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A Survey on Impact of Internet of Medical Things Against Diabetic Foot Ulcer

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Abstract

INTRODUCTION: In this study, we explore the intricate domain of Diabetic Foot Ulcers (DFU) through the development of a comprehensive framework that encompasses diverse operational scenarios. The focus lies on the identification and classification assessment of diabetic foot ulcers, the implementation of smart health management strategies, and the collection, analysis, and intelligent interpretation of data related to diabetic foot ulcers. The framework introduces an innovative approach to predicting diabetic foot ulcers and their key characteristics, offering a technical solution for forecasting. The exploration delves into various computational strategies designed for intelligent health analysis tailored to patients with diabetic foot ulcers.
OBJECTIVES: The primary objective of this paper is to present a technical solution for forecasting diabetic foot ulcers, utilizing computational strategies for intelligent health analysis.
METHODS: Techniques derived from social network analysis are employed to conduct this research, focusing on diverse computational strategies geared towards intelligent health analysis for patients with diabetic foot ulcers. The study highlights methodologies addressing the unique challenges posed by diabetic foot ulcers, with a central emphasis on the integration of Internet of Medical Things (IoMT) in prediction strategies.
RESULTS: The main results of this paper include the proposal of IoMT-based computing strategies covering the entire spectrum of DFU analysis, such as localization, classification assessment, intelligent health management, and detection. The study also acknowledges the challenges faced by previous research, including low classification rates and elevated false alarm rates, and proposes automatic recognition approaches leveraging advanced machine learning techniques to enhance accuracy and efficacy.
CONCLUSION: The proposed IoMT-based computing strategies present a significant advancement in addressing the challenges associated with predicting diabetic foot ulcers. The integration of advanced machine learning techniques demonstrates promise in improving accuracy and efficiency in diabetic foot ulcer localization, marking a positive stride towards overcoming existing limitations in previous research.

Keywords: Diabetic Foot Ulcer, Classification, Smart Health, Smart analysis prediction, Detection, Internet of Medical Things

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1. Introduction

Diabetic foot ulcers have ignited intense debate surrounding functional implications and patient-related expenditures. The potential consequences of these ulcers and their associated outcomes drive efforts to prevent adverse health impacts. Addressing the substantial costs of ongoing medical treatment and personalized patient care, especially in light of the rising expenses, has been examined through the lens of the IoMT. This study taps into IoMT's potential to revolutionize the detection and analysis of diabetic foot ulcers, proposing an innovative approach to their localization.

The research delves into the continuous monitoring and prediction aspects crucial for effective diabetic foot ulcer disease management. As communication, flexibility, and reliability challenges persist, this investigation delves into the realm of constant monitoring. To comprehend the impact of the Internet of Things on diabetic foot ulcers at various stages, this research classifies the literature review into several distinct categories, providing an overview of the disease's intricacies.

The investigation unveils a series of methodologies that leverage IoMT, ushering in advancements such as:

• IoMT-based Reservoir Computing for Diabetic Foot Ulcer Localization
• Advanced Machine Learning Approach for Diabetic Foot Ulcer Classification Assessment
• IoT-enabled Smart Health Management for Diabetic Foot Ulcers, comparing home-based care with hospital-based care
• IoT-enabled Health Data Collection and Analysis for Diabetic Foot Ulcers, utilizing high-definition images
• IoT-enabled Detection and Classification of Diabetic Foot Ulcers
• IoT-enabled Image Segmentation Analysis of Diabetic Foot Ulcers with Virtual Sensing

The analysis of this research hinges on the IoMT-driven evaluation of diabetic foot ulcers, combined with an integrated intelligent approach to management, which emphasizes automatic recognition. A critical discourse surrounding classification and assessment explores the potential of machine learning advancements, prompting the application of practical methods to enable in-depth diabetic foot ulcer analysis. The study also introduces the concept of hierarchical classification, tailored to handle unstructured data within the IoT framework, thereby facilitating automated hierarchical clustering for managing DFU patients.

Incorporating a home care ecosystem empowered by IoT services, this research probes the efficacy of this approach in mitigating diabetic foot ulceration complications. Effective patient-physician communication, informed by medical, personal, and lifestyle histories, underpins this method, enhancing self-care practices and overall management. Furthermore, the study delves into the potential of IoT-driven health data collection and analysis for intelligent diabetic foot ulcer assessment, underscoring the utility of technology-based healthcare methods and their cost-effectiveness. The research also validates and verifies its findings through a comprehensive algorithmic approach, ensuring a robust foundation for further exploration.

