



## Expert System for Diagnosing Rheumatoid Arthritis (RA) in the Elderly Using the Certainty Factor Method

M Zaki Putra<sup>1\*</sup>, Yohanni Syahra<sup>2</sup>

Information Systems Study Program, Faculty of Computer Science and  
Information Technology, Universitas Muhammadiyah Sumatera Utara, Medan,  
Indonesia

**Corresponding Author:** M Zaki Putra: [putrazaki752@gmail.com](mailto:putrazaki752@gmail.com)

---

### ARTICLE INFO

*Keywords:* Expert System,  
Rheumatoid Arthritis, Elderly,  
Certainty Factor,  
ACR/EULAR 2010

*Received :* 27, July

*Revised :* 20, August

*Accepted:* 23, September

©2026 Putra, Syahra (s): This is an  
open-access article distributed under  
the terms of the [Creative Commons  
Atribusi 4.0 Internasional](https://creativecommons.org/licenses/by/4.0/).



### ABSTRACT

Elderly-onset rheumatoid arthritis (EORA) is difficult to diagnose at primary healthcare facilities because elderly patients report vague and subjective symptoms and specialists are scarce. This study aims to design and develop a web-based expert system for diagnosing rheumatoid arthritis (RA) in the elderly by translating the ACR/EULAR 2010 classification criteria into IF-THEN rules and applying the Certainty Factor (CF) method, which combines the Measure of Belief and the Measure of Disbelief, as the inference engine. System performance was evaluated with a confusion matrix using 50 historical medical records of elderly patients. The system achieved 92.00% accuracy and 93.33% precision, recall, and F1-score. These results indicate that the approach is reliable as an early screening tool in primary healthcare.

---

## INTRODUCTION

The rapid development of information systems (IS) has transformed many sectors of life, including healthcare, through the application of knowledge-based decision support systems such as expert systems (Luger & Stubblefield, 2004). Information systems are also increasingly used to support decision-making in other domains, for example IoT-based early warning of flood disasters (Dewi & Syahra, 2025). In the discipline of information systems, a major challenge is how to process, map, and transfer complex and tacit expert knowledge into a structured and intelligent information system that users at various organizational levels can access easily. An expert-system-based information system offers a computational solution by modeling human reasoning as a knowledge base and an inference engine, so that it can provide precise decision recommendations without the limitations of time and place (Luger & Stubblefield, 2004).

At primary healthcare facilities such as community health centers (Puskesmas) and integrated service posts for the elderly (Posyandu Lansia), the management and dissemination of clinical information is often hindered by the limited number of specialists. Limited access to specialist information creates an information gap and delays decision-making in identifying high-risk diseases in the elderly, one of which is rheumatoid arthritis (RA), especially elderly-onset rheumatoid arthritis (EORA), which manifests at the age of 60 years or older (Baimukhamedov, 2020, 2024; Lahaye et al., 2019). Elderly patients with EORA often report complaints that are non-specific or overlap with ordinary degenerative joint disease. Without the support of a reliable clinical information system, the risk of inaccurate or delayed diagnosis at the primary care level is therefore very high.

To overcome these barriers to information flow and to support medical decision-making at primary facilities, an information system capable of integrating global clinical guidelines, such as the ACR/EULAR 2010 classification criteria (Kay & Upchurch, 2012), into computational IF-THEN logic rules is required. The 2010 criteria emphasize early detection before permanent joint damage occurs, so that disease-modifying antirheumatic drug (DMARD) therapy can be started promptly (Smolen et al., 2020); the diagnosis and management of rheumatoid arthritis are also addressed in the Indonesian clinical guideline (Hidayat et al., 2021). Through an information system approach, these qualitative medical criteria are transformed into structured digital data entities that can be processed automatically. This enables systematic screening and documentation of patient health data, which ultimately accelerates the referral workflow and improves the operational efficiency of health information services.

However, in designing interactive information systems for laypeople or elderly users, a major problem arises from uncertainty and bias in data input. Elderly patients often describe their symptoms vaguely, subjectively, or inconsistently because of cognitive limitations or hesitation. Handling imprecise data in information systems requires an appropriate computational inference method. The Certainty Factor (CF) method (Shortliffe & Buchanan, 1984) accommodates user hesitation by quantitatively calculating the difference

between the Measure of Belief (MB) and the Measure of Disbelief (MD), so that the system can still produce an objective and valid degree of diagnostic certainty.

