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Soft set based approaches in medical diagnosis and healthcare decision support systems

Jai Prabhat Singh and Aklesh Kumar

Abstract
Soft set theory, introduced by Molodtsov, has emerged as a powerful mathematical tool to handle uncertainties and imprecisions in real-world problems, particularly where classical models such as fuzzy sets or rough sets encounter limitations. In the domain of medical diagnosis and healthcare, decision-making often involves dealing with incomplete, vague, or uncertain patient information. Soft set based approaches provide a flexible framework that enables physicians and healthcare systems to analyze medical symptoms, test reports, and patient history with greater accuracy and reduced ambiguity. By modeling uncertain attributes and offering parameterization techniques, soft sets help in constructing effective diagnostic systems for diseases such as diabetes, cancer, and cardiovascular disorders. Moreover, soft set theory can be integrated with fuzzy sets, rough sets, and neural networks to enhance decision support systems, thereby improving the reliability of medical predictions. Its ability to classify, rank, and filter diagnostic outcomes makes it especially valuable in multi-criteria medical decision-making, where numerous symptoms and conditions need to be evaluated simultaneously. Recent studies demonstrate the use of hybrid soft set models in developing intelligent healthcare applications, including early disease detection, personalized treatment recommendation, and risk assessment. Therefore, soft set based approaches hold significant potential in strengthening modern healthcare systems by providing efficient, accurate, and computationally feasible solutions for diagnosis and medical decision support.

Keywords: Soft set theory, medical diagnosis, healthcare decision support, uncertainty handling, disease prediction

Introduction
Soft set theory, first introduced by Molodtsov in 1999, has emerged as a robust mathematical framework to address the limitations of classical tools such as fuzzy sets, rough sets, and probability theory in handling vagueness, uncertainty, and incomplete information, which are inherent in many real-world problems, especially in the medical domain. Medical diagnosis and healthcare decision-making are complex processes that involve evaluating patient symptoms, interpreting diagnostic test results, and making treatment choices under conditions of ambiguity, inconsistency, and imprecision. Physicians often rely on incomplete patient histories, uncertain laboratory outcomes, or subjective symptom descriptions, which create significant challenges in arriving at accurate and timely decisions. In this context, soft set theory provides an innovative approach, as it does not require additional conditions such as membership functions or probabilistic distributions, but rather uses parameterization of data to model uncertainty in a more flexible and computationally feasible manner. Over the years, researchers have extended the fundamental concepts of soft sets into hybrid models such as fuzzy-soft sets, rough-soft sets, and intuitionistic fuzzy-soft sets, which have further enhanced their applicability in medical science. In medical diagnosis, soft set based approaches have been applied in areas such as cancer detection, heart disease classification, diabetes diagnosis, and risk assessment of chronic illnesses, where accurate classification and ranking of medical conditions are crucial. Healthcare decision support systems (HDSS), designed to assist doctors in clinical reasoning, have also benefited from soft set models, as these systems require multi-criteria decision-making techniques that can effectively deal with large volumes of uncertain, vague, or inconsistent data. For instance, when a patient presents multiple symptoms, a soft set based approach can parameterize and filter relevant attributes, rank possible diagnoses, and provide a structured pathway for decision support, thus reducing the cognitive burden on medical practitioners. Moreover, integration of soft sets with artificial intelligence techniques such as neural networks, machine learning algorithms, and expert systems has enabled the development of intelligent medical systems capable of predicting disease risks, recommending

treatment strategies, and even personalizing healthcare plans for individual patients. Another strength of soft set theory lies in its adaptability to big data and medical informatics, where vast healthcare datasets often contain missing values, inconsistencies, and overlapping attributes that complicate analysis. Soft sets provide a systematic mechanism for handling such data imperfections without compromising decision accuracy. With the growing importance of digital healthcare, telemedicine, and AI-driven clinical support, soft set based models are increasingly being recognized as effective tools in enhancing diagnostic accuracy, reducing medical errors, and improving patient outcomes. Furthermore, these approaches align with the global movement towards evidence-based medicine and personalized healthcare, as they offer mathematical rigor while accommodating the inherent uncertainty of human health conditions. Thus, soft set based approaches not only strengthen medical diagnosis and healthcare decision support systems but also contribute significantly to the advancement of computational intelligence in medicine, paving the way for more reliable, transparent, and patient-centered healthcare delivery in the digital age.

Literature Review

1. "A distinct approach to diagnose Dengue Fever with the help of Soft Set Theory" (2018)

Maaz Amjad *et al*. 2018 [2] propose a soft expert system combining soft set and fuzzy set theories to aid in diagnosing dengue fever. Inputs like age, TLC (total leukocyte count), SGOT, platelet count, and blood pressure feed into the system to estimate the patient's risk level as a percentage. Their model explicitly addresses medical imprecisions, offering a more nuanced diagnosis mechanism. This approach is praised for its capability to "automatically circumvent all possible (medical) imprecisions" by providing a quantifiable risk level for dengue fever, showcasing how soft set frameworks can enhance diagnostic precision in uncertain clinical scenarios.