To fulfil the research's goals, the authors are recommended to incorporate two additional introductory paragraphs that explicitly outline the paper's contributions and provide a clear problem statement. This expansion will enhance the reader's understanding of the study's significance and objectives.

1.1 Objective and Need for the Study:

In recent years, the prevalence of DFU has seen a significant rise, posing a considerable challenge to healthcare professionals worldwide. The complications associated with DFU not only impact the quality of life for patients but also lead to substantial economic burdens on healthcare systems. This study aims to address the pressing need for advanced, technology-driven solutions to monitor, predict, and manage DFU more effectively.

The primary aim of this study is to investigate the inherent techniques for classifying and predicting DFUs naturally. Additionally, it seeks to explore privacy-preserving approaches while locating DFUs within IoT-based systems, as outlined in Shi et al.'s research [35].

Specific Objectives

• To enhance the accuracy of classification, prediction, and DFU localization while reducing error rates and computation time.
• To refine the Privacy-Preserving measures and enhance execution time and data efficiency in DFU analysis.
• To optimize the handling of DFU images, ensuring both accuracy and security.

1.2 Contribution of this Paper

This paper makes the following key contributions:

• IoMT-based Detection and Analysis: Introduces emerging technologies for locating and analyzing diabetic foot ulcers using automated systems powered by IoMT.
• Continuous Monitoring: Highlights the importance of constant monitoring in DFU management and addresses challenges related to communication, flexibility, and reliability in IoMT systems.
• Machine Learning in DFU Analysis: Discusses the potential of advanced machine learning techniques in classifying and assessing DFUs, offering a novel approach to handling unstructured data in this context.
• Home Care vs. Hospital Care: Investigates the efficacy of home care treatment measures for DFUs using IoT services, emphasizing the benefits of effective patient-physician communication.
• Cost-Benefit Analysis: Examines the economic implications of technology-based healthcare methods for DFUs, weighing the costs against the benefits derived from improved patient outcomes.

1.3 Problem Statement

Despite the advancements in medical technology, the effective management of diabetic foot ulcers remains a challenge. Traditional methods often fall short in early detection and continuous monitoring, leading to adverse health outcomes for patients. Furthermore, the economic burden of DFU treatment is substantial. This research seeks to address these challenges by harnessing the power of the Internet of Medical Things and machine learning. The primary question driving this research is: How can IoMT, combined with advanced machine learning techniques, revolutionize the detection, analysis, and treatment of diabetic foot ulcers?

2. Related works

The following is a summary of the article's content. Part 2 discusses recent studies on IoMT- based diabetic foot ulcers. Part 3 of the methodological analysis section covers the research gap and their respective research question with the suggested solution of this study. Part 4 offers the conclusion and summarises the debate.

2.1 IoMT-based Reservoir Computing for Locating Diabetic Foot Ulcer

IoMT-based reservoir computing has been used for localizing diabetic foot ulcers, as summarized in the table below, with recent technological advancements highlighting its potential in nonlinear system dynamics. This approach, rooted in neural networks, has been integrated into diabetic foot ulcer analysis. Researchers have introduced computational models and mobile apps for wound size measurement and explored larval microbiological therapy for ulcer treatment. Intelligent mats and Sox are also being used for ulcer monitoring.