Previous studies have built expert systems for disease diagnosis using forward chaining (Aeni, 2018; Hairani et al., 2019), production rules (Aldjawad et al., 2021), Bayes' theorem (Angkat et al., 2024), and the Dempster-Shafer method (Amri & Siahaan, 2021). The CF method has also been widely applied to handle uncertainty in diagnosis, for example in plant, animal, and human diseases, including joint and degenerative diseases (Alim et al., 2020; Astono et al., 2019; Borman et al., 2020; Hariyanto & Leidiyana, 2020; Kurniawan, 2022; Pasaribu et al., 2023; Sulistiyanto et al., 2023). Other work has combined CF with fuzzy logic (Ambara et al., 2017) or examined CF and clinical expert systems for primary healthcare (Amaliya et al., 2021; Anam et al., 2021). This study differs in that it explicitly anchors the rule base to the ACR/EULAR 2010 criteria for elderly patients and evaluates the resulting system on empirical medical records.

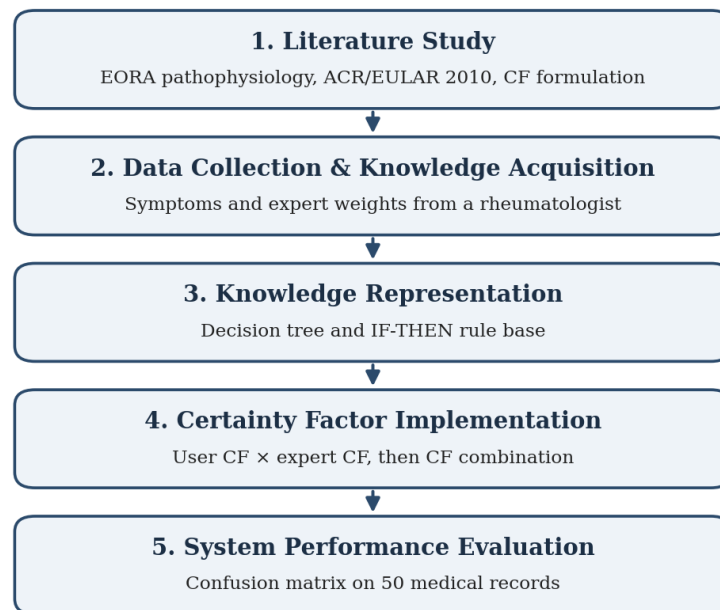
Based on these problems of information flow and the need for decision automation, this study aims to design and build a web-based expert system for diagnosing rheumatoid arthritis in the elderly using the Certainty Factor method. The information system is designed to facilitate knowledge acquisition, chained inference processing, and a user-friendly interface (UI/UX), and to evaluate the performance of the system model using a confusion matrix based on empirical medical record data.

## **METHODS**

### **Research Design and Framework**

This study applies a quantitative research design combined with the System Development Life Cycle (SDLC) (Ahmad, 2024; Badrul & Ardy, 2021). The sequential research framework consists of five main stages, as shown in Picture 1. First, a literature study examined the pathophysiology of EORA, the ACR/EULAR 2010 criteria, and the formulation of the Certainty Factor. Second, data collection and knowledge acquisition identified clinical symptoms and expert weights through structured interviews with a rheumatology specialist (Sp.PD-KR). Third, knowledge representation arranged a decision tree and mapped the rules into an IF-THEN knowledge base. Fourth, the Certainty Factor algorithm was implemented by calculating the user CF and the expert CF with the CF combination function. Fifth, system performance was evaluated with a confusion matrix using 50 empirical medical record samples. The system was implemented as a web application, with system modeling and algorithm implementation following standard practice (Setiawan & Putra, 2024; Tiara, 2024).

**Picture 1. Research framework**



### Knowledge Base and Rule Base

The reasoning rules were compiled by adapting the ACR/EULAR 2010 criteria. The criteria require the patient to have at least one unexplained swollen joint and then apply a scoring system across four analytical domains: joint count, rheumatoid factor (RF)/anti-citrullinated protein antibody (ACPA) serology, elevation of acute-phase reactants (C-reactive protein [CRP]/erythrocyte sedimentation rate [ESR]), and a symptom duration of more than six weeks. A patient is classified as positive for RA when the accumulated score reaches 6 out of a total of 10 points (Kay & Upchurch, 2012). The main rule base is presented in Table 1.

