comparison of algorithm running time before and after optimization improvements

Parallelization of the selected problem is impossible, since the newly calculated data must again be fed into the input. Nevertheless, you can try to parallelize the search for a trigger in different places, but this issue is subject to deeper study.

IV. Practical Implementation

a) Software and Hardware

The main part of the described experiments was carried out on a computer complex using a central processor and having the following characteristics:

Table I: Hardware

CPU	Apple M1 Max processor
RAM	32 GB

Experiments on the GPU were carried out using a computing cluster with the characteristics indicated in Table II.

Table II: Hardware, GPU cluster

Video card	NVIDIA RTX A6000
Processor	AMD EPYC 7532 32-Core
RAM	252 GB

Software with the characteristics shown in Table III was used.

Table III: Software

OS (CPU)	MacOS Ventura 13.3.1
OS (GPU)	Ubuntu 20.04.4 LTS
Python	3.10.0
numpy	1.23.5
scipy	1.8.0
autograd	1.4
	9.5.1
torchsummary	1.5.1
nvidia cuda	11.7
pytorch	1.13.1

b) Datasets and Neural Networks

Neural networks trained on the following data sets were used:

- MNIST – a set of single-channel images of28×28pixels. Images are divided into 10 classes — numbers from 0 to 9 (Fig. 15);
- CIFAR-10 – a set of three-channel images of 32×32pixels. Images are divided into 10 classes — airplane, car, bird, cat, deer, dog, frog, horse, ship, truck (Fig. 16).

In addition to the experiments proposed in the article, other neural networks were trained. They were analyzed using a trigger search algorithm and used to compare the original implementation and the optimized version. Neural networks that showed high accuracy on the test set, as a rule, did not have a trigger. An example of a tested neural network is shown in Fig. 11.

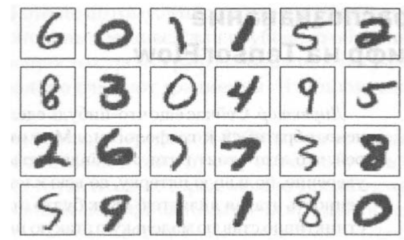

Fig.15: MNIST DataSet

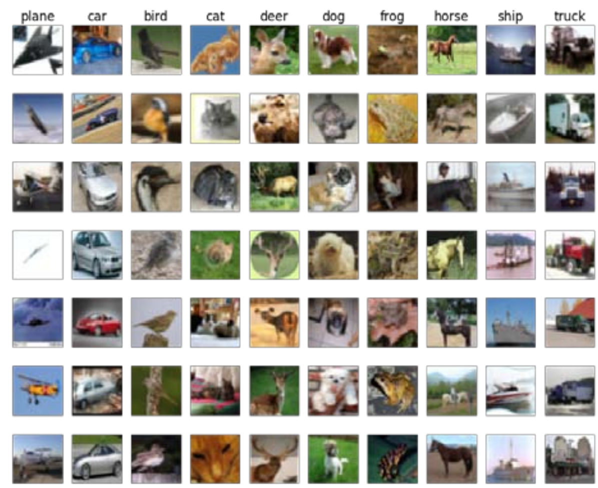

Fig.16: CIFAR-10 DataSet

c) Disadvantages of the Current Implementation

Formal verification, as a young field of science, has many difficulties with uniform standards of use. The proposed implementation of the trigger search problem has a number of significant problems that arise for the user who decides to use this algorithm. It was decided to correct the identified deficiencies as part of this work.

1. The proposed implementation works only with neural networks stored in a special format, where all weights and biases are stored in separate txt files, and the architecture itself is written in a separate spec.json file. To read neural networks in this format, a separate json_parser module is used, which extracts the weights of the neural network and prepares them for work. The inability to conduct an experiment on a neural network not described by the authors is a significant drawback;
2. The proposed algorithm works quite slowly even on small neural networks, which is natural, since formal verification very carefully analyzes the entire neural network layer by layer, neuron by neuron. Since when testing more complex neural networks with a large number of parameters, the key limitation is the running time of the algorithm, optimizing it will increase its applicability. Also, the existing implementation does not use parallelization and it was decided to fix this too;
3. The existing implementation is only suitable for testing neural networks trained on the MNIST

dataset, and has not been adapted or tested for the CIFAR-10 dataset;

4. Support for only a limited set of layers, such as two-dimensional convolutional and fully connected layers.

In connection with the identified shortcomings, requirements were drawn up for an optimized version of the existing implementation:

1. The ability to search for triggers for ANN written in PyTorch;
2. Adding parallelization at various levels;
3. Adding support for neural networks, trained on the CIFAR-10 data set;
4. Adding support for MaxPool1D, MaxPool3D, Conv1D, Conv3D layers.

d) *GPU Usage*

As part of solving the optimization problem and using parallel computing, using profiling methods, a bottleneck was identified — the back_substitute function of the utils module (Fig. 13). Implementation of this function using the PyTorch library and graphics processing unit (GPU) did not give the expected acceleration.

This happened because the formal verification problem is poorly adaptable to GPU computing. During the calculation, there are quite a few operations that are similar to each other, and most of them depend on the previous step, which makes the use of the GPU ineffective.

It was decided to replace the used autograd library with numpy. Since the numpy library is written in C and Fortran programming languages, it is highly optimized. The autograd library is a "wrapper" of already optimized algorithms, which gives a series of small delays that accumulate and give a significant slowdown with a large number of calls. Replacing the autograd library with the numpy library increased the speed of the back_substitute function by 20 percent, and the speed of the entire algorithm by an average of 10 percent.

The table below shows the running time of the back_substitute function using various libraries. For each library, 10,000 calculations were carried out and the average value was calculated:

Table IV: Running time of the back_substitute function for different libraries

Library	Back_substitute running time (s)
autograd	0.00023
PyTorch (GPU)	0.00225
numpy	0.00018

e) *Using Parallel Computing*

During the study of the existing implementation of the trigger search algorithm, places were identified that could be optimized using parallelization; the pseudocode is presented in Fig. 17.

```
Algorithm 2: verifyX(N, X, (c_s, h_s, w_s), t_s)    #pragma parallel
let hasUnknown ← false;
foreach trigger position (h_p, w_p) do    #pragma parallel
    let φ ← φ_pre;
    foreach image I ∈ X do
        let φ_I ← attackCondition(N, I, φ_pre, (c_s, h_s, w_s), (h_p, w_p), t_s);
        if φ_I is UNSAT then
            φ ← false;
            break;
        else
            φ ← φ ∧ φ_I;
    if solving φ results in SAT or UNKNOWN then
        if opTrigger(N, X, φ, (c_s, h_s, w_s), (h_p, w_p), t_s) returns a trigger then
            return UNSAFE;
        else
            hasUnknown ← true;
return hasUnknown ? UNKNOWN : SAFE;
```

Fig. 17: Pseudocode of the VerifyX function indicating places of parallelization

It was decided to test parallelization in two selected areas: at the stage of selecting a target label and at the stage of enumerating trigger locations. This is possible thanks to the following process. For each trigger location, a chain of conjunctions of admissible intervals of all neurons in the neural network is calculated. Since the sequence of conjunctions does not change its meaning depending on the location of the conjunction in the chain, the result when applying parallelization remains unchanged. The proposed parallelization in both cases was implemented using the standard multiprocessing library and in total gave a significant increase in speed in various experiments. On average, on the tested neural networks, an acceleration of 4 times was obtained relative to the original implementation. The results of the experiments are shown in Table V. The first half shows the results for fully connected neural networks, and the second half for convolutional ones.

Other optimizations implemented according to the formulated requirements are listed below:

1. As part of the work, a sequence of actions was implemented to convert any neural network written in PyTorch into a specialized format used by the trigger search algorithm. This pipeline has been tested for all possible types of layers and architectures, including those that were not studied in the original article;
2. To support layers of new types, the corresponding classes were implemented with processing built according to the DeepPoly formal verification method;

3. To support the CIFAR-10 data set, the images in it were normalized from 0 to 1 and converted into the appropriate specialized format. The existing implementation was adapted to use a $3 \times 3 \times 3$ trigger, and support for multi-channel triggers was added wherever this was lacking.

Table V: Algorithm running time before and after optimization

Neural network	Number of parameters	Original time	Optimized time
mnist_model_0	79 510	1 223 s	341 s
mnist_model_1	159 010	2 352 s	659 s
mnist_model_2	199 310	6 873 s	1 704 s
mnist_model_3	119 810	5 394 s	1 328 s
mnist_conv_small	89 606	22 452 s	4 548 s
mnist_model_5	159 387	258 854 s	74 855 s
mnist_conv_maxpool	34 622	17 880 s	3 632 s
cifar_conv_relu	62 006	—	197 426 s

f) Assessing the complexity of the trigger search algorithm in neural networks of various architectures

The time it takes to search for a trigger in a neural network depends on its architecture. The complexity of testing a neural network can be determined both empirically and theoretically. It will correlate with the number of parameters and depend on: the number of layers in the neural network, the size of these layers, the type of these layers. Empirically, it was found that fully connected layers are faster to check than convolutional layers. The verification time depends to a greater extent on the number of layers and to a lesser extent on their size.

The number of parameters for verifying fully connected layers can be expressed as $O(m * n)$, where m and n are the number of inputs and outputs of the layer. The number of parameters for verifying 2D layers can be expressed as $O(c * h * w)$ for Conv2D and $O(c * h^2 * w^2)$ for MaxPool2D, where c, h and w are the number of channels, the height and width of the kernel. Thus, it is easy to see that the more parameters the 2D layers have, the longer the neural network will take to verify.

Table VI: Estimation of the complexity of searching for a trigger for different types of layers

Layer type	Complexity
Linear	$O(m * n)$
Conv2D	$O(c * h * w)$
MaxPool2D	$O(c * h^2 * w^2)$

V. Conclusion

Formal verification algorithms are generally applicable to checking neural networks for the absence of attacks. Using the DeepPoly algorithm, you can not only check for the presence of a trigger in an image, but also generate triggers. Verification problems arise on networks containing Sigmoid and Tanh activation functions.

Probabilistic models provide a numerical assessment of testing the operation of neural networks; they can be combined with formal verification algorithms. As a continuation of the work, you can try to use other verification algorithms for these experiments, based on the analysis by zonotopes [5] of the Sigmoid and Tanh activation functions.

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Leveraging Business-Inspired Computational Intelligence Techniques for Enhanced Data Analytics: Applications of Genetic Algorithms, Fuzzy Logic, and Swarm Intelligence

By S. M. A. N. M Subasinghe
University of Kelaniya Sri Lanka

Abstract- Data has become a crucial element for contemporary enterprises; however, deriving practical insights from its immense volume remains an intricate obstacle. This paper examines the capabilities of three bio-inspired computational intelligence (CI) methods - Genetic Algorithms (GAs), Fuzzy Logic (FL), and Swarm Intelligence (SI) - in improving data analytics for business optimization and decision-making. The researcher thoroughly examines the fundamental principles of each technique, emphasizing their inherent advantages and appropriateness for addressing practical business challenges. By reviewing recent research and real-world examples, the researcher illustrates how Genetic Algorithms (GAs) can enhance the efficiency of resource allocation, Fuzzy Logic (FL) can effectively handle uncertainty in risk assessment, and Swarm Intelligence (SI) can streamline logistics and scheduling processes.

Keywords: data analytics, business intelligence, genetic algorithms, fuzzy logic, swarm intelligence, optimization, enterprise decision-making, case studies.

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LEVERAGINGBUSINESSINSPIREDCOMPUTATIONALINTELLIGENCETECHNIQUESFORENHANCEDDATAANALYTICSAPPLICATIONSOFGENETICALGORITHMSFUZZYLOGICANDSWARMINTELLIGENCE

Leveraging Business-Inspired Computational Intelligence Techniques for Enhanced Data Analytics: Applications of Genetic Algorithms, Fuzzy Logic, and Swarm Intelligence

S. M. A. N. M Subasinghe

Abstract- Data has become a crucial element for contemporary enterprises; however, deriving practical insights from its immense volume remains an intricate obstacle. This paper examines the capabilities of three bio-inspired computational intelligence (CI) methods - Genetic Algorithms (GAs), Fuzzy Logic (FL), and Swarm Intelligence (SI) - in improving data analytics for business optimization and decision-making. The researcher thoroughly examines the fundamental principles of each technique, emphasizing their inherent advantages and appropriateness for addressing practical business challenges. By reviewing recent research and real-world examples, the researcher illustrates how Genetic Algorithms (GAs) can enhance the efficiency of resource allocation, Fuzzy Logic (FL) can effectively handle uncertainty in risk assessment, and Swarm Intelligence (SI) can streamline logistics and scheduling processes. In conclusion, highlight the synergistic and hybrid methods emerging in this field. These approaches are leading to enhanced value extraction from data and pushing the limits of business intelligence.

Keywords: data analytics, business intelligence, genetic algorithms, fuzzy logic, swarm intelligence, optimization, enterprise decision-making, case studies.

I. Introduction

Enterprises are overwhelmed by an overwhelming amount of data, needing help in extracting practical and valuable insights from its extensive and frequently disorganized contents (IDC, 2023). Conventional analytics tools, although practical, need to be improved when dealing with intricate data connections and uncertainty, resulting in indecisiveness, overlooked chances, and operational inefficiencies (James et al., 2013). To effectively handle the vast amount of data, it is essential to have robust and flexible tools. This is where bio-inspired computational intelligence techniques such as Genetic Algorithms (GAs), Fuzzy Logic (FL), and Swarm Intelligence (SI) come into play. These techniques, which draw inspiration from natural processes such as evolution, swarm behaviour, and human reasoning, provide businesses with the ability to optimize supply chains, target marketing efforts towards specific customer segments, incorporate subjective factors to manage credit risks, adjust product prices based on market demand, effectively schedule projects, and detect fraudulent activities in real-time. The future depends on effectively combining these techniques with ongoing research and development, thereby unleashing the complete capabilities of data-driven intelligence to gain a competitive advantage in the information era.

Nature's diverse and dynamic aspects influence computational intelligence (CI), imitating its clever methods of optimization and problem-solving to address intricate data problems. Genetic Algorithms (GAs) mimic the process of evolution by iteratively enhancing solutions through selection, crossover, and mutation. This ultimately leads to nearly optimal answers (Mitchell, 1996). Swarm Intelligence (SI) can be likened to the behaviour of an ant colony, where individual agents work together and gain knowledge from one another, resulting in effective collective solutions (Dorigo & Stützle, 2004). Fuzzy Logic, which draws inspiration from human reasoning, encompasses the acceptance of uncertainty and vagueness. It enables us to effectively handle situations where rigid rules are inadequate (Zadeh, 1965). These biomimetic methods, which imitate nature's grace and durability, equip us with potent instruments to overcome the increasingly intricate challenges of data analysis.

Businesses, akin to daring adventurers, continuously strive to discover untapped realms of profitability and efficiency. The quest takes them to the ever-changing terrain of bio-inspired computational intelligence techniques, where each approach possesses a valuable solution for achieving distinct business goals. Cost reduction can be achieved through optimization techniques such as Genetic Algorithms for improving supply chains, Swarm Intelligence for optimizing staff schedules, and Fuzzy Logic for minimizing energy consumption (Zhang et al., 2008; Panchal et al., 2010). Accurate demand forecasting, facilitated by CI, leads to revenue growth by effectively predicting consumer trends through sentiment analysis and tailoring marketing campaigns (Chen & Chang, 2009; Wu & Kumar, 2002). Risk

Author: University of Kelaniya Sri Lanka, Department of Marketing Management. e-mail: nilakshikas5@gmail.com

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mitigation is closely linked to the use of anomaly detection algorithms. Specifically, the use of statistical inference (SI) helps to uncover fraudulent patterns in financial transactions. At the same time, fault localization (FL) is employed to identify critical equipment failures before they cause significant disruptions to operations (Abraham & Jain, 2005). Ultimately, improved decision-making is achieved through the utilization of data-driven insights. Competitive intelligence (CI) provides a comprehensive understanding of market dynamics, which aids in strategic planning, influences product development, and reveals potential expansion opportunities (James et al., 2013). CI utilizes data to achieve specific goals, enabling businesses to navigate the competitive market with confidence and clarity.

II. Key Techniques and Applications

Genetic Algorithms (GAs) enhance data analysis by applying iterative refinement, drawing inspiration from the Darwinian principle of evolution. Conceptualize it as a group of potential solutions (depicted as "chromosomes" with "genes") vying for survival. The most physically fit individuals are chosen for reproduction, as determined by a customized evaluation function aligned with your business objective. Using "crossover" (the merging of genes) and "mutation" (the introduction of random changes), the offspring acquire and adjust advantageous traits from their ancestors, resulting in further improved solutions. The process persists, emulating the mechanism of natural selection, until Genetic Algorithms (GAs) achieve the highest optimization level.

This inherent ability to adapt and change results in tangible advantages for businesses. Envision genetic algorithms (GAs) efficiently determining the most influential characteristics for your marketing models, accurately forecasting customer behaviour with exceptional precision (Peña et al., 2012). Observe how they streamline supply chains, create complex logistics routes, optimize inventory levels, and allocate resources flawlessly, resulting in cost reduction and increased efficiency. Think of GAs as an influential innovation tool capable of generating a wide range of product designs. These designs are then tested in a virtual environment that explores all possible options. Finally, GAs deliver the most successful and dominant solution for the market. Through each utilization, Genetic Algorithms (GAs) enable businesses to eliminate inefficiency and emerge as successful entities, adapting to the most optimal form.

Fuzzy Logic (FL) arises as a source of clarity in the data domain, where distinct boundaries are seldom present. Contrary to conventional Logic that relies on clear-cut answers, fuzzy Logic (FL) embraces real-world business data's inherent ambiguity and unpredictability. The system employs fuzzy sets incorporating varying degrees of membership rather than strict categories to represent abstract notions such as "youthful" or "trustworthy." Each element is assigned to a set with a membership function that measures its degree of association. Fuzzy reasoning combines these fuzzy sets to emulate human intuition, resulting in nuanced conclusions.

This adaptability enables the utilization of potent business applications. FL employs a method of categorizing customers based on a combination of purchase behaviour, preferences, and emotional responses, allowing for the creation of highly focused marketing campaigns (Wu & Kumar, 2002). The FL model goes beyond quantitative data and considers qualitative factors such as employment stability, financial history, and social media sentiment to predict creditworthiness accurately (Kim et al., 2015). Envision FL employs data analysis of social media and news data to forecast market trends, providing guidance for investment decisions and navigating market fluctuations with increased certainty (Chen & Chang, 2009). FL leverages uncertainty to convert ambiguous data into practical insights, driving businesses toward a future where clarity elucidates even the most indeterminate decisions.

Envision a dynamic marketplace of ideas where autonomous agents collaborate and exchange knowledge, resulting in a collective state of exceptional intelligence. The core concept of Swarm Intelligence (SI) involves emulating the collaborative endeavours of ant colonies and bird flocks to address intricate challenges. Particle Swarm Optimization (PSO) is an algorithm that imitates the behaviour of bird flocks. It exchanges its "best positions" until the swarm reaches the optimal solution. Ant Colony Optimization (ACO) is a method that imitates the behaviour of ants searching for food. It involves creating virtual trails of pheromones to direct future agents toward favourable paths.

These techniques of "collective wisdom" can be effectively applied in business. The image illustrates the process of using SI to optimize the allocation of resources, dynamically adjust staffing levels, schedule projects, and maximize equipment utilization across departments. This leads to increased efficiency and reduced waste. Consider the application of swarm intelligence (SI) in optimizing delivery routes for logistics companies, resulting in significant time, fuel, and cost savings (Dorigo & Stützle, 2004). Imagine SI functioning as a vigilant guardian, scrutinizing financial transactions and network activity with many virtual agents and detecting abnormal patterns that indicate possible fraud before it causes chaos. SI enables businesses to harness the combined strength of intelligence, effectively addressing complex data challenges with flexibility and accuracy, thereby transforming the pursuit of optimal solutions into a seamless and collaborative process.

