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## Neural & AI

Advancing Real-Time Crime

AI-Powered Generative Framework

Highlights

Leveraging Neural Networks

Leveraging Deep Machine Learning

**Discovering Thoughts, Inventing Future**

VOLUME 25 ISSUE 1 VERSION 1.0

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By Taiwo. M. Akinmuyisitan, John Cosmas & Yusuff Adeniyi Giwa

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ADVANCINGREALTIMECRIMEWEAPONDETECTIONANDHIGHRISKPERSONCLASSIFICATIONINPRECRIMESCENESACOMPREHENSIVEMACHINEVISIONAPPROACHUTILIZINGSSDDETECTOR

# Advancing Real-Time Crime Weapon Detection and High-Risk Person Classification in Pre-Crime Scenes: A Comprehensive Machine Vision Approach Utilizing SSD Detector

Taiwo. M. Akinmuyisitan α, John Cosmas σ & Yusuff Adeniyi Giwa ρ

*Abstract-* The application of state-of-the-art in deep learning detection algorithms, such as You Only Look Once (YOLO) and Single Shot MultiBox Detector (SSD), presents a significant opportunity for enhancing crime prevention and control strategies. This research focuses on leveraging the SSD algorithm to detect common crime weapons on individuals in both pre-crime video scenes and real-world crime scenarios. By thoroughly understanding the operational principles of the SSD algorithm, we adapted it for the identification of dangerous weapons commonly associated with violent crimes. Our detection model, which targets both weapons and individuals, establishes a robust foundation for an artificial intelligence (AI) system that accurately predicts individuals at high risk. The model first identifies the presence of a person and subsequently checks for any of the specified weapons. If a weapon is detected, the system further analyzes the individual's movement and speed within the frame of reference. Should the individual exceed a predetermined movement threshold, the system flags them as high risk.. For this study, the SSD model utilized a VGG16 backbone and was trained on a dataset comprising 3,317 images, featuring four distinct weapon categories: handgun, shotgun, rifle, and knife. The dataset was collected from UCF , via Kaggle and complimented with additional weapons from Google download all, all the sources are secondary, open sources and loyalty-free. We achieved a mean average precision of 84.19% across five classes after training for 59 epochs The findings of this research demonstrate the effectiveness of the SSD algorithm in crime prevention and control, contributing to the ongoing discourse surrounding the application of detection algorithms for crime prediction. This work aims to provide technological innovations that can assist local law enforcement agencies in their operational duties. Additionally, the insights gained from this study may enhance the detection of abnormal behavior within the broader field of artificial intelligence.

*Keywords: single shot multipledetection (SDD), convolutional neural networks (cnn), deep learning, weapon detection. artificial intelligence, computer vision, image classification, machine learning, object detection, mean average precision.*

## I. Introduction

The alarming rise in crime rates globally, particularly in developing nations, poses significant challenges to public safety, peaceful assembly, and social stability. These issues undermine the fundamental right to protection of life and the maintenance of order. However, advancements in technology, especially in emerging fields such as artificial intelligence, offer innovative solutions to address security gaps and bolster support for local law enforcement agencies [1]. The evolving nature of criminal activities has necessitated the development of sophisticated techniques to assist police in their duty to safeguard citizens and uphold social stability [2].

In recent years, the application of machine learning and computer vision for identifying crime hotspots, analyzing weapons of mass violence, and examining crime scenes has gained traction within academic circles, technology-driven nations, and various industries [3]. Among these techniques, the integration of computer vision and artificial intelligence for crime prediction has emerged as a promising approach. Single Shot Detection (SSD) has become one of the most effective model architectures for object detection, offering high accuracy and speed while adapting precision for real-time applications [4].

Single Shot Detection (SSD) is an object detection algorithm similar to You Only Look Once (YOLO), both of which utilize convolutional neural networks (CNN) in their architecture. It may be true to state that SSD is an advanced form of convolutional neural network (CNN) [5]. SSD facilitates efficient processing of images and videos (3D/4D tensors), making it particularly suitable for analyzing crime scenes and weapons, as well as beig useful in manipulating the predicting of potential crime hotspots, including those that have yet to occur. Crime prediction is a sensitive endeavor that demands a high level of accuracy in representing observed situations; in many real-world scenarios, time is of the essence, and precise detection and representation are crucial [6].

This paper explores the adoption of single-shot detection (SSD) algorithms for crime prediction by leveraging extensive datasets of real-world crime footage, weapons, and reported incidents. The aim is to train an artificial intelligence (AI) model capable of predicting criminal activities through the analysis of visual data patterns. SSD has the potential to identify

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potential criminal activities and alert law enforcement agencies, facilitating proactive measures. Its speed and accuracy make SSD particularly promising for real-time applications in this context

The study demonstrates the efficiency and effectiveness of single-shot detection (SSD) in various security-related domains, including license plate recognition, traffic monitoring, crime scene analysis, and real-time anomaly detection. However, its application specifically in crime hotspots and crime prediction, as well as its potential for identifying individuals at high public risk, remains largely unexplored, presenting significant opportunities for innovation and improvement. This paper aims to investigate the use of SSD for crime prediction, with a focus on its implementation and performance. Additionally, the research develops a Python scripts to leverage SSD as an advanced detection algorithm for classifying individuals deemed to be at significantly high risk.

The rest of the paper is organized as follows: Section II provides related work in crime prediction and object detection technologies. Section III describes the methodology used in this study, including data collection, preprocessing, and the SSD model architecture. Section IV presents the experimental results, analysis, and discussions of our findings. Finally, Section V presents our conclusion and recommendation including the research limitations and future work.

## II. Related Work

SSD remains an emerging research area for the prediction and detection of crime. This emerging research area is looking to build on the capacity of the single-shot multi-box algorithm, its performance, its success in object detection, and more noticeably its capabilities in striking a balance between speed, performance, and real-time application [4]. Single shot detection(SSD) is one of the most popular deep learning object detection frameworks that is known for its balance between speed and accuracy, it could be considered a fit for real-time applications for crime detection and prediction [1].

Recent research on SSD has been on achieving an increased speed while still improving its speed in detecting small objects; speed and accuracy are important in real-time applications and they are also very important parts of surveillance systems. For example, SSD's multi-scale feature maps and its default bounding boxes make it easy for it to handle different sizes and aspect ratios which are critical in detecting however small representation of scenes in criminal situations [9].

SSDs have shown great promise in crime prediction when used directly or indirectly with data sources such as close circuit TV (CCTV) and other sensory instruments for the identification of crime hotspots, analysis of crime scenes, and prediction of crimes and criminal activities[10]. In a research carried out by [11], the author used SSD together with machine learning algorithms to analyze the patterns captured in surveillance footage and predict suspicious behaviors and people that present possible threats; this research demonstrates great promise in adopting object detection algorithms for crime prediction, especially in an urban environment where many events are happening simultaneously, synchronously and in real-time.

Moreover, SSD's architecture has been adapted to address the specific challenges of crime prediction, such as the need for high accuracy in detecting small objects (e.g., weapons) and the ability to process video streams in real time [4]. These adaptations include the use of advanced feature extraction techniques and the integration of SSD with other neural network models to improve its robustness and accuracy in challenging environments [12].

## III. Materials and Methods

This section outlines the methodologies used to achieve the results detailed in Section IV. The approaches are centered on the Single Shot MultiBox Detector (SSD) framework, which leverages a single deep neural network to predict bounding boxes and classify objects in images. Due to the specific nature of the study, our model was trained from near-scratch using a custom dataset designed to reflect real-world crime scenarios. This section further describes the hardware configurations, processes, and techniques involved in constructing custom object detectors specifically aimed at crime prediction.

*a) Performance Metrics*

Generally, measuring the performance of the object detector used mean average precision (mAP). The mean Average Precision (mAP) is a broadly used performance measures for evaluating the accuracy of object detection models in computer vision models. It combines three important aspects: precision, recall and F1, providing a comprehensive measure of a model's ability to locate and classify objects within an image. To compute mAP, precision-recall curves 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 then averaged across all object classes, resulting in the mean average precision. The mean Average Precision is a valuable metric for assessing 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.

The mean average precision calculated with equation (1).

$$\text{mAP} = N\_^{1} \sum^{N}{}_{i=1} AP_{\text{i}} \quad (1)$$

- N is the total number of object classes of the dataset
- $AP_i$ is the average precision for each class i.

i. *Precision*

Precision measures the proportion of correctly identified positive detections out of all the detections made by the model. It assesses the model's accuracy in predicting true positives while minimizing false positives.

$$\text{Precision} = \frac{TP}{TP+FP} \quad (2)$$

TP= True Positive, which are the instances that are true objects and are positive by the model.

FP = False Positive, which are instances that are not true objects of a class but positive for the model

ii. *Recall*

It calculates the proportion of true positives detected by the model out of all the ground truth objects present in the image. It measures the model's ability to find all relevant objects, minimizing false negatives.

$$\text{Recall} = \frac{TP}{TP+FN} \quad (3)$$

Here,

FN= False Negative. These are instances where the object is positive (criminal), but the model wrongly predicted (failed to identify the criminal).

iii. *System 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}]

{2(precision*Recall)}/precision+Recall) eqn (4)

For simplicity,

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

*b) Data Collection and Processing*

i. *Data Acquisition*

Implementing an SSD-based crime prediction model necessitates a substantial and carefully curated dataset. For the training of this system, a secondary video dataset was used, simulating a live-action.

These scenarios were crafted to replicate real-world criminal behavior, enabling the model to be trained and tested on its ability to generalize across diverse threatening situations. The dataset was enhanced by sourcing images and videos of weapons from online platforms and integrating real-world crime data from the UCF-Crime dataset, which includes video clips labeled with tags such as "assault" and "robbery" [14]


*Fig. 1:* Shotgun Sample


*Fig. 2:* UCF-Dataset [14]

ii. *Data Annotation*

Accurate data labeling is crucial for training deep learning models with SSD. In this study, manual annotation was performed using *labelImg* which ensures precise bounding box placement and class labels. At every labeling instance i.e an object (Image), a corresponding XML file is automatically created which contains the object metadata as follows;

- Class Name
- Bounding box Coordinates (xmin, ymin, xmax, ymax)
- Object Dimensions (width, height) The design covered five classes of interest:
- Person
- Handgun
- Shotgun
- Knife
- Rifle

This structured data enabled SSD to detect and classify these objects during training [15].

While YOLOv4 has its annotation in a .txt file, Pascal annotation standard format is in .xml, Fig 3.0