**Table 1. Rule base of the expert system**

| Rule | Code | Condition (IF)                                             | Conclusion (THEN) | CF <sub>expert</sub> |
|------|------|------------------------------------------------------------|-------------------|----------------------|
| R1   | G01  | Symmetrical swelling of proximal joints                    | RA                | 0.75                 |
| R2   | G02  | Inflammation of more than one large joint, asymmetrical    | RA                | 0.55                 |
| R3   | G03  | Morning joint stiffness lasting more than 60 minutes       | RA                | 0.75                 |
| R4   | G04  | Acute onset accompanied by systemic fatigue and mild fever | RA                | 0.40                 |
| R5   | G06  | Symptom duration of more than 6 weeks                      | RA                | 0.75                 |
| R6   | G09  | Abnormal elevation of ESR/CRP                              | RA                | 0.65                 |

The user's subjective confidence (CF<sub>user</sub>) is mapped onto eight levels, as shown in Table 2.

**Table 2. User confidence scale ( $CF_{user}$ )**

| User answer     | $CF_{user}$ |
|-----------------|-------------|
| Definitely not  | -1.0        |
| Most likely not | -0.6        |
| Maybe not       | -0.4        |
| Do not know     | 0.0         |
| Maybe yes       | 0.4         |
| Most likely yes | 0.6         |
| Almost certain  | 0.8         |
| Definitely yes  | 1.0         |

### Certainty Factor Method

The Certainty Factor method was introduced by Shortliffe and Buchanan (1984) to measure the degree of belief based on expert judgment that is subjective but rich in clinical experience. The basic concept of CF relies on the difference between the Measure of Belief (MB) and the Measure of Disbelief (MD). CF frees the system from the requirement to satisfy the global conditional probabilities of Bayes' theorem, so it is computationally efficient and adaptive to vague data. In medicine, diagnostic certainty is rarely binary (absolutely yes or no); therefore, a CF scale ranging from -1.0 to +1.0 gives a natural mathematical representation of human doubt and degree of certainty. The basic CF equation differentiates the belief (MB) and disbelief (MD) values assigned by the expert:

$$CF(H, E) = MB(H, E) - MD(H, E) \quad (1)$$

The user's subjective confidence ( $CF_{user}$ ) is multiplied by the expert rule weight ( $CF_{expert}$ ) to obtain the value of observation E:

$$CF(E) = CF_{user} \times CF_{expert} \quad (2)$$

When several symptoms appear simultaneously to support a single diagnosis, two positive CF values are combined ( $CF_{combine}$ ). The combination is repeated iteratively: the result of the previous combination ( $CF_{old}$ ) is combined with the next CF value.

$$CF_{combine}(CF_1, CF_2) = CF_1 + CF_2 \times (1 - CF_1) \quad (3)$$

### Performance Evaluation

System reliability was tested using 50 historical medical record samples of elderly patients from an autoimmune referral center, which had been validated by a rheumatology specialist and served as the ground truth. The predictions of the system were compared with the specialist's diagnosis in a confusion matrix, from which four evaluation metrics were derived (Sathyanarayanan & Tantri, 2024):

$$Accuracy = (TP + TN) / (TP + TN + FP + FN) \quad (4)$$

$$Precision = TP / (TP + FP) \quad (5)$$

$$Recall = TP / (TP + FN) \quad (6)$$

$$F1-score = 2 \times (Precision \times Recall) / (Precision + Recall) \quad (7)$$

where TP, TN, FP, and FN denote true positives, true negatives, false positives, and false negatives, respectively.

## RESULTS AND DISCUSSION

### Simulation of the Certainty Factor Inference Engine

To demonstrate the validity of the mathematical calculation of the inference engine, a sample case of a 65-year-old elderly patient was tested with four symptom inputs: symmetrical swelling (G01, most likely yes), morning stiffness of more than 60 minutes (G03, almost certain), symptom duration of more than six weeks (G06, definitely yes), and abnormal ESR/CRP elevation (G09, most likely yes). Table 3 shows the extraction of the single CF values using Equation (2), and Table 4 shows the iterative combination using Equation (3).