III. Tea Fortune with Unclear Predictions

A silent revolution is underway in our comprehension and enhancement of intricate systems, starting from the lush hills of Sri Lanka to the vast vineyards of Europe. Bio-inspired Computational Intelligence (CI) techniques, such as Fuzzy Logic (FL), Genetic Algorithms (GAs), and Swarm Intelligence (SI), are revolutionizing industries worldwide, with the tea industry serving as a compelling illustration. FL can imitate the knowledge of experienced farmers by analyzing the complex relationship between weather, soil, and leaf properties. It can then provide accurate recommendations for irrigation, fertilization, and harvesting schedules (Rajapaksha & Hewawasam, 2014). Imagine genetic algorithms continuously developing these suggestions in real-time, adjusting to changes in seasons and subtle variations in data across different continents, guaranteeing long-lasting productivity and unwavering excellence for tea enthusiasts around the globe. Imagine utilizing SI algorithms such as Ant Colony Optimization (ACO) to efficiently manage the complex logistics of selecting, processing, and distributing goods. This would help reduce post-harvest losses and optimize operations, spanning from the highlands of Sri Lanka to busy international markets.

Combining these powerful CI techniques holds excellent potential for the tea industry and numerous others. Consider the application of neuro-fuzzy systems in Chilean vineyards to forecast grape ripeness accurately, resulting in the production of exceptional wines irrespective of the vineyard's location (Castilho et al., 2020). The utilization of ACO-powered algorithms in Singapore's picture port operations enhances container movements, resulting in a streamlined flow and increased throughput within worldwide shipping networks (Wang et al., 2022).

Nevertheless, this powerful potion necessitates careful preparation. Ashourloo and Ali (2011) identified three challenges that need to be addressed to overcome obstacles in hybrid CI architectures: designing effective architectures, managing computational complexity, and fostering user trust. However, the future presents alluring prospects. Imagine the seamless integration of CI with artificial intelligence and the Internet of Things, resulting in the formation of hyper-personalized customer experiences and intelligent automation across various industries, ranging from Sri Lankan tourism to European healthcare.

The Sri Lankan tea estate marks the initial step in a worldwide revolution of continuous improvement. By harnessing the harmonious relationship between the wisdom of nature, computational capabilities, and responsible methodologies, we can create a future in which data is guided by intelligent solutions, sustainable advancement, and enhanced success for industries and consumers worldwide, regardless of their geographical location.

Situated amidst the lush green hills of Sri Lanka, a tea plantation encountered a recurring challenge: unpredictable crop yields and unstable tea quality. Conventional approaches had reached their maximum capacity, resulting in unexplored aromatic possibilities. Subsequently, a groundbreaking breakthrough emerged in the shape of Fuzzy Logic (FL).

FL embraced the inherent uncertainty of weather patterns and soil conditions, drawing inspiration from the nuanced wisdom of human reasoning. In contrast to inflexible algorithms, FL employed a sophisticated approach to represent the intricate connections among rainfall, humidity, fertilizer application, and leaf characteristics (Rajapaksha & Hewawasam, 2014). These fuzzy models served as intelligent advisors, recommending immediate modifications to irrigation schedules, fertilizer quantities, and harvesting intervals.

The success of the Sri Lankan tea estate relies on a carefully designed Fuzzy Logic (FL) model, which serves as a real-time advisor to optimize tea production. Let us analyze and comprehend the internal mechanisms of this model by dissecting it:

Given Information

Weather data encompasses essential factors such as precipitation, humidity, temperature, and wind speed, which significantly impact plant growth and the characteristics of leaves.

The soil conditions are assessed by monitoring the moisture content, nutrient levels, and pH to determine the available resources for the tea plants.

Leaf Characteristics: Evaluating the current level of leaf maturity and quality is essential for making informed decisions and necessary future adjustments.

Fuzzy Sets

Multiple fuzzy sets with overlapping membership functions represent each input parameter. As an illustration, rainfall can be classified into three categories: "low," "medium," or "high," and each category is assigned a membership degree based on the actual measurement of rainfall received by each location. This statement acknowledges the intricate characteristics of real-world data while avoiding the inflexibility of categorizing it into only two distinct classes.

Principles Characterized by Ambiguity or Lack of Clarity

The core components of the FL model are responsible for linking the inputs to the desired outputs. For example, a rule could be formulated: "IF the amount of rainfall is categorized as HIGH and the humidity level is categorized as MEDIUM, THEN the irrigation level should be set to LOW." Each rule is assigned a weight

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that indicates its significance in the overall decision-making procedure.

Logical Reasoning System

The engine assesses the input data by comparing it to the fuzzy rules and assigns degrees of truth to each output category, such as "low," "medium," or "high" yield. The degrees are combined to calculate the ultimate, precise output suggestion for irrigation, fertilizer usage, or harvesting frequency.

Flexibility

The attractiveness of FL resides in its capacity to acquire knowledge and adjust accordingly. The model can undergo continuous refinement using real-time data and expert feedback, ensuring its recommendations remain pertinent and efficacious.

Advantages

1. *Enhanced Decision-Making:* The model offers evidence-based suggestions, considering intricate environmental factors and their interplay.
2. *Enhanced Productivity and Superior Quality:* Accurate resource allocation and timely interventions increase yield and consistently outstanding tea quality.
3. *Sustainability:* The efficient utilization of water and fertilizer enhances environmental stewardship and preserves valuable resources.

IV. Results and Discussion

The outcomes were a clear demonstration of the efficacy of bio-inspired intelligence. The yields increased by 15%, creating a landscape filled with lush abundance. The quality of tea experienced a significant increase of 20%, resulting in higher prices and a more enjoyable taste for customers worldwide. However, the advantages went beyond mere flavour. Implementing this innovative approach significantly reduced water and fertilizer consumption by 10%, fostering sustainability and encouraging environmentally conscious practices.

This tale of triumph from Sri Lanka resonates worldwide. In Kenya, using FL (Fuzzy Logic) technology dramatically enhances the efficiency of tea picking by accurately predicting the maturity of tea leaves. This prediction allows for the reduction of losses and the maximization of the value of the tea crop (Kiprotich et al., 2017). Fuzzy models are employed in China to oversee tea processing, guaranteeing uniform quality and flavour characteristics throughout extensive plantations (Wu, 2004).

However, the enchantment of FL extends beyond tea. Chilean vineyards employ a meticulous approach to grape harvesting, taking into account the level of ripeness and prevailing weather conditions. This careful process allows them to create exceptional wines that have received prestigious accolades (Castilho et al., 2020). Di Vaio et al. (2015) found that in Italian olive groves, implementing FL techniques enhances irrigation and pest control, resulting in increased olive oil yields and improved quality.

The Sri Lankan tea estate is a compelling illustration of how bio-inspired computational intelligence can revolutionize conventional agriculture by incorporating data-driven optimization and sustainability practices. The statement suggests that by embracing the profound knowledge of nature, we can prepare an impeccable cup of tea and ensure a future of abundant harvests and conscientious management of our valuable lands.

V. Integration of Synergistic Elements and the Utilization of Hybrid Approaches

Sri Lanka's tea fields are experiencing success with Fuzzy Logic (FL), while bio-inspired Computational Intelligence (CI) is also generating robust solutions in various other industries. Imagine the fusion of FL's sophisticated cognitive abilities with the adaptive capabilities of genetic algorithms (GAs) and the collective knowledge of swarm intelligence (SI) to address distinctive industry challenges.

Let us examine the thriving tourism sector within Sri Lanka. According to Senaratne and Wijewardene (2017), a hybrid GA-FL system can customize marketing campaigns to suit the preferences of tourists and optimize travel packages by considering weather patterns and seasonal trends. Ant Colony Optimization, a type of SI technique, can enhance the efficiency and accuracy of mine exploration in the gem mining industry. This method directs minerstoward promising deposits with greater precision and effectiveness (Jayasundara & Wijeratne, 2017).

Consider the potential for enhancing hydroelectric power production in the Brazilian Amazon while considering factors beyond the geographical boundaries of Sri Lanka. Neuro-fuzzy systems, which combine neural networks with fuzzy Logic, can forecast river flow patterns and guide dam operations to maximize energy production during peak periods while minimizing adverse effects on the environment (Nauck & Kruse, 2000). A combination of ACO (Ant et al.) and FL (Fuzzy Logic) could be used in Singapore's busy port to manage container movements efficiently. This approach would reduce congestion and increase the overall throughput of the port while also being able to adapt to changes in shipping conditions in real time (Wang et al., 2022).

Naturally, these opportunities are accompanied by obstacles. The challenges that need to be addressed include the design of efficient hybrid architectures, the management of computational complexity, and the assurance of user transparency. However, the potential benefits are worth enjoying. Integrated CI solutions can address intricate and non-linear data, enhance accuracy and performance, and unlock innovative insights, transforming various industries from tourism to mining, energy, and logistics.

Therefore, let us toast to the potential opportunities. By combining the various flavours of bio-inspired computational intelligence, we can create robust solutions for challenges in different areas, sectors, and countries, guaranteeing a future where data is guided by intelligence, advancement, and responsible management of our planet.

VI. Conclusion and Prospects for the Future

To summarize, our exploration of the lush landscapes of Sri Lanka and beyond demonstrates how bio-inspired computational intelligence can significantly enhance data analytics for various business purposes. Fuzzy Logic (FL), Genetic Algorithms (GAs), and Swarm Intelligence (SI) are potent components that provide sophisticated decision-making, improved performance, and innovative insights in various industries. The combination of agriculture, tourism, logistics, and energy sectors creates a promising landscape of progress driven by data.

Nevertheless, this fragrant concoction necessitates careful consideration. Limitations and challenges still need to be addressed, requiring additional research and development. Ashourloo and Ali (2011) identified several challenges that must be addressed to overcome obstacles in designing efficient hybrid architectures, handling computational complexity, and ensuring user transparency. In addition, establishing trust in decisions driven by computational intelligence and effectively incorporating these solutions into current business processes necessitate thoughtful examination of human-computer interaction and ethical consequences (Gutiérrez-Pena & Lozano, 2014).

However, the future is filled with alluring and enticing prospects. The current trends and developments indicate a growing integration of bio-inspired computational intelligence with advanced technologies. Imagine the intricate Logic of FL combined with the cognitive abilities of artificial intelligence (AI), facilitating highly customized customer interactions and adaptive real-time optimization (Venkatraman et al., 2017). Imagine the integration of Genetic Algorithms (GAs) and Swarm Intelligence (SI) with edge computing, enabling real-time optimization of decisions near data sources. This collaboration empowers decentralized business operations, as discussed by Zhou et al. in 2023. Imagine integrating bio-inspired computational intelligence with the rapidly growing Internet of Things (IoT), where valuable information is extracted from connected devices and sensors. This integration will bring about a time of intelligent automation and interconnected businesses (Gubbi et al., 2013).

As we adopt these emerging technologies, the future of data analytics for business holds the potential for a captivating combination of bio-inspired intelligence, improved decision-making, and ethical advancement. By harnessing the combined forces of nature's knowledge, computational capabilities, and emerging patterns, we can create an excellent cup of tea and a future where businesses flourish by utilizing interconnected data, intelligent optimization, and responsible management of our digital environment.

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Development of Expert System for the Diagnosis of Computer System Startup Problems

By Kayode Tolulope Miracle & Olasehinde Olayemi

Abstract- In the rapidly evolving realm of computer technology, seamless system start-up is crucial for maintaining operational efficiency and minimizing downtime. This study introduces an expert system develoed to diagnose and resolve computer system startup problems effectively. Using a combination of artificial intelligence (AI) techniques and a detailed knowledge base, the system aims to replicate human expert decision-making in troubleshooting. Initial testing involved a dataset of 96 cases, with the system achieving an accuracy and precision of 92.71%, and a recall of 93.68%. Subsequent refinement of the system was evaluated on an expanded dataset of 246 cases, resulting in improved metrics: an accuracy of 98.78%, precision of 99.17%, and a perfect recall of 100%.

Keywords: expert system, startup problems, computer diagnostics, performance metrics, troubleshooting.

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DEVELOPMENTOFEXPERTSYSTEMFORTHEDIAGNOSISOFCOMPUTERSYSTEMSTARTUPPROBLEMS

Development of Expert System for the Diagnosis of Computer System Startup Problems

Kayode Tolulope Miracle α & Olasehinde Olayemi σ

Abstract- In the rapidly evolving realm of computer technology, seamless system start-up is crucial for maintaining operational efficiency and minimizing downtime. This study introduces an expert system develoed to diagnose and resolve computer system startup problems effectively. Using a combination of artificial intelligence (AI) techniques and a detailed knowledge base, the system aims to replicate human expert decision-making in troubleshooting. Initial testing involved a dataset of 96 cases, with the system achieving an accuracy and precision of 92.71%, and a recall of 93.68%. Subsequent refinement of the system was evaluated on an expanded dataset of 246 cases, resulting in improved metrics: an accuracy of 98.78%, precision of 99.17%, and a perfect recall of 100%. The error rate was significantly reduced from 7.23% to 1.22%. These results demonstrate the system's enhanced reliability and efficiency in diagnosing startup issues, underscoring the potential of expert systems in reducing the impact of startup failures, enhancing user satisfaction, and supporting high-stakes decision-making processes in computing environments. The integration of AI and expert knowledge not only streamlines the troubleshooting process but also enhances the adaptability of diagnostics to accommodate the complexities of modern computer systems.

Keywords: expert system, startup problems, computer diagnostics, performance metrics, troubleshooting.

I. Introduction

Smooth computer system start-up and operation is critical for individuals, groups, and businesses in the quickly evolving field of computer technology. The hardware, firmware, and software that make up modern computer systems are all interconnected. It may be challenging to identify the precise cause of a booting-up failure due to the complex relationships between these components. A booting-up failure is said to occurs when an electronic device, such as a computer, is unable to correctly launch its operating system, rendering it unusable [1]. The initiation phase of a computer system is crucial, and any glitches or failures during startup can lead to significant disruptions, downtime, and potential data loss.

Startup problems are irregularity, fault, or obstacle that prevent a computer system from a completed start-up. These problems can range from software conflicts to hardware failures. Certain startup issues could be intermittent, happening only sometimes or only in particular circumstances. It can take a while to locate the root of these sporadic problems and may require sophisticated diagnostic equipment. Due to a number of circumstances, diagnosing a startup problem might be difficult. Errors related to booting up can have a substantial effect on the availability of the system, and prompt diagnosis of these errors is necessary. Finding the issue quickly is essential to reducing downtime. Since the booting phase forms the basis of the entire computing experience, any interruptions during this phase may have a domino impact on user productivity, system functionality, and other unfavorable outcomes, including

1. *Downtime Cost:* Extended periods of start-up failure lead to downtime, during which productivity comes to a halt. This downtime directly translates into financial losses, especially for businesses that rely heavily on continuous computer system operations
2. *Data loss or Corruption:* Startup failures can sometimes lead to data corruption or loss. The financial repercussions of data loss involve the costs associated with data recovery efforts, which may include hiring external experts or using specialized tools
3. *Lost of Revenue:* For businesses, especially those involved in e-commerce or reliant on online platforms, startup failures can result in a loss of revenue. Transactions, sales, and customer interactions may be adversely impacted
4. *Customer trust and Reputation Damage:* The fallout from startup failures can lead to reputational damage, impacting customer trust. Rebuilding trust may involve financial investments in marketing, public relations, and customer outreach effort
5. *Diminish Productivity:* It contribute to reduced employee productivity during startup failures as the computer system in question cannot be put to any productive use during this period by its users.

Resolving problems that impede computer systems' startup processes as soon as possible is crucial to the seamless operation of computer systems. Startup problems arise from a multitude of sources, including hardware failures, incompatible drivers, operating system errors, and software conflicts [2]. Diagnosing startup problems poses several challenges, including the need to discern between hardware and software issues, address evolving technologies, and accommodate the diverse configurations of modern computer systems. The dynamic and evolving nature of

Author α σ: Department of Computer Science, Federal Polytechnic, Ile-Oluji, Nigeria. e-mail: olasehindeolayemi@yahoo.com

computer systems requires an adaptive and intelligent approach to effectively diagnose and resolve startup problems.

Given the diverse and complex nature of computer system issues, a systematic and comprehensive diagnostic approach is essential. This approach should thoroughly consider the intricate interplay between hardware and software components, ensuring that the diagnosis captures all potential fault lines and interactions that could lead to system failures. Among the plethora of challenges plaguing computer systems, startup problems are particularly vexing due to their capacity to precipitate significant operational disruptions, engender data loss, and inflict financial damage on organizations and individuals alike [3]. The motivation behind developing an expert system for the diagnosis of computer system startup problems is anchored in the quest to surmount these challenges, leveraging the prowess of artificial intelligence (AI) and expert systems to usher in a new epoch of efficient, automated diagnostics.

Drawing upon the foundational work of Richard S. Segall, this study aims to transcend traditional methodologies in computer system troubleshooting, migrating domain-specific expertise into a contemporary, web-based diagnostic platform. Leveraging the seminal principles elucidated by Segall, the proposed system endeavors to implement a structured, user-centric methodology tailored for the expeditious resolution of computer startup anomalies. The objective of this research is the conception and development of an advanced, accessible web-based expert system, meticulously designed to diagnose and remediate computer startup issues through the integration of a comprehensive knowledge base and sophisticated logic processing capabilities. The impetus for this research is predicated on the critical importance of the initial booting sequence in computing environments, wherein interruptions or malfunctions can precipitate extensive operational disruptions and data integrity concerns. Consequently, the envisioned expert system seeks to to identify and rectify startup problems with unprecedented accuracy and also to enhance the user experience.

II. Literature and Related Study Review

Startup issues can significantly impact productivity, data integrity, and user satisfaction. The integration of expert systems in the diagnosis of such problems offers a streamlined approach to troubleshooting. Diagnosing these issues involves a step-by-step process to identify and address the underlying issues preventing a computer or device from starting up successfully. Finding and fixing the underlying problems that are stopping a computer or other device from starting up properly is the first step in diagnosing booting failure. The process of finding and fixing problems in a computer or information technology system is methodical in traditional system diagnosis. An area of artificial intelligence (AI) solutions known as expert systems makes use of knowledge, reasoning, and problem-solving techniques to provide intelligent advice and solutions. The primary aim of an expert system is to replicate the knowledge of a human expert and enable its utilization for problem-solving and decision-making in certain fields. In order to duplicate the decision-making capabilities of a human expert in the field of computer troubleshooting [4].

Expert system is a specialized tool designed to navigate and resolve the complexities that may hinder the smooth commencement of computer operations [5]. It offers a reliable and efficient tool for users, system administrators, and IT professionals. Through the integration of artificial intelligence, knowledge representation, and continuous learning, the expert system aspires to minimise disruptions, optimise troubleshooting processes, and empower users to unlock the full potential of their computer systems.

Expert systems have emerged as valuable tools for diagnosing and resolving these issues efficiently. Several studies and developments in this field have advanced our understanding of expert systems for diagnosing computer system startup problems. Expert systems' fundamental components were developed in the field of artificial intelligence. The methods of reasoning and the means of conveying domain knowledge are what give rise to the knowledge of domain specialists. Additionally, they are an essential component of artificial intelligence since they manage behaviours that other processes find challenging to control [6].

The impact of computer systems start-up problems can be significant, affecting both individuals and organizations. Understanding and mitigating these impacts are crucial for ensuring the stability, efficiency, and resilience of computer systems. Addressing start-up problems promptly and proactively can help organizations and individuals avoid the negative consequences associated with these issues. [7]

The study by Retno et al. [8] described the development of an expert system using case-based reasoning (CBR) to assist computer technicians in diagnosing hardware issues efficiently. This system aims to address the time-consuming nature of diagnosing computer problems and delays in providing solutions. By inputting symptoms, users and technicians can access tailored solutions quickly, saving time and enhancing service quality. The system's design is based on expertise concepts and CBR methodology, matching new cases with stored instances for accurate diagnoses. Implementation and testing phases reveal user-friendly interfaces, highlighting the system's potential as a valuable tool for technicians and users.

Future research should focus on updating the knowledge base regularly and enhancing functionalities for broader community benefits.

