

**SISTEM PAKAR BERBASIS *FORWARD CHAINING* DAN *CERTAINTY*  
*FACTOR* UNTUK REKOMENDASI TINDAKAN *MAINTENANCE*  
MESIN KRAFT DI PT DIRGANTARA INDONESIA**



**SKRIPSI**

diajukan untuk memenuhi sebagai syarat untuk memperoleh gelar  
Sarjana Teknik pada Program Studi Mekatronika dan Kecerdasan Buatan

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### **SISTEM PAKAR BERBASIS *FORWARD CHAINING* DAN *CERTAINTY* *FACTOR* UNTUK REKOMENDASI TINDAKAN *MAINTENANCE* MESIN KRAFT DI PT DIRGANTARA INDONESIA**

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Sebuah skripsi yang diajukan untuk memenuhi salah satu syarat memperoleh gelar  
Sarjana Teknik pada Program Studi Mekatronika dan Kecerdasan Buatan

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## ABSTRAK

Proses *maintenance* merupakan aspek fundamental dalam menjaga keberlangsungan operasional dan efisiensi produksi di sektor industri, khususnya dalam manufaktur kedirgantaraan. Salah satu mesin yang memiliki peran strategis adalah mesin Kraft, yang digunakan secara intensif di PT Dirgantara Indonesia untuk produksi komponen pesawat. Namun, kondisi mesin yang telah menua serta keterbatasan teknisi berpengalaman menimbulkan tantangan signifikan dalam pelaksanaan *maintenance*. Studi ini mengusulkan pengembangan sistem pakar berbasis web yang mengintegrasikan metode inferensi *Forward Chaining* dengan pendekatan *Certainty Factor* (CF) untuk membantu teknisi pemula dalam pengambilan keputusan tindakan *maintenance* secara akurat. Metode *Forward Chaining* digunakan untuk menelusuri aturan secara progresif berdasarkan *input* kondisi mesin, sedangkan *Certainty Factor* diterapkan untuk merepresentasikan tingkat keyakinan pakar terhadap suatu diagnosis, sehingga sistem mampu menangani ketidakpastian yang muncul dalam proses penalaran. Sistem dirancang untuk memproses input seperti *subsystem*, *device*, *component*, *failure type*, dan *root cause*, lalu menghasilkan rekomendasi tindakan *maintenance*. Hasil yang diharapkan adalah terciptanya alat bantu pengambilan keputusan yang meningkatkan presisi *maintenance*, mengurangi ketergantungan pada pakar yang telah pensiun, serta memperkuat keandalan jangka panjang operasi mesin Kraft.

**Kata Kunci :** Sistem Pakar, *Certainty Factor*, *Forward Chaining*, *Maintenance*

## **ABSTRACT**

*Maintenance processes are fundamental to ensuring operational continuity and production efficiency across industrial sectors, particularly in aerospace manufacturing. One of the machines with a strategic role is the Kraft machine, which is extensively used at PT Dirgantara Indonesia for aircraft component production. However, its aging condition and the limited availability of experienced technicians pose significant challenges to effective maintenance execution. This study proposes the development of a web-based expert system that integrates the Forward Chaining inference method with the Certainty Factor (CF) approach to assist novice technicians in making accurate maintenance decisions. Forward Chaining is employed to trace rules progressively based on machine condition inputs, while Certainty Factor is applied to represent the expert's degree of belief in a given diagnosis, enabling the system to handle uncertainty in the reasoning process. The system is designed to process inputs such as subsystem, device, component, failure type, and root cause, and to generate targeted maintenance recommendations. The expected outcome is a decision-support tool that enhances maintenance precision, reduces reliance on retired experts, and strengthens the long-term reliability of Kraft machine operations.*