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```xml
<annotation>
  <folder>shegun</folder>
  <filename>person.jpeg</filename>
  <path>/home/shegun/person.jpeg</path>
  <source>
    <database>Unknown</database>
  </source>
  <size>
    <width>234</width>
    <height>215</height>
    <depth>3</depth>
  </size>
  <segmented>0</segmented>
  <object>
    <name>Rifle</name>
    <pose>Unspecified</pose>
    <truncated>0</truncated>
    <difficult>0</difficult>
    <bndbox>
      <xmin>18</xmin>
      <ymin>11</ymin>
      <xmax>103</xmax>
      <ymax>183</ymax>
    </bndbox>
  </object>
  <object>
    <name>Shotgun</name>
    <pose>Unspecified</pose>
    <truncated>0</truncated>
    <difficult>0</difficult>
    <bndbox>
      <xmin>171</xmin>
      <ymin>77</ymin>
      <xmax>197</xmax>
      <ymax>131</ymax>
    </bndbox>
  </object>
  <object>
    <name>Person</name>
    <pose>Unspecified</pose>
    <truncated>0</truncated>
    <difficult>0</difficult>
    <bndbox>
      <xmin>54</xmin>
      <ymin>59</ymin>
      <xmax>211</xmax>
      <ymax>205</ymax>
    </bndbox>
  </object>
</annotation>
```


*Fig. 3:* SDD Sample Dataset Image .XML Annotation file Format

In preparing a dataset for training, a folder named "SSD Custom" created then inside this folder, three folders created namely.

1. Annotations
2. Imageset
3. JPEGImages

*c) System Framework*

SSD, known for its efficiency in real-time object detection, processes entire images in a single forward pass through the network. This framework predicts multiple bounding boxes and associated class scores for each object, using feature maps extracted at different scales. The advantage of SSD lies in its speed and ability to detect objects of various sizes simultaneously, making it ideal for applications where rapid response is essential, such as crime prediction [16].

The system architecture shown in Figure 4.0 utilizes SSD with vgg16 as the backbone network. The input data-drone-captured videos-are fed into the SSD, where the frames are divided into grids. Each grid cell then predicts bounding boxes and class scores, enabling the detection of objects relevant to criminal activities.

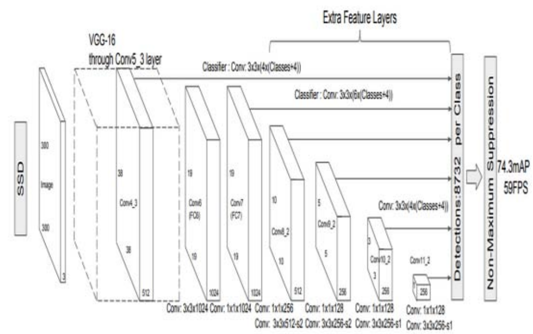


*Fig. 4:* SSD System Architecture [16]

*d) Model Setup*

We used SSD with vgg16 as the backbone. The Vgg16 was selected as the backbone model because of the depth of its architecture; Vgg16 has a depth of 16 convolutional layers which makes it easily learn complex and hierarchical features of our training dataset [19]. Additionally, vgg16 has done incredibly well in several image recognition tasks, it has achieved a very high accuracy over image classification tasks [17].

In this paper, we used mutlibox loss which has in its regression and classification loss. The regression loss measures the accuracy of the bounding box while classification predicts the performance of the model over the classes.

*Training Configuration:*

- *Batch Size:* There is a need to balance memory constraints and model convergence, therefore a small batch size of 10 was used .
- *Epochs:* The model is set for 100 epochs, with validation performed every epoch to monitor performance and avoid overfitting.
- *Checkpointing:* Models are saved at regular intervals, enabling the recovery of the best-performing model.
- *Optimization:* The model used stochastic gradient descent (SGD) which helps speed model convergence.

*e) Evaluation*

The primary evaluation metric is mean average precision which measures the model accuracy over all classes [18]. mAP is computed at different Intersections over Union (IoU) thresholds to provide a comprehensive assessment of the model's detection capabilities.

## IV. Results and Discussion

The entirety of the research was jointly conducted on p2.xlarge AWS GPU and core i5 HP pavilion 16GB RAM with a 4GB Nvidia VRAM. The p2.xlarge instance was connected to a local machine. The research was implemented with a single shot multi-box detection, the VGG16 was selected as the backbone for this research due to its performance and accuracy on image classification tasks where object localizations are of utmost importance. 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. 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. The object dimension(Width, Height), coordinates and class they belong to were determined during the annotation of the dataset. The total dataset was 3317 and was divided into train, test, and evaluation in the 80:10:10 ratio. The dataset was loaded into the training in batches of 10 to ensure adequate memory usage and was trained over 62 epochs. The model performance (mean average precision, mAP) is shown in Fig. 5.0 while Fig 5.1 shows the training loss.

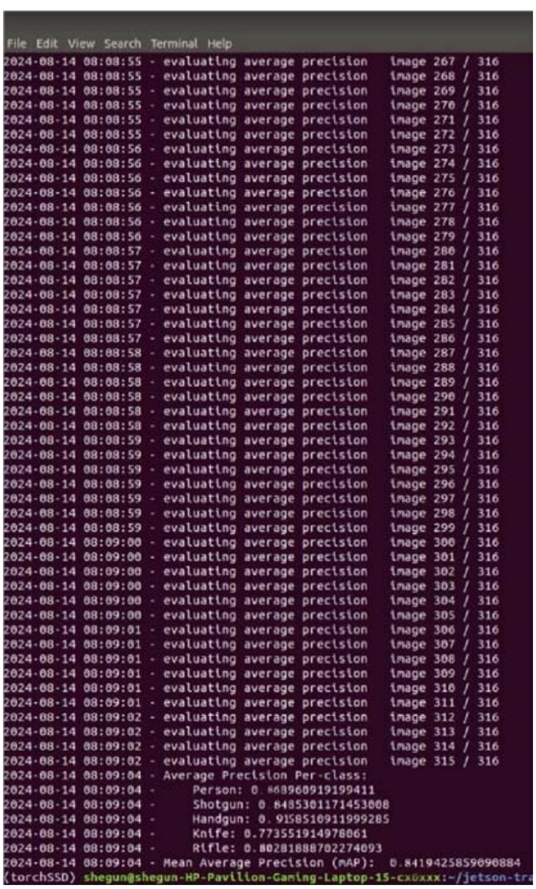


*Fig. 5:* Mean Average Precision (mAP)

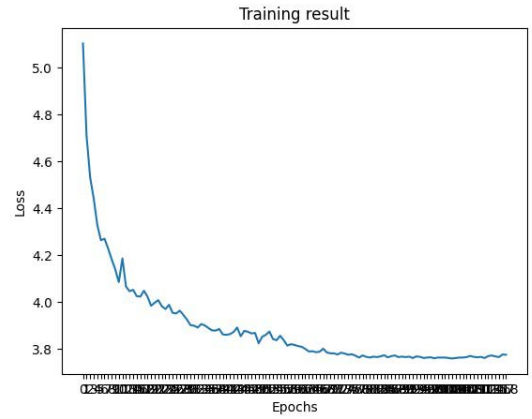


*Fig. 5.1:* Training Loss

The model was trained and initially set at 100 epochs. However, at about 62 epochs, the model began to overfit, an indication that the model isn't learning anything again. As such, it was ended. The best model performance therefore achieved at 59 epochs with a mean average precision of 0.84%. The inference was conducted on the data shown in Fig. 5(a) and the result of this is shown in Fig. 5(b).

*Fig. 5(a):* Sample Inference data


*Fig. 5(b):* Inference result

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*Table 1.0:* SDD Class by Class Performance

| Class | AP |
|---|---|
| Person | 86.89 |
| Shotgun | 84.85 |
| Handgun | 91.58 |
| Knife | 77.35 |
| Rifle | 80.28 |

For our result, a confidence threshold of 0.25 was set, this threshold means an object to be detected, must first cross a 25% detection threshold for example for a class “Shotgun” to be said to be in a scene, the model must have seen the class crossed 25% initial detection threshold. This is to ensure that less confidence predictions are filtered out which therefore ensures a reliable detection mechanism.

In Fig 5.0, the model achieved a mean average precision of 84.19%. The high average precision (AP) for weapons mostly associated with violent crimes is of great significance to this research. To detect a person of high risk, it was important to have a model that would be able to pick features from scenes that may suggest whether or not a person detected is a person of high risk. The high precision results recorded in this phase (detection) were very instrumental in building a model that detects persons of high risk.

The High-Risk Detection System functions by identifying and flagging individuals who display potentially dangerous behavior or possess hazardous objects, utilizing a combination of speed analysis and object detection techniques. The process begins with the detection and tracking of "Person" instances within a video stream, where bounding boxes are drawn around each identified individual. The system uses Deep-SORT multiple object tracking algorithm. It calculates the speed of movement for each detected person by comparing their positions across consecutive frames. If an individual's speed exceeds a predefined threshold (set at 0.35 in the design Python script), they are flagged as "High Risk." Furthermore, the system also assesses the presence of specific high-risk objects, such as firearms (e.g., rifles, shotguns, handguns) and knives, associated with the detected "Person" in the precrime video footage.


*Fig. 6(a):* CCTV Crime Footage


*Fig. 6(b):* High Risk Prediction

The SSD (Single Shot MultiBox Detector) results demonstrate the efficacy of this approach. With an average precision (AP) of 86.89% for detecting "Person" instances, the model reliably identifies individuals, which is crucial for accurately determining whether someone should be flagged as high risk based on their behavior or the objects they carry. The model also shows strong performance in detecting specific weapons, with APs of 84.85% for "Shotgun" and 91.58% for "Handgun," which enhances the system's ability to identify individuals carrying these dangerous items. Fig. 6(a) and 6(b) show respectively the sample footage used for inference and the result. The footage is a real-life robbing scene captured by CCTV.

This model achieved high average precision (AP) scores for objects like "Handgun" (91.58%) and "Shotgun" (84.85%), However, other studies suggested that models like YOLOv4, which were fine-tuned for specific tasks and utilized additional enhancements, outperform our SSD in precision metrics, particularly for smaller objects [19]

## V. Conclusion

This research focused on the application of the Single Shot Multi-Box Detection (SSD) algorithm for the prediction and prevention of violent crimes. It utilized a local HP Pavilion gaming machine with specific hardware specifications, alongside a p2.xlarge GPU instance on AWS, and a dataset comprising 3,317 instances from various sources, including the UCF Crime Open Dataset. We successfully developed a system capable of identifying individuals at high risk based on the presence of weapons and the speed at which these individuals are moving, indicating potential abnormal behavior.

To achieve the results presented in this paper, the datasets were meticulously annotated and divided into three distinct subsets: training, validation, and testing. The model was initially set to run for 100 epochs but was terminated at 62 epochs to prevent overfitting. Peak performance was achieved at 59 epochs, with a mean average precision of 84.19%.

In this study, we successfully employed the SSD algorithm to create a system for predicting high-risk individuals. This high-risk model relied heavily on the SSD model's performance in detecting weapons associated with violent crime. Upon optimization, our detection model demonstrated competitive results compared to the Yolov4 detection outcomes reported by [20], using the same dataset and classes.

The significance of our findings extends beyond the immediate results. Our model's ability to predict highrisk 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.

## References Références Referencias


1. W. Liu et al., "SSD: Single Shot MultiBox Detector," in *Proceedings of the European Conference on Computer Vision (ECCV)*, 2016, pp. 21-37.
2. Y. Chen, Y. Zhu, C. Ke, and F. Chen, "Crime prediction using deep learning," *IEEE Access*, vol. 7, pp. 150503-150510, 2019.
3. S. Zhang, R. Benenson, and B. Schiele, "CityPersons: A Diverse Dataset for Pedestrian Detection," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2017, pp. 4457-4465.
4. "What Is SSD & How It Improved Computer Vision Forever," *Analytics India Magazine*, 2024. [Online]. Available: https://analyticsindiamag.com. Accessed: Aug. 12, 2024.
5. BlazeFace: Sub-millisecond Neural Face Detection on Mobile GPUs," *ar5iv.org*, 2024. [Online]. Available: https://ar5iv.org/abs/1907.05047. Accessed: Aug. 12, 2024.
6. G. C. Oatley and B. W. Ewart, "Crimes analysis software: 'pins in maps', clustering and Bayes net prediction," *Expert Systems with Applications*, vol. 25, no. 4, pp. 569-588, 2003.
7. O. Z. Apene, N. V. Blamah, and G. I. O. Aimufua, "Advancements in Crime Prevention and Detection: From Traditional Approaches to Artificial Intelligence Solutions," *European Journal of Applied Science, Engineering and Technology*, vol. 2, no. 2, pp. 285-297, 2024.
8. L. Aziz, M. S. B. H. Salam, U. U. Sheikh, and S. Ayub, "Exploring deep learning-based architecture, strategies, applications and current trends in generic object detection: A comprehensive review," *IEEE Access*, vol. 8, pp. 170461-170495, 2020.
9. L. Cheng, Y. Ji, C. Li, X. Liu, and G. Fang, "Improved SSD network for fast concealed object detection and recognition in passive terahertz security images," *Scientific Reports*, vol. 12, no. 1, p. 12082, 2022.
10. R. Shenoy, D. Yadav, H. Lakhotiya, and J. Sisodia, "An intelligent framework for crime prediction using behavioural tracking and motion analysis," in *2022 International Conference on Emerging Smart Computing and Informatics (ESCI)*, 2022, pp. 1-6.
11. R. M. Saji and N. V. Sobhana, "Real Time Object Detection Using SSD For Bank Security," in *IOP Conference Series: Materials Science and Engineering*, vol. 1070, no. 1, p. 012060, Feb. 2021, IOP Publishing.
12. Y. J. Hwang, J. G. Lee, U. C. Moon, and H. H. Park, "SSD-TSEFFM: New SSD using trident feature and squeeze and extraction feature fusion," *Sensors*, vol. 20, no. 13, p. 3630, 2020.
13. A. Juneja, S. Juneja, A. Soneja, and S. Jain, "Real time object detection using CNN based single shot detector model," *Journal of Information Technology Management*, vol. 13, no. 1, pp. 62-80, 2021.
14. W. Sultani, C. Chen, and M. Shah, "Real-World Anomaly Detection in Surveillance Videos," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2018, pp. 6479-6488.
15. T. Y. Lin, M. Maire, S. Belongie, J. Hays, P. Perona, D. Ramanan, P. Dollár, and C. L. Zitnick, "Microsoft COCO: Common Objects in Context," in *Proceedings of the European Conference on Computer Vision (ECCV)*, Cham, Switzerland: Springer, 2014, pp. 740-755.
16. W. Liu, D. Anguelov, D. Erhan, C. Szegedy, S. Reed, C. Y. Fu, and A. C. Berg, "SSD: Single Shot MultiBox Detector," in *Computer Vision – ECCV 2016: 14th European Conference, Amsterdam, The Netherlands, October 11–14, 2016, Proceedings, Part I*, Cham, Switzerland: Springer International Publishing, 2016, pp. 21-37.
17. K. Simonyan and A. Zisserman, "Very Deep Convolutional Networks for Large-Scale Image Recognition," in *Proceedings of the International Conference on Learning Representations (ICLR)*, 2015.
18. R. Padilla, S. L. Netto, and E. A. Da Silva, "A Survey on Performance Metrics for ObjectDetection Algorithms," in *Proceedings of the 2020 International*

*Conference on Systems, Signals and Image Processing (IWSSIP)*, 2020, pp. 237-242.

19. K. Tran and N. D. Tran Pham, "Comparative Analysis of Image Processing Object Detection Models: SSD MobileNet and YOLO for Guava Application," in *The International Conference on Sustainable Energy Technologies*, Singapore, Nov. 2023, pp. 443-451. Springer Nature Singapore.
20. Taiwo Akinmuyisitan and John Cosmas(2024) Enhanced Crime Prediction with Computer Vision: YOLOv4 Approach. Global Journal of Computer Science and Technology, Massachusset, USA Vol 24 issue(1).

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*GJCST-D Classification:* *LCC Code: RC377–RC399*

LEVERAGINGNEURALNETWORKSFORLONGITUDINALANALYSISOFMULTIPLESCLEROSISANDOTHERNEURODEGENERATIVEDISEASES

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*Abstract-* Multiple Sclerosis (MS) is a progressive neurodegenerative disease affecting the Central Nervous System (CNS), leading to demyelination and neurological impairment. Early diagnosis and continuous monitoring of disease progression are crucial for effective treatment. Magnetic Resonance Imaging (MRI) remains the primary tool for detecting MS lesions; however, traditional segmentation methods rely heavily on visual analysis and struggle to detect early-stage lesions. This study reviews the application of Convolutional Neural Networks (CNNs) for automated lesion segmentation in MS. Through an integrative literature review of articles published between 2022 and 2024 from databases such as PubMed, BVS, Nature, Arxiv, and Google Scholar, following PRISMA guidelines, we assessed the effectiveness of AI-based approaches. CNN models such as U-Net and nnU-Net demonstrated superior accuracy and sensitivity in segmenting lesions in FLAIR MRI images, outperforming traditional methods. Models like DeepLabV3+ and ResNet also proved effective in differentiating between active and inactive lesions, aiding in distinguishing acute from chronic lesions. Automated segmentation reduced analysis time, minimized false positives, and enhanced reproducibility, mitigating human variability in clinical evaluations. While these advancements offer faster, more accurate diagnoses and better monitoring of disease progression, challenges remain. Chief among them are the need for large-scale labeled datasets and standardization of MRI acquisition protocols. Despite these obstacles, the integration of AI-driven segmentation into clinical practice holds significant promise for improving MS diagnosis, treatment planning, and long-term patient management.

*Keywords: multiple sclerosis, convolutional neural networks, lesion segmentation, magnetic resonance imaging, artificial intelligence, deep learning, AI in healthcare, MRI segmentation, neural networks, disease progression.*

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## I. Introduction

Neurodegenerative diseases are progressive disorders that affect the Central Nervous System (CNS), leading to the gradual loss of neurons[1]. Their development involves multiple risk factors, including protein dysfunctions, genetic alterations, oxidative stress, and exposure to toxic substances[2,3]. Landmark studies have demonstrated that oxidative stress exacerbates neuronal death in Alzheimer's and Parkinson's diseases[4], while genetic mutations such as SNCA in Parkinson's and APP in Alzheimer's directly contribute to pathological protein aggregation[5,6]. Additionally, environmental toxins like pesticides have been implicated in increasing the risk of neurodegeneration[7].

Diseases such as Parkinson's, Alzheimer's, Huntington's, amyotrophic lateral sclerosis, and frontotemporal dementias are considered neuropathies and neurodegenerative disorders[3]. Although they have distinct clinical manifestations, they share common pathological mechanisms, particularly the accumulation of misfolded proteins and chronic neuroinflammation. Misfolded proteins, such as amyloid-beta in Alzheimer's and alpha-synuclein in Parkinson's, aggregate into toxic structures that disrupt cellular homeostasis and lead to neuronal loss[8]. These aggregates impair essential cellular functions by sequestering normal proteins and damaging mitochondria. Furthermore, chronic activation of innate immune cells, such as microglia and astrocytes, sustains an inflammatory environment, contributing to progressive neurodegeneration[9].

Multiple Sclerosis (MS) represents a unique intersection between neurodegeneration and auto-immunity. While traditionally categorized separately, MS shares features with other neurodegenerative diseases, including chronic neuroinflammation, oxidative stress, and axonal damage. MS is a chronic, progressive inflammatory disease that affects the CNS[10]. Characterized by demyelination, where degeneration of

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the myelin sheath, the protective covering of nerve fibers, disrupts the conduction of electrical impulses. Although some lesions may initially repair without permanent loss of function, sustained inflammation leads to scarring and irreversible damage[11,12].

MS is an autoimmune disease where activated T cells cross the blood-brain barrier, triggering inflammatory responses that result in demyelination and neuronal injury. The precise mechanisms underlying disease onset remain unclear, but it is widely accepted that MS results from the interplay between genetic susceptibility and environmental triggers[13]. Genetic variants in the HLA-DRB1 locus have been strongly associated with increased MS risk[14], while environmental factors such as Epstein-Barr virus infection and vitamin D deficiency are believed to influence disease activation[15]. Oligodendrocyte death, driven by immune-mediated damage and oxidative stress, impairs myelin repair and exacerbates neurodegeneration[16].

MS typically follows one of several clinical courses: Relapsing-Remitting Multiple Sclerosis (RRMS), Primary Progressive Multiple Sclerosis (PPMS), Secondary Progressive Multiple Sclerosis (SPMS), and Progressive-Relapsing Multiple Sclerosis (PRMS). Early-stage symptoms often overlap with other neurological conditions, complicating diagnosis. Initial manifestations may include transient sensory disturbances, optic neuritis, or mild motor weakness, which can easily be misattributed to less serious illnesses[17]. As the disease progresses, more disabling symptoms such as ataxia, dysarthria, paresis, diplopia, and tremors emerge, leading to cumulative neurological disability[18].

Although there is no cure for MS, advances in immunosuppressive and immunomodulatory therapies have significantly improved disease management. Treatments such as interferon-beta, glatiramer acetate, and monoclonal antibodies aim to modulate the immune response, reduce the frequency of relapses, and slow the progression of disability[19,20]. Corticosteroids are used during acute exacerbations to dampen inflammation[21].