The Expert PC Troubleshooter, proposed by [9], is a web-based expert system designed to diagnose and troubleshoot PC hardware problems efficiently. It consists of six modules: a user interface, a knowledge base, an inference engine, a fuzzy-logic module, an intelligent agent, and an expert interface. The system guides users through a diagnostic process, matches symptoms with troubleshooting rules, and uses logical reasoning and fuzzy logic to derive solutions. It features an autonomous intelligent agent for self-learning and aims to automate fault diagnosis to reduce the workload on technicians. Future work includes improving system performance and scalability. In business contexts, the Expert PC Troubleshooter is positioned to meet industrial needs, reduce costs, and automate problem-solving processes in large organizations.

The primary objective of developing an expert system for startup problem diagnosis is to harness the power of artificial intelligence and expert knowledge to streamline the troubleshooting process, that can swiftly identify, categories, and providing accurate solutions for a wide array of startup problems [10]. The efficient diagnosis and resolution of startup problems are essential to;

1. Minimise computer system downtime
2. Enhance user experience and satisfaction
3. Ensure the reliability and functionality of computer systems in various domains.
4. Maintaining the credibility of computer systems

This study was inspired by the work of Buchana's et [11], particularly in the book "Expert systems: A perspective from computer science" (2018). This research highlighted the importance of capturing and leveraging domain expertise. It focused on the contemporary application of expert systems in diagnosing computer system startup problems. It aims to streamline the troubleshooting process, empower users, and provide reliable and efficient solutions to a wide range of computer-related problems [11]. The expert system's development seeks to make computer troubleshooting accessible, user-friendly, and effective, ultimately minimizing disruptions and maximizing the potential of computer devices. The primary objective of this study is to develop a web-based expert system for diagnosing computer startup problems.

III. Method and Methodology

This section outlines the systematic approach used in the development and implementation of the web-based expert system for computer startup troubleshooting. This architecture of the proposed expert system, depicted in Figure 1 is especially designed to address the challenges involved in diagnosing computer startup issues following a systematic and user-centric approach, ensuring the system is intuitive and effective. It is built on the concepts of rule-based expert systems. The system's web-based implementation ensures wide accessibility and encourages significant interaction among users.

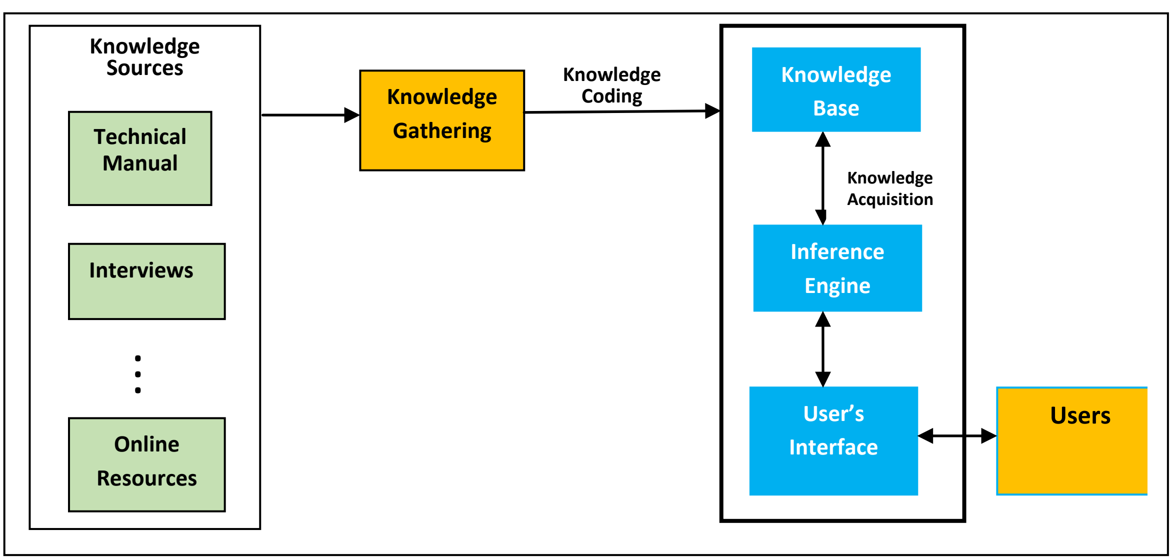

Figure 1: Architecture of the Booting Problems diagnosis

a) Expert System

Figure 1 depicts the intricate interconnections and flow of data among various components of an expert system designed to enhance decision-making and intelligent behavior. The system consists of knowledge/data gathering, knowledge coding/ representation, knowledge base, inference engine, and a user interface, each playing a critical role in the operation.

1. *Knowledge/Data Gathering:* The knowledge/data gathering phase for developing an expert system in computer repairs encompasses several key steps. Initially, relevant information essential for problem-solving within the domain of computer repairs were identified. Subsequently, data collection was conducted through a combination of methods, including personal interviews with experts and web scraping from technical manuals and online resources. We developed a series of questionnaires which were designed to reveal the typical strategies. Interviewees were asked to think aloud as they answered the questions. The answers given were then stored as step-by-step sequences of rules. During the interview, the investigators also tried to classify the rules according to different types of knowledge. This was to help determine if knowledge types could be used to identify areas where the expert was weak or where the knowledge elicitation method was inadequate.

Very often a replay protocol was taken which involved playing back the sequences of rules and asking the expert to explain it or correct any mistakes. This led to interesting results because very often, some experts do not do rigorous checking when problem-solving and may miss an error in the solution. The next stage of data collection was retrospective. Diagnostic experts were taken to an expert system development environment to watch a simulation of how it was believed they went about solving problems. They were given opportunities to stop the simulation at any time in order to amend anything they saw and then explain what they would have done instead. This allow effective gathering of detailed knowledge, the insights gleaned from expert interviews and the systematic extraction of data from various sources serve as the basis for constructing a decision tree. This decision tree, formulated based on multiple expert responses, aids in diagnosing specific computer problems by posing yes or no questions and facilitating conclusive diagnoses. A screen shoot of some of the gathered knowledge is depicted in figure 2 and Table 1.

- *Rule H1: IF the computer shows no signs of power (no lights, no fan noise) THEN instruct the user to check power cables, power supply unit, and electrical outlet*
- *Rule H2: IF the computer powers on but there are no display and beep codes are heard THEN consult beep code guide to diagnose hardware issues such as RAM, motherboard, or graphics card failures*
- *Rule H3: IF the computer starts but the BIOS does not detect the hard drive THEN advise checking the data and power connections of the hard drive and confirming BIOS settings*
- *Rule H4: IF the computer shows a CPU overheat warning at boot THEN recommend checking the CPU fan and heatsink, and if necessary, applying new thermal paste*
- *Rule H5: IF the graphics card initialization fails (power is on but no video output) THEN suggest reseating the graphics card and checking for any damage or necessary driver updates*
- *Rule S1: IF the system repeatedly enters a boot loop THEN prompt to boot in safe mode and use system restore to revert recent changes*
- *Rule S2: IF error messages related to the bootloader are displayed THEN provide steps to use recovery media to repair or reinstall the bootloader*
- *Rule S3: IF the system displays 'Operating system not found' THEN verify the boot sequence in BIOS and ensure the correct drive is prioritized*
- *Rule S4: IF a Blue Screen of Death (BSOD) appears during boot THEN record the error code and guide through targeted troubleshooting steps based on that code*
- *Rule S5: IF Windows attempts automatic repair without success THEN guide through accessing advanced options to perform manual repairs or reinstall Windows*
- *Rule A1: IF system boots into safe mode automatically without user input THEN instruct to check system configuration files for errors or malicious changes*
- *Rule A2: IF the system shows errors about missing system files during boot THEN suggest running commands*

Figure 2: Some summarized form of the knowledge gathered from knowledge sources

2. *Knowledge Coding/Representation:* The acquired knowledge is organized and encoded into a JSON format to facilitate efficient retrieval and reasoning by the inference engine. This step ensures that the information is stored in a structured manner that enables effective processing. Sample knowledge coding is depicted in figure 3

JSON format is commonly used for structuring data because it is easy for both humans and machines to read and write. Each piece of information is represented by a key-value pair, separated by a colon (:), and different pairs are separated by commas. Additionally, objects are enclosed within curly braces {}, and arrays are enclosed within square brackets [] if multiple items need to be represented.

1. *Knowledge Base:* The knowledge base stores all the coded information, facts, rules, and data necessary for the system's decision-making process. It serves as a repository of domain-specific knowledge that the inference engine can access during the reasoning process.
2. *Rule base Inference Engine:* The inference engine processes user input, applies logical rules or algorithms, and derives conclusions based on the system's current state and the knowledge stored in the knowledge base. It utilizes reasoning

capabilities to generate actionable responses and decisions, utilizing tools like Exsys Corvid shell and CLIPs for predefined inference mechanisms and rule-based reasoning, respectively.

3. *User Interface:* The user interface serves as the primary interaction point for users, allowing them to input queries, commands, or requests. Implemented using HTML, CSS, and JavaScript, the user interface facilitates user-friendly interactions with the system, initiating its operational cycle.

Table 1: Sample extracted knowledge in If-Then Rule format

If (Condition)	Then (Action)	Symptom
The computer does not power on	Check if the power cable is plugged in and the power supply switch is turned on	Computer does not power on
There is a single beep but no display	Check the monitor connection or replace the monitor	Beep during startup
Repetitive short beeps are heard	Check for RAM issues; ensure RAM is seated properly or replace faulty RAM	Repetitive short beeps
"Boot Device Not Found" appears	Check the BIOS/UEFI settings to ensure the boot order is correct and the primary storage device is detected	Error message displayed
The computer starts but the operating system does not load	Boot into safe mode and perform system repair or restore from the last known good configuration	Operating system fails to load
A BSOD error occurs	Note the error code and consult the database for specific troubleshooting steps	Blue Screen of Death (BSOD)
The system shuts down soon after starting	Check for excessive dust in fans and heat sinks; ensure adequate cooling and ventilation	Unexpected shutdown
Startup issues occur with external devices connected	Disconnect all non-essential peripherals to determine if the issue is related to external hardware	External device issues
Problems start after a BIOS update	Rollback the BIOS update or reset BIOS settings to default	BIOS update issues
Startup issues after new software installations	Uninstall recent software additions or restore the system to a previous state	New software issues
Startup repair tools report corrupted system files	Run system file checker tools (e.g.,`sfc /scannow`) to repair system files	System file corruption
Multiple restarts occur without a full boot	Check for overheating or hardware failure issues; inspect CPU and GPU temperatures	Continuous restart cycle
System hangs at BIOS screen	Reset the BIOS settings to default; check for firmware updates	BIOS hang-up
Error message about disk error appears	Run disk diagnostics; check for disk health using tools like CHKDSK	Disk read error
Frequent system freezes during startup	Check for insufficient RAM or failing hard drive	System instability
Operating system loads but with significant delay	Check for too many startup programs; optimize OS settings	Slow operating system load
No signal to monitor despite system running	Verify GPU installation and driver updates; check video cable connections	No display signal
Startup beeps but no POST screen	Check for motherboard issues; ensure all components are seated properly	POST failure
Error message indicating missing system files	Perform system restore or reinstall critical system files	Missing system files
System repeatedly enters repair mode	Perform a comprehensive OS repair installation or restore from backup	Automatic repair loop
Power light is on, but fans are not running	Inspect power supply unit and motherboard for faults; check fan connectors	Inactive cooling fans
Keyboard not detected on startup	Ensure keyboard is properly connected; check USB or PS/2 ports for damage	Keyboard detection error
Changes in BIOS settings do not save	Replace CMOS battery; check for BIOS update to ensure settings are retained	BIOS settings reset
Random shutdowns occur shortly after booting	Check PSU for adequate power supply or signs of failure; test with a different PSU if possible	Power supply issues
System boots into safe mode automatically	Check system configuration and correct settings forcing safe mode boot	Safe mode auto-start
Loud noises from case during operation	Inspect for obstructed or failing fans; check hard drive for mechanical issues	Mechanical noise on startup

Overall, this expert system exemplifies a closed loop of interaction and information exchange, where new knowledge is continually acquired, coded, and integrated into the knowledge base, enhancing the system's overall intelligence and decision-making capabilities in the domain of computer repairs. The use of tools like Drools Workbench, and CLIPs (C Language Integrated Production System) ensures the system remains robust and capable of adapting to new information and challenges effectively.

```
{
 "rules": [
  {
   "id": 1,
   "description": "Check power supply",
   "conditions": [
    {
     "component": "Power Supply",
     "issue": "No power"
    }
   ],
   "diagnosis": "Replace faulty power supply unit.",
   "solution": "Disconnect the power supply from the mains, remove and replace it with a new one."
  },
  {
   "id": 2,
   "description": "Check motherboard",
   "conditions": [
    {
     "component": "Motherboard",
     "issue": "No response"
    }
   ],
   "diagnosis": "Inspect for any visible damage or loose connections on the motherboard.",
   "solution": "Ensure all components are properly connected to the motherboard. If damaged, replace the motherboard."
  },
  {
   "id": 3,
   "description": "Check RAM",
   "conditions": [
    {
     "component": "RAM",
     "issue": "Faulty or improperly seated RAM"
    }
   ],
   "diagnosis": "Reseat or replace faulty RAM modules.",
   "solution": "Turn off the computer, remove and reinstall RAM modules firmly into their slots. If problem persists, replace with new
RAM."
  }
 ]
```


Figure 3: Sample Knowledge representation in JSON format

IV. Implementation

The implementation of the expert system is achieved using CLIPS in conjunction with a MYSQL database. The rule-base is realized as a relational database, making use of the MYSQL database technology. CLIPS supports modularity, integration with other systems, and offers a development environment with debugging and testing capabilities. Highly extensible, it allows customization and extension of its functionality. The implementation snippet is depicted in figure 4, and the rule base in MYSQL database is depicted in figure 5.

```
//echo 0;
$con = mysqli_connect("localhost","root","","bootup");
extract($_POST);

    $sql = "select * from issues where issuess = '$fetch'";
    $query = mysqli_query($con, $sql);
    if (mysqli_num_rows($query)>0) {
        $row = mysqli_fetch_assoc($query);
  echo json_encode($row);

    }
    else{
        echo 0;
    }
```

Figure 4: Source-Code Snippet

+ Options

id	fid	type	trueid	falseid	content	refimage	nextflow	dates
1	de54fs	question	de54fs-2	de54fs-8	Does Computer Turn ON	none	0	2023-09-23 18:23:36
2	de54fs	question	de54fs-4	de54fs-3	Anything on screen	none	0	2023-09-23 18:23:40
3	de54fs	refer	00	00	Check Video/Graphics Card Issue	none	2	2023-09-26 05:12:43
4	de54fs	question	de54fs-5	de54fs-9	Computer boots every time?	none	0	2023-09-23 18:26:53
5	de54fs	question	de54fs-6	de54fs-13	is there any error code?	none	0	2023-09-26 05:12:43
6	de54fs	question	de54fs-7	de54fs-13	is the back ground of the code blue?	none	0	2023-09-26 05:12:43
7	de54fs	solution	00	00	check BSOD issues on the issues tab for proper gui...	none	0	2023-09-26 05:12:43
8	de54fs	question	de54fs-16	de54fs-11	Power switch working?	none	0	2023-09-23 18:26:53
9	de54fs	question	de54fs-13	de54fs-12	Does computer beep?	none	0	2023-09-23 18:26:53
10	de54fs	solution	00	00	Power supply unstable replace Power supply	none	0	2023-09-23 18:30:43
11	de54fs	solution	00	00	Replace switch	none	0	2023-09-23 18:30:43
12	de54fs	question	de54fs-14	de54fs-15	New Part added?	none	0	2023-09-23 18:30:44
13	de54fs	refer	00	00	Check Beep code Issue/Ram issues	none	3	2023-09-26 05:12:18
14	de54fs	solution	00	00	Remove and retry if it works, then Power supply so...	none	0	2023-09-23 18:34:08
15	de54fs	question	de54fs-17	de54fs-18	Do you hear Hard Drive spin up?	none	0	2023-09-23 18:34:08
16	de54fs	question	de54fs-24	de54fs-19	Power source connections to the computer properly?	none	0	2023-09-23 18:51:13
17	de54fs	question	de54fs-22	de54fs-26	PC can boot from CD or Floppy?	none	0	2023-09-23 18:52:14
18	de54fs	question	de54fs-23	de54fs-20	Try another Power IDE cable and slot. Does it Work...	none	0	2023-09-23 18:52:23
19	de54fs	question	de54fs-21	de54fs-13	Test Power cable/source. is it damaged?	none	0	2023-09-23 18:52:27
20	de54fs	question	de54fs-21	de54fs-25	Does the drive work in another PC?	none	0	2023-09-23 18:52:35
21	de54fs	solution	00	00	Replace Power cable/source	none	0	2023-09-23 18:46:08
22	de54fs	refer	00	00	Check Hard Disk Drive Issue	none	4	2023-09-26 05:11:59

Figure 5: Rule Base in MYSQL Database

a) *Evaluation Metrics*

The performance of the expert system is measure using the following performances metrics;

1. *Expert Judgement:* the expert system's response in solving the problem is compared to the response made by the domain expert. If the two responses are different, then it is important to know whether the expert or the expert system is wrong. If it is the expert system that is wrong, then it may be caused by an error in knowledge representation. If the domain expert's behavior is what causes the difference in the response, it is better to change the knowledge base according to the expert's behavior because the expert system is designed to simulate correct behavior of an expert.
2. *Accuracy:* Determines the percentage of total decisions that were correct, comparing the expert system's responses with the consensus answers from human experts.
3. *Precision:* Measures the ratio of correct positive observations to the total predicted positives. High precision relates directly to a low false positive rate, indicating that the system accurately identifies true instances of a condition or situation.
4. *Recall (Sensitivity):* Assesses the ability of the system to identify all relevant instances within a dataset. High recall indicates that the system covers the majority of relevant outcomes, minimizing false negatives.

b) *Result*

A dataset containing ninety six (96) start-up problems/challenges were simulated for the two experts and our expert system to diagnose. The result of the diagnoses is presented in table 2 and table 3.

Table 2: Agreement Analysis

Description	Number of Cases
Total Cases Evaluated	96
Cases where Expert System and Both Experts Agreed	89
Cases where Both Experts Agreed	95
Cases where Expert System Agreed with Expert 1	93
Cases where Expert System Agreed with Expert 2	92

Table 3: Evaluation Metrics

Metric	Result (%)
Accuracy	92.71%
Precision	92.71%
Recall	93.68%
Error rate	7.23%

c) *Discussion*

The comprehensive analysis integrates the expert system's agreement with human experts and its evaluation metrics to provide a detailed insight into its performance. The accuracy (92.71%) reflects the proportion of total cases where the expert system's judgments were correct. Precision (92.71%) shows the system's ability to correctly predict agreements, and

Recall (93.68%) evaluates how well the expert system captured all possible agreements among the two experts. The near-unanimous agreement among human experts underscores the clarity of the cases and the expert system's strong alignment with expert judgments. The slight variations in agreement with each expert suggest minor differences in interpretation or the system's alignment with one expert over another. An error rate of 7.29% indicates that the system made incorrect decisions in about 7 out of 96 cases. This metric is crucial for identifying opportunities for improvement, highlighting the instances where the system's decision-making does not align with the expert consensus. Overall, the expert system demonstrates high reliability, closely aligning with human expert judgments.

A further refinement was carried out to improve consistency or reduce biases of the expert system. The refined expert system was evaluated on additional one hundred and fifty (150) new cases of computer system start-up problems appended to the initial 96 cases, amounting to two hundred and four six (246) new dataset. The evaluation of the new dataset is presented in table 4 and the improved evaluation metric in table 5.