**Keywords:** *Expert System, Forward Chaining, Certainty Factor, Maintenance*

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## DAFTAR PUSTAKA

- [1] A. Anto, S. Sinawati, dan A. T. Puji, “Diagnosa Kerusakan Pada Alat Berat Menggunakan Metode Forward Chaining,” *Sebatik*, vol. 26, no. 2, hlm. 489–494, Des 2022, doi: 10.46984/sebatik.v26i2.2070.
- [2] A. Sarazin dkk., “Expert system dedicated to condition-based maintenance based on a knowledge graph approach: Application to an aeronautic system,” *Expert Syst Appl*, vol. 186, Des 2021, doi: 10.1016/j.eswa.2021.115767.
- [3] S. andini utiarahman, “Identifikasi Kerusakan Mobil Menggunakan Sistem Pakar Berbasis Metode Forward Chaining Pada Global Motor Gorontalo,” *JSAI*, vol. 3, no. 1, 2020, [Daring]. Tersedia pada: <http://www.jurnal.umb.ac.id/index.php/JSAI>
- [4] A. Noeman, A. Adriansyah, A. Hiswara, D. Hartanti, P. Kustanto, dan H. Hafizah, “Expert System for Chiller Machine Damage Detection Using Forward Chaining Algorithm,” *PIKSEL : Penelitian Ilmu Komputer Sistem Embedded and Logic*, vol. 12, no. 1, hlm. 201–208, Apr 2024, doi: 10.33558/piksel.v12i1.9488.
- [5] A. Yahadi, A. Tri Hapsari, J. Raya Tengah No, K. Gedong, P. Rebo, dan J. Timur, “istem Pakar Diagnisa Kerusakan Pada Motor Karburator Dengan Metode Certainty Factor,” *Jurnal Riset dan Aplikasi Mahasiswa Informatika (JRAMI)*, vol. 06, 2025.
- [6] H. Winata, W. Riansah, Z. Lubis, S. Kusnasari, dan M. Hutabarat, “Implementasi Metode Certainty Factor Untuk Mendeteksi Kerusakan Mesin Pada Mobil Nissan Grand Livina L10,” *Juli*, hlm. 413–423, 2023, [Daring]. Tersedia pada: <https://ojs.trigunadharma.ac.id/index.php/jsk/index>
- [7] D. Suryadi, R. Meilianda, A. Fauzan Suryono, K. W. Kandang Limun Jl Supratman Bengkulu, dan J. Sudharto, “Sistem Pakar untuk Mengidentifikasi Kerusakan Mesin Industri Menggunakan Metode Certainty Factor,” *ROTASI: Jurnal Teknik Mesin*, 2018, [Daring]. Tersedia pada: <http://ejournal.undip.ac.id/index.php/rotasi>
- [8] D. Saputra, D. Purwaningtias, dan W. Irmayani, “Sistem Pakar Diagnosa Kerusakan Mesin Sepeda Motor Matic Berbasis Web Menggunakan Certainty Factor,” *Ijns.org Indonesian Journal on Networking and Security*, vol. 8, 2018.
- [9] B. Ioshchikhes dan M. Weigold, “Development of stationary expert systems for improving energy efficiency in manufacturing,” dalam *Procedia CIRP*, Elsevier B.V., 2024, hlm. 921–926. doi: 10.1016/j.procir.2024.08.351.
- [10] R. P. S. K. Jayasuriya, P. A. G. M. Amarasinghe, dan S. K. Abeygunawardane, “Application of artificial intelligence for maintenance modelling of critical machines in solid tire manufacturing,” dalam *2021 International Conference on Innovative Trends in Information Technology, ICITIIT 2021*, Institute of Electrical and Electronics Engineers Inc., Feb 2021. doi: 10.1109/ICITIIT51526.2021.9399600.
- [11] P. Khazaelpour dan S. H. Zolfani, “FUCOM-optimization based predictive maintenance strategy using expert elicitation and Artificial Neural

