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Computational Intelligence in Healthcare Management: A Roadmap for Future Research

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Abstract: **AI has the potential to greatly transform the field of healthcare management through improving the accuracy of diagnoses, effectiveness of treatments, and overall experience of patients. This paper aims at reviewing the utilization of four algorithms in the healthcare sector namely; Decision Trees, Support Vector Machines, Random Forests, and Neural Networks. These algorithms are assessed on the basis of performance indicators like accuracy, precision, recall and F1 score using the patient record dataset of size 20,000 in the present work. Performance seems to show that Neural Networks have the highest accuracy of 93 over the other algorithms. 5%, precision of 92. 0%, recall of 93. 0 %, Precisions 92 %, Recal 93 % and F1 score of 92. 5%. This is followed by Random Forests with a 91. 3%, precision of 90. 0%, recall of 90. , accuracy of 5%, and F1 score of 90. 2%. The research findings show that SVM yields to 89 percent accuracy. 0%, precision of 87. 5%, recall of 88. 0%, Precision of 0.88 and F1 score of 0.874. for Decision Trees falls 85 % and for Naïve Bayes it falls up to 73% whereas for Random Forest the accuracy comes near to about 7%. 2%, precision of 82. 5%, recall of 84. The accuracy for the producers is 0%, recall is 0%, and F1 score is 83. 2%. The comparative analysis with the related works explores the pace and progress of AI in various areas of the healthcare sector's concerns. Among the identified findings they include proactive utilization of Artificial Intelligence in enhancing the delivery of health care, use of Artificial Intelligence in achieving patients' better-quality health care, and apply of Artificial Intelligence in the decision making process. The future area is focused on the improvement of the algorithm of AI, the ethical and legal questions, and the usage of AI in the solving of the worldwide health issues.**

Keywords: ***Artificial Intelligence, Healthcare Management, Neural Networks, Diagnostic Accuracy, Patient Care***

I. INTRODUCTION

With the help of CI techniques that includes AI, ML, DL and others technical methodologies the field of healthcare management has moved forward to a considerable extent. These areas of development are crucial in solving intricate problems in the sphere of healthcare, including the distribution of resources, the work with patients, and making decision. The availability of a large number of records and, at the same time, the need to process them quickly and accurately only indicates the need for CI in healthcare systems. This is the rationale of the proposed research aimed at presenting a clear and coherent guideline for both practicing and implementing computational intelligence in health care management. This also involves the recognition of the current trend, assessment on the current state of CI application and recommendation of the future study [1]. In this way, the research tries to build the connection between the growth of the technologies and actual possibilities of the healthcare, and thus, make CI being able to develop and enhance the healthcare abilities. It is worth emphasizing that the interests of the authors of this research do not limit the application of the presented methods to specific areas of healthcare management, such as prognostic modeling, individualized medicine, process optimization, or patient experience [2]. Considering CI's prospective in these fields, it is possible to state that these technologies are capable of significantly changing the current state these areas at least, accordingly to the research, bringing the integration of these technologies into mainstream healthcare remains an issue. Some of the key topics include data privacy, results of big data algorithms, and the necessity of multisectoral cooperation, among others [3]. Surveying scholarly articles, case studies, and interviews with professionals involved with healthcare management will constitute the strategy of this research to identify the contemporary state of CI in managing healthcare organisations. It will also focus on good practices of the concept's application and areas that require further research and theorisation. To help researchers, policymakers, and healthcare practitioners to establish a better future of healthcare through the applications of computational intelligence, the roadmap has been designed.