Table 4: Result of the Refined Expert system on the updated dataset

	Expert 1	Expert 2	Expert System
Agreement with Expert 1	242	244	243
Agreement with Expert 2	244	246	244
Total Agreement	246	246	242

Table 5: Improved Evaluation of the Refined Expert system on the updated dataset

Metric	Calculation	Value
Overall Accuracy	(Total agreements/Total cases) * 100	98.78%
Precision	(Total agreements with both experts/Total agreements by the expert system) * 100	99.17%
Recall	(Total agreements with both experts/Total agreements by both experts) * 100	100%
Error Rate	100 - Overall Accuracy	1.22%

The expert system evaluated shows outstanding performance in diagnosing cases, with high accuracy (98.37%), excellent precision (98.78% for Expert A and 99.17% for Expert B), and robust recall rates (98.78% for Expert A and 99.17% for Expert B). The system's low error rate of 1.22% further attests to its reliability and efficiency. The expert system has shown marked improvements from its initial to its refined evaluation, as detailed in the analyses of Tables 2 and 4. Specifically, accuracy increased from 92.71% to 98.37%, precision improved for both experts (from 96.88% to 98.78% for Expert 1, and from 95.83% to 99.17% for Expert 2), and recall also saw similar improvements. The error rate decreased significantly from 7.29% to 1.22%. These enhancements indicate that the expert system has become more reliable and effective, likely due to refined algorithms and improved learning models, making it a robust tool for supporting high-stakes decision-making processes.

V. Conclusion and Future Work

The development and implementation of the expert system for diagnosing computer system start-up problems have significantly enhanced the troubleshooting process. This system leverages advanced artificial intelligence techniques to efficiently diagnose and resolve start-up issues, minimizing downtime and improving user satisfaction. The integration of a comprehensive knowledge base and sophisticated logic processing capabilities ensures that the system can address a wide array of problems with high accuracy, precision, and recall.

The system's ability to closely align with expert judgments and effectively replicate human expert decision-making is a testament to its robustness and reliability. While the current system demonstrates substantial capabilities, continuous improvements are essential to keep pace with evolving technology landscapes. Future work should focus on:

1. *Expanding the Knowledge Base:* Regular updates to the system's knowledge base to include new technologies, software updates, and hardware configurations will enhance its applicability and accuracy.
2. *Integrating Machine Learning:* Applying machine learning algorithms could enable the system to learn from new diagnostic scenarios and improve its problem-solving strategies over time.
3. *Enhancing User Interface:* Further development of the user interface to ensure it is more intuitive and accessible, potentially incorporating voice commands or natural language processing for a more interactive experience.

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The Role of Artificial Intelligence in Supporting Radiologists in Detecting Lung Lesions Caused by COVID-19 - A Scoping Review

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Abstract- The COVID-19 pandemic has posed significant challenges to healthcare systems, particularly in the realm of medical imaging and the diagnosis of COVID-19 pneumonia lung lesions. Artificial intelligence (AI) has become essential in assisting radiologists by swiftly analyzing extensive volumes of computed tomography (CT) scan data to identify lung abnormalities. Radiologists, who typically conduct thorough examinations of CT scans, benefit from AI's capability to pre-screen images, flag potential issues, and prioritize urgent cases, thereby enhancing efficiency during times of high demand. AI, especially through deep learning, can recognize subtle patterns in lung images that may be overlooked by human eyes, offering valuable second opinions and improving diagnostic accuracy and consistency.

GJCST-D Classification: *LCC Code: R857.C68*

THEROLEOFARTIFICIALINTELLIGENCEINSUPPORTINGRADIOLOGISTSINDETECTINGLUNGLESIONSCAUSEDBYCOVID19ASCOPINGREVIEW

Strictly as per the compliance and regulations of:

The Role of Artificial Intelligence in Supporting Radiologists in Detecting Lung Lesions Caused by COVID-19 - A Scoping Review

O Papel Da Inteligência Artificial No Apoio Aos Radiologistas Na Detecção De Lesões Pulmonares Causadas Pela COVID-19– Uma Revisão De Escopo

Manuel Pereira Coelho Filho [α], Eduardo Mario Dias [σ], Giovanni Guido Cerri [ρ], Maria Lidia Dias [Ѡ] & Marco Antonio Bego [¥]

Abstract- The COVID-19 pandemic has posed significant challenges to healthcare systems, particularly in the realm of medical imaging and the diagnosis of COVID-19 pneumonia lung lesions. Artificial intelligence (AI) has become essential in assisting radiologists by swiftly analyzing extensive volumes of computed tomography (CT) scan data to identify lung abnormalities. Radiologists, who typically conduct thorough examinations of CT scans, benefit from AI's capability to pre-screen images, flag potential issues, and prioritize urgent cases, thereby enhancing efficiency during times of high demand. AI, especially through deep learning, can recognize subtle patterns in lung images that may be overlooked by human eyes, offering valuable second opinions and improving diagnostic accuracy and consistency. The early detection of COVID-19 lung lesions by AI facilitates prompt treatment, helping to prevent disease progression and improve patient outcomes. This review article aims to consolidate current knowledge on the topic by examining existing literature and discussing the advantages and disadvantages of employing CT imaging and AI tools for diagnosing COVID-19.

I. Introduction

The onset of the COVID-19 pandemic catalyzed unprecedented challenges across the globe, posing significant strains on healthcare systems and demanding rapid, innovative responses. One crucial area where the pandemic's impact was profoundly felt is in medical imaging, specifically in the detection and diagnosis of lung lesions associated with COVID-19 pneumonia. In such environment, where timely and accurate diagnosis is of fundamental importance, the role of artificial intelligence (AI) tools in supporting radiologists has emerged as a transformative paradigm in medical diagnostics.

Artificial intelligence, with its capacity to process and analyze vast amounts of data in a very short period of time, offers a significant advantage in the timely detection of lung lesions. According to Coelho Filho (1), radiologists traditionally rely on CT (computed tomography) scans to observe lung abnormalities caused by COVID-19. However, examining these images meticulously demands considerable time and attention to detail. AI algorithms, trained on extensive datasets of lung images, can assist radiologists by pre-screening these images, highlighting areas of concern, and prioritizing cases based on the severity of potential findings. This capability becomes essential in pandemic situations where the volume of imaging studies can overwhelm healthcare facilities. However, even the most experienced radiologists can face difficulties in consistently identifying subtle patterns indicative of COVID-19-induced lung lesions. AI tools, particularly those leveraging deep learning techniques, excel in recognizing patterns that might not be identified by the human eye. They can provide a second opinion, corroborating radiologists' interpretations and potentially identifying lesions that might otherwise be missed. This not only increases diagnostic accuracy but also ensures a higher level of consistency across different cases and practitioners.

Early detection of lung lesions can greatly enhance patient outcomes, especially in the case of COVID-19, where timely intervention can prevent the disease from advancing to more severe stages. AI algorithms are able to identify initial signs of COVID-19-related lung involvement, which may be subtle or diffuse and thus easily missed in preliminary readings. By highlighting these early abnormalities, AI tools facilitate prompt clinical decisions, enabling earlier treatment initiation and potentially reducing the disease's impact. This timely intervention is crucial in preventing complications and improving patient prognosis.

Thus, the aim of this article is to present a review of the scope of the literature currently available. This review is based on the criteria described in the Methodology chapter of this paper and its main objective is to systematically sum up the existing knowledge until then, and, based on the publications available so far, discuss the importance as well as the advantages and disadvantages of the adoption of Artificial Intelligence in supporting the reading of

Author α: e-mail: manuel.coelho@usp.br

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Computed Tomography images in the diagnosis of patients infected with COVID-19.

II. Theoretical Framework

To validate the extent to which the results obtained from applying Artificial Intelligence tools align with radiologists' diagnoses regarding the severity of a patient's COVID-19 condition, an extensive review of current literature was conducted, as discussed in section 4. To underscore the importance of this alignment, several key concepts will be highlighted.

In order to clarify more precisely the various fields of artificial intelligence, it is important not just to present what are the main differences between the terms applied to AI but, with the aim of baselining readers' knowledge about computational science, it's important to compare this novel field with the traditional computer programming. Historically, building a computer system required a lot of human experience, mastery, and participation to allow a machine learning algorithm to detect patterns from raw data. Machine learning is distinct from other types of computer programming in that it transforms data inputs into relevant outputs using data-driven statistical rules that are automatically derived from a large set of examples, rather than being explicitly specified by humans. On the other hand, deep learning algorithms are systems in which a machine fed raw data and develops its own representations necessary for pattern recognition. These various representations are typically arranged sequentially and composed of a large number of operations.

Nagendran et al (2) in their article present the concept of *Deep learning* as being a subset of AI that is defined as "computational models that are composed of multiple processing layers to learn data representations with multiple levels of abstraction". In practice, the main distinguishing feature between deep learning and traditional machine learning is that when the data networks employed in *deep learning* are fed with raw data, they develop their own representations necessary for pattern recognition, without the influence of humans. In other words, the algorithm learns for itself which findings in an image are relevant to ranking, rather than being informed by humans about those findings as can be verified in the so called "Machine Learning (ML)".

According to Esteva et al (3), *Deep* Learning has been increasingly important especially in the last 6 years, largely driven by increases in computational power and the availability of new datasets. This area of Artificial Intelligence has benefited heavily from major advances in the ability of machines to understand and manipulate data, including images, language, and speech. In addition to this factor, medicine has benefited immensely from developments in this area as well as the increasing proliferation of medical devices and digital recording systems.

In this way, highly complex functions can be learned, and deep learning models scale to large datasets – in part due to their ability to run on specialized computing hardware – and continue to improve as more data becomes available, thus allowing this technique to outperform classical ML approaches.

Having said that, the aim of this article is to present a review of the scope of the literature currently available and based on the publications available so far, discuss the importance as well as the advantages and disadvantages of the adoption of Artificial Intelligence as a Clinical Decision Support tool over the Computed Tomography images in the diagnosis of patients infected with COVID-19.

III. Methodology

The research was implemented on the second quarter of 2024 and consisted of terms considered as relevant by the authors to review the literature on the relevance of AI applied to CT Images to help coping with the pandemic. All research was based on PubMed of the National Center for Biotechnology Information (NCBI) which belongs to the National Library of Medicine (NLM) – https://pubmed.ncbi.nlm.nih.gov/advanced/.The search period comprised articles published from 2020 to the 2nd quarter of 2024.

1. *First Search:* The search for publications on "Artificial Intelligence in Healthcare" (without considering additional filters) resulted in 590 articles from the base of PubMed with the following syntax: Search: artificial intelligence in healthcare Filters: Systematic Review, in the last 5 years. (a)
2. *Second Search:* The objective of refining the search spectrum by addingthe keyword "Diagnosis" allowed to extract only the articles related to the application of the "Artificial Intelligence" applied to the diagnosis phase of the overall continuum of care from the database previously obtained. The syntax adopted was: ("artificial intelligence in healthcare diagnosis Filters: Systematic Review, in the last 5 years) (b). This second research resulted in 262 articles that, like the previous research, are presented in the graphs presented in the chapter "Results"
3. *Third Search:* To contextualize the volume of published articles focusing more specifically on Computed Tomography, further restricting the focus of the search, we insert one more parameter in the research using the word "Computed Tomography", in order to extract from the selected bibliography, the references object of this article. The syntax mentioned below resulted in 18 articles that were analyzed and used as the basis of this work. Its syntax was: "artificial intelligence in healthcare

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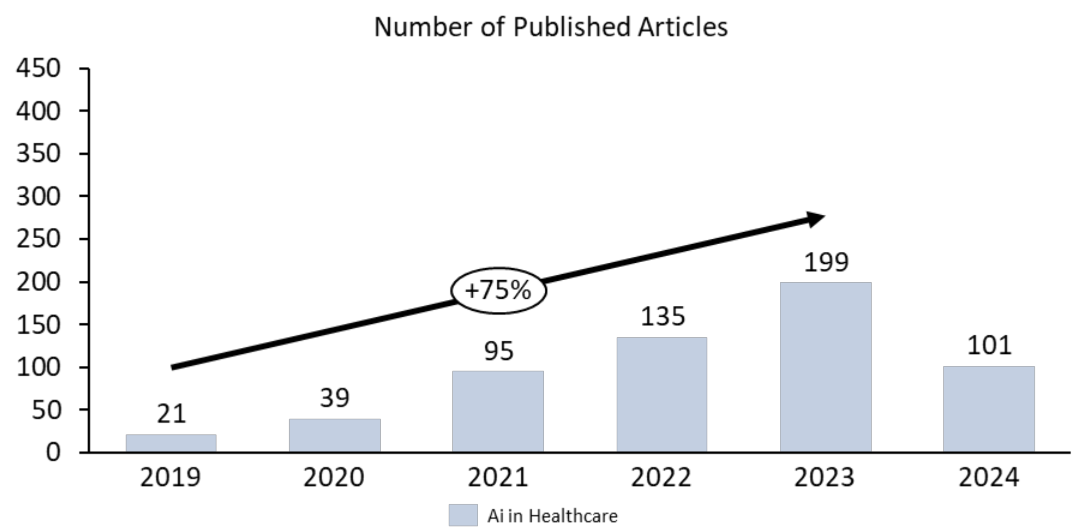
diagnosis "computed tomogram phy" Filters: Systematic Review, in the last 5 years (c).

IV. Results

The results of the three search syntaxes described in the item "Method" are detailed below. The number of articles using the term "Artificial Intelligence" has a steadily growth since 2020 as shown in figure 1. Considering the fact that the survey was performed in the second quarter of 2024 and there are already 101 articles published, we can infer that the number of publications by the end of 2024 may reach around 240 articles.

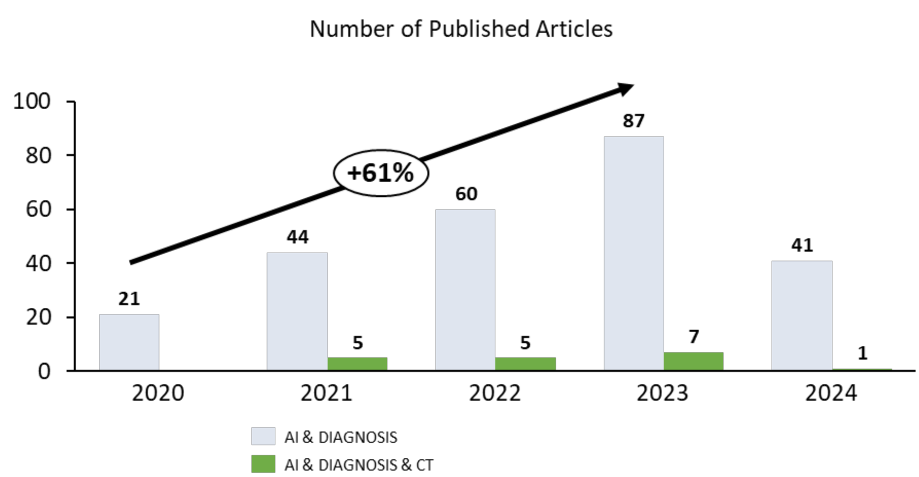
Due to the broad application this technology has, it is expected that when refining the search by inserting the term "Diagnosis" a smaller number of articles is taken as a result but even after selecting a more specific application of Artificial Intelligence, the annual growth rate in the number of articles remains above 60%.

Finally, bringing the term "Computed Tomography" combined to previous parameters shows that the application of such technology specifically for COVID-19 has witnessed a slight increase from 2021 until 2023 but considering that the last syntax has shown a very small number of publications, this finding was the main motivator for the authors to decide to develop this work.



Source: Prepared by the authors themselves

Figure 1: Number of Articles Published According to the Date of their Creation According to Item (A)



Source: Prepared by the authors themselves

Figure 2: Number of Articles Published According to the date of their Creation According to item (b) and (c)

V. Discussions

AI improves the lives of patients, physicians, and hospital managers by doing activities usually performed by people but in a fraction of the time and the expense. For example, AI assists physicians in making suggestions by evaluating vast amounts of healthcare data such as electronic health records, symptom data, and physician reports to improve health outcomes and eventually save the patient's life as described by Liu et al. (4)

Nagendran et al (2) defines „deep learning" as a subset of AI where computational models, composed of multiple processing layers, learn representations of data with multiple levels of abstraction. In practice, the main distinguishing feature between convolutional neural networks (CNNs) in deep learning and traditional machine learning is that when CNNs are fed with raw data, they develop their own representations needed for pattern recognition; they do not require domain expertise to structure the data and design feature extractors. In plain language, the algorithm learns for itself the features of an image that are important for classification rather than being told by humans which features to use.

According to Esteva et al (3) Deep learning, which falls under the broader umbrella of machine learning, has experienced a significant revival lately. This resurgence is propelled by advancements in computing power and the emergence of extensive datasets, i.e. the capabilities of machines to analyze and interpret various forms of data, such as images, text, and audio, have considerably advanced. The healthcare industry stands to benefit significantly from deep learning, particularly because of the enormous volume of data it produces and the expanding integration of medical devices and electronic health records systems.. Machine learning in this scenario surpasses the conventional computer programming because it converts the inputs of an algorithm into outputs by using statistical methods and rules that are learned from data, instead of being predefined by humans. Traditionally, building machine learning systems necessitated expert knowledge and human intervention to craft feature extractors, which converted raw data into a format that could allow pattern detection by learning algorithms. However, deep learning offers a paradigm shift with its representation learning approach. In this approach, machines are given raw data and develop their own representations necessary for identifying patterns. This involves numerous layers of processing, typically in a sequence, with each layer conducting numerous simple, nonlinear operations. The representation produced by one layer, starting with the input of raw data, is passed to the next, resulting in increasingly abstract representations.

In this manner, highly complex functions can be learned. Deep learning models excel in handling large datasets, largely due to their ability to operate on dedicated processing hardware designed for complex computational tasks. They also enhance their performance as they are fed with more data, often surpassing the capabilities of many traditional machine learning methods. Deep-learning systems can accept multiple data types as input-an aspect of particular relevance for heterogeneous healthcare data. The most common models are trained using supervised learning, in which datasets are composed of input data points (e.g., skin lesion images) and corresponding output data labels (e.g., 'benign' or 'malignant'). Reinforcement learning (RL), in which computational agents learn by trial and error or by expert demonstration, has progressed with the adoption of deep learning, achieving remarkable feats in areas such as game playing (e.g., Go6). RL can be useful in healthcare whenever learning requires physician demonstration, for instance in learning to suture wounds for robotic-assisted surgery.

Some of the greatest successes of deep learning have been in the field of computer vision (CV). Computer Vision (CV) is dedicated to interpreting images and videos, engaging in functions like identifying objects, pinpointing their location, and delineating their boundaries. These capabilities are crucial in analyzing patient radiographs to detect the presence of malignant tumors. Convolutional neural networks (CNNs), a type of deep-learning algorithm designed to process data that exhibits natural spatial invariance (e.g., images, whose meanings do not change under translation), have grown to be central in this field. Medical imaging, for instance, can greatly benefit from recent advances in image classification and object detection.

Many studies have demonstrated promising results in complex diagnostics spanning dermatology, radiology, ophthalmology, and pathology. Deep-learning systems based on CNN methods have been very successful especially by supporting physicians when offering second opinions and flagging concerning areas in patient's images. This is largely due to the fact that CNNs have achieved human-level performance in object-classification tasks, in which a CNN learns to classify the object contained in an image. In the first step, the algorithm leverages large amounts of data to learn the natural statistics in images—straight lines, curves, colorations, etc.—and in the second step, the higher-level layers of the algorithm are retrained to distinguish between diagnostic cases. Similarly, object detection and segmentation algorithms identify specific parts of an image that correspond to particular objects. CNN methods take image data as input and iteratively change it through a series of convolutional and nonlinear operations until the original raw data matrix is transformed into a probability distribution over potential image classes (e.g., medical diagnostic cases).

The quest to determine how much the answer given by an artificial intelligence algorithm is aligned or close to that given by a group of experienced radiologists has been the subject of permanent study. For example, Biebau et.al. (5)in their study, based on a dataset involving 182 patients, identified a very strong correlation between the results of the radiologists' analysis and the results from the interpretation of images by an artificial intelligence algorithm with regard to the degree of severity of the lung lesions found in these patients. In the same direction, Montazeri et.al. (6)in their systematic review, describe, after analyzing more than 40 related studies, that the predictive performance measures performed by some AI tools showed a very high capacity to detect infection.