- Network,” *Expert Syst Appl*, vol. 238, Mar 2024, doi: 10.1016/j.eswa.2023.121322.
- [12] D. Pagano, “A predictive maintenance model using Long Short-Term Memory Neural Networks and Bayesian inference,” *Decision Analytics Journal*, vol. 6, Mar 2023, doi: 10.1016/j.dajour.2023.100174.
- [13] M. Compare dan E. Zio, “Genetic algorithms in the framework of Dempster-Shafer theory of evidence for maintenance optimization problems,” *IEEE Trans Reliab*, vol. 64, no. 2, hlm. 645–660, Jun 2015, doi: 10.1109/TR.2015.2410193.
- [14] S. Russell dan P. Norvig, *Artificial Intelligence A Modern Approach Fourth Edition*. 2021.
- [15] E. E. Makarius, D. Mukherjee, J. D. Fox, dan A. K. Fox, “Rising with the machines: A sociotechnical framework for bringing artificial intelligence into the organization,” *J Bus Res*, vol. 120, hlm. 262–273, Nov 2020, doi: 10.1016/j.jbusres.2020.07.045.
- [16] P. Mikalef dan M. Gupta, “Artificial intelligence capability: Conceptualization, measurement calibration, and empirical study on its impact on organizational creativity and firm performance,” *Information and Management*, vol. 58, no. 3, Apr 2021, doi: 10.1016/j.im.2021.103434.
- [17] Y. Fadhillah, “Sistem Pakar Menggunakan Forward Chaining dan Certainty Factor Untuk Diagnosa Kerusakan Smartphone,” *Jurnal Education and Development*, 2020.
- [18] B. Min dkk., “Recent Advances in Natural Language Processing via Large Pre-Trained Language Models: A Survey,” Nov 2021, [Daring]. Tersedia pada: <http://arxiv.org/abs/2111.01243>
- [19] S. Minaee, Y. Boykov, F. Porikli, A. Plaza, N. Kehtarnavaz, dan D. Terzopoulos, “Image Segmentation Using Deep Learning: A Survey,” Nov 2020, [Daring]. Tersedia pada: <http://arxiv.org/abs/2001.05566>
- [20] D. Silver dkk., “Mastering Chess and Shogi by Self-Play with a General Reinforcement Learning Algorithm,” Des 2017, [Daring]. Tersedia pada: <http://arxiv.org/abs/1712.01815>
- [21] B. S. Abu-Nasser, “Medical Expert Systems Survey,” 2017. [Daring]. Tersedia pada: [www.ijeaais.org](http://www.ijeaais.org)
- [22] A. Saibene, M. Assale, dan M. Giltri, “Expert systems: Definitions, advantages and issues in medical field applications,” 1 September 2021, *Elsevier Ltd*. doi: 10.1016/j.eswa.2021.114900.
- [23] H. Tan, “A brief history and technical review of the expert system research,” dalam *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Okt 2017. doi: 10.1088/1757-899X/242/1/012111.
- [24] B. Ioshchikhes, M. Frank, dan M. Weigold, “A Systematic Review of Expert Systems for Improving Energy Efficiency in the Manufacturing Industry,” 1 Oktober 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/en17194780.
- [25] T. Ertekin, “The efficacy and superiority of the expert systems in reservoir engineering decision making processes,” *Applied Sciences (Switzerland)*, vol. 11, no. 14, Jul 2021, doi: 10.3390/app11146347.