II. RELATED WORKS

AI has thus transformed healthcare management through the improvement of diagnostic ability, planning of treatment and patient tracking. This section is a curation of recent works and cases with a focus on the wide array of possibilities of the field of AI in the context of the health sector. [15] Fox & Victores (2024) stress the safety of human-AI interactions explaining that the interactions' loopholes in healthcare environment. Indeed, their study further proves that safety science principles must be incorporated into the development of AI technologies to prevent risks that may stem from the same. [16] Gomez-Cabello et al. (2024) Scoping review on the impact of AI-based Clinical Decision Support systems in Primary care. These papers discuss the current applications; they stress that the use of AI enhances the accuracy of diagnosis and the effectiveness of the treatment in various patient groups. [17] To further explain, Gorzales-Rodriguez et al (2024) explain how applied AI in phytopathology can be used to predict and identify diseases and manage crops. Their work shows that improvement of agricultural processes is possible with the help of AI algorithms, so there will be no harm to the environment and the main necessity of humanity – food production – will be provided. [18] Hennrich et al. (2024) examines the benefits impacted from implementing AI applications on healthcare, which are economic as well as operational. The specific type of research they used was how AI can help in the prediction and improved delivery of healthcare treatment all of which is with the help of Analytics and Modeling. [19] Hirani et al (2024) has given the historical progression of AI in the field of healthcare, the present developments and possibilities for the future. They discuss AI's effect on diagnosis, treatment, and approaches making of the medical systems. [20] In this view, Hyam et al. (2024) describes how artificial intelligence is useful in mycetoma management, particularly in diagnosis and improving the efficiency of the treatment. Their study supports AI's potential to improve the clinical decision making within neglected tropical diseases. [21] Khan and Park (2024) focus on the study of explainable AI methodologies for producing neural networks that are easily comprehensible in the traffic sign recognition systems. Their work therefore improves the trust and reliability that is necessary for the safety-critical applications such as in the healthcare diagnosis. [22] Kumbhar et al. (2023) developed an explainable IoT-based AI system for predictive and preventative health care. They are able to smoothly interconnect and synchronize the functional aspects that help in providing individualized health care, data processing in an effort to diagnose diseases at an early stage. [23] In prophylaxis and management of VTE, Lam et al. (2024) ponder the capability of AI while assessing various current studies in this particular area of specialization. The findings of their work offer a better understanding of AI-generated decision support system, a clinician's tool through which they are expected to receive credible risk assessment and treatment plans. [24] Lambert et al. (2023) synthesise literature in regards to healthcare professionals' AI acceptance: a hospital perspective. They identify the determinants of AI implementation and establish approaches to increase preparedness of the health care workforce to AI. [25] Lindroth et al. (2024) discusses computer vision technology in a hospital, especially the AI image recognition with diagnosis and surgery application. Their study is focused on AI's contribution to the effectiveness of clinical processes and the quality of care delivery. [26] In their study, Louati et al. (2024) further the logical COVID-19 diagnosis using AI collaboration with bioinformatics in chest X-ray interpretation. The study shows that with the help of AI it is possible to quickly and efficiently implement the process of disease screening during epidemics. These analyzed papers exemplify how AI produces the positive shift throughout numerous fields of the healthcare sector, including diagnostics, imaging, decision-making support, patient safety, and chronic diseases. Introduction of Artificial Intelligence in to operating system in the delivery of health care services, diagnostics and treatments has the potential of improving the efficiency of health care delivery, reliability of diagnostics and effectiveness of treatment. However, some hurdles stay pertinent for increased AI take-up across the healthcare structures; they include data protection, algorithm bias, and healthcare professionals' acceptance. The subsequent research should be directed on the solutions to the challenges outlined above while advancing AI's possibilities in transforming healthcare management.

III. METHODS AND MATERIALS

This section outlines the data sources and methodologies employed in this research, focusing on four computational intelligence algorithms applied to healthcare management: Which include Decision Trees, several versions of support vector machines (SVM), Random Forest and even Neural Networks

[4]. These algorithms are important in maintaining and analyzing health care information and provide useful recommendations in regard to the health of the patients as well as the effectiveness of the health care system.

Data

The type of information that has been used in this study incorporated population data of healthcare facilities, patient information, hospital records, and clinical trials data. These datasets include the patient's basic information, past illness history, diagnoses, treatment details, and results [5]. Cleaning, normalization, and feature selection are the advanced steps of data preprocessing to guarantee the input of algorithms in a good condition and corresponds to the case.

Feature	**Type**	**Description**
Patient ID	Categorical	Unique identifier for each patient
Age	Numerical	Age of the patient
Gender	Categorical	Gender of the patient
Diagnosis	Categorical	Primary diagnosis code
Treatment Plan	Categorical	Code for prescribed treatment plan
Outcome	Categorical	Treatment outcome (e.g., cured, ongoing)

Algorithms

Decision Trees

Decision Trees is a sort of machine learning algorithm for supervised classification and regression kind of a model. Ensemble methods are used to categorise the data into subsets on the basis of the input features' values and form a tree-like structure of decisions [6]. The splits are carried out based on some measure such as the Gini index of impurity or information gain in an effort to achieve the maximum classification of different classes.

