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Emergency patient analysis using the certainty factor method

Natashya Toding Bua [a,1], Aden Resso Pratama [a,2], Heny Pratiwi [a,3]

[a] Information Systems, STMIK Widya Cipta Dharma, Samarinda, Indonesia
[1]2341015@wicida.ac.id; [2]2441903@wicida.ac.id; [3]henypratiwi@wicida.ac.id

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Abstract

Emergency departments (EDs) serve as the frontline of hospital care, managing patients with a wide spectrum of medical urgency. Accurate and timely triage is essential to prioritize treatment and prevent adverse outcomes. However, the growing volume of ED visits has placed increasing pressure on clinical staff, who must make rapid decisions often under uncertainty. Expert systems that incorporate uncertainty-handling methods offer a promising solution to support clinical decision-making in such environments. This study analyzes a hospital emergency department dataset comprising 9,216 patient records, encompassing key variables such as patient age, gender, race, waiting time, department referral, inpatient admission status, and patient satisfaction score. The Certainty Factor (CF) method was applied to quantify the confidence level in determining whether a patient requires hospitalization, based on three clinically relevant indicators: elderly patient age group (age ≥ 60 years), waiting time exceeding 40 minutes, and referral to a specialist department. Each factor was assigned user and expert confidence weights, and the combined CF was computed using the standard sequential combination formula. Manual calculation using all three factors yielded a final CF value of 0.9322, corresponding to a diagnostic confidence level of 93.22%. This high confidence value indicates that the simultaneous presence of these three clinical and operational indicators is a strong predictor of hospitalization need. Descriptive analysis further revealed that 50% of patients were admitted, 25% belonged to the elderly group, and 39.9% experienced extended waiting times. The results demonstrate that the Certainty Factor method is effective in handling diagnostic uncertainty in ED triage scenarios and can serve as a reliable foundation for developing clinical decision support systems in hospital emergency settings

1. Introduction

The Emergency Department (ED) is one of the most critical and high-pressure components of modern hospital healthcare services. Unlike other hospital departments, the ED operates continuously, receiving patients with a wide range of medical conditions at any time of day or night. The speed and accuracy with which medical personnel determine the appropriate course of action for each patient have a direct and significant impact on patient safety and overall treatment outcomes [1][2]. Delayed or inaccurate triage decisions can result in patients with serious conditions not receiving timely care, while resources may be unnecessarily allocated to lower-priority cases.

Triage is the systematic process of sorting and prioritizing patients based on the severity of their condition. In practice, triage decisions are often made under considerable uncertainty, as clinical signs may be ambiguous and patient histories incomplete. Traditionally, these decisions rely heavily on the experience and expertise of medical personnel, particularly senior nurses and emergency physicians. However, the rapid increase in patient volumes in emergency departments worldwide has strained clinical resources, making it increasingly difficult to maintain consistent and accurate triage quality [3][4]. This challenge is further

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compounded in settings with limited medical staffing, where the burden on individual clinicians is even greater. Expert systems have emerged as a valuable tool to support medical decision-making by encoding clinical knowledge and reasoning processes into computational frameworks. Among the methods commonly used in medical expert systems, the Certainty Factor (CF) method stands out for its ability to represent and manage uncertainty in diagnostic reasoning [5]. Originally developed by Shortliffe and Buchanan for the MYCIN expert system, the CF method assigns confidence values to both evidence and conclusions, allowing a system to reason about the likelihood of a diagnosis even when evidence is incomplete or probabilistically uncertain [6]. This characteristic makes it particularly well-suited to the ED context, where clinical data may be partial and decisions must be made rapidly.

The dataset used in this study is a hospital ED dataset containing 9,216 patient records with a variety of clinical and operational attributes, including patient age, gender, race, waiting time, referral department, admission status, and satisfaction score. Analysis of this dataset is expected to uncover important patterns in the data that influence hospitalization decisions for ED patients [7]. By identifying key factors associated with the need for inpatient admission, it becomes possible to construct a rule-based expert system that automates or assists in the triage recommendation process.

Previous research has demonstrated the effectiveness of the CF method across various medical domains, including diagnosing infectious diseases, plant diseases, and animal health conditions [8][9]. However, its application specifically to ED patient triage and hospitalization prediction remains an area that warrants further investigation. This study aims to bridge this gap by applying the CF method to a real ED dataset, identifying clinically relevant triage factors, and computing confidence values for hospitalization recommendations.

The findings of this study are intended to serve as a theoretical and practical foundation for the development of clinical decision support systems (CDSS) in hospital emergency settings. By providing medical staff with quantified confidence values for triage recommendations, such a system can enhance decision consistency, reduce cognitive load on clinicians, and ultimately improve patient outcomes [10][11]. The remainder of this paper is organized as follows: Section 2 describes the research methodology, including the dataset and CF calculation procedure; Section 3 presents the results and discussion; and Section 4 concludes with findings and directions for future work.