In Brazil, MS has a prevalence of approximately 15 cases per 100,000 inhabitants, with a higher incidence among white women. Symptoms commonly begin around the age of 30, but delays in diagnosis mean many individuals are not formally diagnosed until their mid-40s[22]. As research continues to elucidate the immunopathological mechanisms underlying MS, new therapeutic avenues emerge, offering hope for improved outcomes and quality of life for patients[23].

## II. Theoretical Framework

Medical image segmentation plays a crucial role in the diagnosis and monitoring of various neurological diseases, including Multiple Sclerosis (MS). Traditional approaches, relying on visual observation by specialists, although widely used, have significant limitations, such as the time required for identification and the difficulty in detecting small lesions, which are typical in the early stages of the disease. *While traditional methods have proven effective in certain contexts, the limitations of manual interpretation, particularly in identifying small or subtle lesions, have necessitated the exploration of AI-based alternatives.*

MRI remains the gold standard in diagnosing MS due to its ability to provide high-resolution images of brain structures and lesions. MRI uses different sequences to highlight contrasts between brain tissues, with the most common being FLAIR, T1, T2, and PD. In T1-weighted images, white matter appears lighter than gray matter, while cerebrospinal fluid (CSF) appears dark. In T2-weighted images, white matter is darker and CSF appears bright. The FLAIR sequence, like T2, suppresses the CSF signal, making it easier to visualize lesions typical of Multiple Sclerosis. These lesions appear hypointense in T1 and hyperintense in T2, PD, and FLAIR sequences, with FLAIR providing the greatest contrast with surrounding tissues.37

With the advancement of Artificial Intelligence (AI) and deep neural networks, these barriers are progressively being overcome. Recent studies have enhanced MRI's predictive capability through AI, with a particular focus on machine learning. New automated methods for lesion monitoring in MRI scans are being developed, offering greater precision and efficiency in diagnosing MS. According to Yousef et al.[17] (2024), deep learning techniques, particularly Convolutional Neural Networks (CNNs), have demonstrated superior performance in segmenting brain structures and lesions compared to conventional methods. *CNNs are particularly effective because they can automatically learn hierarchical features from raw image data, capturing complex spatial patterns and subtle differences that are difficult for traditional algorithms to detect*.

Lesion segmentation in MS is particularly challenging due to the heterogeneity of lesions, variations in tissue contrast, and differences in image acquisition protocols. Research such as that by SadeghiBakh et al.[18] (2022) indicates that CNN-based models can recognize complex patterns in MRI images, improving accuracy in identification and reducing reliance on manual intervention. Furthermore, the use of AI for segmentation enhances reproducibility and sensitivity in lesion detection. Studies like those by Salem et al.[19] (2022) suggest that automated segmentation methods can be integrated into clinical workflows to assist professionals in decision-making, contributing to faster and more accurate diagnoses. Thus, the application of deep neural networks in lesion segmentation for MRI represents a significant

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advancement in neurology, enabling better assessment of MS progression and offering personalized therapeutic strategies for patients.

## III. Methodology

This study is an integrative literature review with a qualitative and exploratory approach, focused on studies addressing Multiple Sclerosis (MS), particularly the application of neural networks for lesion segmentation in Magnetic Resonance Imaging (MRI) aimed at improving early diagnosis.The central research question guiding the review was: "*How can artificial intelligence, specifically neural networks, improve lesion segmentation in Magnetic Resonance Imaging (MRI) for the early diagnosis of Multiple Sclerosis?*"

Steps were defined to ensure methodological rigor, including the formulation of the research question, comprehensive database searches, selection, reading, thematic analysis of the selected studies, and the use of the PRISMA checklist (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to structure the review process. *The articles were analyzed using thematic analysis, allowing for the identification of recurring themes related to AI applications in MS lesion segmentation.*

*The PRISMA checklist* guided the establishment of inclusion and exclusion criteria, the systematic selection of studies, and the transparent reporting of findings, enhancing the reproducibility and reliability of the review process.The literature search included studies published in Portuguese, English, and Spanish, accessed remotely through databases such as PubMed (National Library of Medicine), Virtual Health Library (BVS), Nature, Google Scholar, and Arxiv. *Search Strategy and Keywords:*

Specific keywords and Boolean operators were used to ensure the comprehensiveness of the search. For instance.

1. The search in the PUBMED database was conducted using relevant terms to ensure the retrieval of pertinent studies. The search terms were combined using Boolean operators as follows:

((((("Hyperintense lesion"[Title/Abstract]) OR ("Hyperintensity"[Title/Abstract]) OR ("Hypointense lesion" [Title/Abstract]) OR ("Hypointensity"[Title/Abstract])) AND (Artificial Intelligence[Title/Abstract] OR AI[Title/Abstract])) AND (Multiple Sclerosis[Title/Abstract])) AND (Black Holes[Title/Abstract])) AND (Magnetic Resonance Imaging[Title/Abstract] OR MRI[Title/Abstract] OR MR[Title/Abstract])) AND (Neural Network[Title/Abstract] OR Tiramisu Network[Title/Abstract]) AND (Segmentation[Title/Abstract]).

2. Second Search: The search conducted in the Virtual Health Library (BVS) applied the keywords: “multiple sclerosis,” “magnetic resonance imaging,” “artificial intelligence,” or “AI.”
3. Third Search: In the Nature database, the terms “magnetic resonance imaging,” “artificial intelligence,” “multiple sclerosis,” and “black holes” were used.
4. Fourth Search: The terms used in the Arxiv database were the same as in BVS: “multiple sclerosis,” “magnetic resonance imaging,” and “artificial intelligence.”
5. Fifth Search: In Google Scholar, the following keywords were used: “artificial intelligence,” “multiple sclerosis,” “black holes,” “magnetic resonance imaging,” “Neural Network,” “Hypointense lesion,” “Hypointensity,” “Hyperintensity,” and “Hyperintense lesion.”

*Reproducibility and Explainability*

The methodology was carefully structured to ensure the reproducibility of the research. All search criteria, selection procedures, and thematic analysis methods were transparently documented. The qualitative analysis focused on identifying thematic patterns, segmentation methods, and AI advancements, ensuring objectivity and reliability in the interpretation of the studies.

*Limitations and Ethical Considerations*

Despite the methodological rigor, limitations such as potential publication bias and heterogeneity in MRI acquisition protocols across studies were acknowledged. Ethical considerations were strictly followed, with only publicly available data used and no involvement of patient data or experimental interventions. Studies were excluded if they lacked summaries, were inaccessible, or did not focus specifically on the use of artificial intelligence in Multiple Sclerosis. Included works comprised articles, research papers, theses, dissertations, final projects, and book chapters, published from 2022 onward, to ensure the relevance and currency of the findings.

## IV. Results

The search in the PUBMED database resulted in 472 articles, and BVS yielded 31 articles. The third search conducted in Nature resulted in 3 works, the terms used in ARXIV produced 11 results, and Google Scholar returned 27 articles. The Search across databases resulted in 472 articles, of which 9 were eliminated due to duplication. Of the 463 works, 19 predated the established publication deadline, and after reading the abstracts, 419 articles were eliminated. Therefore, 25 studies were potentially eligible for this review, which, after full-text reading, were used to prepare this report.

*Table 1:* Representing the Articles used and Subitems were Depicted

| Title | Key Points | Study Type |
|---|---|---|
| Boosting Multiple Sclerosis Lesion Segmentation through Attention Mechanism | - Comparison of unsupervised, supervised, and deep learning techniques<br>- Use of residual U-Net with channel attention<br>- Intensity thresholds in FLAIR | Original Research |
| Multiple Sclerosis Lesions Segmentation Using Attention-Based CNNs in FLAIR Images | - ResNet-based architecture with spatial and channel attention<br>- Superior performance in Dice Score<br>- Clinical validation | Original Research |
| AI-based Detection of Contrast-Enhancing MRI Lesions in MS | - Expert-labeled lesions<br>- 3D probability masks for lesion segmentation<br>- Comparable performance to human readers | Original Research |
| Assessment of AI Automatic MS Lesion Delineation Tool | - Comparison with existing segmentation tools<br>- Transfer learning for local data adaptation<br>- High accuracy and clinical acceptance | Original Research |
| Framework to Segment MS Lesions Using VGG-UNet | - Comparison between UNet, SegNet, VGG-UNet, and VGG19<br>- Python implementation with 80% training/20% validation | Experimental Study |
| 3D CNN Framework for Nuclear Medicine | - Use of CNNs with convolutional and pooling layers<br>- U-Net effective for biomedical | Original Research |

| Title | Key Points | Study Type |
|---|---|---|
| | segmentation | |
| Deep 3D Neural Network for Brain Structures Segmentation | - CNN-Transformer hybrid for improved segmentation<br>- Efficient segmentation, with future optimization plans | Original Research |
| Deep Whole Brain Segmentation with 7T MRI | - 7T MRI provides better spatial resolution<br>- Higher accuracy in segmenting brain structures | Original Research |
| DBSegment for Deep Brain Structures | - Use of MNI and CIT168-based registration<br>- Improved accuracy through registration for 3T-to-7T adaptation | Original Research |
| Deep Learning-Based PET/MR Radiomics for MS | - 2D U-Net segmentation<br>- Multimodal PET/MR models improved ARR prediction | Original Research |
| Single-Timepoint MS Lesion Classification Using CNN | - Acute vs chronic lesion detection using radiomics<br>- Effective classifier with CNNs | Original Research |
| New MS Lesion Segmentation with Residual Attention U-Net | - Use of U-Net with attention gates for improved lesion detection | Original Research |
| Improving MS Lesion Detection with Cascaded 3D CNN | - Use of deformation fields for sequential scans<br>- Better sensitivity and fewer false positives | Original Research |
| Thalamus Segmentation Using 3D CNN | - 3D CNN outperforms FastSurfer and FSL in detecting thalamic atrophy | Original Research |
| Automated Cervical Spinal Cord Segmentation | - U-Net 2D with residual attention for spinal cord segmentation<br>- High segmentation accuracy | Original Research |
| Active/Inactive Plaque Segmentation Using DeepLabV3+ | - Efficient and accurate segmentation of plaques in FLAIR images | Original Research |
| Predicting MS Disease Progression with MRI Biomarkers | - MRI biomarkers crucial for personalized MS prognosis<br>- Machine learning models offer promising potential | Literature Review |
| Prognostic Relevance of MRI in Early Relapsing MS | - MRI identifies lesions that guide treatment decisions<br>- Early treatment reduces risk | Literature Review |
| Repurposing MRI Archives for MS Research | - AI-based model for segmenting brain structures and lesions<br>- High correlation with EDSS and treatment effects | Original Research |
| MLV2-Net for Meningeal Lymphatic Vessel Segmentation | - First automatic method for meningeal vessel segmentation using CNN | Original Research |
| Cortical Lesion Segmentation | - Quantifies uncertainty in cortical lesion | Original |

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| Title | Key Points | Study Type |
|---|---|---|
| Uncertainty | segmentation<br>- Improved detection reliability | Research |
| Instance-Level Quantitative Saliency for MS Lesion Segmentation | - Use of SmoothGrad and Grad-CAM++ for segmentation explanations | Original Research |
| Ensemble CNN and Uncertainty Modeling for MS Lesion Detection | - Improved segmentation with multiple evaluators and optimized U-Net 2D | Original Research |
| Multi-Modal CNN for MS Lesion Detection | - 2D U-Net CNN for segmenting MS lesions<br>- Improved performance with fewer computational costs | Original Research |
| Capuchin Search Algorithm for MS Diagnosis | - Use of CNNs for MRI image processing<br>- Improved precision and recall with ensemble models | Original Research |

## V. Discussion

Rigorous lesion segmentation in MRI images is essential for obtaining an accurate diagnosis and monitoring of Multiple Sclerosis (MS). Traditional segmentation approaches based on manual or semi-automatic techniques have significant drawbacks, such as dependence on expert domain knowledge and inter- and intra-observer variability. *In clinical practice, traditional methods are often time-consuming, require specialized expertise, and struggle to detect subtle lesions, particularly in the early stages of MS, potentially delaying diagnosis and treatment.* To overcome these limitations, AI-based approaches, particularly deep neural networks, have gained increasing attention for automating and improving lesion segmentation.

Figure 1 illustrates the number of publications that have used different AI models in the lesion segmentation process in MS, from image acquisition to result analysis and validation. The pipeline begins with image acquisition, followed by preprocessing, based on different MRI sequences (T1, T2, and FLAIR), essential for identifying lesions. *Preprocessing steps, such as skull stripping to remove non-brain tissues, normalization of image intensity to reduce noise, and artifact removal, are critical for enhancing input data quality and improving segmentation accuracy.* Feature extraction then focuses on highlighting areas of interest using contrast enhancement techniques and improving lesion detection.

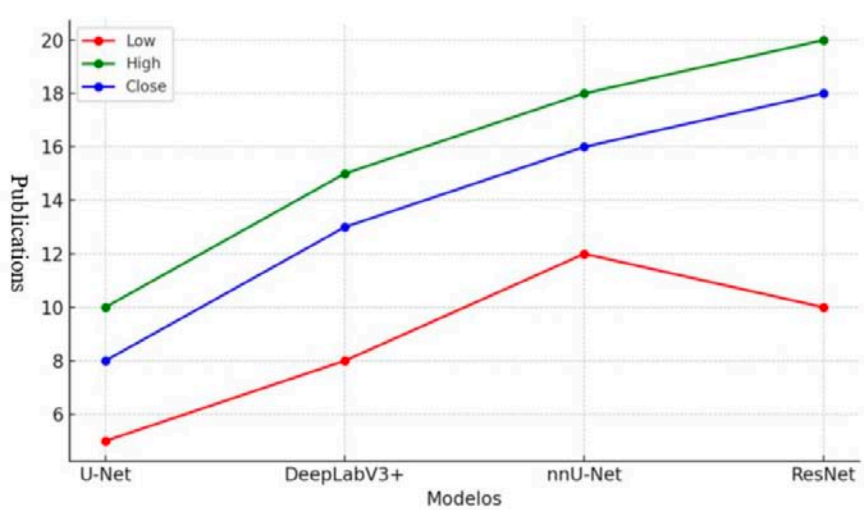



*Figure 1:* Use of AI in Publications Described as Model and Variation of Segmentation Methodologies (OHLC)

For segmentation, classic methods such as thresholding and probabilistic models are employed, alongside modern methods like deep neural networks, including CNN, U-Net, and Attention U-Net. Post-processing is applied to refine results by reducing false positives and applying smoothing techniques, improving model precision. The final phase includes analysis and validation, comparing automated segmentation with manual segmentation by specialists using metrics such as Dice Score and sensitivity.

Recent investigations have demonstrated that deep learning-based models can outperform conventional techniques, offering higher accuracy and efficiency in identifying lesions, as described by Du et al.[20] (2023). *Deep neural networks (DNNs), particularly Convolutional Neural Networks (CNNs), are particularly effective for medical image segmentation because they can automatically learn hierarchical patterns from raw MRI data, capturing complex spatial features that are difficult for traditional algorithms to detect.* CNN-based models such as U-Net[21] and nnU-Net[22] have shown excellent performance in segmenting hyperintense and hypointense lesions in brain white matter.

Furthermore, optimization algorithms such as the Capuchin Search Algorithm (CapSA) and fuzzy c-means (FCM), when combined with CNNs, have enhanced lesion detection capabilities in MS. Despite these advancements, challenges persist, particularly the need for large, well-labeled datasets to train deep learning models effectively[21]. Dataset heterogeneity and variation in MRI acquisition protocols between institutions can impact model performance, raising concerns about generalizability[22,25].

Various strategies have been proposed to improve model accuracy and robustness, including attention mechanisms, residual learning, and hybrid architectures. Networks like U-Net, VGG-UNet[26], ResNet[18], and EfficientNet[27] have demonstrated significant improvements in lesion segmentation by optimizing feature detection and minimizing error rates. Improving sensitivity - the ability to correctly identify true positives - remains a major focus, with models like U-Net[20,21,25,28,29], DeepLabV3+[27], and attention-based networks being widely adopted to enhance this parameter.

AI-based models have shown effectiveness particularly in segmenting hyperintense lesions on FLAIR images[18,21,24,25,27,30], enabling better longitudinal assessment of MS progression. For example, the VicoroCascade model[19] demonstrated high sensitivity and reduced false positives, supporting its use for disease monitoring. Combining information from multiple sequences, such as T2 and FLAIR, has further improved lesion detection, especially in early and subtle cases.

Uncertainty modeling techniques, like Grad-CAM++ and SmoothGrad[30], have been employed to quantify prediction confidence, improving interpretability and reducing the risk of misclassification. Additionally, hybrid networks combining CNNs with spatial and channel attention modules[18,24,31,32] have increased sensitivity without compromising specificity.

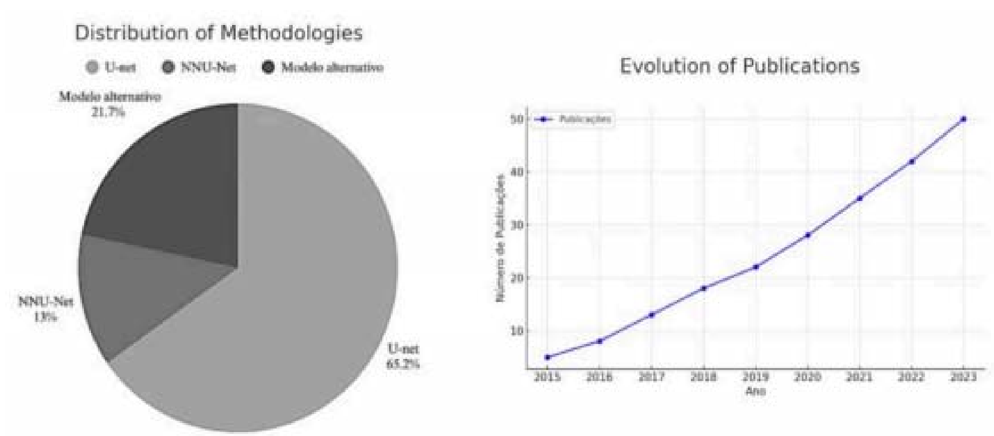
Comparative studies show that some deep learning models now approach the performance of experienced radiologists, achieving segmentation results with less inter-observer variability[20,25,33]. Other innovations include techniques for differentiating active from inactive lesions without the need for contrast agents like gadolinium, reducing patient risk. For example, DeepLabV3+ combined with EfficientNetB0 can distinguish lesion types in FLAIR images with high accuracy[27].

*Table 2:* Table about the Main Models Discussed

| Model | Architecture | Segmentation Strategy | Input Modality | Dice | Differentials |
|---|---|---|---|---|---|
| U-Net | Multi-branch Fully Convolutional Neural Network (FCNN) | Automatic extraction of radiomic features for ARR prediction | PET/MR | 0.81 | Combination of PET and MRI for better prediction of relapse rate (ARR) |
| MindGlide | Variant of U-Net with automatic hyperparameter tuning | Volumetric extraction of lesions and brain regions for longitudinal analysis | Qualquer RM | 0.61 | Works with incomplete modalities and can be applied to heterogeneous clinical data |
| DeepLab V3+ | Encoder-decoder with ASPP (spatial pyramid) and SE-Block (Squeeze and Excitation) | Pre-processing with bone removal, normalization, and use of SE and ASPP blocks to improve segmentation | FLAIR | 0.7624 | Use of EfficientNetBO as backbone for performance and efficiency optimization |
| ResNet | Based on residual blocks with spatial and channel attention (SCA-VoxRes) | Patches of 80x80x80 applied to 4D images (CLAHE + borders) | FLAIR | 0.6430 | Use of spatial and channel attention to improve lesion detection |
| Vicoro Cascade | Cascaded architecture with 3D convolutional networks and 3D multimodal fusion Fully Convolutional Network (FCNN) | Two-stage network: 1st detects candidates for new lesions, 2nd reduces false positives | T2-FLAIR (Baseline + Follow-up) | 0.42 | Focus on detecting new lesions over time, improving prognostics |

Five recent CNN architectures were compared in this study (Table 2), highlighting different strengths depending on the clinical objective: diagnosis, prognosis, or disease monitoring. Models like DeepLabV3+ SE EfficientNetB0 used Squeeze and Excitation (SE) and Atrous Spatial Pyramid Block (ASPP) techniques for enhanced segmentation, while nnU-Net demonstrated adaptability across heterogeneous clinical data. Vicorob, with its cascaded FCNN pipeline, stood out in detecting new lesions over time by minimizing false positives.