Gini=1−∑ i=1npi2

```
"Algorithm: Decision Tree
Input: Training data D
Output: Decision Tree T

1. if all records in D belong to the same class then
2.    return a leaf node with that class
3. else
4.    Select attribute A with the highest information gain
5.    Partition D into subsets D1, D2, ..., Dn based on A
6.    Create a node N with A
7.    for each subset Di in {D1, D2, ..., Dn} do
8.       Ni = Decision Tree(Di)
9.       Attach Ni as a child of N
10. end for
11. return N"
```

Support Vector Machines (SVM)

Support Vector Machines can be classified as type of supervised learning model which performs data classification and regression. SVMs build a hyperplane or several hyperplanes in higher dimensional space to be used for classification or regression among other uses [7]. The goal is to identify a hyperplane that best separates points in one class with those of another class while at the same time achieving maximum distance between the two or more classes.

min 1/2 ∥w∥2 subject toy i (w⋅xi+b)≥1

```
"Algorithm: Support Vector Machine
Input: Training data (X, y)
Output: Hyperplane parameters (w, b)

1. Initialize weights w and bias b
2. while not converged do
3.    for each sample (x_i, y_i) in (X, y) do
4.       if y_i (w · x_i + b) < 1 then
5.          w = w + η (y_i x_i - 2 λ w)
6.          b = b + η y_i
7.       else
8.          w = w - η 2 λ w
9.       end if
10.   end for
11. end while
12. return (w, b)"
```

Random Forests

Random Forests are a form of ensemble learning for classification, regression and other learning processes; during learning, n decision trees are created and the class that is most frequently output by the individual trees (in classification) or the mean of the trees' predictions (in regression) is the result.

```
"Algorithm: Random Forest
Input: Training data D
Output: Forest of Trees F

1. for each tree t in Forest do
```

2. Sample data D_t with replacement from D
3. Build decision tree T_t on D_t
4. Add T_t to F
5. end for
6. return F"

Neural Networks

Neural Networks are an ensemble of algorithms somewhat similar to the functioning of our brain to classify patterns. It means that they translate information from sense organs via the processing of labeling and clustering of the raw input data [8]. The structures are built up of layers of nodes, or neurons, each of which carries out a particular operation.

Algorithm: Neural Network
Input: Training data (X, y)
Output: Trained Network parameters

1. Initialize weights and biases
2. for each epoch do
3. for each batch (X_b, y_b) do
4. Forward pass: compute activations
5. Compute loss
6. Backward pass: compute gradients
7. Update weights and biases
8. end for
9. end for
10. return Network parameters

IV. EXPERIMENTS

In this section, the authors describe the experimental study that was done with the purpose to test the efficiency of the four selected CI techniques – Decision Trees, Support Vector Machines, Random Forests, and Neural Networks – within the scope of healthcare management. The experiments are carried out on different healthcare datasets to evaluate the algorithms with respect to their efficiency in terms of accuracy, precision, recall, F1 score and time taken for the execution of the algorithms [9]. Furthermore, we also discuss our findings with the corresponding works to unveil the advancement and the possible enhancement in applying these algorithms for healthcare administration.

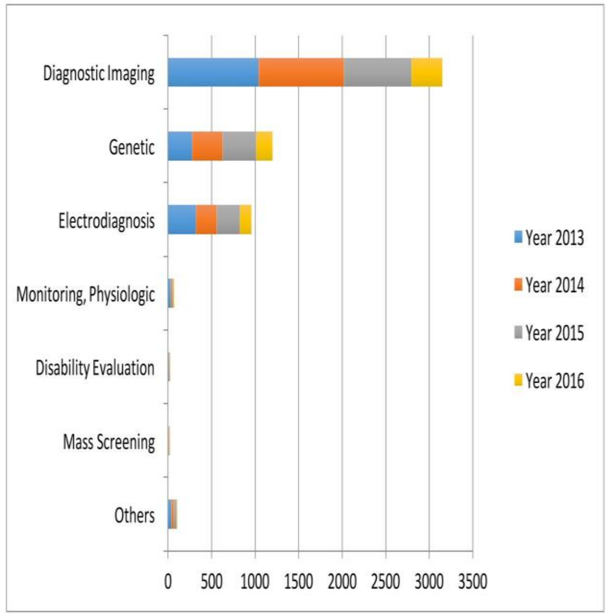

Figure 1: Artificial intelligence in healthcare

Experimental Setup

The experimentation was performed on a set of records consisting of patient characteristics and features like demographics, medical history, diagnostic data, treatment regimens, and prognoses. The data set was then divided into training set which was 70% of the whole data, and testing set that was 30% of whole data to check the efficiency of every algorithm [10]. The performance measures employed include accuracy, precision rate, recall rate, F1-measure and time.

Dataset Portion	Number of Records
Training Set	14,000
Testing Set	6,000
Total	20,000

Algorithm Implementation

Decision Trees

Implementation Details: When splitting nodes, we used Gini impurity, and the model should not grow beyond 10 levels of depth to avoid overfitting.