Table 1. Investigation of IoMT-based computing for locating diabetic foot ulcer

Author and year	Proposed Method	Research Uses	Analysis
Gupta et al. [18]	A computational model of finding the diabetic foot ulcer, the size of the ulcer, and the location of the ulcer is proposed	The identification of all possible locations of the ulcer and the additional ulcer of stress location analyzed	The statistical analysis method is used to predict the location of foot ulcers.
Kuang et al.[14]	The measurement of the wound size is determined by the volume and the accuracy of the foot ulcer size.	The mobile app is used to measure the wound size and the measurement.	NDK mobile phone application used in the wound in the 2-dimensional measurements for wound care.
Szczepanowskiet al. [36]	L sericata larvae treat the patient. The microbiological analysis for the study of larval therapy is done to treat foot ulcers.	It is used in treating the person affected by a leg ulcer. Hence, the diagnosis of the diabetic foot and limb ulcers is treated by ozone therapy.	Markov chain Monte Carlo (MCMC) algorithm and Bayesian statistics are used in the statistical distribution of foot ulcer
Najafi et al.[19]	Smart mat and the smart Sox are introduced to find the diabetic foot ulcer by a continuous screening of the foot of the humans	This research helps detect the foot ulcer early, monitor the risk of foot ulcers, and monitor the stress of mechanical factors.	The clinical decision support system method is used to analyze the foot ulcer.
Gokalgandhi et al.[9]	Smart shoes use IoT devices for the monitorization of the foot.	They were used in recording everyday activities and the conditions of how the foot is viewed.	Skin and the foot temperature finding method is used by Vibration monitors, wireless monitors, and GPS in the shoes to monitor the foot ulcer.
Raviglione et al.[31]	The textile pressure sensor is used in the collection and transferred to the web dashboard. Hence, the foot band with the sensor is used to monitor thefoot ulcer.	Used in monitoring the foot ulcer and the foot's temperature has been calculated.	Analog to digital converters and the clinical decision-making algorithm are used to find the ulcer.

Gokalgandhi et al. [9] introduced smart shoes for foot ulcer monitoring, using skin temperature and GPS. Raviglione et al. [31] employed textile pressure sensors with temperature data, aided by an analog-to-digital converter for decision-making.

2.2 Diabetic Foot Ulcer Classification Employing Advanced Machine Learning

Diabetic foot ulcers, a serious complication of diabetes, are being studied extensively. Machine learning, particularly the

SHAP algorithm, helps predict diseases by analyzing individual patient factors. Methods like Light GBM and ANOVA are used to analyze datasets. Clinical intervention is crucial for treating wound infections, with researchers employing deep learning methods for diabetic wound classification. Mobile apps and cloud-based systems, utilizing networks like ResNet 101, monitor ulcer development. Various algorithms, including SVM and K-nearest, aid ischemia classification and automatic ulcer detection.

Early identification is vital to prevent amputations, a point emphasized by researchers. Understanding the impact of multidrug-resistant organisms (MDRO) on ulcer healing is a focus. Infrared cameras are utilized for early detection. Studies delve into survival rates, amputations, and healing rates, providing important insights. Detailed analyses of ulcer characteristics, such as stages and phagocytic movement efficiency, are contributing to the field. Researchers also explore innovative treatments, including hyperbaric oxygen therapy and placental-derived products, to address challenges like polymicrobial infections [4].

2.3 IoT and Diabetic Foot Ulcer Smart Health Management

Innovations like smart wearables and hospital-at-home technologies enable self-care and remote patient monitoring, as evidenced by various studies. Early identification and management of diabetic foot ulcers have reduced mortality and morbidity, with researchers monitoring patient outcomes. Strategies for wound healing involve analyzing suitable molecules and blood oxygen levels, along with treatments like low-level laser therapy [34]. Wound size and infection assessments, as well as amputation risks, are evaluated through IoT-based data handling methods. Healing outcomes, including factors like ischemic causes, wound size, and location, are thoroughly examined. Offloading strategies, exercise, and improved blood flow play key roles in the healing process. Telehealth services, especially in response to the pandemic, address the needs of diabetic foot ulcer patients. Studies explore patient feelings and experiences, utilizing temperature measurements to identify ulcers and assess pressure patterns. Continuous monitoring of skin temperature at home provides valuable data for assessment, representing recent advancements in empowering self-care and remote monitoring for diabetic foot ulcer patients [8].

2.4 Smart Analysis of Diabetic Foot Ulcer adopting high-definition foot ulcer images

Deep learning algorithms are used to analyze medical images, specifically those related to diabetic foot ulcers. Ongoing challenges from previous research are being addressed through method improvements. ALA-PDT has shown promise in enhancing diabetic foot ulcer treatments and preventing amputations [7]. Natural wound healing processes are integrated, considering various risk factors. Researchers explore the impact of protein levels like MMP9 and propose utilizing molecules such as lncRNA H19 and miR-29b for healing.

Terahertz imaging aids in early diagnosis by exploring neuropathy and cutaneous dehydration. Maggot treatment is being considered as a healing approach based on previous concepts. Hyperspectral imaging and photonics-based analysis are utilized for non-invasive healing prognosis and ulcer assessment, respectively. Deep learning techniques are employed for ulcer detection, and topical oxygen therapy is investigated as a potential treatment method.