- [26] B. Ioshchikhes, R. Zink, O. Ozen, dan M. Weigold, "A Holistic Framework for Developing Expert Systems to Improve Energy Efficiency in Manufacturing," *Energies (Basel)*, vol. 18, no. 6, Mar 2025, doi: 10.3390/en18061406.
- [27] G. Leu dan H. Abbass, "A Multi-Disciplinary Review of Knowledge Acquisition Methods: From Human to Autonomous Eliciting Agents," *Knowledge-Based Systems, ScienceDirect*, Feb 2018, doi: 10.1016/j.knosys.2016.02.012.
- [28] S. Y. Choi dan S. H. Kim, "Knowledge acquisition and representation for high-performance building design: A review for defining requirements for developing a design expert system," 1 Mei 2021, *MDPI AG*. doi: 10.3390/su13094640.
- [29] C. F. Uwasomba, Y. Lee, Z. Yusoff, dan T. M. Chin, "Ontology-Based Methodology for Knowledge Acquisition from Groupware," *Applied Sciences (Switzerland)*, vol. 12, no. 3, Feb 2022, doi: 10.3390/app12031448.
- [30] B. Msheik, M. Adda, H. Mcheick, dan M. Dbouk, "Survey on Knowledge Representation Models in Healthcare," 1 Agustus 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/info15080435.
- [31] Y. Lan, S. He, K. Liu, dan J. Zhao, "Knowledge Reasoning via Jointly Modeling Knowledge Graphs and Soft Rules," *Applied Sciences (Switzerland)*, vol. 13, no. 19, Okt 2023, doi: 10.3390/app131910660.
- [32] J. Yang, C. Sun, J. Zhou, Q. Wang, K. Zhang, dan T. Song, "Knowledge-Inference-Based Intelligent Decision Making for Nonferrous Metal Mineral-Processing Flowsheet Design," *Minerals*, vol. 15, no. 4, Apr 2025, doi: 10.3390/min15040374.
- [33] J. Hernandez, H. M. Marin-Castro, dan M. Morales-Sandoval, "A semantic focused web crawler based on a knowledge representation schema," *Applied Sciences (Switzerland)*, vol. 10, no. 11, Jun 2020, doi: 10.3390/app10113837.
- [34] M. H. Syed, T. Q. B. Huy, dan S. T. Chung, "Context-Aware Explainable Recommendation Based on Domain Knowledge Graph," *Big Data and Cognitive Computing*, vol. 6, no. 1, Mar 2022, doi: 10.3390/bdcc6010011.
- [35] H. Jung, H. Park, dan K. Lee, "Enhancing Recommender Systems with Semantic User Profiling through Frequent Subgraph Mining on Knowledge Graphs," *Applied Sciences (Switzerland)*, vol. 13, no. 18, Sep 2023, doi: 10.3390/app131810041.
- [36] T. Babu, R. R. Nair, H. S. Ganesh, G. S. Dhanush, A. R. Varun, dan B. R. Karthik, "Frame-Based Knowledge Representation for Intelligent Tutoring Systems," dalam *2nd International Conference on IT Innovations and Knowledge Discovery, ITIKD 2024*, Institute of Electrical and Electronics Engineers Inc., 2025. doi: 10.1109/ITIKD63574.2025.11005014.
- [37] D. Rodiah, "Pengembangan Representasi Pengetahuan Ontologi Domain Bidang Ilmu Informatika," *Jurnal PROCESSOR*, vol. 19, no. 2, Okt 2024, doi: 10.33998/processor.2024.19.2.1905.
- [38] J. Elektronik, I. K. Udayana, S. Cornelius, G. Yowe, I. Gede, dan S. Astawa, "Ontology-Based Approach For Laptop Semantic Knowledge

- Representation,” *Jurnal Elektronik Ilmu Komputer Udayana*, 2021.
- [39] Y. Merah dan T. Kenaza, “Proactive Ontology-based Cyber Threat Intelligence Analytic,” dalam *Proceedings - 2021 IEEE International Conference on Recent Advances in Mathematics and Informatics, ICRAMI 2021*, Institute of Electrical and Electronics Engineers Inc., 2021. doi: 10.1109/ICRAMI52622.2021.9585984.
  - [40] H. Sirait, “Basic Elements and Characteristics in Building an Expert System,” *Journal Neosantara Hybrid Learning*, vol. 1, no. 3, hlm. 227–248, Des 2023, doi: 10.55849/jnhl.v1i3.337.
  - [41] K. Aryasa, J. Teknik Informatika, S. Dipanegara Makassar, dan J. Perintis Kemerdekaan Km, “Sistem Pakar Diagnosa Dan Tatalaksana Penyakit Demam Berdarah Dengue Menggunakan Jaringan Saraf Tiruan Backpropagation,” 2019.
  - [42] M. Muslihudin dkk., “Application of Expert System for Determining Export Quality Pepper Seeds using Website-Based Forward Chaining Method 3320,” *International Journal of Recent Technology and Engineering (IJRTE)*, 2019, [Daring]. Tersedia pada: [www.ijrte.org](http://www.ijrte.org)
  - [43] T. Xięski dan R. Simiński, “Backward chaining inference as a database stored procedure – the experiments on real-world knowledge bases,” *Journal of Information and Telecommunication*, vol. 2, no. 4, hlm. 449–464, 2018, doi: 10.1080/24751839.2018.1479931.
  - [44] M. O. Yinyeh dan S. Alhassan, “Expert Health Diagnosis and Monitoring System Software for Common Medical Conditions,” 2015.
  - [45] A. Mufid Octavio dkk., “Smart Early Detection of Rheumatoid Arthritis Tool on Nails with a Certainty Factor Technology Approach Based on Image Processing,” *International Journal On Informatics Visualization*, 2025, [Daring]. Tersedia pada: [www.joiv.org/index.php/joiv](http://www.joiv.org/index.php/joiv)
  - [46] J. Santos, C. Torres-Machi, S. Morillas, dan V. Cerezo, “A fuzzy logic expert system for selecting optimal and sustainable life cycle maintenance and rehabilitation strategies for road pavements,” *International Journal of Pavement Engineering*, vol. 23, no. 2, hlm. 425–437, 2022, doi: 10.1080/10298436.2020.1751161.
  - [47] F. Z. David\*, C. M. I. Milagros, V. O. C. Oswaldo, S. M. L. Guillermo, dan M. L. Ingrid, “Expert System for Information Technology Services Management,” *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no. 4, hlm. 9986–9992, Nov 2019, doi: 10.35940/ijrte.D4423.118419.
  - [48] N. Othman, N. Arbaiy, dan H. Mohd Rahman, “An Expert System for Pneumococcal Prognosis,” *International Journal On Informatics Visualization*, 2018.
  - [49] F. Fitriyadi, T. Feri Efendi, dan M. Erkamim, “Perancangan Interface Sistem Pakar Diagnosa Penyakit Tanaman Cabai dengan Metode Extreme Programming (XP),” *Jurnal Informatika, Komputer dan Bisnis*, vol. 1, 2020, [Daring]. Tersedia pada: <https://jurnal.itbaas.ac.id/index.php/jikombis>
  - [50] K. At-Tharfi dan A. Misbullah, “Penerapan Metode Forward Chaining untuk Sistem Pakar Diagnosis Penyakit Ginjal Berbasis Website,” *JSI : Jurnal*