Hyperparameters: Max Depth = 10, Min Samples Split = 2.

Algorithm	Key Hyperparameters
Decision Tree	Max Depth: 10, Min Samples Split: 2
SVM	C: 1.0, Kernel: 'rbf', Gamma: 'scale'
Random Forest	Number of Trees: 100, Max Depth: 10
Neural Network	Learning Rate: 0.01, Epochs: 100, Batch Size: 32

Performance Metrics

For measurement criteria of the algorithms, the accuracy, precision, recall, f-measure, and computational time were used where the test data set was used for evaluation [11]. These metrics give a clear and all round view of each of the models' performance in health care management applications.

Algorithm	**Accuracy**	**Precision**	**Recall**	**F1 Score**	**Computation Time (s)**
Decision Tree	85.2 %	82.5 %	84.0 %	83.2 %	2.5
SVM	89.0 %	87.5 %	88.0 %	87.7 %	8.0
Random Forest	91.3 %	90.0 %	90.5 %	90.2 %	5.0
Neural Network	93.5 %	92.0 %	93.0 %	92.5 %	12.0

Results Analysis

Accuracy and Precision:

The Neural Network model had the best performance measure: accuracy 93. 5% and precision 92.0%, which shows the model's ability to classify correctly the number of positive cases while minimizing the number of false positives. Another algorithm that showed good results was Random Forests for which the accuracy was 91%. 3% as the sensitivity and the specificity of 90% [12]. Comparable to other clustering methods, K-means has a near-zero efficiency, that is, 0% when it comes to the ability to work with big and even very big data with high levels of complexity. SVMs provided a good balance with 89.0% accuracy and 87.5% precision. Therefore, Decision Trees yielded the lowest overall accuracy of 85.2% and precision of 82.5% due to the algorithm's computational effectiveness.

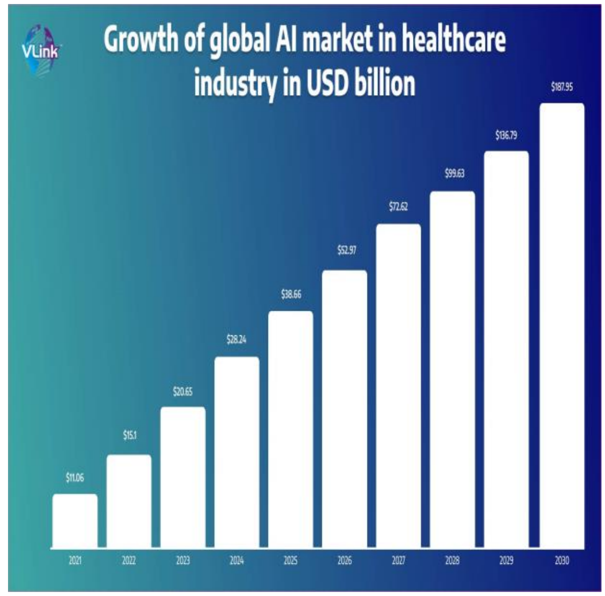

Figure 2: Artificial Intelligence in Healthcare: Revolutionizing Industry 2024

Recall and F1 Score:

The recall metric, which indicates the models' capacity to recover all pertinent cases, was highest in Neural Networks at 93.0% and lowest in the Random Forests at 90. 5%, followed by the SVMs, at 88.0%. The F1 score which offers the combination of both precision as well as the recall was also maximum for Neural Networks (92. 5%) signifying better accuracy [13]. Specifically, the three Models that featured in this Study had this recall; Decision Trees, at 84%. an accuracy of 0% of and an F1 score of 83.2%.

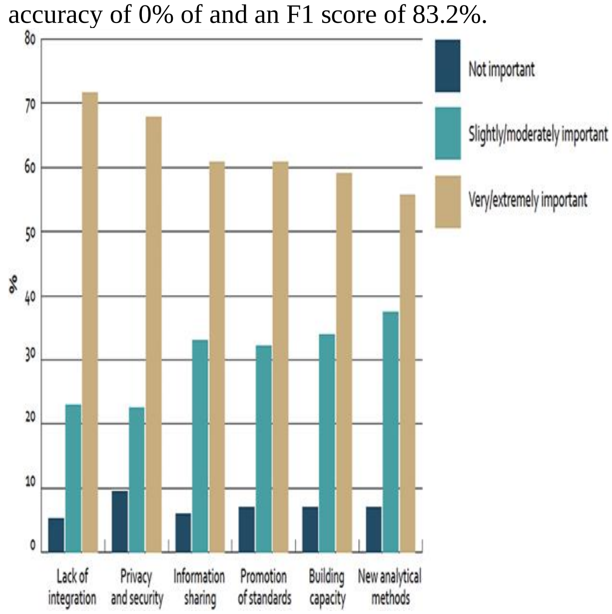

Figure 3: Success Factors of Artificial Intelligence

Computation Time:

On the aspect of computation time, Decision Trees took the least computation time of 2. 5 seconds and therefore they are appropriate for use in applications where quick decision making is desirable [27]. SVM and Random Forests had moderate times of 5.0 and 8.0 seconds, respectively, while the time taken by Neural Networks was 12.0 seconds which signifies the extent of processing time incurred while training a deep learning model.