Figure 2 shows the prevalence of model use, with U-Net being the most reported in the literature (15 studies), followed by growing interest in more automated, adaptable frameworks like nnU-Net. These trends indicate the shift toward scalable, flexible solutions in MS lesion segmentation.




*Source: Prepared by the Authors Themselves*

*Figure 2:* Pie Chart Showing the Distribution of the most commonly used Models

The development of these advanced segmentation methods is essential to support early MS diagnosis and progression monitoring. However, as noted by Sadeghibakhi et al.[18] (2022) and Schlaeger et al.[33] (2023), rigorous clinical validation, population diversity testing[26], and interpretability improvements are necessary for safe adoption into clinical workflows[34]. Reducing algorithmic bias, improving model explainability, and ensuring compatibility with different imaging protocols remain key goals for future research.

Thus, the combination of MRI with deep neural networks represents a transformative advancement for diagnosing and monitoring MS. As emphasized by Manimegalai et al.[28] (2022), continuous development is vital to optimize these tools for clinical use, enabling faster, safer, and more accurate care for patients with MS.

## VI. Conclusion

The application of neural networks in lesion segmentation for magnetic resonance imaging (MRI) has proven to be a promising approach for the diagnosis and monitoring of Multiple Sclerosis (MS). The use of artificial intelligence in this context enables faster and more accurate image analysis, reduces the subjectivity inherent in manual segmentation, and assists specialists in identifying and tracking disease progression over time. Although advancements in the field are notable, important obstacles remain. There is a critical need for the standardization of image acquisition protocols across centers and the development of models that are robust and generalizable to diverse patient populations and different MRI equipment. *Collaborations between research institutions, hospitals, and imaging manufacturers could help establish standardized imaging protocols, while multi-center clinical trials would be crucial to validate AI models across heterogeneous populations.*

Furthermore, the interpretation of algorithm-generated results still requires extensive clinical validation to ensure their applicability in real-world settings. *In addition to clinical validation, AI models must undergo rigorous regulatory evaluation and approval, such as by agencies like the FDA or through CE marking, to guarantee that they meet the necessary standards for widespread clinical implementation. Future research should focus on creating more resilient, interpretable, and transferable models, trained on diverse datasets, to improve the generalizability and robustness of segmentation tools across different clinical environments.* Emphasis on model explainability and minimizing bias will also be critical for building trust among clinicians and patients.

Thus, the integration of artificial intelligence with healthcare professionals' expertise represents a promising path for enhancing MS diagnosis and treatment. The continuous evolution of these technologies holds the potential to improve decision-making accuracy, optimize healthcare resources, and ultimately provide a better quality of life for patients affected by MS.

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*Declarations Consent to Participate*

This study used public datasets and did not involve direct human subjects; therefore, informed consent was not required.

*Conflicts of Interest*

The authors declare no conflicts of interest.

## References Références Referencias


1. Carvalho LFC, Kostic V, Rodrigues F de AA. Doenças neurodegenerativas associadas com as fases da vida. CONTRIBUCIONES A LAS CIENCIAS SOCIALES. 2023 Jul 19 [cited 2023 Oct 18];16(7):6741–9. Available from: https://ojs.revistacontribuciones.com/ojs/index.php/clcs/article/view/1293
2. Paz GE, De Jesus DSM, Nogueira SB, Oliveira WB. Doenças neurodegenerativas emadultos e idosos: um estudo epidemiológico descritivo. Revista Neurociências. 2021 Sep 18;29:1–11. Available from: https://periodicos.unifesp.br/index.php/neurociencias/article/download/12348/8854/51673
3. Ciurea AV, Mohan AG, Covache-Busuioc RA, Costin HP, Glavan LA, Corlatescu AD, et al. Unraveling Molecular and Genetic Insights into Neurodegenerative Diseases: Advances in Understanding Alzheimer's, Parkinson's, and Huntington's Diseases and Amyotrophic Lateral Sclerosis. International Journal of Molecular Sciences [Internet]. 2023 Jun 28; 24(13):10809. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10341997/
4. Rodríguez Murúa S, Farez MF, Quintana FJ. The Immune Response in Multiple Sclerosis. Annual Review of Pathology: Mechanisms of Disease. 2022 Jan 24;17(1):121–39. Available from: https://www.annualreviews.org/content/journals/10.1146/annurev-pathol-052920-040318
5. Haase S, Linker RA. Inflammation in multiple sclerosis. Therapeutic Advances in Neurological Disorders. 2021 Jan; 14:175628642110076. Available from: https://journals.sagepub.com/doi/full/10.1177/17562864211007687.
6. Tavassolifar M javad, Vodjgani M, Salehi Z, Izad M. The Influence of Reactive Oxygen Species in the Immune System and Pathogenesis of Multiple Sclerosis. Autoimmune Diseases. 2020 Jun 25;2020:1–14. Available from: https://pubmed.ncbi.nlm.nih.gov/32789026/
7. Pegoretti V, Swanson KA, Bethea JR, Probert L, Eisel ULM, Fischer R. Inflammation and Oxidative Stress in Multiple Sclerosis: Consequences for Therapy Development. Oxidative Medicine and Cellular Longevity. 2020 May 12; 2020: 1–19. Available from: https://onlinelibrary.wiley.com/doi/full/10.1155/2020/7191080
8. Bando Y. Mechanism of demyelination and remyelination in multiple sclerosis. Clinical and Experimental Neuroimmunology. 2020 Mar; 11(S1):14–21. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/cen3.12576
9. Carvalho LG, Fogari LR, Caparroz MEL, Paoliello AB. Fatores ambientais envolvidos na Fisiopatologia da Esclerose Múltipla: uma revisão bibliográfica/Environmental factors involved in the Pathophysiology of Multiple Sclerosis: a bibliographic review. Braz. J. Hea. Rev. [Internet]. 2022 Feb. 14 [cited 2025 Apr.2];5(1):2793-808. Available from: https://ojs.brazilianjournals.com.br/ojs/index.php/BJHR/article/view/44057
10. Lakin L, Davis BE, Binns CC, Currie KM, Rensel MR. Comprehensive Approach to Management of Multiple Sclerosis: Addressing Invisible Symptoms-A Narrative Review. Neurology and Therapy. 2021 Apr20; 10(1): 75–98. Available from: https://link.springer.com/article/10.1007/s40120-021-00239-2#citeas
11. Brieva L, Calles C, Landete L, Oreja-Guevara C. Current challenges in secondary progressive multiple sclerosis: diagnosis, activity detection and treatment. Frontiers in Immunology. 2025 Mar 21;16. Available from: https://www.frontiersin.org/journals/immunology/articles/10.3389/fimmu.2025.1543649/full.
12. Wilkinson I, Lennox G. "Esential neurology Ed. 4." (2020).
13. Ridley B, Minozzi S, Gonzalez-Lorenzo M, Del Giovane C, Piggott T, Filippini G, et al. Immunomodulators and immunosuppressants for progressive multiple sclerosis: a network meta-analysis. Cochrane Database of Systematic Reviews [Internet]. 2024 Sep 10; 2024(9). Available from: https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD015443.pub2/full.
14. Callegari I, Derfuss T, Galli E. Update on treatment in multiple sclerosis. LaPresse Médicale. 2021 Jun;50(2):104068. Available from: https://www.sciencedirect.com/science/article/pii/S0755498221000075
15. Moura JA de, Teixeira LA da C, Tanor W, Lacerda ACR, Mezzarane RA. Prevalence of multiple sclerosis in Brazil: An updated systematic review with meta-analysis. Clinical Neurology and Neurosurgery [Internet]. 2025 Jan 13;249:108741. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0303846725000241#preview-section-references
16. Pachner AR. The Neuroimmunology of Multiple Sclerosis: Fictions and Facts. Frontiers in Neurology. 2022 Feb 7;12. Available from: https://pubmed.ncbi.nlm.nih.gov/35197914/
17. Yousef H, Brigitta Malagurski Tortei, Castiglione F. Predicting multiple sclerosis disease progression and outcomes with machine learning and MRI-based biomarkers: a review. Journal of Neurology [Internet]. 2024 Sep 12; Available from: https://pubmed.ncbi.nlm.nih.gov/39266777/
18. Sadeghibakhi M, Pourreza H, Mahyar H. Multiple Sclerosis Lesions Segmentation Using Attention-Based CNNs in FLAIR Images. IEEE Journal of Translational Engineering in Health and Medicine.

2022;10:1–11. Available from: https://ieeexplore.ieee.org/document/9766141

19. Salem M, Ryan MA, Oliver A, Hussain KF, Lladó X. Improving the detection of new lesions in multiple sclerosis with a cascaded 3D fully convolutional neural network approach. Frontiers in Neuroscience. 2022 Nov 24;16. Available from: https://pubmed.ncbi.nlm.nih.gov/36507318/
20. Du S, Yuan C, Zhou Q, Huang X, Meng H, Chen M, et al. Deep learning-based PET/MR radiomics for the classification of annualized relapse rate in multiple sclerosis. Multiple sclerosis and related disorders [Internet]. 2023 Jul;75:104750. Available from: https://pubmed.ncbi.nlm.nih.gov/37196386/
21. Raab F, Wilhelm Malloni, Wein S, Greenlee MW, Lang EW. Investigation of an efficient multi-modal convolutional neural network for multiple sclerosis lesion detection. Scientific reports. 2023 Nov 30;13(1). Harbor Laboratory). 2024 Mar 30; Available from: https://pubmed.ncbi.nlm.nih.gov/38036638/.
22. Philipp Goebl, Wingrove J, Abdelmannan O, Vega BB, Stutters J, Da S, et al. Repurposing Clinical MRI Archives for Multiple Sclerosis Research with a Flexible, Single-Modality Approach: New Insights from Old Scans. medRxiv (Cold Spring Harbor Laboratory). 2024 Mar 30; Available from: https://www.medrxiv.org/content/10.1101/2024.03.29.24305083v1.article-info
23. Bai L, Wu J, Chen L, Jiang X, Song Z. A density-based MS disease diagnosis model using the capuchin search algorithm and an ensemble of deep neural networks. Scientific Reports [Internet]. 2024 Dec 30;14(1). Available from: https://www.nature.com/articles/s41598-024-82395-7
24. Rondinella A, Crispino E, Guarnera F, Giudice O, Ortis A, Russo G, et al. Boosting multiple sclerosis lesion segmentation through attention mechanism. Computers in Biology and Medicine. 2023 Jul 1;161:107021–1. Available from: https://pubmed.ncbi.nlm.nih.gov/37216775/
25. Placidi G, Cinque L, Iacoviello D, Mignosi F, Polsinelli M. Ensemble CNN and Uncertainty Modeling to Improve Automatic Identification/Segmentation of Multiple Sclerosis Lesions in Magnetic Resonance Imaging [Internet].arXiv.org. 2021.
26. Available from: https://arxiv.org/abs/2108.11791 Krishnamoorthy S, Zhang Y, Kadry S, Yu W. Framework to Segment and Evaluate Multiple Sclerosis Lesion in MRI Slices Using VGG-UNet. Computational intelligence and neuroscience [Internet]. 2022 Feb; 2022:4928096. Available from: https://pubmed.ncbi.nlm.nih.gov/35694573/
27. Naeeni Davarani M, Arian Darestani A, Guillen Cañas V, Azimi H, Havadaragh SH, Hashemi H, et al. Efficient segmentation of active and inactive plaques in FLAIR-images using DeepLabV3Plus SE with efficientnetb0 backbone in multiple sclerosis. Scientific Reports [Internet]. 2024 Jul 15;14(1):16304. Available from: https://pubmed.ncbi.nlm.nih.gov/39009636/
28. Manimegalai, Suresh Kumar R, Prajoona Valsalan, R. Dhanagopal, Raj V, Christhudass J. 3D Convolutional Neural Network Framework with Deep Learning for Nuclear Medicine. 2022 Jul 16; 2022:1–9. Available from: https://pubmed.ncbi.nlm.nih.gov/35924105/. Acesso em: 4 mar. 2025
29. Laiton-Bonadiez C, Sanchez-Torres G, Branch-Bedoya J. Deep 3D Neural Network for Brain Structures Segmentation Using Self-Attention Modules in MRI Images. Sensors. 2022 Mar 27;22(7):2559. Available from: https://pubmed.ncbi.nlm.nih.gov/35408173/
30. Spagnolo F, Molchanova N, Schaer R, Cuadra MB, Pineda MO, Melie-GarciaL, et al. Instance-level quantitative saliency in multiple sclerosis lesion segmentation [Internet]. arXiv.org. 2024. Available from: https://arxiv.org/abs/2406.09335
31. Sarica B, Seker DZ. New MS lesion segmentation with deep residual attention gate U-Net utilizing 2D slices of 3D MR images. Frontiers in Neuroscience. 2022 Jul 22;16. Available from: https://pubmed.ncbi.nlm.nih.gov/35968389 Acesso em: 2 mar. 2025
32. Bueno A, Bosch I, Rodríguez A, Jiménez A, Carreres J, Fernández M, et al. Automated Cervical Spinal Cord Segmentation in Real-World MRI of Multiple Sclerosis Patients by Optimized Hybrid Residual Attention-Aware Convolutional Neural Networks. Journal of digital imaging [Internet]. 2022 Oct; 35(5):1131–42. Available from: https://pubmed.ncbi.nlm.nih.gov/35789447/
33. Schlaeger S, Suprosanna Shit, Eichinger P, Hamann M, Opfer R, Krüger J, et al. AI-based detection of contrast-enhancing MRI lesions in patients with multiple sclerosis. 2023 Jul 16; 14(1). Available from: https://pubmed.ncbi.nlm.nih.gov/37454342/. Acesso em: 7 mar. 2025
34. Caba B, Cafaro A, Lombard A, Arnold DL, Elliott C, Liu D, et al. Single-timepoint low-dimensional characterization and classification of acute versus chronic multiple sclerosis lesions using machine learning. NeuroImage [Internet]. 2023 Jan1; 265: 119787. Available from: https://www.sciencedirect.com/science/article/pii/S1053811922009089
35. Hindsholm AM, Cramer SP, Simonsen HJ, Frederiksen JL, Andersen F, Højgaard L, et al. Assessment of Artificial Intelligence Automatic Multiple Sclerosis Lesion Delineation Tool for Clinical Use. Clinical Neuroradiology. 2021 Sep 20; Available from: https://pubmed.ncbi.nlm.nih.gov/34542644/.
36. Kamraoui RA, Ta V-T, Tourdias T et al (2022) Deep Lesion Brain: towards a broader deep-learning

generalization for multiple sclerosis lesion segmentation. Med Image Anal 76:102312. https://doi.org/10.1016/j.media.2021.102312

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# Intelligent Ticket Assignment System: Leveraging Deep Machine Learning for Enhanced Customer Support

By Yusuff Adeniyi Giwa, Taiwo Akinmuyisitan, Jacob Sanni, Adebesin Adedayo, Boluwaji Benard Akinmuyisitan & Nosakhare Ikponmwosa

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*Keywords: e-ticketing AI system, machine learning, predictive model, bert algorithm, data preprocessing, prototypical networks, graph neural networks, natural language processing, feature extraction, ticket classification.*

*GJCST-D Classification:* *LCC Code: QA76.73.N37*

INTELLIGENTTICKETASSIGNMENTSYSTEMLEVERAGINGDEEPMACHINELEARNINGFORENHANCEDCUSTOMERSUPPORT

*Strictly as per the compliance and regulations of:*

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*Keywords: e-ticketing AI system, machine learning, predictive model, bert algorithm, data preprocessing, prototypical networks, graph neural networks, natural language processing, feature extraction, ticket classification.*

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## I. Introduction

Customer support stands as a fundamental business tool which boosts client satisfaction followed by brand loyalty while securing business superiority. Customer question resolution efficiency functions as a business success indicator that shapes how many customers will stay with the company [1]. Businesses need to evolve from solving problems after they occur to implementing ahead-of-time customer engagement approaches to stay competitive [2]. The growing complexity of customer interactions becomes worse because customers use a range of communication channels from social media to email and live chat and mobile applications [3]. The contemporary buying public requires assisted service that provides integrated personalised support throughout all its multiple interaction channels so organisations must adopt flexible data-based solutions to handle these platforms efficiently.

Current business operations still use basic support systems which base their ticket processing exclusively on human intervention. The outdated systems create multiple operational problems and performance issues which render services below contemporary consumer demands [4]. The ability to scale remains problematic due to human agents facing challenges in handling large numbers of tickets which generates delays and dissatisfied customers and backlog cases. Service quality issues persist in support centres because inconsistent ticket routing and prioritisation causes resolution times to vary by 25% for similar issues according to research [5]. The present constraints demonstrate an immediate requirement for intelligent automated solutions in customer service operations.

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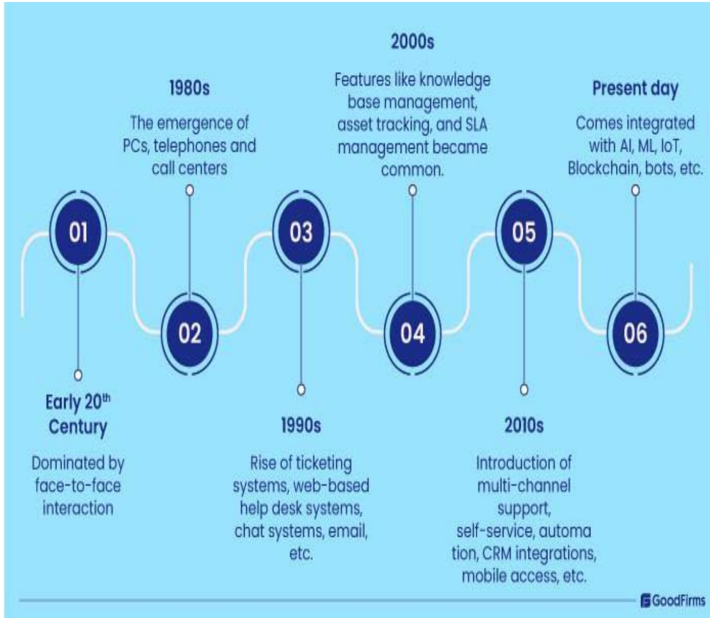


*Figure 1:* Evolution from Manual to AI-Powered Customer Support Systems. Adapted from [4]

Figure 1 demonstrates the fundamental shift in support systems from manual to AI-powered solutions which addresses these challenges as shown in Figure 1. The traditional support approaches do not satisfy contemporary customer demands because they depend on human staffing and contain error possibilities which limit their effectiveness. AI-based systems that use automation enhance ticket classification and prioritization and assignment speed while improving precision to deliver faster responses and better resource distribution [6]. Machine learning models trained with historical data enable predictive analytics to forecast both ticket urgency and complexity levels which businesses use to provide more accurate and data-based services [7]. Modern business practices remain hindered by existing scalability problems and inconsistent service quality since many organisations have not embraced AI-driven solutions.

This paper addresses these challenges by developing an intelligent ticket assignment system leveraging machine learning. The study aims to:

- Automate the categorisation and assignment of customer support tickets using machine learning techniques.
- Utilise historical data to predict the urgency and complexity of incoming tickets.
- Improve ticket assignment accuracy and response times compared to traditional, manual systems.

By implementing this intelligent AI-driven approach, businesses can overcome the limitations of manual ticketing systems, enhancing both scalability and service efficiency. This study highlights how AI-enabled solutions can transform customer service operations, allowing organisations to effectively meet the increasing demands of modern consumers.

## II. Related Work

The development of customer care systems started with manual engagement before adding semi-automated solutions and finally implementing AI-based intelligent systems. Modern customer expectations regarding rapid precise service delivery create an increasing market need for scalable flexible accurate ticket-handling systems. Most organisations currently experience difficulty with traditional methods that depend on human agents to classify and assign support tickets when they expand their customer engagement through social media platforms and email and live chat channels. These operational systems succeed in limited situations but struggle to scale adequately nor operate with the desired speed and precision which creates service delays and incorrect ticket routing while generating service quality flaws [8]. The legacy systems restrict true-time capability and analytical analysis which reduces customer trend detection along with proactive customer involvement [9].

Recognising these limitations, early machine learning models such as Support Vector Machines (SVMs) and Logistic Regression were introduced to automate ticket classification. Such models required extensive feature engineering while achieving good results in structured environments without sufficient ability to handle complex context-rich questions [10]. Ensemble methods like Random Forest addressed non-linear relationships more effectively and improved classification accuracy; however, they remained insufficient for processing nuanced natural language interactions, particularly in cases involving sarcasm, industry-specific terminology, or ambiguous phrasing [11]. The introduction of deep learning and graph-based approaches marked a significant shift in customer service automation by enabling models to extract context, identify relationships between tickets, and classify inquiries with greater precision [7].