**Table 3. Extraction of single CF values**

| Symptom (code)                   | CF <sub>user</sub> | CF <sub>expert</sub> | Single CF = CF <sub>user</sub> × CF <sub>expert</sub> |
|----------------------------------|--------------------|----------------------|-------------------------------------------------------|
| Symmetrical swelling (G01)       | 0.6                | 0.75                 | CF <sub>1</sub> = 0.6 × 0.75 = 0.450                  |
| Morning stiffness > 60 min (G03) | 0.8                | 0.75                 | CF <sub>2</sub> = 0.8 × 0.75 = 0.600                  |
| Symptom duration > 6 weeks (G06) | 1.0                | 0.75                 | CF <sub>3</sub> = 1.0 × 0.75 = 0.750                  |
| Abnormal ESR/CRP (G09)           | 0.6                | 0.65                 | CF <sub>4</sub> = 0.6 × 0.65 = 0.390                  |

**Table 4. Iterative combination of CF values**

| Iteration | Values combined                        | Calculation                 | Result                      |
|-----------|----------------------------------------|-----------------------------|-----------------------------|
| 1         | CF <sub>1</sub> and CF <sub>2</sub>    | 0.450 + 0.600 × (1 – 0.450) | 0.780 (CF <sub>old1</sub> ) |
| 2         | CF <sub>old1</sub> and CF <sub>3</sub> | 0.780 + 0.750 × (1 – 0.780) | 0.945 (CF <sub>old2</sub> ) |
| 3         | CF <sub>old2</sub> and CF <sub>4</sub> | 0.945 + 0.390 × (1 – 0.945) | 0.96645 (96.65%)            |

The patient was diagnosed as positive for elderly-onset rheumatoid arthritis (EORA) with a certainty of 96.65% (very confident/definite). Across all confirmed positive samples, the average diagnostic certainty reached 88.50%.

### Performance Based on the Confusion Matrix

Table 5 presents the confusion matrix of the 50 test samples. Of the 30 patients diagnosed as positive by the physician, the system correctly identified 28 (TP) and missed 2 (FN). Of the 20 patients diagnosed as negative, the system correctly identified 18 (TN) and wrongly classified 2 as positive (FP).

**Table 5. Confusion matrix of the expert system evaluation**

| Physician diagnosis (ground truth) | System: RA positive | System: RA negative | Total |
|------------------------------------|---------------------|---------------------|-------|
| RA positive                        | 28 (TP)             | 2 (FN)              | 30    |
| RA negative                        | 2 (FP)              | 18 (TN)             | 20    |
| Total                              | 30                  | 20                  | 50    |

Based on the values in Table 5, the evaluation metrics were calculated using Equations (4)–(7) and are summarized in Table 6.

**Table 6. Performance metrics of the RA diagnosis expert system**

| Metric               | Calculation                                       | Result (%) |
|----------------------|---------------------------------------------------|------------|
| Accuracy             | $(28 + 18) / 50$                                  | 92.00      |
| Precision            | $28 / (28 + 2)$                                   | 93.33      |
| Recall (sensitivity) | $28 / (28 + 2)$                                   | 93.33      |
| F1-score             | $2 \times (93.33 \times 93.33) / (93.33 + 93.33)$ | 93.33      |

## DISCUSSION

The accuracy of 92.00% and the F1-score of 93.33% show that combining the ACR/EULAR 2010 medical criteria with the Certainty Factor method effectively resolves the ambiguity of medical data in the elderly. Precision and recall are equally high (93.33%), indicating that the system is balanced in avoiding false diagnoses (false positives) and in avoiding missing patients who are truly ill (false negatives).

The four misclassified cases (two FP and two FN) were caused by overlapping symptoms between early-stage EORA and severe osteoarthritis accompanied by secondary inflammation. The false positive cases arose because swelling in several degenerative joints was interpreted by patients as synovitis, whereas the false negative cases occurred in elderly patients with a very early-stage seronegative rheumatoid arthritis profile.

A direct quantitative comparison with earlier studies is beyond the scope of this paper because those studies used different data and reasoning methods; nevertheless, the results suggest that anchoring a CF rule base to the ACR/EULAR 2010 criteria is a promising approach for elderly patients (Baimukhamedov, 2024; Kay & Upchurch, 2012). The transparency of the CF calculation details displayed by the system also provides valuable clinical education for Posyandu nurses and health cadres at the primary care level.

Several limitations should be acknowledged. The evaluation used 50 records from a single referral center, so the reported metrics should be validated on larger and more diverse samples. In addition, because only four cases were misclassified, the error patterns described above should be regarded as indicative rather than conclusive.