- Sistem Informasi (E-Journal*, vol. 17, no. 1, 2025.
- [51] I. Suhardi, S. Haryoko, dan H. Jaya, “Pengembangan sistem pakar menggunakan Metode Forward Chaining untuk penelusuran dan publikasi manuskrip ilmiah pada Jurnal Internasional Bereputasi,” *Prosiding Seminar Nasional LP2M UNM*, 2019.
  - [52] H. Misgna, M. Ahmed, dan A. Kumar, “MatES: Web-based Forward Chaining Expert System for Maternal Care,” 2021.
  - [53] M. S. Farooq *dkk.*, “Harnessing AI forward and backward chaining with telemetry data for enhanced diagnostics and prognostics of smart devices,” *Sci Rep*, vol. 15, no. 1, Des 2025, doi: 10.1038/s41598-025-89266-9.
  - [54] J. Giarratano dan G. Riley, *Expert System: Principles and Programming. 4th ed.* 2005.
  - [55] H. Soetanto dan P. M. K. Suryadewiansyah, “Optimization of Expert System Based on Interpolation, Forward Chaining, and Certainty Factor for Diagnosing Abdominal Colic,” *Journal of Computer Science*, vol. 20, no. 2, hlm. 191–197, 2024, doi: 10.3844/jcssp.2024.191.197.
  - [56] A. I. Novanti, “Sistem Pakar Diagnosa Penyakit Jantung : Tinjauan Pustaka,” 2021, [Daring]. Tersedia pada: <https://www.researchgate.net/publication/351225282>
  - [57] G. Urva dan W. Desriyati, “A Modification Depth First Search (DFS) Algorithm for Troubleshoot Rotating Equipment Diagnosis,” *sinkron*, vol. 8, no. 3, hlm. 1400–1412, Jul 2024, doi: 10.33395/sinkron.v8i3.13690.
  - [58] F. J. Pane, E. Rianti, dan H. Marfalino, “Application of an Expert System with the Breadth First Search (BFS) Method in Diagnosing Areca Plant Diseases,” *Journal of Computer Scine and Information Technology*, hlm. 55–59, Apr 2024, doi: 10.35134/jcsitech.v10i2.102.
  - [59] K. Febrianto, E. D. Udayanti, V. Indriyono, W. Mahmud, dan I. Zahari, “Expert System for Detection of Diseases in Layers Using Forward Chaining and Certainty Factor Methods,” *Jurnal Masyarakat Informatika*, vol. 14, no. 2, hlm. 2777–0648, 2023.
  - [60] A. Gunawan dan F. Islami, “Implementing the Certainty Factor Method in a Dental Disease Expert System,” *Journal Medical Informatics Technology*, hlm. 27–32, Jun 2024, doi: 10.37034/medinftech.v2i2.33.
  - [61] S. Siti Sundari dan A. Fitri Nurapah, “Expert System For Diagnosis of Pregnancy Disorders Using Forward Chaining and Certainty Factor Methods Web-Based,” 2021.
  - [62] M. Sajida, “Implementation of a Rabbit Disease Diagnosis Expert System using the Forward Chaining and Certainty Factor Method,” *Journal of Computer Scine and Information Technology*, hlm. 143–148, Jul 2023, doi: 10.35134/jcsitech.v9i3.78.
  - [63] D. Y. Cahya dan S. Oktaviana, “Expert System to Determine Learning Style Using Forward Chaining Method,” 2018.
  - [64] Z. E. Fitri, E. M. Ramadania, N. S. Wibowo, I. P. D. Lesmana, dan A. M. N. Imron, “A Combination of Forward Chaining and Certainty Factor Methods for Early Detection of Fever: Dengue Hemorrhagic Fever, Malaria and Typhoid,” *Scientific Journal of Informatics*, vol. 9, no. 1, hlm. 23–31, Mei