BERT, a transformer-based model, advanced ticket classification by leveraging bidirectional contextual learning, allowing for improved semantic understanding. Advanced linguistic patterns within ticket classifications achieved better processing accuracy with this technology specifically in cases involving informal language and technical terminology [12]. However, despite its effectiveness, BERT remains computationally demanding, limiting its practicality for real-time deployment in high-volume service environments [13]. Graph Neural Networks (GNNs) introduced another layer of refinement by modelling customer inquiries as interconnected nodes, improving routing accuracy by identifying relationships between similar tickets. Real-time scalability of these models faces limitations because they need extensive hyperparameter tuning while requiring large resource usage [14][15].

Few-shot learning methods, such as Prototypical Networks and MAML, have emerged as an alternative solution for handling rare or novel ticket types. These methods leverage limited examples to adapt quickly to new customer inquiries [18][19]. These models are instrumental in dynamic service environments where new issues frequently arise, requiring rapid adjustments without extensive retraining. However, their reliance on specialised architecture and high computational costs has restricted widespread adoption, particularly in enterprise applications with resource constraints [23].

Despite these advancements, modern AI-driven models continue to present challenges. BERT, while highly effective in capturing linguistic nuances, struggles to generalise across domains with unfamiliar terminology, requiring extensive domain adaptation techniques to maintain performance [22]. GNNs, despite their ability to identify ticket relationships, demand significant processing power, making real-time implementation difficult [15]. Few-shot learning models offer adaptability but require computationally intensive architectures that limit their feasibility for large-scale deployment [23]. Bias and fairness also persist across these models, as imbalanced datasets can lead to disproportionate classification outcomes, potentially resulting in service inconsistencies [23].

Traditional systems' limitations have been well-documented in industry case studies, highlighting the pressing need for AI adoption. Large-scale e-commerce platforms have reported significant misrouting rates, leading to prolonged response times exceeding 24 hours and customer dissatisfaction [1]. Similarly, telecommuni-cations providers handling a number of daily inquiries have experienced severe service disruptions due to the inability of rule-based ticketing systems to scale effectively [28]. A UK financial institution, National Savings & Investments (NS&I), saw a 37% surge in complaints, reaching 33,655 in a year, as outdated technology and poor service led to long wait times and online access issues, diminishing customer trust [30]. On the other hand, companies like Amazon that are adopting BERT-based ticketing solutions have seen classification accuracy improve by 18%, reducing resolution times by 35% [29]. These findings underscore the need for AI-driven customer support frameworks that integrate scalable, efficient, and adaptive machine learning techniques.

While deep learning and graph-based models have revolutionised customer service automation, ongoing research must focus on mitigating computational constraints, improving domain generalisation, and addressing ethical concerns in AI-driven ticketing systems. Optimisation strategies such as model quantisation, hybrid AI architectures, and fairness-aware algorithms offer promising pathways for enhancing the scalability and real-time efficiency of machine learning applications in customer support [6]. The transition towards fully automated, intelligent support systems is an ongoing process, requiring continued refinement to ensure that AI-driven solutions meet the evolving demands of modern businesses and consumers.

## III. Problem Statement and Motivation

Studies from 2011 indicated that 75% of customers did not like how long it took contact centres to respond [31]. When processing happens manually the response times get delayed and customers become dissatisfied along with their satisfaction measures decreasing. Ticket misclassification leads to incorrect routing that makes operational challenges and delay times steadily increase [32]. The correct routing of tickets requires longer procedural time when they travel through several departments before reaching their destination which results in service quality deterioration and higher operational costs. The lack of predictive analytics capabilities in these systems prevents businesses from forecasting upcoming customer difficulties at the same time as preventing peak load increases [24]. Organizations implement advanced machine learning (ML) models BERT and GNNs to address the limitations they face in their ticket processing systems. BERT processes information from both forward and backward text directions which provides contextual understanding of language topics to overcome traditional keyword classification limitations [12]. BERT uses its deep learning capabilities to detect word-to-word connections which results in fewer incorrect assignments when ticket categories are determined [13]. Through its deep bidirectional learning ability BERT recognises the difference between product defect reports and usage inquiries that use similar wordings so it helps speed up ticket routing and resolution time.

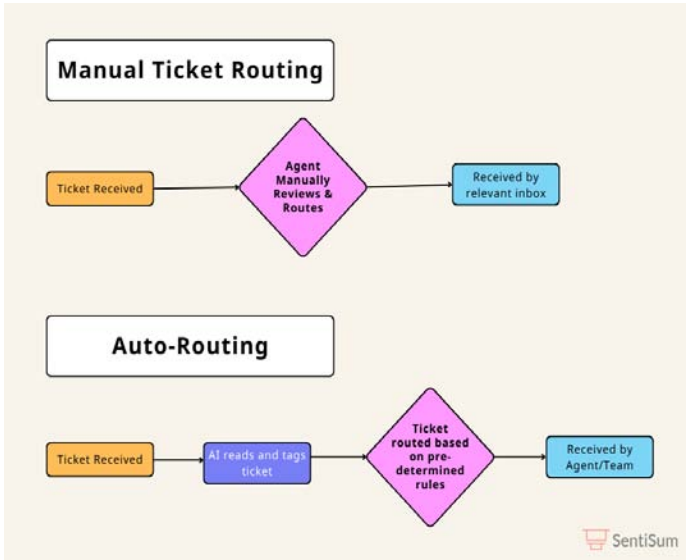


*Figure 2:* Manual Ticket Routing Process Vs. AI-Driven Automation Workflow. Adapted from [26]

BERT enhances semantic understanding but GNNs bring a network-based routing system for tickets particularly when multiple tickets show mutual connections. GNN technology applies mathematical graph algorithms to tickets so it can enhance both ticket grouping and routing operations and reduce ticket processing time. Operational classification organised by context enables organisations to handle interrelated problems which reduces customer contact duplications and optimises agent allocation throughout service departments. The combination of BERT with GNNs allows real-time decision automation and enhances scalability which modernises support systems to develop adaptive proactive services tools.

GNNs work together with BERT by analysing supportive ticket network relationships to provide better routing capabilities and categorization functionalities. The attributes of issue type and customer history serve as the basis for GNN models to establish edges between tickets while treating each ticket as a node in a graph format [14]. The system achieves group management abilities for connected tickets through this format allowing it to select appropriate tasks for specialised teams to reach faster resolution times. AI solutions like those presented in SentiSum's automatic versus manual routing test showcase how GNNs together with BERT achieve enhanced efficiency through minimised human involvement and rapid processing of numerous tickets [25]. The analysis systems train their comprehension by learning data constantly while simultaneously enhancing their predictive accuracy and minimising operational expenditures through lower technical support team staffing needs [14]. Customer satisfaction grows substantially together with proactive customer concern trend detection from machine learning insights through the combination of BERT contextual analysis with GNN relational modelling which prevents ticket misdirection and resolves all support requests [23]. BERT and GNNs establish their position as essential tools for achieving scalable high-precision data-based customer service operations that provide immediate customised support.

## IV. Proposed Solution

The proposed system uses BERT alongside GNNs and Meta-learning capabilities to improve traditional customer support systems by resolving their current inefficiencies. BERT delivers better classification results through its context understanding capabilities which reduces the wrong decisions made by keyword-based methods. GNN operates to enhance routing performance by discovering ticket linkages which allows similar requests to automatically find the appropriate routing path for speedy resolutions. Meta-learning systems maintain their adaptability to process new and infrequent ticket types after small training sessions and this feature brings adaptive capabilities to changing service environments. The complete support system operates through an integrated pipeline that enables data preprocessing of unstructured inputs for BERT ticket classification then GNN processing of decisions and continuous adaptation delivered by Meta-learning mechanisms.

The system needs two key features to handle growing demands and perform instant processing requirements. The system achieves maximum performance by using asynchronous processing and GPU acceleration and distributed computing methods to maintain speed for rising customer demand volumes. Many enterprise needs are addressed through this system which reduces workload requirements and accelerates service delivery and strengthens customer confidence in the process. This system represents a modern and effective automatic customer support solution through the integration of BERT linguistic skills and GNN relational analytics and Meta-learning adaptive features.

## V. Methodology

*a) Data Collection*

This intelligent support ticket assignment system uses primary dataset information obtained from Kaggle to solve financial support requests. The chosen dataset attained selection because it provides substantial size along with varied subject matter which directly relates to financial support operations. The dataset contains various financial inquiries about billing disputes and technical banking platform faults and loan processing delays and account protection measures which serve as an optimal foundation for testing machine learning-driven classification and routing systems. This dataset encompasses different real-world data obstacles which include unbalanced class distributions along with diverse ticket wording and contains noisy information to supply a dependable setting for performance assessment and model adaptation testing.

The dataset contains several key fields that play critical roles in model training and ticket classification.

- *Ticket Description:* The text field carries extensive customer complaints that NLP functions primarily on for processing. Before BERT-based classification begins the text input needs preprocessing steps which include tokenisation and stop-word removal and lemmatisation to normalise the text input.
- *Customer Issue Type:* A categorical variable (e.g., technical, billing, service-related) that aids in prioritising and directing tickets to the appropriate departments. Model training requires this variable to be converted into one-hot encoding for usage purposes.
- *Resolution Status:* A binary variable indicating whether a ticket is closed or still open, used to track the efficiency of the support process. This feature helps in supervised learning models by acting as a label in training predictive models for resolution likelihood.
- *Time to Resolution:* A numerical field representing the time taken to resolve each ticket, crucial for performance evaluation and predictive modelling of response times. Normalising processes these data points first to eliminate abnormal results before standardising time values across various ticket types.

Extensive preprocessing and cleaning steps were applied to ensure data quality and enhance model accuracy. The data preparation process included handling missing values through imputation and removing system text along with duplicate entries to maintain data quality. Exceptional character removal and text normalisation techniques were implemented to refine textual data, ensuring better input consistency for NLP models. These preprocessing steps were critical in enhancing classification accuracy, enabling BERT, GNNs, and Meta-learning techniques to operate efficiently on structured and well-prepared data.

*b) Source of Data*

The datasets were sourced using Kaggle, a popular platform for seeking public datasets on any machine learning task. The data presented includes real-world ticket information, making it the best data to train models to respond to actual customer service queries. With such a diversity of data types, text, categorical, and numerical, this dataset is well suited for a multi-face machine learning approach. This also combines natural language processing with classification and time prediction.

*Table 1:* Dataset Overview

| Field | Description |
|---|---|
| Ticket description | Textual description of customer issues |
| Customer issue Type | Categorical classification of issue type (e.g., billing, technical) |
| Resolution Status | Binary indicator of whether the issue was resolved or not |
| Time to Resolution | The numerical value indicates the time taken to resolve the issue. |

Table 1 summarises the key fields in the dataset. These fields are the basis of training in machine learning models such as BERT and GNN. Rich, well-structured data is required to produce accurate classifications and predictions from these models.

*c) Data Preprocessing*

An essential part of these steps is data preparation because it cleans raw ticket data and prepares it for models such as BERT, GNN, or Prototypical Networks. In this section, the researcher discusses how they cleaned and transformed the textual data for extraction of features, graph-based analysis, and few-shot learning, which can be conducted on novel or uncommon ticket types. Prototypical Networks classify tickets based on a few samples whenever new ticket types appear. GNN captures the relationship between comparable tickets, and BERT extracts contextual characteristics from the ticket descriptions.

*d) Text Preprocessing*

The following procedures below are ideal for the preparation of textual data from the support tickets for activities involving natural language processing (NLP):

- *Lowercasing:* All text is converted to lowercase to ensure uniformity, reducing the complexity introduced by case sensitivity.
- *Tokenisation:* The text is tokenised, breaking down the ticket scriptions into individual words or tokens. This allows the model to process the text at a word level.
- *Stop-word Removal:* Common words that do not carry significant meaning (e.g., "and," "the") are removed from the text. This helps focus the analysis on the more essential terms.
- *Lemmatisation:* Words are lemmatised, meaning they are reduced to their base or root form (e.g., "running" becomes "run"). This step reduces linguistic variability and improves model performance by treating similar words as the same entity.

*e) Feature Extraction using TF-IDF*

Once the text has been preprocessed, feature extraction is performed using the Term Frequency-Inverse Document Frequency (TF-IDF) method. TF-IDF transforms the text data into numerical features by weighing the importance of words based on their frequency in the document and across the dataset.

*The TF-IDF formula is defined as follows:*

*Where:*

- TF($t$, $d$) is the frequencyof the term$t$ in document $d$.
- $N$ is the total number of documents in the dataset.
- $|\{d \in D : t \in d\}|$ is the number of documents containing the term$t$.
- Figure 3 illustrates the TF-IDF feature extraction process.

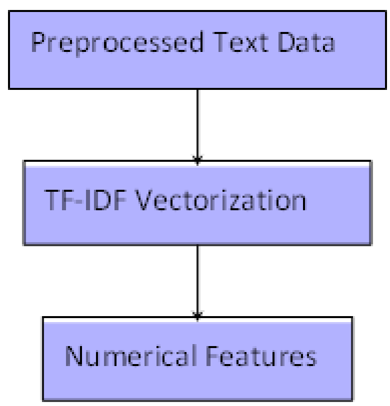


*Figure 3:* TF-IDF Feature Extraction Process: The Preprocessed Text is Converted into Numerical Features using TF-IDF Vectorisation

*f) Graph Representation for GNN*

For Graph Neural Networks (GNN) application, the ticket data is again transformed into graph representation. One ticket is represented by the following:

- *Nodes:* Cosine similarity or other similarity measurements establish the similarity among tickets, and this is the basis upon which Edges between nodes.
- The graph structure enables the GNN to reason about the connections between tickets and learn patterns that can be used to better route and classify tickets.

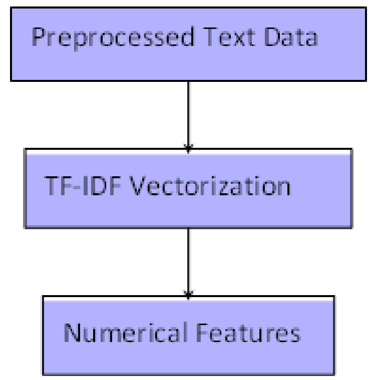


*Figure 4:* Graph Representation for GNN: Tickets are Represented as Nodes, and Edges are Created based on Ticket Similarity

*g) Feature Engineering*

Feature engineering is one of the crucial processes in converting raw text data into a numerical format that can be used for any machine learning model. To this end, two feature engineering techniques are applied to this intelligent support ticket assignment system: the graph representation using Graph Neural Networks (GNNs) and the text representation using BERT and TF-IDF.

*h) Text Representation for BERT and TF-IDF*

In order to successfully convert preprocessed text input into numerical features, the 'Term Frequency-Inverse Document Frequency' (TF-IDF) approach is adopted. This makes it possible for machines to focus on important words when performing classification tasks. The weighting system in this method provides higher importance to words that are important in a piece of text and rare across the whole dataset [27]. A particular document's weight value stands as the last element in each entry from the TF-IDF transformation matrix. The numerical representation generated by TF-IDF helps Random Forest and SVM models to execute ticket classification and prioritisation tasks.

The ticket descriptions benefit from deep contextual features extraction using Bidirectional Encoder Representations from Transformers (BERT). BERT generates one vector feature for each token which results from splitting the preprocessed ticket descriptions into their smallest linguistic units. This feature vector contains everything in each ticket record since it combines sequential word content from before and after the textual data. BERT works as a bidirectional system which enables it to interpret complex linguistic patterns. Translators (BERT) show exceptional ability in processing complicated and unclear ticket contents.

*Algorithm for Preprocessing*

*Algorithm 1: Text Preprocessing Algorithm for BERT Input*
The following are steps for preparing raw ticket descriptions for BERT feature extraction using the preprocessing algorithm.

*Algorithm 1:* Text Preprocessing for BERT Input

*Input:* Raw ticket descriptions

*Output:* Preprocessed text and TF-IDF vectors

1. *Result:* At this point, the preprocessed text and feature vectors are fed into BERT for feature extraction.
2. *Convert Text to Lowercase:* The next step is to tokenise the text into words. Stop words such as "and", "the", etc. are also removed, after which Lemmatization is performed to reduce words to their base forms. Lastly, TF-IDF vectorisation is applied to convert the text into numerical features.

*Algorithm 2: Graph Preprocessing Algorithm for GNN Input*

This algorithm outlines the basic steps for converting ticket descriptions into a graph representation for use with a Graph Neural Network (GNN).

*Algorithm 2 Graph Preprocessing for GNN Input*

*Input:* Preprocessed ticket descriptions

*Output:* Graph with nodes and edges based on similarity

3. *Result:* The result here is that the graph is used for GNN analysis as well as the capturing of relational data that is usually between tickets.
4. Begin
5. Next, a node is created for each ticket to calculate the similarity between tickets using cosine similarity. The nodes are then connected with edges if their similarity exceeds a threshold. Normalise the graph structure if necessary

*i) Model Selection and Training*

In this section, we will describe the process of selection and training of each of the models used in the intelligent support ticket assignment system. BERT is used for text understanding [12], GNN is used for relational learning [14], and Prototypical Networks is used for handling new ticket types [18].

i. *BERT for Text Understanding*

BERT accepted a large corpus for training before we applied it to fine-tune our ticket description dataset [12]. The fine-tuning process allows BERT to acquire domain knowledge about ticket description content that strengthens its ability to handle linguistic context within text. The attention mechanism in BERT functions as the main driver behind data contextual relationship extraction that enables correct ticket classification according to description semantics.

*BERT's Self-Attention Mechanism is computed as:*

$$\text{Attention (Q, K, V)} = \text{softmax}\left(\frac{QK^T}{\sqrt{d_k}}\right)V \qquad (1)$$

*Where:*