## CONCLUSIONS AND RECOMMENDATIONS

This study designed and evaluated a web-based expert system for diagnosing rheumatoid arthritis in the elderly. First, modeling the knowledge base with IF-THEN rules adapted from the ACR/EULAR 2010 criteria successfully transformed qualitative clinical diagnostic criteria into a precise and structured inference system. Second, the Certainty Factor algorithm proved reliable in handling the uncertainty of data input from elderly users, producing an average diagnostic certainty of 88.50% on confirmed cases. Third, the confusion-matrix evaluation on 50 empirical medical records yielded an accuracy of 92.00%, a precision of 93.33%, a recall of 93.33%, and an F1-score of 93.33%, so the system is feasible to implement as an early screening and decision support tool at first-level healthcare facilities.

Three recommendations are proposed for future work. First, a hybrid inference method such as Fuzzy–Certainty Factor could be integrated to smooth the determination of laboratory variable thresholds linearly. Second, the knowledge base could be extended to detect other geriatric joint diseases, such as osteoarthritis, gout arthritis, and polymyalgia rheumatica, simultaneously. Third, the application could be developed for mobile platforms (Android/iOS) as an offline-capable progressive web app (PWA), so that Posyandu Lansia cadres in remote areas can use it.

## ACKNOWLEDGMENT

The authors would like to thank the rheumatology specialist who served as the domain expert and the referral center that provided the historical medical record data used in this study.

## REFERENCES

- Aeni, K. (2018). Penerapan metode forward chaining pada sistem pakar untuk diagnosa hama dan penyakit padi [Application of the forward chaining method in an expert system for diagnosing rice pests and diseases]. *Intensif*, 2(1), 79.
- Ahmad, M. (2024). *Rekayasa perangkat lunak terapan* [Applied software engineering]. Mitra Wacana Media.
- Aldjawad, A., et al. (2021). Penerapan sistem pakar diagnosa penyakit menggunakan metode production rule [Application of a disease diagnosis expert system using the production rule method]. *Jurnal Informasi dan Teknologi*, 3(2), 45–51.
- Alim, S., Lestari, P. P., & Rusliyawati, R. (2020). Sistem pakar diagnosa penyakit tanaman kakao menggunakan metode certainty factor [Expert system for diagnosing cacao plant diseases using the certainty factor method]. *Jurnal Data Mining dan Sistem Informasi*, 1(1), 26–31.
- Amaliya, R., et al. (2021). Analisis metode certainty factor pada sistem pakar diagnosa medis [Analysis of the certainty factor method in medical diagnosis expert systems]. *Jurnal Teknologi Informasi*, 5(3), 88–94.
- Ambara, B., Putra, D., & Rusjyanthi, D. (2017). Fuzzy expert system of dental and oral disease with certainty factor. *International Journal of Computer Science Issues*, 14(3), 22–30.
- Amri, S., & Siahaan, R. F. (2021). Sistem pakar mendiagnosis penyakit pada tanaman mentimun menggunakan metode Dempster Shafer berbasis Android [Expert system for diagnosing cucumber plant diseases using the Dempster-Shafer method on Android]. *JNKTI*, 4(2), 178–184.
- Anam, C., et al. (2021). Development of clinical expert systems for primary healthcare. *Journal of Medical Systems*, 45(8), 77.
- Angkat, C. I., Sianturi, I. M., Sinambela, S. H., Iqbal, M., & Farta, R. (2024). Sistem pakar diagnosa rheumatoid arthritis dengan menerapkan algoritma teorema Bayes [Expert system for diagnosing rheumatoid arthritis by applying the Bayes theorem algorithm]. *Jurnal Ilmu Komputer dan Sistem Informasi*, 7(1), 8–15.