2. Research Methodology

2.1. Literature Review

A literature review was conducted by examining theories related to expert systems, the Certainty Factor method, and hospital health data analysis. References were drawn from relevant scientific journals on the application of CF in healthcare, particularly to support clinical decision-making in the emergency department [8].

2.2. Research Framework

This research framework consists of four main stages. First, data collection and analysis from the ED dataset comprising 9,216 patient records. Second, identification of relevant factors/symptoms for determining patient hospitalization needs. Third, application of the Certainty Factor method to calculate confidence values. Fourth, discussion and interpretation of the analysis results.

2.3. Dataset

The dataset used consists of hospital ED data containing 9,216 patient records. Table 1 presents an overview of the variables in the dataset.

Table 1. Hospital ED Dataset Description

Variable	Description	Value/Notes
Patient Age	Patient age (years)	Range: 0-78 years, Average: 39.86
Patient Gender	Patient gender	Male: 4.705 (51%), Female: 4.487 (49%)

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Patient Waittime	Waktu tunggu (menit)	Average: 35.26 minutes
Patient Satisfaction Score	Patient satisfaction score	Range: 0-10, Average: 4.99
Patient Admission Flag	Hospitalization status	TRUE: 4.612 | FALSE: 4.604
Department Referral	Department referral	General Practice, Orthopedics, etc.
Patient Race	Patient race/ethnicity	White, African American, Asian, etc.

2.4 Factor (Symptom) Identification

Based on dataset analysis, three main factors were identified as indicators of ED patient hospitalization needs. These factors were selected based on their clinical relevance and distribution in the data. Table 2 shows the code and description of each factor.

Table 2. ED Patient Factor (Symptom) Data

Factor Code	Description Faktor	Supporting Data
F1	Patient belongs to the elderly age group (age ≥ 60 years)	2,307 patients (25.0%) aged ≥60 years
F2	Patient waiting time exceeds 40 minutes	3,683 patients (39.9%) waited >40 minutes
F3	Patient referred to specialist department (non-None)	3,816 patients (41.4%) received specialist referral

2.5. System Rules

Based on the factor identification above, system rules were constructed using a forward chaining approach. Table 3 shows the rules used in this analysis.

Table 3. Diagnosis Rules

No	Rule
1	IF [F1: Age ≥ 60 years] AND [F2: Waiting time > 40 minutes] AND [F3: Specialist referral] THEN Patient Needs Hospitalization (High Risk)
2	IF [F1: Age ≥ 60 years] AND [F2: Waiting time > 40 minutes] THEN Patient Needs Further Evaluation
3	IF [F3: Specialist referral] AND [F2: Waiting time > 40 minutes] THEN Patient Potentially Needs Hospitalization

3 Result and Discussion

3.1. Descriptive Analysis of Dataset

Based on descriptive analysis of 9,216 ED patient records, the following patient distribution was obtained. In terms of age, the Young Adult group (18-39 years) dominated with 2,652 patients (28.8%), followed by Elderly (≥60 years) with 2,307 patients (25.0%), Adults (40-59 years) with 2,286 patients (24.8%), and Children (<18 years) with 1,971 patients (21.4%).

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Hospitalization status showed a nearly balanced distribution, with 4,612 patients (50.0%) admitted and 4,604 patients (50.0%) not admitted. Meanwhile, the average waiting time for all patients was 35.26 minutes, with 3,683 patients (39.9%) waiting more than 40 minutes. Table 4 summarizes the main descriptive statistics of this dataset.

Table 4. Descriptive Statistics of ED Dataset

Indicator	Value	Notes
Total Patients	9.216	All data records
Average Age	39.86 years	Range: 0-78 years
Average Waiting Time	35.26 minutes	Range: 1-60 minutes
Average Satisfaction Score	4,99	Scale 0-10
Admitted Patients (TRUE)	4,612 (50.0%)	Active admission status
Non-Admitted Patients	4,604 (50.0%)	Discharged/referred
Elderly Patients (≥60 yrs)	2,307 (25.0%)	High-risk group
Waiting Time >40 minutes	3,683 (39.9%)	Long wait category
Specialist Referral Patients	3,816 (41.4%)	Non-None department

3.2. Referral Department Distribution

Analysis of the referral department distribution shows that the majority of patients (5,400 or 58.6%) did not receive a specific department referral (None), indicating conditions that could be managed in the ED without further specialization. Among referred patients, General Practice dominated with 1,840 cases (20.0%), followed by Orthopedics with 995 cases (10.8%), Physiotherapy with 276 cases (3.0%), Cardiology with 248 cases (2.7%), Neurology with 193 cases (2.1%), Gastroenterology with 178 cases (1.9%), and Renal with 86 cases (0.9%). The highest hospitalization rates were found in the Renal department (53.5%) and patients without referral (50.7%), while General Practice had the lowest hospitalization rate (48.2%). This indicates that kidney-related conditions have a higher tendency to require hospitalization.