Researchers analyze cumulative incidence, risk factors, and amputation rates, utilizing advanced approaches for predictions. Proper ulcer segmentation, as emphasized in recent conferences, is crucial for accurate analysis [23]. Various classification methods and image segmentation techniques are explored, often utilizing computational tools like MATLAB for data processing and enhancement.

2.5 Internet of Things enabled Detection and Classification of Diabetic Foot Ulcer

Researchers utilize deep learning for diabetic foot ulcer classification and depth prediction, emphasizing data sharing. Automated diagnosis is enhanced through CNN and machine learning, prioritizing timely wound care. Continuous monitoring and severity evaluation are focused on, employing advanced technologies like infrared thermography and IoT devices. Studies explore the link between foot ulcer healing, microcirculation, and blood pressure measurements [28]. Researchers leverage AI and IoT for remote healthcare in smart cities, emphasizing diabetic foot ulcer management. Chronic disease analysis and disease management proposals are made using IoT devices. Integration of IoT wearable devices aids real-time diagnosis in biomedical science. IoT and AI technologies are suggested for foot ulcer diagnosis and prevention, improving detection accuracy through advanced algorithms and pressure monitoring. Ulcer grades are classified using SINBAD scores and logistic regression, and healing time is predicted based on ulcer location, considering it as a significant risk factor Table 3.

2.6 Internet of Things for Image segmentation analysis of Diabetic Foot Ulcer

The research gap between the current study and the novel analysis of diabetic foot ulcer prediction enhancement strategies from Nguyen et al. [107] is found based on the literature review Table 3 below.

3. Research gap findings

• Challenges in Data Categorization: The existing research reveals that dealing with the vast amount of data related to diabetic foot ulcers is hampered by low categorization rates, indicating a need for improved data organization techniques.

• High False Alarm Rates: Studies in the field of predicting diabetic foot ulcers often suffer from high false alarm rates, indicating a need for more accurate prediction models and algorithms.

• Lengthy Computation Times in Home Care: Comparing home care approaches to hospital care for diabetic foot ulcers, it is apparent that computation times are often unacceptably long in the former, necessitating more efficient algorithms and technologies.

• Extended Training and Testing Times: The execution of models for diabetic foot ulcer detection and classification consumes significant training and testing time, suggesting a need for methods to expedite these processes without compromising accuracy.

• Inefficiencies in Location Determination: When it comes to pinpointing the location of diabetic foot ulcers, the research highlights issues related to processing speed and accuracy, calling for more efficient methods, possibly incorporating multiple prediction approaches.

• Low Clustering Rate and Accuracy in Data Maintenance: The smart analysis of diabetic foot ulcers may suffer from low clustering rates and accuracy in data maintenance, indicating a need for improved data management and analysis techniques.

Table 2. Investigation of IoT-enabled Detection and Classification of Diabetic Foot Ulcer

Author	Purposes	Inspired by the proposed system	Methods Employed
Adhikari et al. [1]	The prediction of the diseases is made for the disorders, and the decision-making is done.	The prediction and the decision-makingof the diabetic foot ulcer can be made from the images of the foot.	The decision-making method for the analysis of certain diseases and comparative analysis
Alshamrani et al. [6]	Monitoring the health-related views using the IoT and AI is analyzed	The monitoring of the health-related data and storing finds types of diabeticfoot ulcers are found using this system	The anomaly detection and the regression analysis method are used in the monitoring of the health data
Anjum et al.[3]	analysis and diagnosis, forecasting, and monitoring of thediseases COVID	using forecasting, monitoring, and diagnosis using the IoT devices for the DFU can be executed	supervised machine learning and the deep learning method is used For image segmentation
Cassidy et al.[13]	The classification of the wound, the treatment, prediction, and wound healing are analyzed	The automatic classification of the images and the segmentation of images are proposed	weakly supervised learning method, and the early detection is done.
Hassan et al.[10]	The diagnosis of the diabetic footulcer using the radiological images.	Using the deep learning method, analyzing the DFU images is also helpful to the proposed design.	The CT diagnosis is made using segmentation; images feature extraction uses a machine-learning algorithm for disease diagnosis
Islam et al.[12]	the collection of the data from the IoT devices is the monitoring the patient who is suffering from the skin lesions	using a classification system, the classification of the DFU is encountered using the data IoT devices data.	Deep learning, classification, and the method are used to classify skindiseases.
Karthiyayini et al.[13]	The analysis of the retina image for predicting the diseases in theretina.	Using the image of the DFU, the prediction, the types of ulcers, or a grade has been executed.	The classification algorithm, SVM, SMO, random forest, and naïve Bayes are used for image analysis.