- Astono, B. Y. T., Febrian, M. S., Laksana, W. P., & Laveri, R. I. (2019). Sistem pakar diagnosa penyakit kucing feline virus menggunakan metode certainty factor berbasis web [Web-based expert system for diagnosing feline viral diseases in cats using the certainty factor method]. *Pseudocode*, 6(2), 149–155.
- Badrul, M., & Ardy, R. (2021). Penerapan metode waterfall pada perancangan sistem informasi pendaftaran siswa baru [Application of the waterfall method in the design of a new student registration information system]. *J-SAKTI*, 5(1), 52–61.
- Baimukhamedov, C. (2020). Elderly-onset rheumatoid arthritis: An outlook from a practicing rheumatologist. *Nauchno-Prakticheskaya Revmatologiya*, 58, 447–450.
- Baimukhamedov, C. (2024). Late-onset rheumatoid arthritis: Justifying the need for international practice guidelines and classification criteria. *Modern Rheumatology*, 34(5), 867–873.
- Borman, R. I., Napianto, R., Nurlandari, P., & Abidin, Z. (2020). Implementasi certainty factor dalam mengatasi ketidakpastian pada sistem pakar diagnosa penyakit kuda laut [Implementation of certainty factor in handling uncertainty in a seahorse disease diagnosis expert system]. *JURTEKSI*, 7(1), 1–8.
- Dewi, M., & Syahra, Y. (2025). Implementasi sistem pendukung keputusan berbasis IoT dengan metode TOPSIS untuk peringatan dini potensi bencana banjir [Implementation of an IoT-based decision support system using the TOPSIS method for early warning of potential flood disasters]. *JUKTISI*, 4(2), 1133–1144.
- Hairani, H., Abdillah, M. N., & Innuddin, M. (2019). Perancangan sistem pakar diagnosis penyakit rematik menggunakan inferensi forward chaining berbasis Prolog [Design of an expert system for diagnosing rheumatic diseases using Prolog-based forward chaining inference]. *InfoTekJar*, 4(1), 8–11.
- Hariyanto, R. D., & Leidiyana, H. (2020). Sistem pakar untuk mendiagnosa penyakit persendian menggunakan metode certainty factor [Expert system for diagnosing joint diseases using the certainty factor method]. *Jurnal Komtika*, 4(1), 27–34.
- Hidayat, R., Suryana, B. P. P., Wijaya, L. K., Ariane, A., Hellmi, R. Y., Adnan, E., & Sumariyono. (2021). *Diagnosis dan pengelolaan artritis reumatoid* [Diagnosis and management of rheumatoid arthritis]. Perhimpunan Reumatologi Indonesia.
- Kay, J., & Upchurch, K. S. (2012). ACR/EULAR 2010 rheumatoid arthritis classification criteria. *Rheumatology*, 51(suppl\_6), vi5–vi9.
- Kurniawan. (2022). Perancangan sistem pakar untuk mendiagnosa penyakit degeneratif pada lanjut usia menggunakan metode certainty factor berbasis web [Design of a web-based expert system for diagnosing degenerative diseases in the elderly using the certainty factor method]. *Jurnal Informatika*, 10(2), 45–55.

- Lahaye, C., Tatar, Z., Dubost, J. J., Tournadre, A., & Soubrier, M. (2019). Management of inflammatory rheumatic conditions in the elderly. *Rheumatology*, 58(8), 1332–1341.
- Luger, G. F., & Stubblefield, W. A. (2004). *Artificial intelligence: Structures and strategies for complex problem solving* (5th ed.). Addison-Wesley.
- Pasaribu, R. M., Syahra, Y., & Kusnasari, S. (2023). Mendiagnosis penyakit anoreksia nervosa pada anak remaja menggunakan metode certainty factor [Diagnosing anorexia nervosa in adolescents using the certainty factor method]. *JURSI TGD*, 2(5).
- Sathyanarayanan, S., & Tantri, B. R. (2024). Confusion matrix-based performance evaluation metrics. *African Journal of Biomedical Research*, 27(4s), 4023–4031.
- Setiawan, A., & Putra, R. (2024). *Buku ajar algoritma dan pemrograman* [Algorithms and programming textbook]. Informatika.
- Shortliffe, E. H., & Buchanan, B. G. (1984). A model of inexact reasoning in medicine. In B. G. Buchanan & E. H. Shortliffe (Eds.), *Rule-based expert systems: The MYCIN experiments of the Stanford Heuristic Programming Project* (pp. 233–262). Addison-Wesley.
- Smolen, J. S., Landewé, R. B. M., Bijlsma, J. W. J., et al. (2020). EULAR recommendations for the management of rheumatoid arthritis with synthetic and biological disease-modifying antirheumatic drugs: 2019 update. *Annals of the Rheumatic Diseases*, 79(6), 685–699.
- Sulistiyanto, S., Saprudin, U., & Devani, F. T. (2023). Sistem pakar diagnosa penyakit autoimun dengan metode certainty factor [Expert system for diagnosing autoimmune diseases using the certainty factor method]. *JTIK*, 9(2), 30–40.
- Tiara, M. (2024). *UML dan pemodelan sistem berorientasi objek* [UML and object-oriented system modeling]. Andi Offset.