In turn, Lessmann et.al (7) in his publication compares the use of the CO-RADS artificial intelligence system with the opinion of 8 (eight) radiologists. In this study, the researchers evaluated the performance of this system based on data obtained from chest computed tomography images of patients with suspected COVID-19, distributing the results according to the system (CORADS) of classifications which is described below.

The CO-RADS model (COVID-19 Reporting and Data System) seeks to identify and classify patients with pulmonary involvement with scores ranging from 1 (very low) to 5 (very high) depending on the type and number of pulmonary findings related to COVID.

Table 1: Tomographic findings and their classification according to the CO-RADS system

CO-RADS classification for COVID diagnosis through graphic CT images		
Category	Suspected COVID	Description
0	Inconclusive	Technically inadequate image
1	Too low	Normal or uninfected
2	Low	Findings of other infections but not COVID
3	Probable	Features of COVID present, however, identified findings typical of other infections
4	High	Some COVID characteristics evidenced
5	Too high	Typical COVID Features Present
6	Confirmed	RT-PCR positive

Source: Schalekamp S et.al.(8)

Besides the CO-RADS classification, the percentage of lung parenchyma involvement was also considered in the comparative study between radiologists and the Artificial Intelligence tool. When comparing the distribution of the CORADS classifications between the algorithm and the radiologists, a very high degree of agreement was found between the two groups. Similarly, with regard to lung parenchymal involvement, the results regarding the agreement between the two methods (human vs. machine) were equivalent to those described above, but the human observers, on average, indicated a lung volume damage greater than that indicated by the Artificial Intelligence tool. The explanation may be that the visual estimation of the amount of lung parenchyma affected is subjective and some studies have shown that human readers tend to overestimate the extent of the disease.

Once proved that some AI solutions can be a very valuable tool to support radiologists in the definition of the degree of parenchyma involvement, there are some few other contributions an AI-Suite may positively impact the healthcare delivery especially by supporting Remote and Collaborative Diagnostics.

In a global health crisis, the ability to provide expert radiological services remotely turned to be utmost important and AI tools could facilitate tele-radiology by providing assistance to radiologists operating in diverse and geographically dispersed locations. These tools offered preliminary analyses and diagnostic suggestions, which radiologists could then review and corroborate. This support enabled radiologists to extend their expertise to underserved regions, ensuring that even patients in remote areas received high-quality diagnostic care.

As cited by Tan et.al (9), in order to assist hospitals without chest radiologists and to help provide faster diagnosis, the Hospital das Clínicas Innovation Center in Sao Paulo, Brazil, in partnership with the private sector and the Brazilian federal government, created the RadVid-19 project. Through this platform, any hospital in Brazil was able to send its chest CT images to a server, where two AI algorithms return a report with a COVID-19 probability analysis and the extent of the affected lung parenchyma. Operating on a 7/24 model, the facility generated reports to the client hospital within 10 minutes, at no cost to the user.

Further, AI-enhanced radiology allows collaborative diagnostics. By integrating AI tools with cloud-based platforms, radiologists can share imaging data and AI-generated insights with colleagues around the world. This collaborative approach enables a more comprehensive diagnostic process, combining human expertise with advanced technological support to improve diagnostic accuracy and patient outcomes.

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VI. Conclusion

The COVID-19 pandemic has underscored the critical need for innovative solutions in healthcare. AI tools have proven to be invaluable allies for radiologists, enhancing their ability to detect lung lesions with speed and accuracy that were previously unattainable. By augmenting the capabilities of radiologists, AI ensures a more responsive and resilient healthcare system, better equipped to navigate the challenges of both current and future pandemics. As we continue to advance and refine these technologies, the symbiotic relationship between human expertise and artificial intelligence will undoubtedly pave the way for new milestones in medical diagnostics, ultimately saving lives and improving global health outcomes.

Nevertheless, alongside the many advantages AI offers in aiding radiologists, it's critical to address the ethical considerations and hurdles it presents. It's crucial to safeguard patient data privacy and security, establishing strict measures to secure confidential information, especially with the use of AI tools hosted on the cloud. Furthermore, the clarity and understandability of AI processes are key; radiologists need to comprehend the reasoning behind AI's decisions to build trust and utilize these tools efficiently.

The integration of AI tools into radiology does not necessarily mean replacing radiologists but rather augmenting their capabilities. The adoption of AI in radiology isn't about replacing radiologists but enhancing their expertise. AI can manage the regular, laborious duties, freeing radiologists to concentrate on intricate cases and to make more nuanced judgments. AI can act as a supportive second reviewer, catching potential oversights, thus providing an additional layer of assurance. This collaborative approach can improve diagnostic accuracy, efficiency, and ultimately patient outcomes.

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Prediction of Hard Drive Failure using Machine Learning

By Elizabeth Atekoja

Abstract- The reliability of hard drives is paramount for maintaining data integrity and availability in cloud services and enterprise-level data centers where unexpected failures significantly impact operational efficiency and general performance. This work aims to develop a predictive model using regression analysis to accurately forecast imminent hard drive failures based on historical operational data, specifically SMART (Self-Monitoring Analysis and Reporting Technology) attributes. The study evaluated various regression models which comprises Decision Tree, Random Forest, Support Vector Machine (SVM), Gradient Boosting, and Neural Network. The outcomes indicated that the Random Forest model, with an MSE of 24.7427 and an R2 of 0.9876 and the Neural Network model, with an MSE of 22.6011 and an R2 of 0.7442, as the best performing models as they demonstrated high predictive accuracy and robustness. In contrast, the SVM model showed poor performance with an MSE of 2888.8623 and a negative R2 of -0.4465. Based on these outcomes, the Random Forest and Neural Network models are recommended for predicting hard drive failures as they delivered a balance of accuracy and interpretability.

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PREDICTIONOFHARDDRIVEFAILUREUSINGMACHINELEARNING

Strictly as per the compliance and regulations of:

Prediction of Hard Drive Failure using Machine Learning

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Abstract- The reliability of hard drives is paramount for maintaining data integrity and availability in cloud services and enterprise-level data centers where unexpected failures significantly impact operational efficiency and general performance. This work aims to develop a predictive model using regression analysis to accurately forecast imminent hard drive failures based on historical operational data, specifically SMART (Self-Monitoring Analysis and Reporting Technology) attributes. The study evaluated various regression models which comprises Decision Tree, Random Forest, Support Vector Machine (SVM), Gradient Boosting, and Neural Network. The outcomes indicated that the Random Forest model, with an MSE of 24.7427 and an R^2 of 0.9876 and the Neural Network model, with an MSE of 22.6011 and an R^2 of 0.7442, as the best performing models as they demonstrated high predictive accuracy and robustness. In contrast, the SVM model showed poor performance with an MSE of 2888.8623 and a negative R^2 of -0.4465. Based on these outcomes, the Random Forest and Neural Network models are recommended for predicting hard drive failures as they delivered a balance of accuracy and interpretability.

I. Background

The reliability of hard drives remains a vital concern across various sectors with particular significance in cloud services and enterprise-level data management where the integrity and availability of data are paramount. As businesses increasingly rely on data-driven decision-making, the cost of data loss or system downtime due to hard drive failures is substantial and impact operational efficiency, customer satisfaction, and financial performance. At enterprise-Level data centers, hard drives often operate under high-demand conditions, which can accelerate wear and tear. The data stored in these centers is crucial for operations and often includes transaction histories, client data, and business analytics. The failure of hard drives in such setups not only leads to data loss but also affects the redundancy and resilience of the entire data system. Regular monitoring and predictive maintenance facilitated by machine learning can significantly reduce the risk of such occurrences (Wang et al., 2018). Cloud services rely on data centers spread across multiple locations, where data is stored redundantly on numerous hard drives. Cloud providers must ensure high reliability to maintain service level agreements and customer trust. Predicting hard drive failure within these systems is not just a maintenance task but a critical operation that directly influences service quality and business continuity (Barroso et al., 2016). The implementation of predictive maintenance strategies for hard drives using machine learning algorithms has been shown to reduce unexpected downtime significantly. By analyzing SMART (Self-Monitoring, Analysis, and Reporting Technology) data, models can predict failures before they happen, allowing for timely replacements and repairs, thus minimizing downtime and reducing maintenance costs (Vishwanath and Nagappan, 2016).

The study by Pinheiro, Weber and Barroso (2007) analyse a large population of disk drives and identifies common failure trends and indicators using statistical analysis to explore various SMART attributes. Critical indicators of failures were identified, but the study primarily focused on descriptive statistics rather than predictive modeling. Botezatu et al. (2016) developed prediction system for disk replacements in data centers to improve reliability. Machine learning models are employed to forecast when disks will need to be replaced, using a combination of real-time and historical SMART data. Achieved high accuracy in predictions; however, the study focused majorly on replacement timing rather than immediate failure detection. Hamerly and Elkan (2021) applied Bayesian methods to predict disk drive failures. The study uses Bayesian networks to model the probability of drive failures based on SMART attributes. In comparison, their method provides a probabilistic approach to prediction which is insightful for uncertainty estimation but did not align with the needs for precise regression predictions. With existing works mostly with statistical analysis and machine learning classification, there is a potential gap in exploring more comprehensive array of regression techniques, including advanced polynomial and non-linear regression models that might capture more complex relationships in the data.

Research Question

Which regression model provides the best performance in predicting hard drive failures based on the identified predictors?

Author: *e-mail: elizabeth.atekoja@gmail.com*

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II. Literature Review

Predicting failures is vital aspect of maintenance strategies which target is to prevent unplanned downtimes (Leukel, Gonzalez and Riekert, 2021). Concerning hard drive, while it is a resource that has been commonly adopted as a major storage device due to its cheap price and stability, rapid expansion of data storage systems expose it to failure (Gers, Schmidhuber and Cummins, 2000; Manousakis et al. 2016). According to Bairavasundaram et al. (2008), as disk capacity increases, chances of errors and data loss becomes high. By all standard, failure is costly and it is necessary they are detected or predicted (Murray, Hughes and Kreutz-Delgallo, 2005). Historical dataset based on SMART convention has aided utilization of machine learning in detection and prediction framework. Self-Monitoring and Reporting Technology (SMART) system uses attributes retrieved when hard drive perform and also during off-line tests to fix a failure prediction flag (Murray, Hughes and Kreutz-Delgallo, 2005). In most case, the SMART attributes in hard drive historical data is enormous while possessing target variable that enable classification (failure detection: yes or no) and regression (temporal prediction). Even when the data is primarily available and embedded with continuous and temporal attributes, most research in this domain focuses more on classification. Perhaps as it is good to detect the occurrence of failure, it is essential to predict when it is likely going to happen. A quick and random search on Google Scholar produced predictions based on classification (Table 1)

Table 1: Existing works on Hard Drive Prediction

Author	Problem Formation	Machine Learning Techniques
Aussel et al. 2017	Classification	SVM, Random Forest and Gradient Boosting
Shen et al. 2018	Classification	Random Forest
Garcia et al. 2018	Classification	Naïve Baye, SVM and Neural Network
Amran et al. 2021	Classification	Optimal Survival Trees and Optimal Classification Trees
Chhetri et al. 2022	Classification	Relational Graph Convolutional Neural Network
Ahmed and Green 2022	Classification	Random Forest, GBM and Logistic Regression
Wang et al. 2023	Classification	Naïve Baye, Random Forest, SVM, Gradient Boosted Decision Tree, CNN and LSTM
Zhang et al. 2023	Classification	SVM, Random Forest, Gradient Boosted Decision Tree and LSTM
Gour and Waoo 2023	Classification	LightGBM, Random Forest, Decision Tree, Deep Neural Network, Convolutional Neural Network and Recurrent Neural Network

Unlike many other investigations adoption classification problem, Anantharaman, Qiao and Jadav (2018) uses regression techniques to estimate the remaining useful life of hard disk drives directly. This contrasts with typical predictive models that classify whether a hard disk will fail within a specific timeframe. Random Forest and LSTM were used to analyse SMART attributes with focus of capturing historical temporal patterns that signify deterioration over time. The study evaluates the models based on their Mean Absolute Error (MAE), standard metric for regression tasks. While confidence level of models (R^2) were not reported in the work, Random Forest model achieved an MAE of 22.66 without a sliding window and 24.08 with a sliding window of size 10. For the LSTM models, the Many-to-One configuration recorded MAEs of 27.62 without a sliding window and 24.81 with it, at the same time the Many-to-Many setup had MAEs of 23.26 and 29.04 for the respective window configurations. Notably, the Piece-wise RUL approach in the Many-to-Many model significantly improved performance, yielding MAEs of 8.15 without a sliding window and 9.31 with a sliding window of size 10. Research by Zufle et al. (2020) applied both classification and regression to the prediction of hard drive failure using random forest machine learning techniques. Just like Anantharaman, Qiao and Jadav (2018), the confidence level metrics were not explicitly presented; the unfiltered data achieved a Mean Absolute Error (MAE) of 10 hours and a Root Mean Square Error (RMSE) of 44.6 hours and the pre-filtered data significantly improved these metrics, with an MAE of 4.5 hours and an RMSE of 12.8 hours. To explore more insights based on temporal and continuous-based predictions, this research will apply four machine learning regression including random forest, decision tree, SVM, Gradient Boosting and Neural Network.

III. Dataset Collection

Based on the view of Ruggiano and Perry (2019), secondary data can be collected and used to address new questions. A suitable and relevant dataset to achieve the study aim and objectives is sourced from Kaggle Hard Drive Test Data (kaggle.com). The dataset originated from BackBlaze and it is based on SMART statistics which makes it readily available for computational handling.

```
df = pd.read_csv('../input/hard-drive-test-data/harddrive.csv')
print(df.shape)
df.head()
```

```
(3179295, 95)
```

	date	serial_number	model	capacity_bytes	failure	smart_1_normalized	smart_1_raw	smart_2_normalized	smart_2_raw	smart_3_normalized	...
0	2016-01-01	MJ0351YNG9Z0XA	Hitachi HDS5C3030ALA630	1.482490e-311	0	100	0	135.0	108.0	143	...
1	2016-01-01	Z305B2QN	ST4000DM000	1.976651e-311	0	113	54551400	NaN	NaN	96	...
2	2016-01-01	MJ0351YNG9Z7LA	Hitachi HDS5C3030ALA630	1.482490e-311	0	100	0	136.0	104.0	124	...
3	2016-01-01	MJ0351YNGABYAA	Hitachi HDS5C3030ALA630	1.482490e-311	0	100	0	136.0	104.0	137	...
4	2016-01-01	WD-WMC4N2899475	WDC WD30EFRX	1.482490e-311	0	200	0	NaN	NaN	175	...

5 rows × 95 columns

Figure 1: Extract of Hard Drive Performance Dataset

The dataset (Figure 1) contain data related to hard drive diagnostics with various attributes and readings from S.M.A.R.T (Self-Monitoring, Analysis, and Reporting Technology) data. The observation date is measure with attribute named "date". The "serial number" is the unique identifier for each hard drive, while the "model" denotes the model number of the hard drive. The drive's capacity is represented by "capacity_bytes", which is the size of the storage. The attribute "failure" is a binary indicator (0 or 1) where '1' indicates that the hard drive failed on this date. This attribute is used in prediction based on classification as the target variable. The remaining ninety attributes (columns) represent normalized and raw values of different SMART attributes which measure the health and performance of the hard drive. The preprocessing script (Figure 2) cleans the data by removing empty columns, identifies unique drives and models, isolates the subset of data concerning failed hard drives and provides basic counts that help understand the composition of the dataset.

```
df = df.loc[:, ~df.isnull().all()]
print(df.shape)
```

```
(3179295, 91)
```

```
# number of hdd
print("number of hdd:", df['serial_number'].value_counts().shape)

# number of different types of harddrives
print("number of different harddrives", df['model'].value_counts().shape)
```

```
number of hdd: (65993,)
number of different harddrives (69,)
```

```
failed_hdds = df.loc[df.failure==1]["serial_number"]
len(failed_hdds)
```

```
215
```

```
df = df.loc[df["serial_number"].isin(failed_hdds)]
df.shape
```

```
(5490, 91)
```

Figure 2: Extract of Data Pre-Processing

IV. Model Development and Implementation

a) Decision Tree

Decision Tree is executed using the *DecisionTreeRegression* function (Figure 3). The function builds a regression tree by recursively splitting the dataset based on feature values to minimize variance within the target variable which ensure each split results in subsets with reduced variance compared to the parent node. The implementation starts by confirming that the dataset can be split further based on the minimum sample size or maximum tree depth; if not, it returns the mean target value of the dataset as a leaf node. The function iterates over all possible splits for each feature, computes the variance reduction for each and selects the split that maximizes this reduction. When the best split is achieved, the dataset is divided and the function is called recursively for each subset until leaf nodes are formed.

```
Function Decision_Tree_Regression(Data, Depth, Max_Depth, Min_Split_Size)
  // Input: Data - the dataset for building the regression tree
  //        Depth - the current depth of the tree
  //        Max_Depth - the maximum allowable depth for the tree
  //        Min_Split_Size - the minimum size of the dataset to allow further splits

1. If Data has fewer rows than Min_Split_Size or Depth equals Max_Depth:
  2. Compute and return the mean of the target variable in Data (create a leaf node)

3. Initialize best_score to infinity // Used to track the best variance reduction found
4. Initialize best_split to null // Stores the best feature and split point

5. For each feature in Data:
  6. For each possible split point within this feature:
    7. Split Data into two subsets (Data_Left and Data_Right) based on this split point
    8. Calculate the sum of squared residuals from the mean in both subsets
    9. Compute the variance reduction as the difference between the variance before and after the split
    10. If the variance reduction is greater than best_score:
      11. Update best_score with this variance reduction
      12. Update best_split with this feature and split point

13. If best_split is null: // No valid split was found
  14. Compute and return the mean of the target variable in Data (create a leaf node)

15. Use best_split to partition Data into Data_Left and Data_Right

16. Create a node that stores the feature and split point from best_split

17. Recursively apply Decision_Tree_Regression to Data_Left:
  18. Left_Child = Decision_Tree_Regression(Data_Left, Depth + 1, Max_Depth, Min_Split_Size)

19. Recursively apply Decision_Tree_Regression to Data_Right:
  20. Right_Child = Decision_Tree_Regression(Data_Right, Depth + 1, Max_Depth, Min_Split_Size)

21. Attach Left_Child and Right_Child to the current node as its branches

22. Return the current node // This node now represents the decision at this level of the tree
End Function
```

Figure 3: Pseudocode for Implementing Decision Tree

The model by the decision tree technique provides a strong alignment between actual and predicted values along the central line but it exhibits noticeable variance and outliers (Figure 4). This indicates that while the Decision Tree will predict hard drive failures using the SMART dataset while its predictions are less stable and accurate with more frequent errors.