Lu et al.[16]	The application of IoT and Artificial intelligence for the study of clinical data has been analyzed	Using the clinical application artificial and the IoT, the monitoring diagnosis, and the healing process processes against the wound of DFU patient	the classification system of the diseases and the prediction encountered using the IoT devicesdata
Mukhtar et al.[17]	COVID 19 uses wearable sensor devices to monitor patients and their body condition.	The wearable sensor devices monitor helps to make the patient treatment who is affected by the DFU using the innovative mat, bright boot, foot selfie,	The classification rules are applied for the management of the data in the IoT devices
Priyadharsini et al.[27]	The removal of the glove from the hand and the automated sensing of the hand are done using the smart sensor for the safe removal of the glove.	The glove is used by the doctor who treated the diabetic foot ulcer patient need to remove the glove safely to avoid any other infection to the doctorcan be proposed.	The image processing technique isused to find reusable gloves.
Rasheed et al.[30]	By analyzing the X-ray of the chest, COVID-19 has been studied.	The x-ray of the foot can be analyzed for diabetic foot ulcers.	Machine learning is used in findingCOVID-19 for making decision making.
Riberio et al.[28]	The diabetic foot ulcer can be prevented using the pressure of thefoot	The diabetic foot ulcer has been analyzed early to find the pressure of the feet.	The machine learning algorithm is used in healthcare
Scebba et al.[32]	The DFU is found, and the imageof the foot is segmented	the DFU can be detected and segment the location of the foot ulcer using the image segmentation process	The deep learning approach and the image segmentation process has been analyzed
Schollemann et al.[33]	the wound infection of the DFU is analyzed, and ulcer location is proposed	The localization of ulcer affected region has been analyzed	To improve the wound automated wound infection marker is proposed
Vimal et al.[38]	The early diagnosis of the DM is made, and the screening of the location and the glaucoma diagnosis is managed.	In detecting the DM, the medical analysis uses the K means.	The algorithm of GLCM is used for the screening and diagnosis of DM.

Table 3. Smart segmentation analysis of Diabetic Foot Ulcer with Virtual sensing

Author	***Verbanic et al.* [85]**	***Van Netten et al.* [5]**	***Wannous et al.* [39]**
Introduction or Background	A diabetic foot ulcer is a primary disease that puts a heavy burdenon people.	Diabetic ulcer needs evidence-based treatment. Hence, they need the clinic and home treatment.	The wound healing process and the classification of the tissues are done.
Purpose or Objective	Wound healing and the treatment for the wound healing are done.	determine the reliability and the validity assessment of the remote DFU	An efficient tool is used to monitor the recovery of the wound.
Existing research works	The clustering of the taxonomic units is done.	Digital photographic images are used in the analysis of diabetic foot ulcers.	Monitored by the images
Overcome thisproblem	The identification of the post andpre-debridement samples.	Improve the accuracy of infra-red temperature with the digital image is executed	A monitoring process is done using sensors anytime.