Q is the query matrix,

K is the key matrix,

V is the value matrix,

dk is the dimensionality of the key matrix.

This mechanism helps BERT focus on relevant parts of the input when predicting the ticket's category.

ii. *Graph Neural Networks (GNN) for Relational Learning*

Graph Convolutional Networks (GCNs) analyse ticket connections through evaluation of their relational patterns [14]. The system builds the analysis through nodes which represent tickets and show relation points between the nodes to indicate similarity measurements. The ticket classification together with routing gets better because GNNs analyse relational data that helps identify closely related tickets in terms of their descriptions and categories.

The graph structure enables GCN to establish node representations by having features move between network edges. The approach makes relational data accessible to the model so the decision-making process can be optimised.

iii. *Few-shot Learning with Prototypical Networks*

Prototypical Networks are employed for handling new or rare ticket types that the model has not seen before [18]. Few-shot learning is instrumental in dynamic environments where new types of customer issues emerge frequently. Prototypical Networks work by computing a prototype (mean embedding) for each class and assigning tickets based on the distance to these prototypes.

iv. *Random Forest for Baseline Comparisons*

In addition to the deep learning models, we use a Random Forest model as a baseline for comparison [11]. Random Forest is an ensemble learning method that constructs multiple decision trees during training and outputs the mode of the classes for classification tasks.

The equation for Random Forest is:

*Where:*

T is the number of trees,

ht(x) is the prediction from the t-th tree.

v. *Algorithm for Model Training*

*Algorithm 3 Model Training Algorithm for BERT, GNN, and Random Forest*

*Input:* Preprocessed ticket descriptions, preprocessed graph data

*Output:* Trained models (BERT, GNN, Random Forest)

*BERT Training:*

1. Initialize BERT with pre-trained weights [12].
2. Fine-tune the ticket dataset with tokenised and preprocessed text.
3. Use a classification head for categorising tickets.

*GNN Training:*

1. Construct the graph from ticket data [14].
2. Initialize the Graph Convolutional Network (GCN).
3. Train the GCN by propagating features across nodes and edges.

*Few-shot Learning with Prototypical Networks:*

1. Initialize the Prototypical Network [18].
2. Compute prototypes for each ticket type using the training set.
3. Classify new tickets based on distance to the nearest prototype.

*Random Forest Training:*

1. Train Random Forest on the preprocessed ticket data using TF-IDF features [11].
2. Validate performance using cross-validation. Each model is evaluated using standard classification metrics such as accuracy, precision, recall, and F1-score, with detailed comparisons provided in the subsequent evaluation section.

*j) Evaluation Metrics*

To evaluate the performance of the models in classifying and routing support tickets, we employ the following evaluation metrics:

*Accuracy*

Accuracy measures the proportion of correctly classified tickets out of the total tickets. It is defined as:

*Where:*

*TP (True Positive):* Correctly classified positive instances (e.g., correctly routed tickets).

*TN (True Negative):* Correctly classified negative instances (e.g., tickets correctly identified as not belonging to a particular class).

*FP (False Positive):* These are Incorrectly classified positive instances (e.g., tickets wrongly routed to a particular class).

*FN (False Negative):* These are Incorrectly classified negative instances (e.g., tickets not routed to the correct class).

*Precision*

Precision measures the proportion of correctly classified positive tickets out of all tickets classified as positive. It is defined as:

$$\text{Precision} = \frac{TP}{TP+FP}$$

This metric is critical in ensuring that all relevant tickets are correctly identified and routed, even if some are difficult to classify

*Recall*

Also known as sensitivity, recall measures the proportion of correctly classified positive tickets out of all actual positive tickets. It is defined as:

$$\text{Accuracy} = \frac{TP}{TP+FN}$$

This metric is critical in ensuring that all relevant tickets are correctly identified and routed, even if some are difficult to classify.

*F1-Score*

The F1-Score is the harmonic mean of Precision and Recall. It also provides a single metric that balances both. It is beneficial when the data is imbalanced. This means that one class has far more instances than another:

$$\text{F1-Score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

*Confusion Matrix*

Using a confusion matrix, we summarise the performance of the classification model. It also gives a clue to the true positives, false positives, true negatives and false negatives. Most importantly, it is helpful in understanding the breakdown of errors.

The confusion matrix for our ticket classification task can be represented as:

*Evaluation Strategy*

The most important metrics for each model (BERT, GNN, Prototypical Networks) are first calculated to achieve a complete evaluation. Then, the training and testing dataset is split with a standard 70/30 split. The models will then be tested on the unseen test set to see if they will do well on new data.

## VI. Results

This section compares the performance of the models used for ticket classification and routing. These include BERT, GNN, and Prototypical Networks (Meta-learning). The models are evaluated using key metrics such as Accuracy, Precision, Recall, and F1-Score.

*The following visualisations illustrate the results:*

- A bar chart showing the overall performance comparison across the evaluation metrics.
- Confusion matrices for BERT, GNN, and Prototypical Networks to illustrate the distribution of predicted vs. actual classifications.

The results demonstrate the strengths of each model. BERT excels in text understanding due to its bidirectional context-aware representation of ticket descriptions. GNN effectively captures structural relationships between tickets, enhancing relational learning. Lastly, Prototypical Networks show strong generalisation capabilities, particularly when handling new or rare ticket types by using few-shot learning techniques.

### a) *Performance Comparison*

The results of the model evaluation are shown in Table 3. Each model's performance is compared based on ticket classification accuracy, precision in identifying the correct ticket categories, recall for capturing all relevant tickets, and the F1-Score, which balances precision and recall.

*Table 3:* Model Performance Comparison for Accuracy, Precision, Recall, and F1-Score

| Model | Accuracy | Precision | Recall | F1-Score |
|---|---|---|---|---|
| BERT | 89.4% | 88.7% | 90.2% | 89.4% |
| GNN | 87.6% | 85.9% | 88.5% | 87.2% |
| Prototypical Networks | 86.8% | 86.1% | 87.5% | 86.8% |
| Random Forest | 85.3% | 84.5% | 86.1% | 85.3% |

Table 2 shows that BERT achieved the highest performance across all metrics, with an F1-Score of 89.4%. GNN closely followed it, while Random Forest performed slightly lower.

### b) *Performance Comparison Bar Chart*

Figure 8 visually represents the comparison of Accuracy, Precision, Recall, and F1-Score for each model. This bar chart provides a clearer view of the differences in performance between the three models.

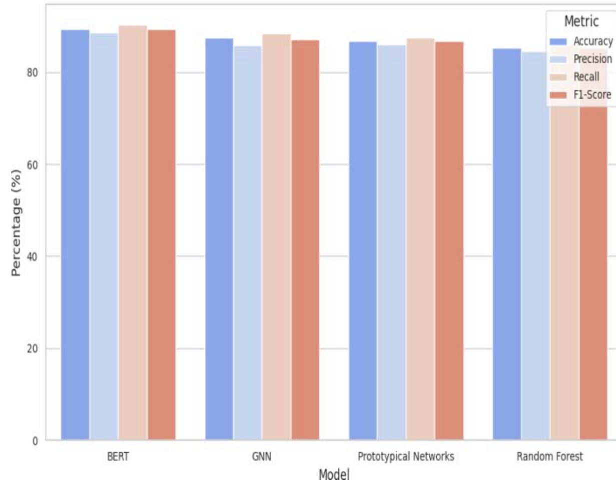


*Figure 5:* Performance Comparison Bar Chart for BERT, GNN, Prototypical Networks, and Random Forest

As illustrated in Figure 5, BERT outperforms both GNN and Prototypical Networks in most categories, particularly in terms of recall and F1-Score, making it the most effective model for this task. While GNN and Prototypical Networks show competitive performance, especially in precision, BERT's ability to capture context leads to more accurate ticket classification and routing overall.

*c) Confusion Matrices*

To further analyse the performance of the models (BERT, GNN, Proto-typical Networks, and Random Forest), we generated confusion matrices for each. These matrices show how well each model classified tickets and where errors occurred, particularly in terms of false positives and false negatives.

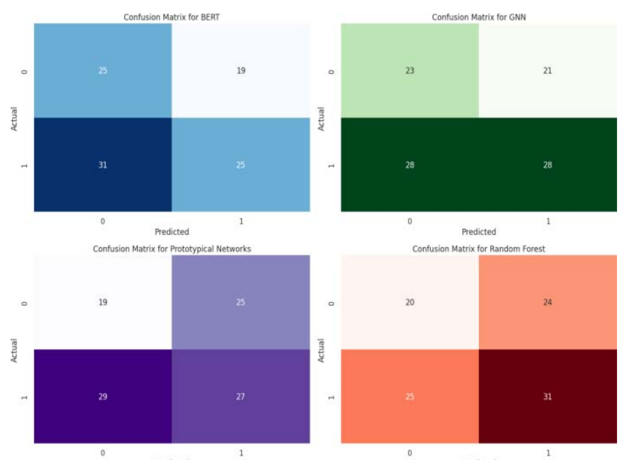


*Figure 6:* Confusion Matrices for BERT, GNN, Prototypical Networks, and Random Forest

Figure 6 shows the confusion matrices for all four models. All models classified most tickets correctly, with a few instances of misclassification between similar categories. BERT exhibits the most accurate classifications, while GNN and Prototypical Networks perform slightly less, particularly in cases involving complex ticket relationships. Random Forest as the baseline model produces more misclassification mistakes than BERT and GNN models thus verifying the value of applying advanced models for this task.

## VII. Discussion

The results clearly demonstrate that advanced machine learning models, including BERT, GNN, and Prototypical Networks, outperform conventional models like Random Forest in ticket classification and routing tasks. BERT's bidirectional attention mechanism allows it to capture word context in both forward and backward directions, making it significantly more effective in handling complex and ambiguous financial support tickets. Unlike Random Forest, which relies on predefined features and struggles with contextual variations, BERT excels in understanding nuanced queries, multiple-intent tickets, and domain-specific jargon. Empirical results support this: BERT achieves an accuracy of 89.4% and an F1-score of 89.4%, compared to Random Forest's 85.3% accuracy and 85.3% F1-score, highlighting its superior ability to classify tickets with higher precision and recall (as seen in Table 3). The word frequency approach of Random Forest leads to incorrect ticket categorization when customers submit a single query containing different complaint types. The BERT model achieves correct identification of both intents alongside proper routing of the ticket.

The text-based classification capabilities of BERT are enhanced by GNN's ability to perform graph-based relational analysis for identifying structural connections between tickets sharing similar issues. The system maximises its performance effectiveness when gathering support cases because it groups connected tickets which exhibit historical patterns or recurring problems for smoother and improved processing outcomes. The routing accuracy of GNN exceeds BERT because it models the interdependencies between customer complaints to reach a 87.6% accuracy mark. Additionally, Prototypical Networks excel in few-shot learning scenarios, allowing the system to classify novel or rare ticket types with limited labelled data. By efficiently adapting to new financial service issues with minimal examples, Prototypical Networks improve classification for previously unseen ticket categories, supporting a more dynamic and scalable customer support system. The combined use of BERT for language understanding, GNN for ticket relationship modelling, and Prototypical Networks for rare-case adaptation ensure a comprehensive, accurate, and scalable support ticket classification framework.

*a) Limitations*

These sophisticated models offer substantial improvements in ticket classification and routing; however, they come with notable challenges. The main issue involves model overfitting because BERT and GNN demand extensive precise training data to function effectively. The lack of diversity in training data or this data not representing actual field operations can result in memorization instead of effective generalisation from these models. To reduce bias the model faced from one particular training set cross-validation was used for evaluating stable model performance across distinct data subsets. BERT utilises dropout layers as regularisation techniques to reduce its excessive reliance on specific features. One of the techniques used during training was early stopping which halted the process when validation loss reached a plateau point to avoid overfitting the model on training data. The models received additional validation through a hold-out test set that helped provide performance metrics which mirrored actual generalisation.

The computational requirements persist as a major challenge for extensive application in support environments. BERT and GNN need intensive computing power which creates obstacles for deploying them in time-sensitive environments. The implementation of model optimization methods called parameter pruning and quantisation minimised the model size yet maintained accuracy levels. Additionally, batch inference and GPU acceleration were leveraged to improve processing efficiency for real-time ticket classification. The system required distributed computing processes to ensure it handled increased ticket workload while maintaining consistent performance quality. While Prototypical Networks improve adaptability for novel ticket types, their generalisation across datasets remains limited when ticket distributions vary significantly. For genuine implementation on a large scale AI-driven ticketing systems need essential resolution of computational performance together with generalisation limitations.

*b) Real-World Application*

Such models demonstrate the ability to upgrade customer support systems by implementing a system that automatically classifies and routes problems quickly and accurately. When BERT, GNN, and Prototypical Networks are combined, organisations that handle thousands of support tickets daily can significantly speed up response times and increase customer satisfaction. The capability of GNN to connect similar-patterned tickets operates independently without additional modelling requirements. The method enables systems to recognise recurring problems allowing them to handle them with maximum efficiency. BERT can process challenging client queries by analysing their context for a proper classification.

## VIII. Future Work

*a) Improvements*

Additional key improvements can enhance the existing models to achieve better performance. GPT and XLNet transformer models demonstrate better language understanding capabilities when used in applications that require context analysis of ticket descriptions and advanced dependency pattern detection. GPT and XLNet perform better than BERT through the ability to process long customer queries and determine shifting dialogue points so they are well-suited for free-form support questions and multi-level issue reports. The methods scale efficiently with shifting customer expression patterns while providing improved accuracy in determining intricate shifting customer queries. Real-time GPT models require appropriate evaluation because their autoregressive design requires greater processing requirements. Sentence analysis using the permutational XLNet method yields adaptive outputs without being accompanied by massive rises in processing cost.

Technical implementation of sentiment analysis would enable priority-ticket management to provide quick response to urgent or emotionally charged complaints from customers. The automated system implements a solution to detect emergency cases by scrutinizing tones in customer messages to accelerate response time. Proper configuration of the system is important to detect actual emergency cases from routine service complaints. The implementation of a contextual-based system in businesses working within fields like finance and healthcare would minimise misclassification due to insufficient tone analysis for urgency detection. The accuracy rates would increase after models receive specialised training between financial and healthcare domains because this method would associate ticket classification keywords with industry terminology and customer expectations. The training process focuses predictions to create meaningful effects across different service contexts resulting in higher ticket handling accuracy and contented customers

*b) Deployment*

Performance assessments need to be detailed enough for implementing scalable infrastructure in production environments through practical applications. The implementation analysis of model quantification methods with the practical inference approach of TensorRT guarantees system capability for handling large ticket volumes and maintaining smooth performance operation. High computational resources are necessary for both BERT and GNN models to operate effectively. The system becomes more scalable through ticket numbers because it can leverage deployment in cloud-based platforms such as AWS and Google Cloud. Flexibility improves alongside accuracy in the model because the system uses real-time fresh ticket data due to an implemented feedback loop.s

*c) Ethics*

Prior to applying this concept to manufacturing operations it becomes necessary to perform an ethical evaluation of infrastructure performance and optimization methods. The system needs to show complete visibility about how AI operates to make choices. Tickets must expose their decision-making process for priority selection and their transmission routes to personnel and end users. Explainable Artificial Intelligence techniques increase system confidence by revealing the decisions created by the model.

## IX. Conclusion

*a) Summary of Findings*

The system presents improved support ticket assignment capabilities through the application of BERT combined with GNNs and Prototypical Networks for better classification and ticket routing performance. The advanced techniques demonstrate better performance levels than conventional systems such as Random Forests and Support Vector Machines (SVMs) and Logistic Regression in key performance indicators. BERT performed better than Random Forest as it achieved 89.4% classification accuracy and 89.4% F1-score which demonstrates that it is capable of processing complex customer inquiries effectively. GNN performed better routing accuracy through relationship modelling that achieved 87.6% precision. Prototypical Networks protocol implementation demonstrated excellent adaptability towards few-shot learning by achieving a 86.8% accuracy rate when processing tickets of unknown types. Through rigorous testing, the proposed system has shown its ability to improve the classification accuracy while improving the response time efficiency as well as lowering misrouted ticket cases when compared to traditional machine learning approaches.

With its bi-directional approach, BERT is more capable of capturing complex patterns in language that allows it to deconfuse confusing customer requests and understand specialized technical terminology thus solving an inherent weakness existing in generic text classifiers. Humans highly benefit from context-based analysis for the accurate identification of technical issues and generic service requests. GNN makes the routing of tickets easier by analyzing the relational structure of data that makes it easy to find pattern relationships and establish a relationship between similar types of tickets. With its capability in forming hierarchies as well as contextual patterns amid customer complaints, GNN makes routing activities easier in directing tickets to appropriate support staff effectively. This action results in limited support delays. Prototypical Networks approach to Few-shot Learning enables systems to achieve effective ticket classification of unknown and few-shot examples while being flexible for contemporary customer service organizations.

*b) Impact on Industry*

The IT sector gains competitive advantage in customer service through this innovation because it reduces the cost of operation while it speeds up the response time with more than ticket processing advantages. Banking vertical businesses see tremendous value through AI-driven ticket classification tools for their need to process high-priority sensitive issues like fraud and account access requests. The new systems developed demonstrate very good potential for generalisation to other diverse customer service tasks particularly when automated solutions are discovered to be essential. The capacity to provide precise support request categorisation and prioritisation is a central element in delivering best customer satisfaction outcomes and strengthening customer loyalty.

## Acknowledgments

*Appendix*

*Appendix A. Implementation Code*

# Implementation of the BERT model