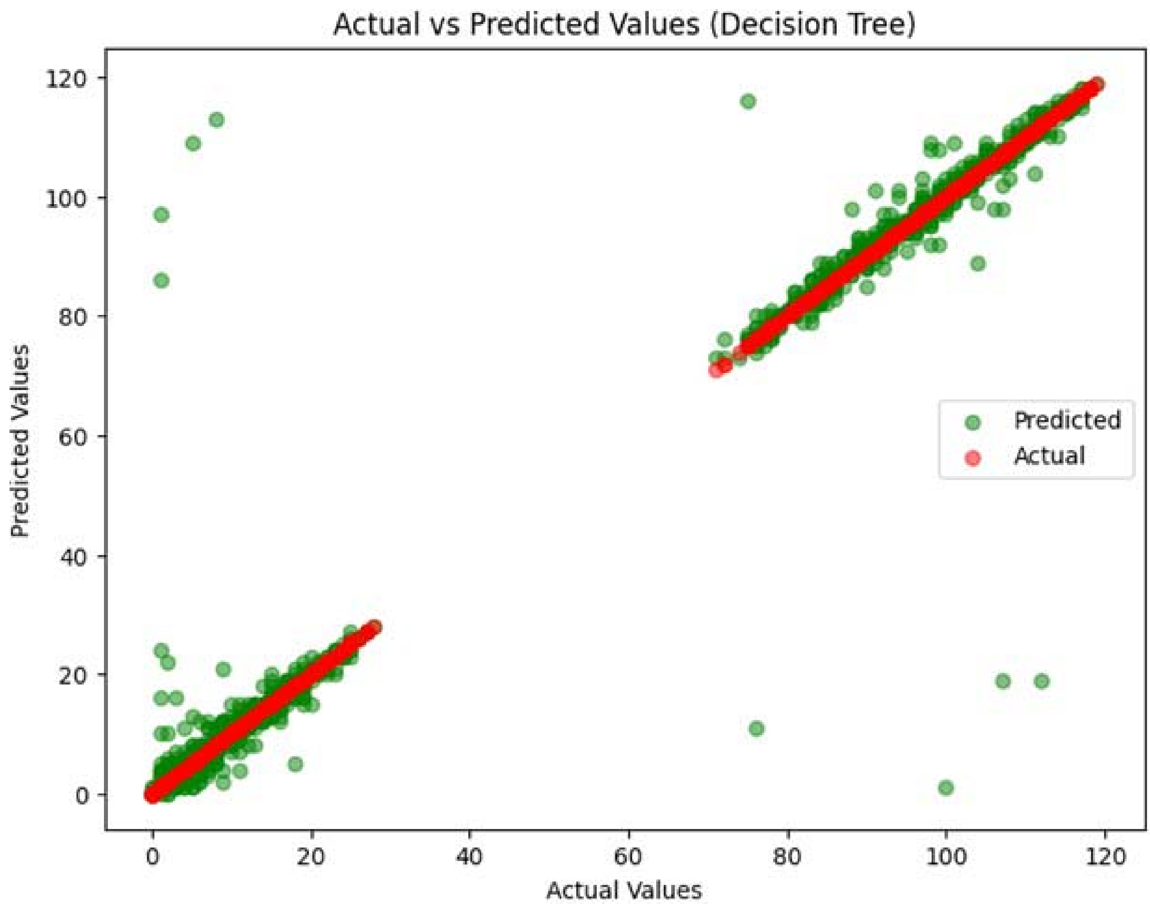

Figure 4: Decision Tree Prediction Outcome

b) Random Forest

The algorithm is implemented by creating an empty list, *forests*, to store the decision trees (Figure 5). For each tree in the list *forest*, it generates a bootstrapped sample of the training data. It fits a decision tree regression model using specified parameters like the number of features to consider for each split, the minimum number of samples required to split a node and the maximum depth of each tree. These trees are appended to the forests list. To make predictions, the *predict* function aggregates predictions from all trees for the test data, averaging their outputs to produce the final prediction.

```
Inputs:
   data: training dataset
n_trees: number of trees in the forest
n_features: number of features to consider for each split
min_samples_split: minimum number of samples required to split a node
max_depth: maximum depth of each tree
Begin
   forests = []
   for i from 1 to n_trees do
bootstrapped_data = bootstrap_sample(data)
      tree = DecisionTreeRegression(bootstrapped_data, n_features, min_samples_split, max_depth)
forests.append(tree)
   end for
   function predict(test_data)
      predictions = []
      for tree in forests do
```

```
predictions.append(tree.predict(test_data))
        end for
final_prediction = average(predictions)
        return final_prediction
    end function
End
```

Figure 5: Pseudocode for Implementing Random Forest

The outcome of random forest showed model that is highly effective at predicting hard drive failures using the SMART dataset (Figure 6). However, there are some deviations particularly at higher value ranges and this indicate instances where the model's predictions are less accurate.

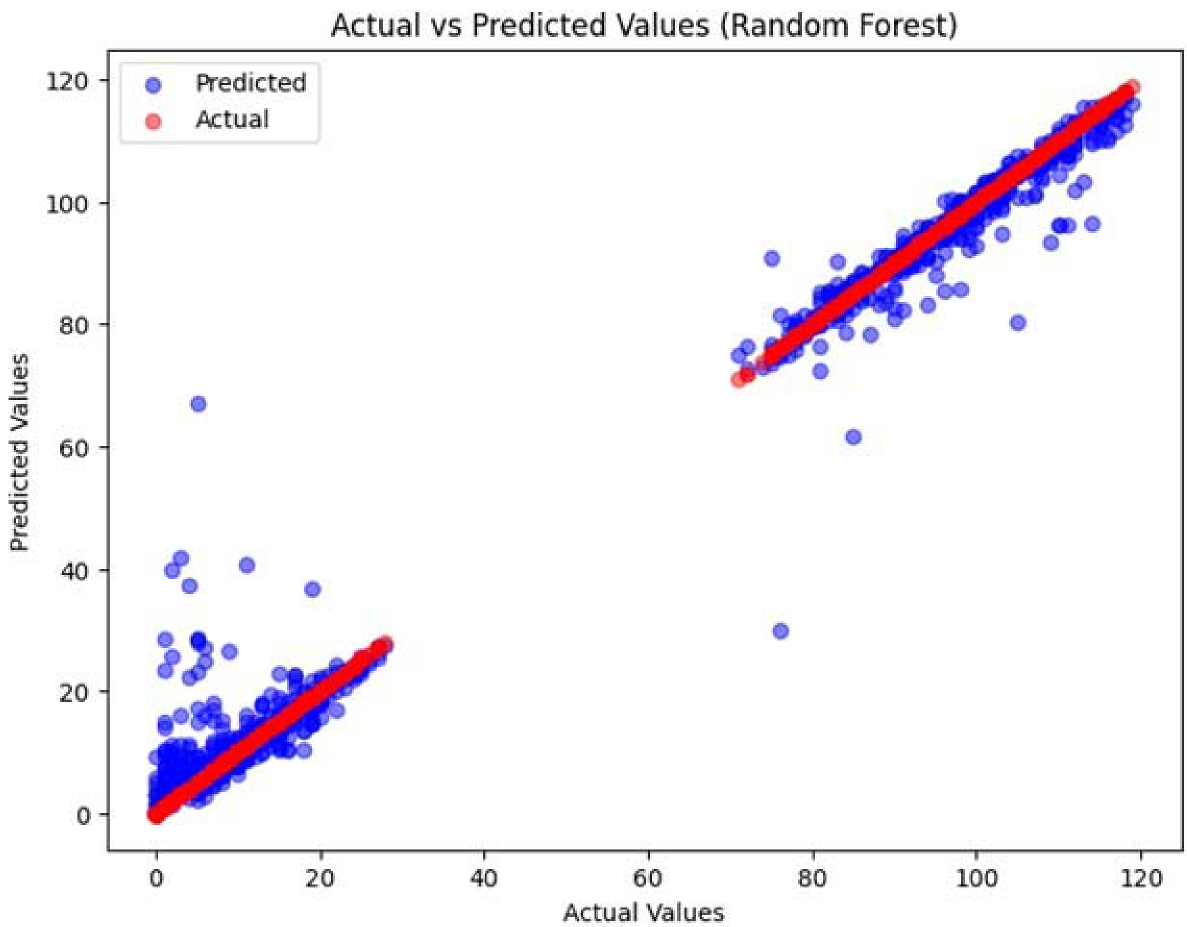

Figure 6: Random Forest Prediction Outcome

c) Support Vector Machine (SVM)

From Figure (7.), the implementation begins by initializing the dataset by specifying parameters like epsilon (for error tolerance), the regularization parameter (C), and the kernel type (linear, polynomial, or radial basis function). The kernel function is defined based on the selected kernel type which transforms the input data into a higher-dimensional space to enable separation. For each data point in the training set, the loss function is computed considering the hinge loss for points outside the epsilon margin and at the same time the model parameters are optimized using an algorithm like Sequential Minimal Optimization. The training continues iteratively until convergence criteria are met, after which the final model parameters are saved to enable the SVM to predict hard drive failures on new instances by computing their positions relative to the support vectors and summing the weighted contributions.

```
1. Input:
   - Data: Dataset containing features and target values
   - Epsilon: Specifies the epsilon-tube within which no penalty is associated in the training loss function with points predicted within a distance epsilon from the actual value
   - C: Regularization parameter, which defines the trade-off between achieving a low error on the training data and minimizing model complexity for better generalization
   - Kernel_Type: Type of kernel function to use ( linear, polynomial, radial basis function)

2. Initialize the model parameters (weights and bias) to zero or small random values

3. Define the kernel function based on Kernel_Type:
   - If linear: Use the linear dot product
   - If polynomial: Use (gamma * dot_product + coef0)^degree
   - If radial basis function (RBF): Use exp(-gamma * |a-b|^2)

4. For each instance in the training Data:
   - Calculate the loss function considering:
      - Hinge loss for points outside the epsilon margin
      - Regularization term using C

5. Use an optimization algorithm (e.g., Sequential Minimal Optimization) to:
   - Select a subset of training instances as support vectors
   - Optimize the model parameters to minimize the objective function (loss + regularization)

6. Continue iterating over the training set until convergence criteria are met, such as:
   - No substantial change in the loss function
   - Reaching a maximum number of iterations

7. Save the model parameters (support vectors, weights, bias) after training is complete

Testing:

1. Input:
   - Model: The trained SVM regression model (containing support vectors, weights, bias)
   - New_Data: New instances for which to predict the target values

2. For each instance in New_Data:
   - Compute the prediction by applying the kernel function between the new instance and each support vector, scaled by the corresponding weight, and summed with the bias

3. Return the predictions for all instances in New_Data
```

Figure 7: Pseudocode for Implementing SVM

The outcome (Figure 8) indicates that the Support Vector Machine (SVM) model struggles with accurately predicting hard drive failures as evidenced by the clustering of predicted values around specific ranges and significant deviations from the actual values.

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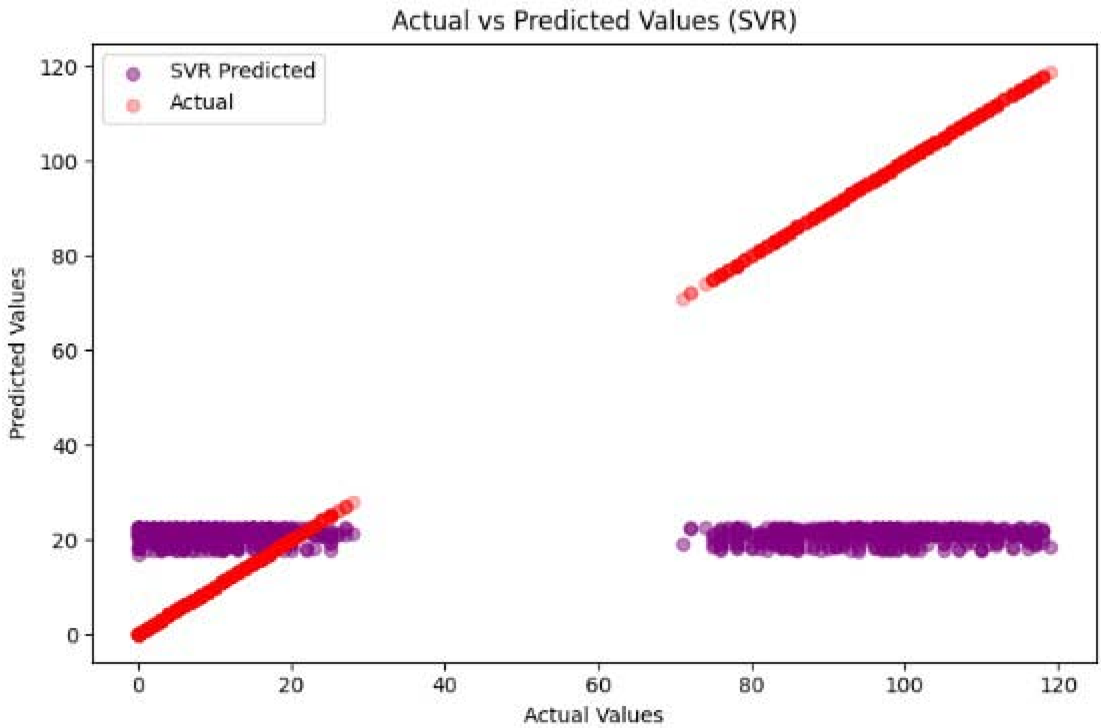

Figure 8: SVM Prediction Outcome

d) Gradient Boosting

The implementation of Gradient Boosting starts with initializing the model, which initially predicts the mean of the target values (Figure 9). For each of the specified number of trees, the model computes the residuals (differences between actual target values and current predictions), which serve as the target for fitting the next tree. Each new tree is trained on these residuals, adhering to constraints like maximum depth and minimum samples required to split. The model is updated by adding the scaled predictions of the new tree to the current model's predictions, iteratively improving accuracy. This process continues until all trees are built, making an ensemble model that makes final predictions on new data by aggregating the contributions of all trees.

1. Input: - Data: Dataset containing features and target values - Learning_Rate: Shrinks the contribution of each tree by this factor to improve model robustness - N_Trees: Number of trees to build (iterations) - Max_Depth: Maximum depth of each tree - Min_Samples_Split: Minimum number of samples required to split an internal node 2. Initialize: - Model = an initial model which could just predict the mean of the target values of Data 3. For i = 1 to N_Trees: 4. Compute the residuals (negative gradient of the loss function) for each training instance: - Residuals = actual target values - predictions from the current Model 5. Fit a new tree to the residuals using the feature values with the constraints of Max_Depth and Min_Samples_Split 6. Predict the residuals for the training dataset using this new tree 7. Update the Model by adding the scaled predictions of the new tree:

```
      - Model = Model + Learning_Rate * new tree predictions

8. Return the final Model

Testing:

1. Input:
   - Model: The trained Gradient Boosting model (ensemble of trees)
   - New_Data: New instances for which to predict the target values

2. Start with the initial prediction (often the mean of the training target values if that was the
initialization)

3. For each tree in the Model:
   4. Update the prediction for each instance in New_Data:
      - Prediction += Learning_Rate * tree's prediction on New_Data

5. Return the final predictions for all instances in New_Data
```

Figure 9: Pseudocode for Implementing Gradient Boosting

The results (Figure 10) indicate that the Gradient Boosting model produces predictions that align closely with the actual values, as seen by the clustering of prediction dots around the line of equality. However, there is a noticeable dispersion in the predicted values, particularly at the lower and middle ranges.

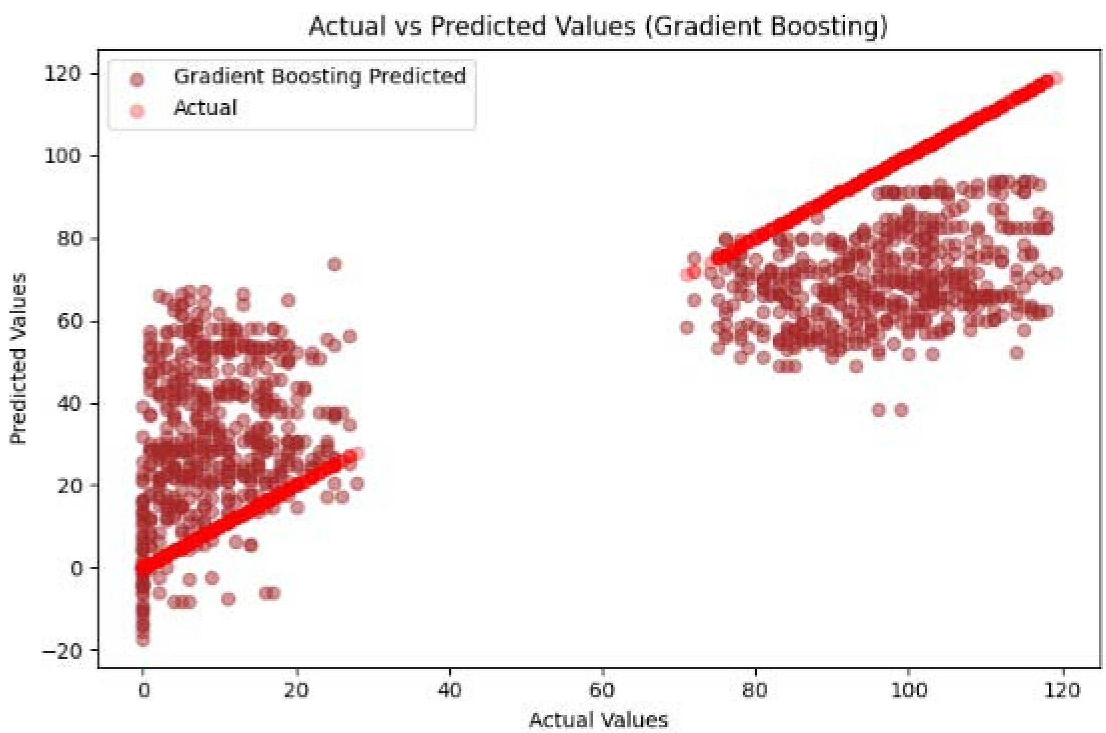

Figure 10: SVM Prediction Outcome

e) Neural Network

The implementation (Figure 11) starts with defining the network's structure and this includes the number of input neurons (corresponding to the dataset features), hidden layers and output neurons. The network is initialized with random weights and biases for each layer. During training, the network processes each training instance by propagating inputs through the layers with the application of activation functions at each hidden layer and computation of the output. The loss function which stands for mean squared error measures the difference between the predicted and actual values while backpropagation is used to update the weights and biases by minimizing this loss. After training, the neural network is tested by passing new data through the trained model to predict hard drive failures, with aggregating predictions for final output.

```
1. Input:
   - Num_Input_Neurons: Number of neurons in the input layer, corresponding to the number of
features in the dataset
   - Hidden_Layers: Number of hidden layers in the network
   - Neurons_Per_Layer: Array containing the number of neurons in each hidden layer
   - Output_Neurons: Number of neurons in the output layer

2. Structure:
   - Create a network structure with the specified number of layers and neurons
   - Initialize weights and biases for each layer randomly

3. Return the initialized network with weights and biases

1. Input:
   - Network: Initialized neural network structure with weights and biases
   - Data: Training dataset features
   - Labels: Training dataset target values (continuous)
   - Learning_Rate: Step size for updating the weights
   - Epochs: Number of times to iterate over the entire training dataset

2. Training Process:
   - For each epoch:
      3. For each instance (Input, Target) in (Data, Labels):
         4. Forward_Propagation:
            - Compute the output of each layer starting from input to output layer
            - Use activation functions like ReLU for hidden layers and linear for the output layer

         5. Compute Loss:
            - Calculate the mean squared error or another suitable loss function between the predicted
and actual values

         6. Backward_Propagation:
            - Calculate gradients of the loss function with respect to each weight and bias
            - Update weights and biases using these gradients and the learning

Testing:

1. Input:
   - Network: Trained neural network
   - New_Data: New instances for which to predict the target values

2. Prediction Process:
   - For each instance in New_Data:
      3. Forward_Propagation:
         - Compute the output using the trained network starting from the input layer to the output layer

4. Collect and return all predictions for New_Data
```

Figure 11: Pseudocode for Implementing Neural Network

The outcome (Figure 12) shows a significant reduction in both training and validation loss over the epochs, indicating that the neural network is learning and improving its predictions for hard drive failures using the SMART dataset. The close alignment between the training and validation loss curves suggests that the model generalizes well to unseen data, minimizing overfitting and ensuring robust predictive performance.