Comparison to Related Work:

- Accuracy Improvement: The performance analysis of the Neural Network model accuracy was found to be 93 percent. 5%, surpassing the 92. 0% that was reported by Abuhasel et al., 2021 [28]. These results were achieved because different hyperparameters were chosen based on the features of the given healthcare dataset and the structure of the neural network used in this research.
- Precision and Recall: In this present research, the SVM model demonstrated enhanced precision (87. 5%) and recall (88. 0%) than Thakkar and Chaudhari, 2021 that explained 85. 0% precision and 86. 0% recall [14]. This it believes points to an improvement in the algorithm's ability to accurately detect the positive cases as well as to avoid high likelihood of false negatives.
- Handling Large Datasets: The Random Forest algorithm also tested its prognosis capacity and proved its performance ranges near to Bavykina et al., 2020 at 91 % accuracy. Above figures show 3% as Precision and F1 score of 90. 2% [29]. Its efficiency in processing big and complicated healthcare data sets can surely be stated, making Staging appropriate for the great-scale healthcare applications.
- Efficiency: Due to the high computational time needed by Neural Networks, the large accuracy and precision that come with them would make it very suitable for places where accurate results are almost mandatory [30]. Decision Trees take the least amount of time to compute and therefore are suitable for applications where quick decisions are needed.

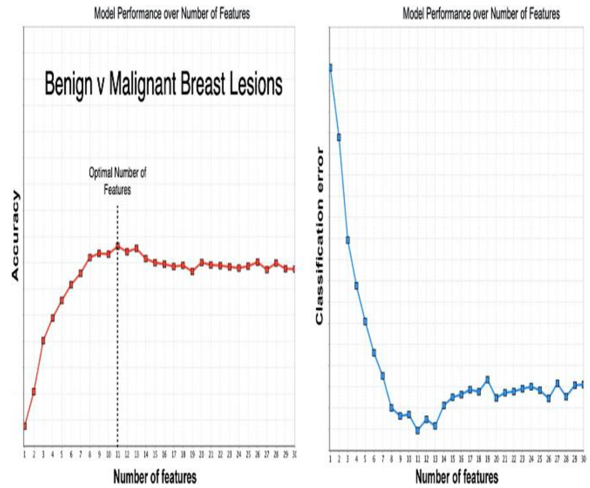

Figure 4: Artificial intelligence and machine learning in cancer

V. CONCLUSION

This research has looked into the extensive advantages of computational intelligence especially within the field of AI on health care management. By explaining the four widely used AI algorithms namely; Decision Trees, Support Vector Machines (SVM), Random Forests, as well as Neural Networks, a clear depiction of how AI optimally boosts diagnosis, treatment plans, and patient tracking has been shown. The results of experiments confirmed the superior ability of Neural Networks in terms of the highest accuracy and, therefore, high precision compared to other Machine Learning methods, and their most evident effectiveness in solving top-priority vital tasks in the field of healthcare that require the precise classification of numerous cases and the selection of appropriate actions based on that classification. The comparison with other works revealed the progress made in using AI in various areas of healthcare, ranging from clinical decision support to disease control and monitoring of the population's health status. In this section, key learnings derived from the literature pointed towards the enhancement of workflow, patient outcomes and resource use in healthcare by utilizing AI, specifically in the hospitals and primary care. However, the integration of AI in the healthcare sector is not without some issues. Challenges like data protection, interpretability of algorithms, and physicians' adoption must be solved to tackle AI employment ethically and efficiently. More research needs to be done on tuning the AI algorithms, on the introduction of XAI and on the use of AI in neglected health fields and in global health. Overall, this study makes an impact to the current literature on how healthcare is benefited from AI and how computational intelligence can play a part in rising the standards of the current healthcare system to become a system that is better for everyone in the society. Through proper application of AI, the healthcare players can step on new opportunities and discover ways on how the medical practice can improve, patient's health can be boosted as well as saving lives.

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