Proposed Approaches	The differential abundance method is newly exposed	Extensive communication platform and the diagnosis accuracy platform.	pen-and-article method, Proposed the human-computer interaction, also wound management
Technology/ Methodology	Bayesian statistical method, DESeq2, and BGLMM method	Computerized machine-learningalgorithms	Semi-automatic method, classification method, classical supervised methods, diagnostic method, uncalibrated vision techniques, merging algorithm.
Data Analysis	Quality control analysis, RNA bioinformatic analyses, Diversity and differential abundanceanalyses	SPSS data analysis	Multi-view strategy
Results/finding	The skincontains bacterial composition and chronic wound microbiomes.	The variations of the healing time have differed from one person to other.	The 3D imaging while the healing and the tissue classification process is done.
Conclusion	A chronic wound is predicted, and then the wound is made healed	Mobile phones are used as a diagnostic instrument for DFU remote assessment.	Using the SVM classifier, the tissue and texture classification are monitored.
Author	***Cassidy et al.* [6]**	***Haque et al.* [11]**	***Ostadabbas et al.* [21]**
Introduction/ Background	Monitoring, treating, and diagnosisof the DFU are made.	The complications are classified using diabetic sensorimotor polyneuropathy (DSPN).	The pressure of the foot is calculated by the clinical tool to assess the problem in the foot.
Purpose/ Objective	Automatic detection of the diabetic foot ulcer has been proposed	The study aims to represent the severityclassification using an adaptive neuro-fuzzy system.	Monitoring the diabetic foot ulcer is done by tracking the plantar area.
Existing Research	Found the foot ulcer, treated, anddiagnosis is made.	The classification of the foot's linear and nonlinear function is analyzed.	Pressure will be monitored continuously using a pressure sensing system.
Overcome thisproblem	Using the detection of the foot ulcer using the cloud-based environment.	Classification is done in high definition images	The foot ware identifies the pressure in the plantar area.
Proposed Approaches	Cloud computing.	ANFIS-based severity classifier	principal component analysis (PCA),
Technology/ Methodology	Non-contact method, deep learningmodel	Machine learning model, Synthetic Minority Oversampling Technique, data argumentation technique,	regression and interpolation methods, Gaussian method, blind interpolation techniques, LSQ method
Data Analysis	Python	MATLAB	MATLAB
Results /finding	The early detection of types of DFU is analyzed, including the ischemia and infection.	The ANFIS and DSPN do the validation and the severity for classification.	The foot ulcer is found in a different location, and the pressure point is analyzed using shoes.

Conclusion	the cloud-based and deep learning technique for the automatic detection of the DFU.	Compared to the machine learning method, the ANFIS method is very efficient for calculating the approximation.	To reduce the model's order and improve the performance, SPCM is used.
Author	***Philimon et al.* [25]**	***Tulloch et al.* [37]**	***Liang et al.* [15]**
Introduction/ Background	The identification of diabetic foot ulcer patients living in low-income countries.	Managing the diabetic foot ulcer by predicting and diagnosing.	The automatic regression of the diabetic foot ulcer patient details is analyzed.
Purpose/ Objective	Develop the diagnosis tool to manage the DFU management.	The comparison and the diagnosis of the diabetic foot ulcer via the application.	The purpose is to search for the best combination of the data.
Existing research	cannot analyze the healing time of the wound.	The diabetic foot ulcer has been diagnosed manually.	Prediction of the clinical data by the laboratory test.
Overcoming this problem	overcomes the delay in the healing of the wound.	To reduce human error, the diagnosis is made using the applications.	The IWBC improves the performance of the analysis.
Proposed Approaches	dye-free approach, non-invasive approach	The fuzzy spectral clustering	Mean prediction performance.
Technology/ Methodology	Monte Carlo method, d laser speckle contrast imaging technique, artificial intelligence technique	ML method, PRISMA-DTA method, a segmentation method, SVM method, classification, and regression,	Two-step feature selection model, Support vector machine model, prediction and selection model.
Data Analysis	SPSS t-Test analysis	Systematic Review and Meta-analysis	Regression analysis, monogenic signal analysis
Results/finding	The tissue oxygen level was calculated, and the diabetic foot ulcer was analyzed.	Image analysis is done for the decision- making of the diabetic foot ulcer.	Excellent results in the prediction of the diabetic foot ulcer in the performance.
Conclusion	The healing range of the wound and the prediction of the diabetic wound has been done.	The accuracy of the patient demographic has been demonstrated.	The feature-based extraction is done for the analysis of diabetic foot ulcers.

3.1 Research Questions

• How can data categorization techniques be enhanced to improve the organization and usability of vast datasets related to diabetic foot ulcers?

• What strategies can be employed to reduce false alarm rates in predicting diabetic foot ulcers, thereby enhancing the accuracy of early detection?

• What technological innovations or algorithms can be developed to significantly reduce computation times in home care approaches for diabetic foot ulcers while maintaining data accuracy?

• How can training and testing times for diabetic foot ulcer detection and classification be optimized to expedite model execution without compromising accuracy?

• What multi-modal or hybrid prediction methods can be explored to improve both the processing speed and accuracy of determining the location of diabetic foot ulcers?

• What approaches and technologies can be implemented to enhance clustering rates and accuracy in the smart analysis of diabetic foot ulcer data, ensuring the reliability of healthcare insights derived from this data?

• These research questions aim to address the identified research gaps and guide future investigations into improving the management, prediction, and treatment of diabetic foot ulcers through technological advancements and innovative methodologies.