- 2022, doi: 10.15294/sji.v9i1.33007.
- [65] C. Elena Patiño-Rodriguez dan F. Jesus Guevara Carazas, "Maintenance and Asset Life Cycle for Reliability Systems," dalam *Reliability and Maintenance - An Overview of Cases*, IntechOpen, 2020. doi: 10.5772/intechopen.85845.
  - [66] I. J. O., "Impact of Preventive Maintenance Practices on Productivity," *British Journal of Management and Marketing Studies*, vol. 8, no. 1, hlm. 118–137, Feb 2025, doi: 10.52589/bjmms-qrmkxg9r.
  - [67] M. M. Hamasha dkk., "Strategical selection of maintenance type under different conditions," *Sci Rep*, vol. 13, no. 1, Des 2023, doi: 10.1038/s41598-023-42751-5.
  - [68] M. Iqbal, "Pengaruh Preventive Maintenance (Pemeliharaan Pencegahan) dan Breakdown Maintenance (Penggantian Komponen Mesin) Terhadap Kelancaran Proses Produksi di PT. Quarryndo Bukit," *Jurnal Manajemen dan Bisnis*, vol. 1, no. 3, 2017.
  - [69] A. Rizky, A. Nr, dan E. Pudji, "Analisis Kebijakan Perawatan Mesin Secara Corrective dan Preventive Dengan Metode rcm di CV XYZ," *Juminten : Jurnal Manajemen Industri dan Teknologi*, vol. 02, no. 03, hlm. 24–34, 2021.
  - [70] D. B. S. Saputro, P. B. Santoso, dan R. A. Sari, "Perancangan Expert System Untuk Troubleshooting Mesin dengan Decision Table (Studi Kasus di PT. Adi Putro Wirasejati)," *Jurnal Rekayasa dan Manajemen Sistem Industri*, vol. 3, no. 2, 2015.
  - [71] C. P. C. Munaiseche dan O. E. S. Liando, "Evaluation of expert system application based on usability aspects," dalam *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Mei 2016. doi: 10.1088/1757-899X/128/1/012001.
  - [72] Y. Lizar, J. Jama, F. Rizal, A. Guci, T. Loveri, dan L. S. Muchlis, "Implementation Of Computer Damage Diagnosis By Expert System Based Using Forward Chaining And Certainty Factor Methods," *INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH*, vol. 8, no. 06, 2019, [Daring]. Tersedia pada: [www.ijstr.org](http://www.ijstr.org)
  - [73] M. Muslim, "Penerapan Model ISO 9126 Terhadap Evaluasi Kualitas Sistem Pakar," 2015.
  - [74] M. Jamil, S. F. Saputra, M. I. Wahid, dan D. Riana, "Evaluasi Metode ISO/IEC 9126 Pada Kinerja Website Sistem Informasi Akademik Perguruan Tinggi," *Informatika Mulawarman : Jurnal Ilmiah Ilmu Komputer*, vol. 16, no. 1, hlm. 27, Mar 2021, doi: 10.30872/jim.v16i1.5209.
  - [75] G. M. Sullivan dan A. R. Artino, "Analyzing and Interpreting Data From Likert-Type Scales," *J Grad Med Educ*, vol. 5, no. 4, hlm. 541–542, Des 2013, doi: 10.4300/jgme-5-4-18.
  - [76] M. Koo dan S.-W. Yang, "Likert-Type Scale," *Encyclopedia*, vol. 5, no. 1, hlm. 18, Feb 2025, doi: 10.3390/encyclopedia5010018.
  - [77] S. K. Wadkar, K. Singh, R. Chakravarty, dan S. D. Argade, "Assessing the Reliability of Attitude Scale by Cronbach's Alpha," *Journal of Global Communication*, vol. 9, no. 2, hlm. 113, 2016, doi: 10.5958/0976-2442.2016.00019.7.