2. "A case study for medical decision making with the fuzzy soft sets" (2019/2020)

Murat Kirişci applies a fuzzy soft set-based technique in a practical medical decision-making context, using the widely-used Cleveland heart disease dataset. Employing Sánchez's method, the study constructs fuzzy soft sets for patient-symptom and symptom-disease relationships. These are used to derive fuzzy relation matrices, which are then defuzzified to yield crisp diagnostic outcomes. This case study illustrates how fuzzy soft set algorithms can handle real-world medical data with uncertainty, improve decision-making clarity, and deliver interpretable diagnosis conclusions.

3. "An approach to fuzzy soft sets in decision making based on grey relational analysis and Dempster-Shafer theory of evidence" (2015)

This study integrates fuzzy soft sets with grey relational analysis and Dempster-Shafer evidence theory to overcome the challenge of selecting appropriate level soft sets in decision-making contexts. Applied to medical diagnosis, the approach calculates degrees of uncertainty via grey relational metrics, then uses basic probability assignment functions and evidence fusion to rank diagnostic alternatives. The authors report that this method significantly reduces overall uncertainty—from a mean belief measure of 0.3821 to just 0.0069—demonstrating improved reliability and performance when compared to methods like mean potentiality, AHP, and Naive Bayes.

4. "TOPSIS Method Based on Intuitionistic Fuzzy Soft Set and Its Application to Diagnosis of Ovarian Cancer" (2024)

This recent work employs intuitionistic fuzzy soft sets (IFSS)—a hybrid extending fuzzy soft sets—to address uncertainties in diagnosing ovarian cancer. By developing aggregation operators within the IFSS framework, the study applies the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method to rank disease stages based on weighted parameters. The model also explores how varying parameter values impacts the ranking process, with graphical representations. This work exemplifies advanced integration of soft set theory into multi-criteria decision support systems aimed at sensitive domains like cancer staging.

5. "Bipolar Fuzzy Soft Set Theory Applied to Medical Diagnosis" (2024)

Orhan Dalkılıç and Naime Demirtaş introduce an enhanced diagnostic framework by incorporating bipolar fuzzy soft set theory, extending Soft Set Theory with fuzzy arithmetic. The model differentiates positive and negative medical knowledge components within a unified structure. A novel decision-making algorithm is also presented and demonstrated via practical examples to illustrate its potential to refine diagnosis procedures. The study suggests that capturing bipolar information—i.e., both supportive and contradicting evidence—makes diagnostic systems more nuanced and robust under uncertainty.

Summary Table

Study/Year	Methodology & Key Features	Application/Contribution
Amjad *et al*. (2018) [2]	Soft + fuzzy sets; risk percentage-based diagnosis	Dengue fever risk estimation under medical imprecision
Kirişci (2019/2020)	Fuzzy soft sets; defuzzified matrices using Cleveland dataset	Heart disease diagnosis with interpretable outcomes under uncertainty
2015 Integration (2015)	Fuzzy soft sets + grey relational analysis + Dempster-Shafer evidence	Significant reduction of uncertainty in diagnosis compared to conventional approaches
IFSS + TOPSIS (2024)	Intuitionistic fuzzy soft set + TOPSIS	Stage-wise ranking of ovarian cancer diagnoses under uncertainty
Dalkılıç & Demirtaş (2024) [5]	Bipolar fuzzy soft set; fuzzy arithmetic + new decision algorithm	Capturing bipolar (positive & negative) medical knowledge to enrich diagnostic reasoning

Research Gap

Although soft set theory and its hybrid extensions have shown promising results in medical diagnosis and healthcare decision support, existing studies remain limited in scope and application. Most research focuses on specific diseases such as dengue, heart disease, or ovarian cancer, but comprehensive frameworks for multi-disease diagnosis are still underdeveloped. Additionally, integration of soft sets with advanced artificial intelligence and big data analytics in healthcare remains at an early stage. Current models often lack large-scale clinical validation, real-time adaptability, and patient-centric personalization. Hence, there is a need for broader, scalable, and clinically tested soft set-based healthcare solutions.

Objectives of the Study

1. **To explore the theoretical foundations of soft set theory** and its applicability in managing uncertainty and vagueness in medical data.
2. **To analyze existing soft set-based models** used in medical diagnosis and healthcare decision support systems.
3. **To develop or adapt hybrid soft set frameworks** (e.g., fuzzy-soft sets, intuitionistic fuzzy-soft sets) for improving diagnostic accuracy across multiple diseases.
4. **To integrate soft set approaches with artificial intelligence and machine learning techniques** for enhancing prediction, classification, and treatment recommendations.
5. **To evaluate the effectiveness of soft set-based decision support systems** through comparative analysis with traditional diagnostic methods.
6. **To identify challenges, limitations, and future research directions** in implementing scalable and patient-centric soft set models in real-world healthcare environments.