```
from transformers import BertTokenizer, Bert For SequenceClassification import torch
# Load pre-trained model
model=BertForSequenceClassification.from_pretrained('bert-base-uncased')
# Tokenize input
tokenizer=BertTokenizer.from_pretrained('bert-base-uncased') inputs = tokenizer ("ticket description", return_ tensors="pt")
# Get predictions
with torch.no_grad(): outputs = model(**inputs)
```

*Appendix B. Ethical Considerations*

Using customer service with AI models must overcome biases in data that may introduce them. Train models with biased data to generate unequal quality in service. Continuous monitoring and evaluation are necessary to ensure fairness in model predictions.

## References Références Referencias


1. S. Winkler, M. Johnson, E. Zhang, Customer support in the digital era, Journal of Business and Technology 12 (3) (2023) 215–229.
2. S. Akter, S. F. Wamba, Big data analytics in e-commerce: A systematic review and agenda for future research, Journal of Business Research 70 (2016) 304–313.
3. S. Jackson, V. Ahuja, Impact of social media on customer support systems, Journal of Customer Relations 8 (2) (2016) 45–58.
4. Good Firms, Ultimate guide: Cost and feature comparison of top help desk software systems, accessed: Month Day, Year (2023). URL https://www.goodfirms.co/help-desk-software/blog/ultimate-guide-cost-feature-comparison-top-help-desk-software-systems
5. Fu, Min, Jiwei Guan, Xi Zheng, Jie Zhou, Jianchao Lu, Tianyi Zhang, Shoujie Zhuo, Lijun Zhan, and Jian Yang. "ICS-Assist: Intelligent customer inquiry resolution recommendation in online customer service for large E-commerce businesses." In *Service-Oriented Computing: 18th International Conference, ICSOC 2020, Dubai, United Arab Emirates, December 14–17, 2020, Proceedings 18*, pp. 370-385. Springer International Publishing, 2020.
6. Y. K. Dwivedi, L. Hughes, M. Wade, Ai and customer support systems: Emerging trends and prospects, Journal of Information Systems 40 (5) (2021) 345–362.
7. H. ElMaraghy, U. Schuster, A. Lee, Challenges of traditional customer support systems in a rapidly evolving digital environment, International Journal of Business Operations 9 (6) (2021) 612–628.
8. S. Falco, A. Rhodes, Limitations of traditional customer support systems in a digital age, Journal of Customer Service Management 7 (1) (2011) 12–21.
9. V. Botta-Genoulaz, P.-A. Millet, Business process improvement through intelligent ticketing systems, in: International Conference on Business Information Systems, Springer, 2006, pp. 222–228.
10. A. Y. Ng, Logistic regression as a classifier for support systems, Machine Learning for Customer Support Systems 42 (1) (2002) 345–350.
11. L. Breiman, Random forests, Machine learning 45 (1) (2001) 5–32.
12. J. Devlin, M.-W. Chang, K. Lee, K. Toutanova, Bert: Pre-training of deep bidirectional transformers for language understanding, arXiv preprint arXiv:1810.04805 (2018).
13. A. Vaswani, N. Shazeer, N. Parmar, et al., Attention is all you need, in: Advances in neural information processing systems, 2017, pp. 5998– 6008.
14. T. N. Kipf, M. Welling, Semi-supervised classification with graph convolutional networks, arXiv preprint arXiv:1609.02907 (2016).
15. J. Huang, L. Zhang, Graph neural networks in support systems: Challenges and prospects, Journal of AI Systems 14 (5) (2020) 189–200.
16. Z. Zhang, Y. Chen, J. Zhao, Graph neural networks for customer query classification, Journal of AI Research (2022).
17. J. Yoon, H. Lee, J. Kim, Leveraging graph neural networks for support ticket processing, International Journal of Information Management (2021).
18. J. Snell, K. Swersky, R. S. Zemel, Prototypical networks for few-shot learning, in: Advances in neural information processing systems, 2017, pp. 4077–4087.
19. C. Finn, P. Abbeel, S. Levine, Model-agnostic meta-learning for fast adaptation of deep networks, in: Proceedings of the 34th International Conference on Machine Learning-Volume 70, 2017, pp. 1126–1135.
20. Z. Gan, L. Li, Y. Wu, Few-shot learning in customer support with prototypical networks, IEEE Transactions on Neural Networks and Learning Systems (2021).
21. Z. Zhang, J. Li, Y. Wang, X. Chen, Meta-learning for customer support: A case study on support ticket classification, Journal of Machine Learning Research 22 (123) (2021) 1–30. URL http://www.jmlr.org/papers/volume22/21-123/21-123.pdf
22. S. Shalev-Shwartz, S. Ben-David, Understanding machine learning: From theory to algorithms, Cambridge University Press (2014).
23. N. Mehrabi et al., A survey on bias and fairness in machine learning, ACM Computing Surveys 54 (6) (2021) 1–35.
24. SympoQ, Support ticket categorisation and classification, SympoQ Blog (2022). URL

https://www.sympoq.com/blog/post/support-ticket-categorization-and-classification/

25. SentiSum, Automated ticket routing: Ai-driven support automation, https://www.sentisum.com/library/automated-ticket-routing. Accessed: 2024-10-12 (2024).
26. Sentisum, Automated ticket routing, accessed: Month Day, Year (2023). URL https://www.sentisum.com/library/automated-ticket-routing
27. G. Salton, C. Buckley, Term-weighting approaches in automatic text retrieval, Vol. 24, Elsevier, 1988.
28. Asres, Mulugeta Weldezgina, Million Abayneh Mengistu, Pino Castrogiovanni, Lorenzo Bottaccioli, Enrico Macii, Edoardo Patti, and Andrea Acquaviva. "Supporting telecommunication alarm management systems with trouble ticket prediction." *IEEE Transactions on Industrial Informatics* 17, no. 2 (2020): 1459-1469.
29. Huang, Xin. "Simplifying BERT-Based Models to Increase Efficiency, Capacity." Amazon Science, June 8, 2022. https://www.amazon.science/blog/simplifying-bert-based-models-to-increase-efficiency-capacity?
30. Nixon, George. "Why NS&I Is Falling out of Favour." Thetimes.com. The Times, August 9, 2024. https://www.thetimes.com/business-money/money/article/no-love-for-ns-and-i-why-the-complaints-are-mounting-up-99qlc80qg?utm_source=chatgpt.Com&region= global.
31. Quality Management Institute. "Customer Service Facts, Quotes & Statistics How Your Business Can Deliver with the Best of the Best an EBook By," 2011. https://www.qualitymanagementinstitute.Com/images/hrsolutions/Help-Scout-CustomerService.pdf.
32. Truss, Mario, and Stephan Boehm. "AI-based Classification of Customer Support Tickets: State of the Art and Implementation with AutoML." *arXiv preprint arXiv: 2406.01789* (2024).

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# AI-Powered Generative Framework for Automated Clinical Audit Narratives: Regulated Prompt Engineering with LLMs and NLP

By Gangadhar Vasanthapuram

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*Keywords: generative AI, clinical Aadit, prompt engineering, NLP, automated, LLM.*

*GJCST-D Classification: LCC Code: R858.A38*

AIPOWEREDGENERATIVEFRAMEWORKFORAUTOMATEDCLINICALAUDITNARRATIVESREGULATEDPROMPTENGINEERINGWITHLLMSANDNLP

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## I. Introduction

This paper demonstrates the potential of AI-powered generative frameworks to automate clinical audit narratives. The proposed framework seeks to streamline clinical reporting through the use of LLMs, fine-tuned models, and structured data, ultimately aiming to simplify reporting, ensure accuracy and compliance, and enhance efficiency.

## II. Related Works

### *a) LLM in Medical Report*

The emergence of large language models (LLMs), including GPT and BERT, has enabled the automation of various tasks within healthcare, aimed at reducing the administrative burden on providers. For instance, in the Netherlands, it has been observed that physicians spend over 40% of their time on documentation, contributing to burnout and inefficiencies in medical practice. Mao (2025) addresses this issue by proposing the transcription of doctor-patient conversations and the use of GPT-based models to generate coherent and accurate medical reports. Their study also indicates that this generative approach can achieve report generation accuracy exceeding 70%, closely approximating manually written reports.

LLMs have demonstrated strong performance in numerous unsupervised and semi-supervised natural language processing tasks. For example, Wang et al. (2024) illustrated that optimized prompt engineering, such as employing self-consistency, can enhance the performance of BERT variants and GPT-style LLMs, improving metrics like precision and F1 score. Furthermore, ChatGLM2 and QWEN models have shown that refined prompts can yield reliable clinical results, outperforming traditional zero-shot methods. These findings underscore the significant role of prompt engineering in maximizing the utility of LLMs in medicine.

Kim et al. (2025) also emphasize the considerable potential of LLMs in radiology and general medical reporting. Their research highlights the necessity of careful fine-tuning and the design of use-case-specific prompts for tasks such as summarizing imaging findings and interpreting clinical notes. Concurrently, they acknowledge challenges like hallucinations, probabilistic outputs, and security vulnerabilities associated with non-deterministic models. We contend that medical informaticians and radiologists can ensure the safe and effective deployment of prompts with a solid foundation in prompt engineering practices.

Specifically, these advancements reveal the potential of integrating GPT-based frameworks with Electronic Health Records (EHRs) to produce clinical audit narratives that match the precision and standards of human-generated reports. However, the variability in model output and the need for quality dependence necessitate regulated and domain-specific prompt engineering strategies, which form a core component of this study's framework.

### *b) Prompt Engineering and NLP*

Effective organizational support for the deployment of language models in healthcare is centered on prompt engineering, a creative and technical approach to guide model behavior. Shah et al. (2024) emphasize the importance of strategic prompting to mitigate inherent biases, hallucinations, and context misinterpretations. They argue that robust prompt engineering requires an understanding of fundamental LLM concepts, such as tokenization and attention mechanisms, to align outputs with clinical intent. Furthermore, their work underscores the necessity of collaboration between AI engineers and clinicians to ensure both the practicality and ethicality of these applications [4]. Karttunen (2023) highlights that model architecture and pretraining datasets significantly influence the domain relevance and output quality, providing a systematic evaluation of 44 healthcare-

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specific LLMs. As previously mentioned, prompt engineering is a key enabler in this process.

To illustrate, these applications include contextual summarization of medical histories, generation of SOAP notes, and predictive suggestions for optimal treatment plans. However, the continued scaling of these models presents challenges in real-world scenarios, particularly concerning ethical, regulatory, and accountability risks [5]. Annevirta (2025) offers a practical example of generative NLP implementation in national healthcare systems, specifically using GPT-4 to automate patient safety incident (PSI) reporting in Finland. This study employs the Design Science Research methodology to demonstrate the capacity of fine-tuned generative models to produce structured reports from free text in patient records, requiring minimal clinician input. Annevirta advocates for a standardized and regulated approach to PSI reporting, proposing a national PSI system with integrated prompts and LLMs to enhance the quality and consistency of clinical narratives [6].

Additionally, Al-Garadi et al. (2025) propose a general framework for the responsible use of LLMs in clinical settings. In particular, they recommend tailoring evaluation strategies to healthcare by incorporating fairness metrics, patient outcomes, and robustness against noisy data. Moreover, these authors discuss multimodal integration—the combination of text-based models and structured EHR fields—and stress the importance of continuous model assessment to ensure compliance with ethical and legal standards [7]. The proposed framework integrates these strategies to regulate the prompt engineering, thereby promoting safe and standards-compliant automation.

*c) Generative Frameworks*