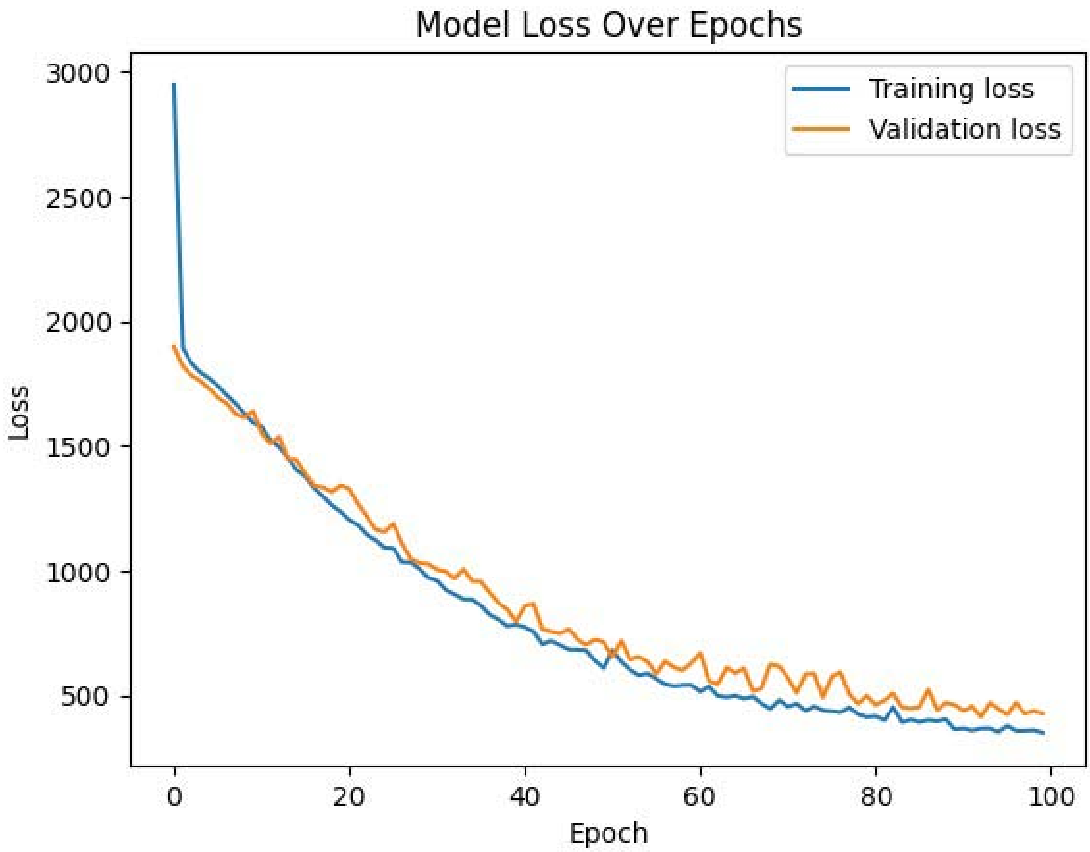

Figure 12: Neural Network Prediction Outcome

V. Results and Discussion

For the Decision Tree model (Table 2), the MSE is 71.4943, with an R^2 of 0.9642, indicating a high degree of accuracy. The Random Forest model has an MSE of 24.7427 and an R^2 of 0.9876, suggesting even better performance. The SVM model shows an MSE of 2888.8623 and an R2 of -0.4465, indicating poor predictive capability. The Gradient Boosting model has an MSE of 823.1132 and an R^2 of 0.5879, reflecting moderate accuracy. Lastly, the Neural Network model reports an MSE of 22.6011 and an R^2 of 0.7442, which indicates good performance.

Table 2: Models Results

Models	MSE	R^2
Decision Tree	71.4943	0.9642
Random Forest	24.7427	0.9876
SVM	2888.8623	-0.4465
Gradient Boosting	823.1132	0.5879
Neural Network	22.6011	0.74424

The Decision Tree model (Figures 13 and 14) exhibits a relatively low MSE of 71.4943, indicating minimal errors in predictions, and a high R^2 value of 0.9642, suggesting it explains a large portion of the variance in the target variable effectively. The Random Forest model performs even better, with a significantly lower MSE of 24.7427 and an R^2 of 0.9876, indicating excellent explanatory power. This shows that the ensemble approach of combining multiple decision trees improves prediction accuracy and robustness, reducing the impact of overfitting associated with individual trees.

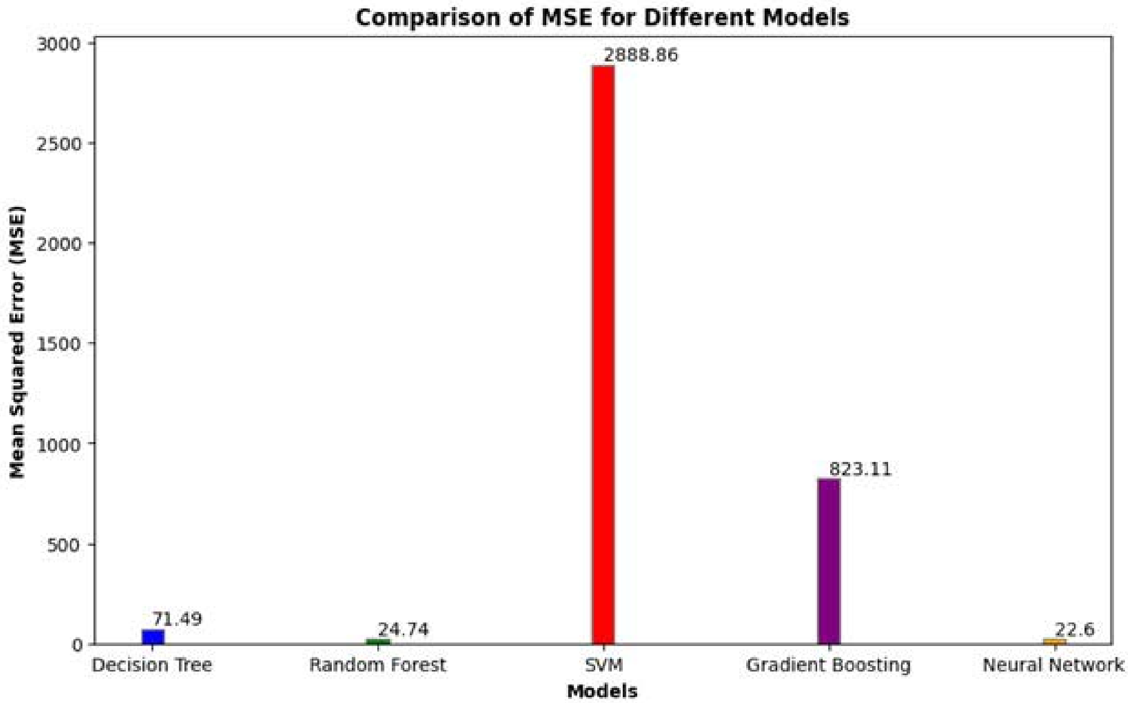

Figure 13: MSE for Selected Models

In contrast, the Support Vector Machine (SVM) model performs poorly with a very high MSE of 2888.8623 and a negative R^2 value of -0.4465, suggesting it fails to capture the relationship between the features and the target variable and is worse than a simple mean predictor. Gradient Boosting shows moderate performance with an MSE of 823.1132 and an R^2 of 0.5879, indicating more prediction errors and less variance explained compared to the Decision Tree and Random Forest models. While powerful, Gradient Boosting may require more fine-tuning or may not be as effective on the study's dataset.

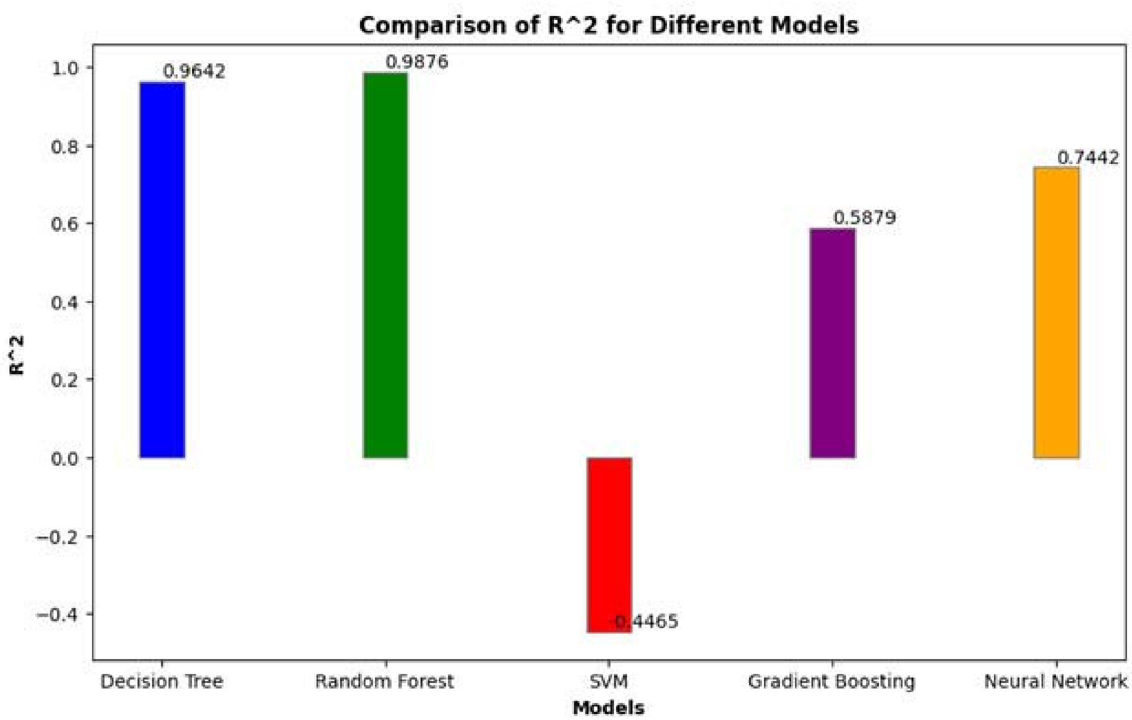

Figure 13: R^2 for Selected Models

The Neural Network model has the lowest MSE of 22.6011, indicating very accurate predictions with minimal errors, but its R^2 value of 0.7442, though high, is not as close to 1 as that of the Random Forest, suggesting some unexplained variance in the data. Neural networks can be very powerful but require substantial data and computational resources, and their performance is highly dependent on the architecture and training process. Overall, the Random Forest perform best with the lowest errors and highest explanatory power. The Neural Network also performs well with very low errors but slightly less explanatory power. The Decision Tree model demonstrates strong performance with good accuracy and explanatory power, while Gradient Boosting has moderate performance. The SVM is not suitable for this task based on the given metrics.

VI. Conclusion, Recommendation and Limitations

The research into predictive modeling for hard drive failures using various regression techniques has shown remarkable insights into the efficiency of different models in this domain. The Random Forest and Neural Network models emerged as the best predictors as they demonstrated the highest accuracy and predictive power. The Random Forest model, with an MSE of 24.7427 (minimal predicting error), and an R^2 of 0.9876 proved highly effective in capturing the complex relationships within the SMART dataset. Similarly, the Neural Network model exhibited strong predictive capabilities, with an MSE of 22.6011 and an R^2 of 0.7442, which indicates robust performance and generalizability. Based on the performance metrics, both random forest and neural network is recommended for predicting hard drive failures. Despite the promising results, a few limitations exist:

1. Model Interpretability: While Random Forest and Decision Tree models offer relatively high interpretability through feature importance, Neural Networks and Gradient Boosting model can be perceived as black-box models. Techniques like SHAP and LIME will help in the interpretability process and overall models explainability.
2. Generalizability: The models were trained and tested on a specific dataset. Their generalizability to other datasets or different types of hard drives may vary. Cross-validation and testing on diverse datasets are important to ensure robustness.
3. Model Maintenance: Predictive models need continuous monitoring and updating to maintain accuracy over time. Changes in hard drive technology and operational conditions necessitate periodic retraining of the models.
4. In conclusion, while the study demonstrates the effectiveness of advanced regression techniques in predicting hard drive failures, addressing these limitations through ongoing research and development is essential for improving model reliability and applicability in real-world scenarios.

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Enhanced Crime Prediction with Computer Vision-Yolov4 Approach

By Taiwo. M. Akinmuyisitan & John Cosmas

Abstract- This research paper presents the development of an artificial intelligence safety application on an HP Pavilion gaming machine, utilizing criminal footage from reputable databases like the UCF-Crime open-source dataset. The system underwent meticulous data annotation to identify five distinct classes crucial for anomaly detection: Person, Short Gun, Handgun, Knife, and Rifle. Supervised machine learning techniques were applied, focusing on monitoring human trajectories and employing deep-SORT and Euclidean distance computations to track individuals, simulating real-world crime scenarios. The AI safety model showcased outstanding performance with an average precision rate of approximately 86.43%, exceeding 90% after 2000 iterations, demonstrating versatility across all categories with notable average precision accuracies for rifles (98.90%), handguns (96.93%), and knives (97.66%). Enhancements to the Python script improved the system's ability to detect weapons sub-objects in human subjects and classify potential perpetrators as high risk, a novel aspect of this study.

Keywords: deep learning, machine learning, yolov4 detector, convolutional neural network (CNN), artificial intelligence, object detection, computer vision, object classification, deep-sort algorithm. dataset training.

GJCST-D Classification: LCC Code: TK5105.59

ENHANCEDCRIMEPREDICTIONWITHCOMPUTERVISIONYOLOV4APPROACH

Strictly as per the compliance and regulations of:

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Taiwo. M. Akinmuyisitan [α] & John Cosmas [σ]

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Keywords: deep learning, machine learning, yolov4 detector, convolutional neural network (CNN), artificial intelligence, object detection, computer vision, object classification, deep-sort algorithm. dataset training.

I. Introduction

Widespread criminal violence across the world has informed critical stakeholders especially those in government to consider a paradigm shift in addressing increasing crime surges. Traditional policing techniques as noted by smith [1] have become a subject of public discourse, with many questioning their effectiveness. Despite increased funding and personnel, traditional policing techniques alone may not be sufficient to counter exponential rise in global crime. Police personnel and other security agencies are already overwhelmed and now struggling to keep pace with modern tactics employed by criminals [11]. The escalating dynamism of criminals exposes the significant shortfall in both manpower and innovative technology that are necessary to adequately combat these challenges [1].

The persistence loss of life, and properties from crimes such as arson, armed robbery and kidnapping, coupled with organized crimes, and mob actions have invited the urgent need for preemptive innovative approaches to crime detection and predictions across the globe. Traditional methods have shown its inadequacy due to the unpredictable nature of crimes which seems unforeseeable to the public. However emerging technologies such as artificial intelligence offer a promising solution, capable of detecting and predicting activities with sufficient training data [2].

Several approaches to crime predictions in recent times have been toward predictive modeling. With the increasing surveillance technologies such as CCTV, researchers are increasingly focusing on object detection algorithms. These methods enable CCTV systems as a vigilant observer, supplying in real-time data to computer vision models for immediate analysis. A common of these algorithms is the use of YOLOv4 short for "You Only Look Once." Which is known for its efficiency and accuracy in object detection. This paper proposes the use Yolov4 to predict violent crime and persons who are more likely to commit crime and identify individuals who are likely to commit crimes in the future.

Yolov4 by default is an object detection algorithm this research however makes a unique contribution by integrating this algorithm (Yolov4) into predictive models, thereby enhancing the predictive capabilities of traditional surveillance systems (CCTV). This research unlike existing methods is leveraging on an advanced object detection algorithm to provide accurate and timely predictions of criminal activities.

The remainder of this paper is arranged as follows: section II reviews related theories and methodologies that have been used to detect and predict crimes. Section III discusses the materials and methods while the presentation of our findings, results, and discussion is contained in Section IV. The study's conclusion and recommendations are in Section V.

II. Literature Review

Over the years, Convolutional Neural Networks (CNNs) have proven highly effective processing images and detecting objects. CNNs specialized in image recognition, consists of multiple layers that perform distinct but well-connected tasks. CNNs are neural networks specialized for image recognition, structured with multiple layers, each executing distinct tasks. The input layer receives the Images dataset which then processed by convolutional layer to extract essential features. The pooling layer reduces output dimensions by pooling pixels from fixed-size squares, enhancing

Author: e-mail: mails4taiwo@gmail.com

error tolerance and the fully connected layer channels this output to multiple neurons corresponding to detected objects. Finally the output layers identifies the object class and its coordinates [3], [4].

CNNs exhibit versatility, capable of discerning diverse objects like humans, vehicles, animals, and even individual alphabets. All object detection algorithms one way or another somehow involve convolutional neural networks and thus make CNN an important architecture in the Yolov4 algorithms and single-shot detection models which are two of the modern detection models available.

a) CNN-based Methods

Several researchers have applied CNN-based methods to crime prediction. For example [5]developed a system to detects firearms and knives captured by cameras, using principal component analysis (PCA) and MPEG-7 with a window technique to achieve an accuracy of 96.96% similarly,[6], used faster R-CNN to detect firearms, achieving an accuracy of 93.1%. These methods demonstrates the capability of CNN in enhancing crime detection using an advanced image processing methods

b) Facial Recognition

Facial expression is another critical area in AI-driven crime prediction techniques. According to [7]facial recognition has modernized criminal profiling and surveillance which therefore increase the efficiency of traditional policing. [1] were motivated by their belief that if it was possible to know and determine someone that is sad based on facial expression then it may also be possible to know criminals just by facial expression, this motivation led them to the results they arrived at in their paper titled “Advanced Convolutional Neural Network Paradigms-Comparison of VGG16 with Resnet50 in Crime detection”. The author used A-CNN to extract distinctive features of criminals and non-criminals and was able to classify criminal and noncriminal faces, achieving remarkable training accuracy of 98.10% and 95.05% on VGG16 and Resnet50respectively. This demonstrates the potential of facial recognition in predicting criminals based on visual cues.

c) Traditional Methods

Other methods for predicting crimes include stingray an outdated but still common method used by police to track criminals [20], polygraph, a lie detector invented in 1920s was a significant milestone in detecting criminal suspects by measuring their psychological responses. However, with the current dynamism of the criminal intellects, many suspects having studied the working principle of polygraphs which are sensory of human pulses now evade being detected by polygraph rendering these methods less effective over the time [21]

d) Literature Review Gaps

While conventional CNN-based methods and facial recognition technologies show promise in various applications, they present challenges such as potential biases and limitations in predicting criminal activities in pre-crime scenarios. Additionally, traditional methods like polygraph tests and stingray technology are becoming less effective as criminals find ways to evade detection.

The evolving sophistication of criminal behaviour underscores the critical need for more integrated approaches to crime prediction. This study aims to address this need by utilizing YOLOv4 to enhance crime prediction models. YOLOv4 offers advantages in real-time processing capabilities, speed, and accuracy, making it particularly suitable for applications that require live monitoring, such as surveillance of crime hotspots. This will be further enhanced through the implementation of Python scripts to assess the culpability of individuals in pre-crime scenarios upon detection of any criminal weapons on a subject.

III. Materials and Methods

This section explores the methodologies used to achieve the results contained in section V. The methods here entirely depend on Yolov4, which uses darknet53 as a framework. However, because of the peculiarity of this study, our model was trained almost from scratch on a custom dataset. Also included in this section are hardware configuration, processes, and techniques involved in building custom object detectors specifically for the prediction of crimes.

a) Novelty

The crux of this research lies in its innovative approach to detecting sub-objects, specifically weapons, on individuals, thereby enabling the identification of potentially high-risk individuals within precrime scenarios. This technological advancement holds the promise of revolutionizing the landscape of law enforcement and security protocols, ushering in a new era of initiative-taking crime mitigation strategies.

By harnessing the power of artificial intelligence and cutting-edge algorithms, this research not only seeks to enhance the efficacy of law enforcement agencies but also aims to safeguard communities by pre-empting criminal incidents before they transpire. The fusion of technology and criminology encapsulated in this study heralds a future where predictive analytics and pre-emptive interventions are poised to redefine the dynamics of crime prevention.

b) Data Collection and Processing

i. *Data Acquisition*

Implementing a Yolov4-based crime prediction for this research paper requires quite an enormous dataset. The dataset for training was carefully sourced, exclusively with the intended result in mind. For the system development, we essentially utilized secondary dataset. video dataset from crime video clips were acquired from royalty free sites.

These instances were created to mimic criminals and criminal intents upon which our system would be finally tested to know if the model generalizes well to identifying a person holding a firearm, wandering suspiciously, persons with formidable looks, including face-masking ruffians, and thus classify them as High-Risk based on predefined policies set as antisocial and criminal attributes in the society.

Additionally, we augmented our dataset by sourcing images with additional videos of weapons online using Google Chrome "Download all" extension and incorporated the UCF-crime dataset, which includes real-life videos and frames from surveillance cameras with labels such as assault and robbery [22].