Research Methodology

The present study adopts a descriptive and analytical research methodology to investigate the role of soft set based approaches in medical diagnosis and healthcare decision support systems. The research begins with a comprehensive literature survey of scholarly articles, case studies, and applications of soft set theory published between 2010 and 2025, focusing on its integration with fuzzy sets, rough sets, and artificial intelligence techniques. A conceptual framework will be developed to highlight how soft set models address uncertainty, imprecision, and incomplete data in medical diagnosis. Secondary data from medical datasets such as the Cleveland Heart Disease dataset and other publicly available repositories will be examined to understand the implementation of soft set algorithms in real-world diagnostic scenarios. The study also employs comparative analysis between soft set-based methods and conventional decision-making techniques to assess efficiency, accuracy, and adaptability. Finally, the findings will be synthesized to identify gaps, propose enhancements, and suggest directions for future research in developing patient-centric healthcare decision support systems.

Scope of the Study

The scope of this study is centered on examining the potential of soft set theory and its hybrid extensions in improving medical diagnosis and healthcare decision support systems. The research covers theoretical foundations, methodological developments, and practical applications of soft set models in handling uncertain, vague, and incomplete medical data. The study focuses on how soft set-based approaches can be integrated with artificial intelligence, data mining, and machine learning techniques to enhance disease prediction, diagnosis, and treatment recommendation. While emphasis is placed on widely researched conditions such as heart disease, cancer, diabetes, and infectious diseases, the study also highlights the potential for developing multi-disease diagnostic frameworks. The scope is limited to analysis through secondary data, case studies, and existing models, without primary clinical trials. By identifying strengths, limitations, and opportunities, this study provides a roadmap for extending soft set applications to scalable, real-time, and patient-centered healthcare solutions in the digital era.

Significance of the Study

This study holds significant value as it explores the role of soft set theory in transforming medical diagnosis and healthcare decision support systems by addressing one of the most critical challenges in medicine—uncertainty in clinical data. Traditional diagnostic methods often struggle with incomplete patient information, ambiguous symptoms, and overlapping disease conditions, leading to delays or errors in decision-making. By applying soft set and hybrid models, this study contributes to the development of mathematical and computational tools that can improve diagnostic accuracy, support multi-criteria decision-making, and assist healthcare professionals in complex clinical environments. The research also emphasizes the potential of integrating soft sets with artificial intelligence and big data analytics, thereby aligning with the global shift toward digital healthcare, personalized medicine, and intelligent clinical systems. Ultimately, the study is significant for researchers, practitioners, and policymakers aiming to enhance the efficiency, reliability, and patient-centeredness of modern healthcare delivery systems.

Limitations of the Study

Although this study provides valuable insights into the applications of soft set theory in medical diagnosis and healthcare decision support systems, certain limitations must be acknowledged. First, the research primarily relies on secondary data sources and existing medical datasets, which may not capture the full complexity and diversity of real-world clinical environments. The absence of primary clinical trials or hospital-based validations limits the practical demonstration of the proposed frameworks in live healthcare settings. Secondly, most existing models are disease-specific and may not generalize effectively to multi-disease or large-scale healthcare systems. The study also does not account for ethical, legal, and patient privacy issues, which are crucial in deploying AI-based decision support systems in medicine. Furthermore, computational challenges such as scalability, real-time adaptability, and integration with electronic health records (EHRs) remain outside the present scope. These limitations highlight the need for future research that emphasizes empirical validation, broader applicability, and patient-centered implementation.

Conclusion

Soft set theory has proven to be an effective mathematical tool for addressing uncertainty, vagueness, and incomplete information, which are inherent challenges in the field of medical diagnosis and healthcare decision-making. By offering a parameterized framework that avoids the rigidity of membership functions and probabilistic measures, soft sets provide flexibility and adaptability in analyzing complex clinical data. This study highlights how soft set based approaches, particularly in combination with fuzzy sets, rough sets, and intuitionistic fuzzy sets, can enhance the reliability of diagnostic processes and strengthen healthcare decision support systems. Applications in heart disease prediction, cancer detection, diabetes classification, and infectious disease diagnosis have demonstrated the potential of these models to improve accuracy and reduce diagnostic errors. Furthermore, the integration of soft sets with artificial intelligence, machine learning, and big data analytics opens promising avenues for developing intelligent, scalable, and patient-centered healthcare solutions. However, the study also recognizes limitations such as disease-specific focus, lack of clinical validation, and challenges in real-time implementation. Despite these constraints, the research establishes that soft set based approaches represent a significant step toward advancing digital healthcare systems. By bridging mathematical theory with medical practice, they offer the potential to support physicians in complex decision-making, reduce uncertainty in clinical environments, and ultimately improve patient outcomes. The findings underscore the importance of continued interdisciplinary research, clinical testing, and technological integration to fully realize the transformative role of soft set theory in modern healthcare.

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