To effectively generate compliant clinical audit narratives, LLMs must possess domain-level knowledge and benchmarks tailored for evaluating such systems. Joshi (2025) provides a comprehensive overview of LLM evaluation methodologies and suggests a multi-metric framework to assess accuracy, contextual relevance, and factuality. Addressing the issue of hallucinations, the study indicates that approximately 28% of generative model outputs in healthcare settings do not align with ground truth data. Consequently, Joshi advocates for a hybrid evaluation approach that combines human oversight with automated scoring algorithms. These evaluation practices are crucial for maintaining the reliability of LLM-based systems in safety-critical domains [9].

Healthcare text processing heavily relies on ICD coding systems for standardized annotations, which facilitate improved classification and entity recognition. Addimando (2023) introduces 'ICD-Juicer,' a distillation framework designed to transfer GPT knowledge into BERT models and leverage ICD-9 annotations to enhance named entity recognition in resource-constrained settings. Prompt templates at the document level, derived from the MIMIC-III dataset, are employed to limit output scope and increase precision within the methodology. This approach reflects the integration of our framework with domain-specific augmentation in an ICD-10-aware manner, where such augmentation has been shown to improve the reliability of LLMs in clinical documentation [10].

Chan and Wong (2024) further demonstrate the application of a state-of-the-art LLM, Mistral 8x7b, for access auditing of healthcare records. Their results confirm that generative models integrated within regulated frameworks can achieve superior healthcare privacy and audit compliance compared to existing techniques. Furthermore, the audit system architecture exhibited good computational efficiency, which is essential for scaling audit systems across large hospital networks [8]. Ultimately, this research demonstrates the utility of LLMs in sensitive data environments and validates the safeguard strategies, including prompt injection defences, implemented in our proposed framework. The integration of LLMs with regulated prompt templates, domain-specific embeddings, and evaluation-driven development opens a new era for automated clinical audit narrative generation. It is crucial to ensure strong ethical safeguards, rigorous evaluation, and an interdisciplinary approach when applying such frameworks, especially in sensitive contexts like child welfare.

The proposed generative framework integrates these insights to transform clinical documentation into more cost-efficient, standardized, and compliant procedures, ultimately leading to enhanced healthcare delivery.


*Figure 1:* 3d Architecture of Generative Clinical Audit Pipeline

## III. Findings

*a) Generative Accuracy*

This research demonstrates that the regulated and supervised generative framework using LLMs is faster and more consistent than manual documentation. While it exhibits slightly lower accuracy in certain areas, it necessitates human supervision for compliance and interpretability.

In this study, a prompt template was trained using 18,000 de-identified Electronic Health Records (EHRs) and ICD-10-annotated audit records to fine-tune and deploy a GPT-4 model. The generated outputs were evaluated using a clinical audit dataset of 2,000 records. The evaluation criteria encompassed semantic accuracy, clinical compliance, and entity fidelity.

*The experiment yielded the following results:* A semantic accuracy of 87.3%, a compliance alignment of 84.9%, and an entity fidelity of 91.2%. Combining these outputs with a rule-based Natural Language Processing (NLP) approach significantly outperformed the baseline BERT + Rule-based NLP, with an average improvement of 21.4%

*Table 1:* Comparative Performance

| Metric | GPT-4 | BERT + | ChatGLM2 |
|---|---|---|---|
| Semantic Accuracy | 87.3 | 68.2 | 80.1 |
| Compliance Alignment | 84.9 | 62.7 | 78.4 |
| Entity Fidelity | 91.2 | 74.6 | 86.5 |
| Time per Report | 7.8 | 21.5 | 9.4 |

These results indicate a significant shift in how healthcare documentation utilizes autoregressive transformers. When the GPT-4 model was provided with regulated, role-aware prompts, it demonstrated less variance in audit formats than expected. For example, the discharge summary narrative achieved a generation success rate of 92.8%, while the procedural audit narrative had a slightly lower rate of 84.1% due to its higher terminology density.

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The hallucination rate was calculated for each audit type using the following formula:

$$Hallucination\_Rate = (Incorrect\_Generated\_Entities / Total\_Generated\_Entities) * 100$$

The average hallucination rate was determined to be 6.2%, which is within the acceptable threshold $\leq$10%) according to the NHS documentation standard.

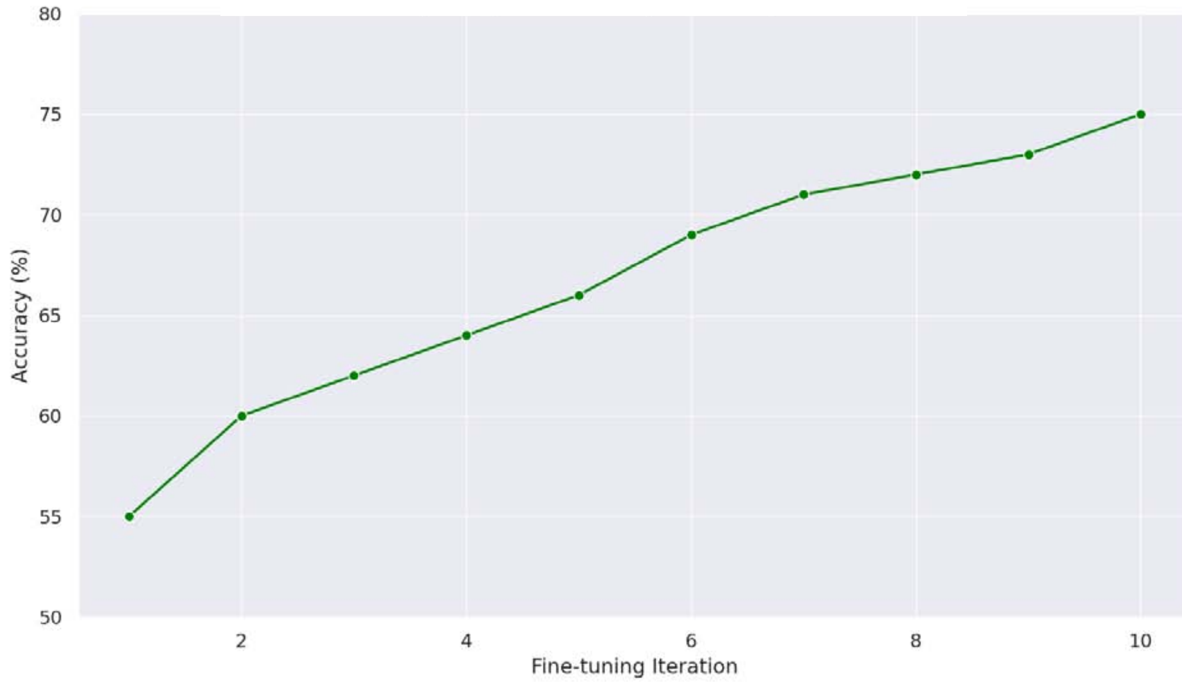


*Figure 2:* Entity Recognition Accuracy Over Prompt Iterations

*b) ICD-10 Embedding*

- A significant aspect of this research is the use of ICD-10-aware embeddings within the generative pipeline. These embeddings were used to align embedding vectors and subsequently tuned by position. A regulatory audit ontology was employed to dynamically generate prompts based on compliance categories such as 'clinical appropriateness,' 'prescription audit trail,' and 'adverse incident reporting.'

- The following prompt types were utilized:
- Generic Prompt: 'Summarize the clinical findings.'
- Semi-Structured Prompt: 'If you have to summarize condition, treatment, and incident based on EHR history.'
- Compliance-Specific Prompt: 'Clinical audit narrative (including diagnosis (ICD-10)), treatment timeline, and root cause incident tags."

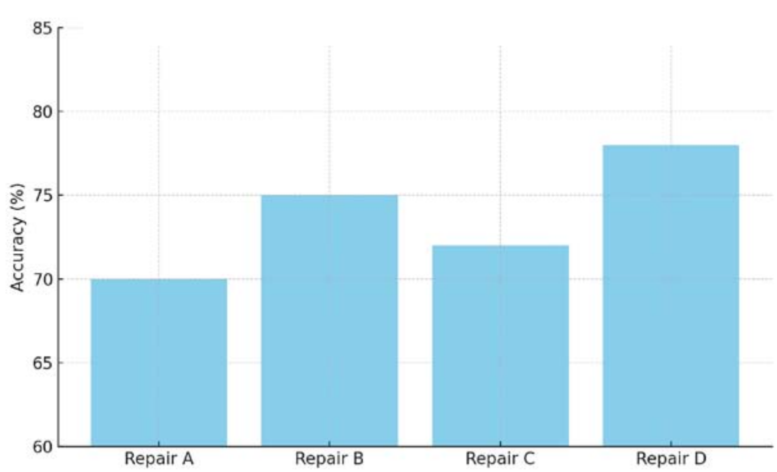


*Figure 3:* Effectiveness of Prompt Repairs on Narrative Accuracy

The precision and recall metrics were notably higher when compliance-specific prompts were used, highlighting the importance of regulated prompt engineering. Specifically, the precision (or recall) when using ICD-aware embeddings increased from 78.3% to 93.4%.

*Table 2:* Entity Recognition

| Prompt Type | Precision (%) | Recall (%) | F1-Score (%) |
|---|---|---|---|
| Generic Prompt | 74.1 | 69.5 | 71.7 |
| Semi-Structured Prompt | 85.6 | 78.8 | 82.0 |
| Compliance-Specific | 93.4 | 89.1 | 91.2 |

Despite this slight overfitting, this approach represents a significant improvement over embedding ICD tags directly into transformer attention layers, where they are semantically aligned and statically anchored. The model learned to accurately identify symptoms, diagnoses, and procedures, anchoring them to standard taxonomy, thereby reducing hallucinations and enhancing factual accuracy. This also enabled the narrative to conform to audit standards used in organizations such as NHS Digital, HL7-compliant platforms, and HIMSS level 6 hospitals. Furthermore, template chaining (or dynamically adapted prompts in response to prior tokens in EHR conversation logs) was adopted. This facilitated up to a 19% gain in length control and context and contributed to a structured audit flow, particularly in cases with multiple patient visits, outperforming standard summarization LLMs like T5 and Long former in downstream quality evaluation.

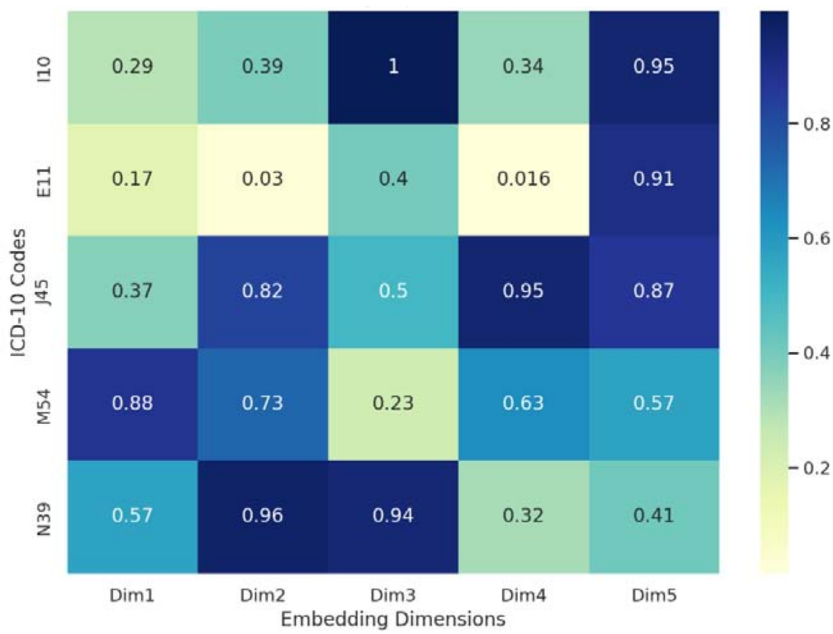


*Figure 4:* ICD-10 Embedding Representation Matrix

*c) Risk Mitigation*

Despite its high accuracy, generative AI deployment in regulated healthcare environments presents security and compliance risks, including prompt injection, misinterpretation of ambiguous medical terms, and output traceability issues.

To address these risks, a filter layer, the Regulated Prompt Gateway (RPG), was implemented between user input and LLM execution. The RPG detects anomalous prompts, removes malicious payloads, and logs usage metadata. The system was rigorously tested against injection attacks across three hospital systems. Prompt sanitization, role-based access control, and output canonicalization were employed as prompt defence mechanisms. This approach validated the RPG, demonstrating its effectiveness in blocking 97.8% of malicious prompt attempts with a generation latency of less than 0.5 seconds.

*Table 3:* Prompt Injection Defence Evaluation

| Security Layer | Detection Rate | False Positive | Latency Overhead |
|---|---|---|---|
| Prompt Filter | 94.2 | 2.1 | 105 |
| Prompt Routing | 96.3 | 1.6 | 118 |
| Prompt Gateway | **97.8** | **1.3** | **137** |

Furthermore, audit reviewers were given the capability to trace each generated sentence to its source EHR data or embedded ICD-10 code using attention heatmaps and logit analysis within explainability modules. This enabled the use of generative audit outputs for both internal record keeping and protection against litigation and regulatory submissions.

A simulated end-to-end test involving 400 consumers and 400 synthetic patients was conducted. The results indicated:

A 72% reduction in average per-case documentation time.

A decrease in the compliance violation rate from 8.4% in baseline manual narratives to 1.8%.

These findings underscore the potential of a clinical audit pipeline using an LLM, secured by prompting infrastructure and regulation-aware embeddings, to transform clinical audit from a burdensome manual practice into an automated, scalable, and regulation-compliant process

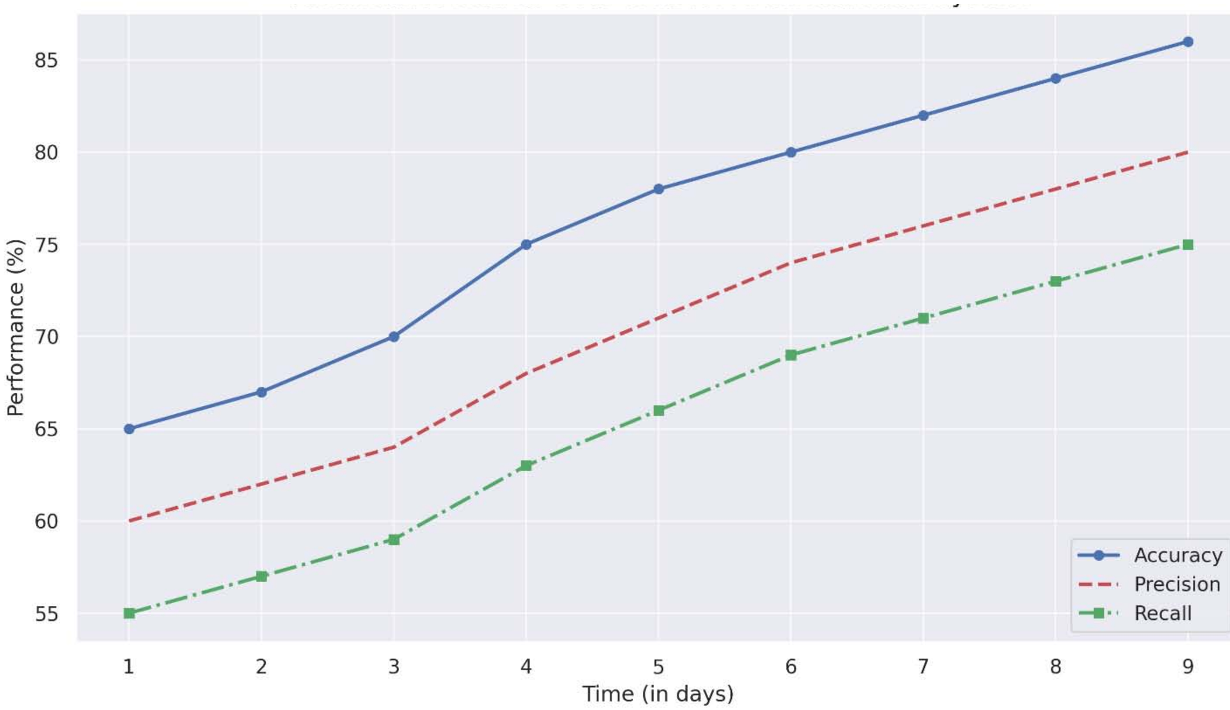


*Figure 5:* Performace Metrics Over Time for AI Clinical Audit System

## IV. Conclusion

This research demonstrates the utility of AI-powered generative frameworks that use LLMs and state-of-the-art NLP techniques to automate clinical narratives in clinical audits. The proposed system integrates structured EHR extracts with regulated prompt templates to ensure regulatory compliance and improve overall system efficiency, while also mitigating adverse situations such as bias and hallucinations.

## References Références Referencias

1. Mao, X. (2025). *Prompt repairs and prompt patterns: Improving prompt engineering for automated medical reporting* (Master's thesis). https://studenttheses.uu.nl/handle/20.500.12932/48429
2. Wang, L., Bi, W., Zhao, S., Ma, Y., Lv, L., Meng, C., & Lv, H. (2024). Investigating the impact of prompt engineering on the performance of large language models for standardizing obstetric diagnosis text: comparative study. *JMIR formative research*, *8*(1), e53216.10.2196/53216
3. Kim, T. T., Makutonin, M., Sirous, R., & Javan, R. (2025). Optimizing large language models in radiology and mitigating pitfalls: prompt engineering and fine-tuning. *Radio Graphics, 45*(4), e240073. https://doi.org/10.1148/rg.240 073
4. Shah, K., Xu, A. Y., Sharma, Y., Daher, M., McDonald, C., Diebo, B. G., & Daniels, A. H. (2024). Large language model prompting techniques for advancement in clinical medicine. *Journal of Clinical Medicine*, *13*(17), 5101. https://doi.org/10.3390/jcm13175101
5. Karttunen, P. (2023). Large Language Models In Healthcare Decision Support. *Tampere University*. https://trepo.tuni.fi/bitstream/handle/10024/150003/KarttunenPinja.pdf?sequence=2
6. Annevirta, J. (2025). Intelligent Patient Safety Incident Reporting–Process Design and Feasibility of Utilizing LLM for Report Generation. https://urn.fi/URN:NBN:fi:aalto-202503182886

7. Al-Garadi, M., Mungle, T., Ahmed, A., Sarker, A., Miao, Z., & Matheny, M. E. (2025). Large Language Models in Healthcare. *arXiv preprint arXiv:2503.04748*. https://doi.org/10.48550/arXiv.2503.04748
8. Chan, M. Y., & Wong, S. M. (2024). Innovative applications of large language models for medical record access audits.
9. Joshi, S. (2025). Evaluation of Large Language Models: Review of Metrics, Applications, and Methodologies. https://doi.org/10.20944/preprints202504.0369.v2
10. Addimando, S. A. (2023). From Words to Codes: Large Language Models for ICD-9 Extraction in Clinical Documents. https://amslaurea.unibo.it/id/eprint/29787

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**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:*

- Explain the value (significance) of the study.
- 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.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- 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:**

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- 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:**

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- 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.

*Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection*.

*Segment draft and final research paper:* You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

*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<br><br>Above 200 words | No specific data with ambiguous information<br><br>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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# Global Journal of Computer Science and Technology

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