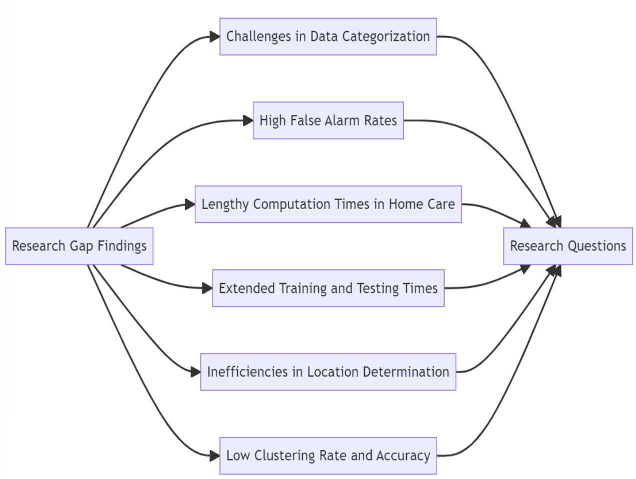

Fig. 1. Research gaps and questions

4. Results and Discussion

Based on the aforementioned research topic, the suggested study's scope improved diabetic foot ulcer categorization, prediction, and localization. With the aid of smart analysis, this research improves the real-time classification, prediction, and location of diabetic foot ulcers. The vast majority of suspect afflicted areas in the defined classification, prediction, and Locating results from Paun et al. [22] are managed and predicted using the diabetic foot ulcer reliability evaluation. The IoT and machine learning environments are used for the smart study of diabetic foot ulcers to handle sensitive data quickly and automatically. The deep learning approaches from Peng et al. [24] are particularly consumed by the reliability evaluation and validation procedure.

In order to identify photos from structured datasets and unstructured datasets using hierarchical classification and compositional pattern-producing networks, we can categorize diabetic foot ulcers. The Diabetic Foot Ulcer Classification Assessment's automatic recognition concentrates on identifying the numerous groups and clusters inside a Diabetic Foot Ulcer image from Preti et al. [26]. The IoMT has made it possible to use internet-based automatic recognition to handle the process of locating a diabetic foot ulcer precisely. This work uses numerous Deep learning approaches for image enhancement to demonstrate the visual prediction of a diabetic foot ulcer.

The Internet of Things-enabled Health Harvesting and Analysis from Raghavan et al. [29] is used in the picture analysis for the Diabetic Foot Ulcer. This may improve the outcome in the fight against smart analysis of diabetic foot ulcers, especially at the crucial stage of image prediction. This work applies an Internet of Things-assisted classifier for smart analysis, such as the detection and classification of diabetic foot ulcers, in this situation. The trained data classification research experiment's classification score analysis is used for the precise Foot Ulcer image prediction analysis. The picture and data categorization against diabetic foot ulcers is improved by this study experiment. This may bring back Raghavan et al.'s [29] Smart analysis of Diabetic Foot Ulcer's higher reliability assessment of Diabetic Foot Ulcer.

5. Conclusion

IoMT based investigations are made against the diabetic foot ulcer by introducing the analysis of diabetic foot ulcer stages and in-depth knowledge about "diabetic foot ulcer" based on the IoT-based automatic recognition. The advanced machine learning method employs the classification assessment of diabetic foot ulcers. This procedural aspect denies the dataset image-based processing idea. Hence this investigation gives the IoT and machine learning techniques to enhance the automatic hierarchical clustering to classify diabetic foot ulcers from the existing dataset images. This advanced machine learning practical methodology creates the "Compositional pattern- Producing Network" for computation in dataset image pattern recognition to classify structured and unstructured dataset images. This procedural aspect helps establish the IoT based diabetic foot ulcer clustering using automatic hierarchical clustering. However, the IoT and diabetic foot ulcer smart health management make specific treatment measures investigations of diabetic foot ulcer care against hospital care methods. This research investigation concentrates on the IoT as a home and hospital care ecosystem service against the health harvesting and analysis of diabetic foot ulcers. This process maintains the smart analysis of diabetic foot ulcers adopting the high definition of foot ulcer images. Finally, the internet of things assisted image analysis of several levels of image segmentation are investigated with the respective image functional description. This IoT-enabled sensing takes real-time diabetic foot ulcer image prediction and classification more smartly. This idea was implanted and took the survey for the Internet of Things and the validity and reliability assessment service analysis.

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