3.3. Certainty Factor Calculation

Certainty Factor calculation was performed to determine the diagnostic confidence level for patients requiring hospitalization. In this study, CF was calculated based on the three main factors that had been identified. Table 5 shows the weight values from the user and expert for each factor.

Table 5. User and Expert Weight Values

No	Factor Name	User Weight	Expert Weight
1	Patient age ≥ 60 years (Elderly)	0,8	0,9
2	Waiting time exceeding 40 minutes	0,7	0,8
3	Referred to specialist department	0,6	0,75

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Based on the weights above, the CF calculation for each factor is as follows:

CFfactor1 = CF(user) × CF(expert)
= 0,8 × 0,9
= 0,72

CFfactor2 = CF(user) × CF(expert)
= 0,7 × 0,8
= 0,56

CFfactor3 = CF(user) × CF(expert)
= 0,6 × 0,75
= 0,45

Since there are more than one factor, the combined CF is calculated using the following formula:

CFcombine1(CFfactor1, CFfactor2) = CFfactor1 + CFfactor2 × (1 - CFfactor1)
= 0,72 + 0,56 × (1 - 0,72)
CFold1 = 0.8768

CFcombine2(CFold1, CFfactor3) = CFold1 + CFfactor3 × (1 - CFold1)
= 0,8768 + 0,45 × (1 - 0,8768)
CFold2 = 0.9322

Based on the CF calculation results above, the diagnostic confidence percentage is calculated as follows:

Percentage = CFdiagnosis × 100
= 0.9322 × 100
= 93.22%

Based on the calculation results, the CF value for diagnosing ED patients requiring hospitalization is 0.9322, or 93.22%. This value indicates a very high confidence level according to the expert interpretation table, indicating that the combination of these three factors strongly suggests the patient requires hospitalization.

3.4. Racial Distribution and Service Implications

Analysis of patient racial distribution shows that the White group dominated with 2,571 patients (27.9%), followed by African American with 1,951 (21.2%), Two or More Races with 1,557 (16.9%), Asian with 1,060 (11.5%), Declined to Identify with 1,030 (11.2%), Pacific Islander with 549 (6.0%), and Native American/Alaska Native with 498 (5.4%). This demographic diversity underscores the importance of a non-discriminatory triage system that can be universally applied to all patient groups.

4 CONCLUSION

This study successfully analyzed a hospital emergency department dataset comprising 9,216 patient records using the Certainty Factor (CF) method. Three main factors were identified as influential indicators in determining the need for patient hospitalization: elderly patient age group (≥60 years), waiting time exceeding 40 minutes, and referral to a specialist department. These factors were selected based on their clinical relevance and their statistical prevalence within the dataset. The application of the Certainty Factor method yielded a combined confidence value of 0.9322, corresponding to a diagnostic confidence level of 93.22%. This high value confirms that the simultaneous presence of all three identified factors is a strong and reliable predictor of the need for inpatient hospitalization among ED patients. The CF method demonstrated its suitability for handling uncertainty in clinical reasoning, particularly in the time-sensitive environment of the emergency department. The descriptive analysis further revealed a near-equal split between admitted and non-admitted patients (50% each), and highlighted the significance of elderly patients (25%) and those with extended waiting times (39.9%) as high-risk subgroups.

The analysis of referral department distributions also showed that renal-related cases carried the highest hospitalization rate (53.5%), which may inform resource allocation strategies in ED management. In conclusion, this study demonstrates that the CF method is an effective tool for supporting clinical decision-making in emergency triage, capable of providing quantified confidence recommendations that assist medical personnel in prioritizing patient care. The findings provide a strong foundation for the development of a web-based or mobile clinical decision support system (CDSS) tailored to ED environments.

Several directions are proposed for future research. First, the expert system developed in this study should be implemented as a fully functional web-based or Android application, enabling real-time use by ED clinical staff. Second, additional clinical variables — such as blood pressure readings, oxygen saturation levels, chief complaint category, and comorbidity history — should be incorporated as new diagnostic factors to improve the precision and scope of the system. Third, a comparison study could be conducted between the CF method and other uncertainty-handling approaches, such as the Dempster-Shafer theory or Bayesian networks, to evaluate their relative performance in ED triage scenarios. Fourth, the system could be validated through clinical trials in a real hospital setting to assess its practical accuracy, usability, and acceptance among medical professionals. Finally, integrating machine learning techniques alongside the CF method may further enhance prediction accuracy and allow the system to adapt to emerging patient patterns over time.

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