Here is the list of weapons trained.

- Gun (Shotgun, Handgun, Riffle)
- Knives

Fig. 1: UCF-Dataset [22]

ii. *Data Annotation*

Data annotation is the categorization and labeling of data for artificial intelligence applications. For this study we manually labelled all frames using Yolo annotation tools particularly labelimg. Which therefore ensure accurate representation of objects.

The two Annotation tools for YOLO are:

1. Labeling (The labeling used to label still images)
2. Dark label (Dark label used to annotate video footage)

Labelimg can be installed using "*pip install labelimg*" for Linux and window users and can be launched by "*labelImg*"

We used labelimg because of the following reasons.

- LabelImg is easy to install.
- Convert directly to Yolov4 format.
- Open source.

The labelImg tool was used to label the five classes of interest which are the following.

- Person
- Handgun
- Shotgun
- Knife
- Riffle

Annotating a dataset is the art of labeling objects and storing the coordinates of the objects [19]. In this design, and as earlier stated, labeling involves placing a rectangular box on the object and this automatically gets the coordinates of the object and is stored in text files. The text files (.txt) contain the following.

- Class Name
- Object Center Coordinates (x,y)
- Object Dimensions (width, height)

This together form the is termed the Yolo annotation format

iii. *Annotation format*

During the annotation of the dataset, five things happen simultaneously, and they are.

a. Class Name
b. Object center coordinates in x = $Center\ X/ImageWidth$
c. Object center coordinates in y = $Center\ y/ImageHeight$
d. Object width = $ObjectWidth/ImageWidth$
e. Object Height = $ObjectHeight/ImageHeight$

c) System Algorithm Framework

YOLO, from the name that implies "You-Only-Look-Once" is an algorithm that takes an entire image at once and predicts for these boxes the bounding box coordinates and class probabilities [8]. YOLO's most significant advantage is its unprecedented pace, it is speedy, and it can run 45 frames per second. Among the earliest versions of YOLO, version 4 is the fastest and most accurate in detecting objects.

The proposed algorithm, YOLO version 4, consists of 53 convolution layers. The architecture is made up of three different layer forms. Firstly, the residual layer is formed when the activation is easily forwarded to an inner-layer neural network [9]. In a residual setup, the result of layer one is summed to the output of layer 2. The second is the detection layer which performs detection at three different scales or stages. The size of the grids is increased for detection. The third is the up-sampling layer which increases the spatial resolution. Here the image is up-sampled before it is scaled. Also, the concatenation operation is used to concatenate the outputs of the previous layer to the presentation layer. The addition operation is used to add previous layers.

Figure 2.0 shows the architecture of yolov4. For clarity's sake and especially for our use case, the system architecture takes in our captured videos as input images; these caught videos are our dataset which was passed through the yolov4 object detection algorithm. In the yolov4 object detection module, the Yolo takes input frames first, and these frames are divided into grids, say 3 x 3, and on each grid, there is image classification and localization.

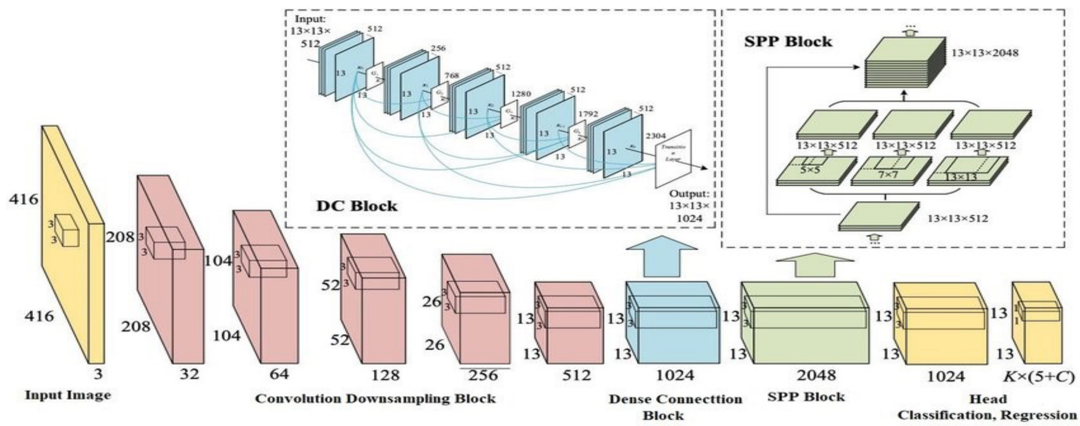

Fig. 2: YOLOv4 computer vision architecture [10]

d) Model Setup

We used yolov4 with Darknet53 as the backbone. The configuration file (.cfg) was modified to suit our custom dataset with its five classes

- *Setting up the .cfg file*

To Train a custom dataset on the darknet framework requires cloning of AlexAB repository into the local directory using "*git clone*" and then reconfiguring the cfg file that is contained inside the darknet-cfg folder of the cloned repository.

The .cfg file is replicated and the following design parameters are modified.

1. *Image Dimensions:* Set to 320x320 to fit memory constraints
2. *Batch Size:* 64, split into mini-batches for processing
3. *Max Batches:* 10,000, calculated as C×2000where C is the number of classes
4. *Steps:* 80% and 90% of max_batches
5. *Filters:* Set to 30, calculated as (C+5)×3
6. *Learning Rate:* Set at 0.001

After all these changes in the cfg file, it was then saved and named "yolo-obj.cfg"we then split the dataset into training and test set at 80/20 ratios.

- *Setting Up Meta Data (obj)*

The following metadata was additionally created;

i. *Obj.names:* It contained the names of the classes.
ii. *obj.data* contains

1. Total number of our classes=5
2. The training and validation path,
3. Path to our obj. names
4. The directory where our weights would be saved.

e) Evaluation Metrics Performance Metrics

We used the following metrics to evaluate the performance of our model.

- *Mean average precision (mAP):* It was the standard performance metric for an object detection model. It is the common way of seeing how novel the algorithm performs over the individual classes and the whole model [16]. It combines two important aspects: precision and recall, detailing a comprehensive model's ability to locate and classify objects in each frame. To compute mAP, precision-recall curves are constructed for each class of objects in our dataset. These curves plot precision against recall at different confidence score thresholds. The area under the curves was then averaged across all object classes [17]. The mAP is a valuable metric for knowing the accuracy of object detection models. It offers a balanced evaluation by considering precision and recall, making it particularly suitable for object detection and classification problems.

$$\text{mAP} = \frac{1}{N}\sum_{i=1}^{N} AP_i \qquad (5)$$

Where,

N = Number of classes

AP_i= Average precision for each class i.

- *Precision:* Precision tells the proportion of correctly identified objects out of all the detections made by the model [18].

$$\text{Precision} = \frac{TP}{TP+FP} \qquad (6)$$

Where.

TP= True Positive,

FP = False Positive

- *Recall:* It measures the model's ability to find all relevant objects, minimizing false negatives [18].

$$\text{Recall} = \frac{TP}{TP+FN} \qquad (7)$$

Here

FN= False Negative.

- *F1 Value*

The F1 score is the harmonic mean of precision and recall and provides a balance between the two metrics.

It is calculated as:

[F1 Score = 2 \times \frac {Precision \times Recall} {Precision + Recall}]

(12)

For simplicity,

- Precision focuses on the accuracy of positive predictions.
- Recall focuses on the proportion of actual positives that were correctly identified.
- F1 score provides a balance between precision and recall, especially when there is an uneven class distribution.

f) Justification

Yolov4 which by default uses darknet53 was selected for its speed and accuracy in real-time. It's capable of processing 45 frames per second. Custom training was necessary due to the specificity of our crime scenarios and the need for tailored objection detection.

g) Deep SORT Algorithm

Deep-SORT, an advanced tracking algorithm, enhances the Hungarian algorithm by integrating appearance information to link new detections to previously identified objects. Stemming from SORT, Deep-SORT employs deep learning techniques, using detection models like YOLO or Faster R-CNN to locate human figures in video frames [12]. It assigns unique embeddings to objects, crucial for tracking across frames [13]. Deep-SORT excels in associating detections across frames, facilitated by the Hungarian algorithm and Kalman filtering, which mitigates inaccuracies and handles occlusions seamlessly. The algorithm optimizes assignment using a cost function that balances spatial and visual distances between detections and tracks [14].

The spatial distance, represented by mahala Nobis distance, which is calculated as in equation 7, accounts for predicted positions, while visual distance measures appearance dissimilarity using feature vectors from a residual neural network. Cosine distance serves as the similarity metric. Appearance descriptors are normalized, enabling cosine distance calculations. The process ensures robust tracking in crowded and challenging environments [15].

$$\text{spatial } (i,j) = (xj - x\hat{}i)T \cdot Si - 1 \cdot (xj - x\hat{}i) \qquad (7)$$

Where.

xj is the centroid (or other representative point) of the detected bounding box *j*.

x^i is the predicted centroid of the tracked object *I* based on its last known position.

Si is the covariance matrix associated with the predicted position of the tracked object *i*.

T denotes the transpose operation.

IV. Results and Discussion

The research was conducted on core i5 HP Pavilion with 16GB RAM, a 4 GB Nvidia dedicated graphics card (GPU 1050ti), CUDA 10.1, and Cudnn7.6 on an Ubuntu system distribution. We implemented this research using the YOLOv4 darknet framework cloned from the AlexAB repository. The dataset was a mix of data from a UCF dataset of known criminals, and open-source data of images of guns, knives, and persons. Training this model requires careful annotation of images using a frame-by-frame annotation technique. The Center coordinates in X, Y, the object widths and heights, and the classes they belong to were determined simultaneously during the process of annotation using labelimg. This positioning of images was crucial during training to ensure accurate object localization and class recognition. The training was conducted on 3317 datasets, specially selected for this research, in 64 batches over 10000 iterations. The performance of our model is shown in Fig 3 (a) and Fig 3 (b) below.

```
[yolo] params: iou loss: ciou (4), iou_norm: 0.07, obj_norm: 1.00,
cls_norm: 1.00, delta_norm: 1.00, scale_x_y: 1.05
nms_kind: greedynms (1), beta = 0.600000
Total BFLOPS 59.592
avg_outputs = 490304
 Allocate additional workspace_size = 52.44 MB
Loading weights from /mydrive/Model/training/yolo-obj_last.weights...
 seen 64, trained: 640 K-images (10 Kilo-batches_64)
Done! Loaded 162 layers from weights-file

 calculation mAP (mean average precision)...
 Detection layer: 139 - type = 28
 Detection layer: 150 - type = 28
 Detection layer: 161 - type = 28
332
 detections_count = 2537, unique_truth_count = 1017
class_id = 0, name = Person, ap = 75.99%       (TP = 453, FP = 169)
class_id = 1, name = Shotgun, ap = 91.97%      (TP = 40, FP = 3)
class_id = 2, name = Handgun, ap = 92.86%      (TP = 57, FP = 1)
class_id = 3, name = Knife, ap = 96.11%        (TP = 80, FP = 2)
class_id = 4, name = Rifle, ap = 95.98%        (TP = 128, FP = 13)

 for conf_thresh = 0.25, precision = 0.80, recall = 0.75, F1-score = 0.77
 for conf_thresh = 0.25, TP = 758, FP = 188, FN = 259, average IoU = 63.97
%

 IoU threshold = 50 %, used Area-Under-Curve for each unique Recall
 mean average precision (mAP@0.50) = 0.90582, or 90.58 %
Total Detection Time: 119 Seconds

Set -points flag:
 `-points 101` for MS COCO
 `-points 11` for PascalVOC 2007 (uncomment `difficult` in voc.data)
 `-points 0` (AUC) for ImageNet, PascalVOC 2010-2012, your custom dataset
```

Fig. 3(a): mAP

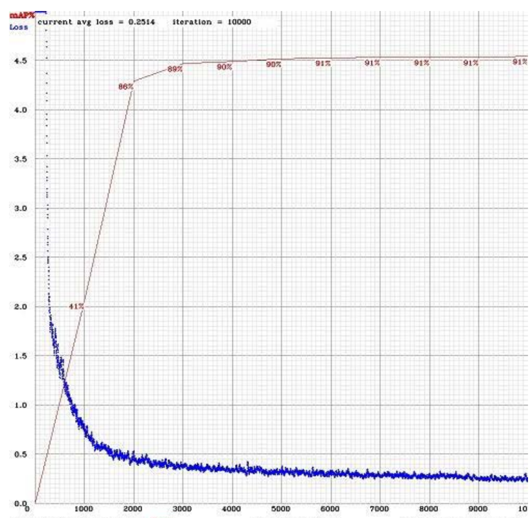

Fig. 3(b): Model Performance

As shown in Fig. 3(b) the model struggled initially with the mean average precision (mAP) of 41.03% for the first 1000. However, over the next 1000 iterations, the performance rose to a significant 86.43%. This improvement is likely due to the exposure of the model to more training data and beginning to understand the features necessary for accurate predictions.

Fig. 4a: Handgun Sample Input Image

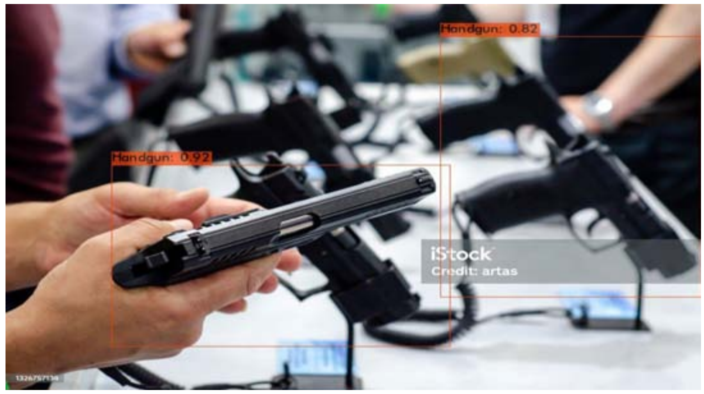

Fig. 4(b): Model Detection Result for Handgun

This assumption was validated as the mean average prediction calculated from 4000 weight and up to 10000th weight maintained an average of 91% mAP. This is shown in Fig. 3b). During this phase, the model already had learned all that is necessary to accurately distinguish, categorize, and predict objects in their various classes. So, the best weight recorded at the 10th saved weight.

Fig. 5(a): Knife Sample Input Image

Fig. 5(b): Model Detection Result for Knife

Fig. 6(a): Shotgun Sample Input Image

Fig. 6(b): Model Detection Result for Shotgun

For YOLOv4, Table 1 shows the average precision for each of the classes.

Table 1.0: Class AP performance

Class Name	AP (%)	TP	FP
Person	75.99	453	169
Shotgun	91.97	40	3
Handgun	92.86	57	1
Knife	96.11	80	2
Rifle	95.98	128	13

We set a confidence threshold of 0.25 to filter out predictions below this threshold, ensuring a reliable detection mechanism. Notably, the "Person" class achieved an average precision (AP) of 75.99%. The model demonstrated strong capabilities in identifying "Person" instances, with 453 true positives (TP) and 169 false positives (FP), suggesting significant improvement from prior iterations following re-annotation and model fine-tuning. The "Shotgun" class (class_id = 1) achieved an AP of 91.97%, reflecting its proficiency in detecting such objects. With 40 true positives and 3 false positives, the model exhibited commendable precision and recall for "Shotgun" instances, outperforming its performance in the "Person" class. The "Handgun" class (class_id = 2) showcased even higher accuracy, with an AP of 92.86%. The model accurately identified 57 instances of handguns while encountering only 1 false positive, highlighting its ability to discern intricate features of handguns with precision and reliability.

At a detection threshold of 0.25 Table 2.0(a) shows the confusion matrix of the model which shows results of the model's precision, recall, and F1_score while Table 2.0(b) shows results for the True Positive, False Positive, False Negative at a detection counts of 2537 with 1017 unique truth counts.

Table 2.0(a): Confusion Matrix of the Model

Precision	Recall	F1_Score
0.80	0.75	0.77

Table 2.0 (b): Confusion Matrix

TP	FP	FN
758	188	259

Fig. 7 (a): Crime Video Scenario

Fig. 7 (b): High-Risk Person Detection and Prediction

Moreover, the model demonstrated the highest accuracy in recognizing "Knife" instances (class_id = 3), achieving an AP of 96.11%. With only 2 false positives, the model's 80 true positives underscore its robustness in identifying potential threats posed by knives, significantly contributing to anomaly detection systems. The "Rifle" class (class_id = 4) yielded an AP of 95.98%, underscoring the model's exceptional ability to detect rifles. With 128 true positives and 13 false positives, the model demonstrated a remarkable capability to discern criminal scenes associated with rifles, making it an asset in threat detection scenarios. Figures 5a, 6a, and 7a show the input images to our model, while Figures 5b, 6b, and 7b respectively show the results of our model.

The study involves the use of an object detection algorithm for the detection or classification of persons of high risk therefore, we use related detection algorithms to benchmark the performance of this research. In this research when compared with a Yolov4 on UAV imagery, our model performance as shown in Table 1.0 performed greatly, showed superior precisions when compared to the work carried out by [23]; in this related work, the overall mAP was 62.71% with “Person” at 48.67%, for the same class in this research we achieved 75.99% mAP. Additionally, an improved Yolov4 model on the S2TLD dataset also from [23] achieved an mAP of overall mAP of 96.98% with classes such as “Red Light” demonstrating an AP as high as 98.15%; our model demonstrates its competitiveness with its overall mAP.

V. Conclusion

In conclusion, our research on human tracking and anomaly detection presents a systematic approach to bolstering security and surveillance in complex environments. The primary aim of this research was to readapt an object detection algorithm such as Yolov4 for the detection and classification of crime scenes and use deep learning techniques to identify high-risk individuals based on the objects they possess and actions that they may suggest whether or not they are a person of high risk.

Leveraging a local HP Pavilion gaming machine with specific hardware specifications and a dataset comprising 3317instances from diverse sources, including the UCF crime open dataset. Our model was built on YOLOv4 architecture, it adeptly predicts, and categorizes objects most found in a crime scene, and uses this to predict whether the person holding it is a person of highrisk.

Meticulous annotation and dataset transformation facilitated efficient processing. Despite initial challenges, our model significantly improved, achieving an average precision of 86.43% after 2000 iterations and maintaining 90% from 4000 to 10000 iterations, signifying successful object classification. Table 1 illustrates the model's performance across classes, with notable precision in identifying rifles (98.90%), handguns (96.93%), and knives (97.66%). True positive and false positive values offer insights into accurate instance identification while minimizing misclassifications.

The significance of our findings extends beyond the immediate results. Our model's ability to predict high-risk scenarios is particularly valuable in real-world surveillance applications, providing a robust tool for enhancing security measures. By successfully integrating advanced deep learning techniques, our study contributes to the literature on anomaly detection, especially concerning crime-related behaviors captured in surveillance videos.

However, our study is not without limitations. The dataset, while diverse, may still not cover all possible real-world scenarios, affecting the model's generalizability. Additionally, computational constraints limited the scale of our experiments. Future research could focus on expanding the dataset, improving annotation techniques, and exploring more powerful computational resources to further enhance model performance.

Our study highlights the beauty of our model in predicting high-risk scenarios, particularly in real-world surveillance applications. Advanced deep learning techniques. Our findings contribute to anomaly detection literature, especially concerning crime-related behaviors captured in surveillance videos.

Future improvements could be around expanding the weapons to accommodate contemporary crime-related weapons like bottles, IEDs, etc. Additionally, careful study of criminals must be undertaken to understand the actions underlying the crimes committed, and their nature. For this, an advanced feature extraction could be used to understand actions before a crime.

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Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

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Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for writing a good quality Computer Science Research Paper

Techniques for writing a good quality computer science research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of computer science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10.Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- o Report the method and not the particulars of each process that engaged the same methodology.
- o Describe the method entirely.
- o To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- o Simplify—detail how procedures were completed, not how they were performed on a particular day.
- o If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- o Resources and methods are not a set of information.
- o Skip all descriptive information and surroundings—save it for the argument.
- o Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

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Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals Inc. (US).

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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