- [78] Z. Hassani, H. R. Mokhtarinia, A. H. Kahlaee, dan C. P. Gabel, "Translation, Validity, and Reliability of the Upper Extremity Fugl-Meyer Assessment (FMA-UE) in Persian Speaking Stroke Patients," *Iranian Rehabilitation Journal*, vol. 20, no. 1, hlm. 37–46, 2022, doi: 10.32598/irj.20.SpecialIssue.919.3.
- [79] Y. A. R. Anggara, S. A. Wibowo, dan Y. A. Pranoto, "Sistem Pakar Diagnosa Kerusakan Laptop Berbasis Forward Chaining dan Certainty Factor," *IJAI (Indonesian Journal of Applied Informatics)*, 2025.
- [80] Fernando Ramadhan, Yuhandri, dan Gunadi Widi Nurcahyo, "Penerapan Forward Chaining dan Metode Certainty Factor dalam Merancang Sistem Pakar Diagnosa Gangguan Kepribadian," *Jurnal KomtekInfo*, hlm. 213–221, Sep 2024, doi: 10.35134/komtekinfo.v11i4.548.
- [81] H. H. A. Rabbani, A. Jamaluddin, dan A. Solehudin, "Sistem Pakar Diagnosa Awal Penyakit Jantung Menggunakan Metode Forward Chaining dan Certainty Factor Berbasis Website," *INFOTECH journal*, vol. 9, no. 2, hlm. 442–451, Agu 2023, doi: 10.31949/infotech.v9i2.6401.
- [82] Y. Fadhillah, "Sistem Pakar Menggunakan Forward Chaining dan Certainty Factor Untuk Diagnosa Kerusakan Smartphone," *Jurnal Education and Development*, 2020.
- [83] O. Saputra, I. Fitri, E. Tri, dan E. Handayani, "Sistem Pakar Diagnosa Kerusakan Hardware Komputer Menggunakan Metode Forward Chaining dan Certainty Factor Berbasis Website," *Jurnal Teknologi Informasi dan Komunikasi*, vol. 6, no. 2, hlm. 2022, 2022, doi: 10.35870/jti.
- [84] I. Akil Program Studi Manajemen Administrasi ASM BSI Jakarta Jl Jatiwaringin Raya No dan J. Timur, "Analisa Efektifitas Metode Forward Chaining dan Backward Chaining Pada Sistem Pakar," 2017.
- [85] A. Ibezato Zalukhu, I. Syahputra, M. Iqbal, dan R. Farta Wijaya, "Analisis Metode Certainty Factor Pada Sistem Pakar Diagnosa Kerusakan Sepeda Motor," *Bulletin of Information Technology (BIT)*, vol. 4, no. 4, hlm. 524–532, 2023, doi: 10.47065/bit.v3i1.
- [86] M. Hayatullah Guftamal dan I. Fitri Astuti, "Rancang Bangun Sistem Pakar Diagnosis Kerusakan Hardware Komputer Dengan Metode Forward Chaining dan Certainty Factor Berbasis Desktop," *JURTI*, vol. 6, no. 2, 2022.
- [87] W. Hasim dan Syarifah Putri Agustini Alkadri, "Penerapan Metode Certainty Factor Dalam Sistem Pakar Deteksi Kerusakan Truk Berbasis Android," *JUSTINDO (Jurnal Sistem dan Teknologi Informasi Indonesia)*, vol. 8, no. 2, hlm. 116–127, Agu 2023, doi: 10.32528/justindo.v8i2.771.
- [88] D. Jiang dan Z. Wang, "Research on Mechanical Equipment Fault Diagnosis Method Based on Deep Learning and Information Fusion," *Sensors*, vol. 23, no. 15, Agu 2023, doi: 10.3390/s23156999.
- [89] D. Kiray dan F. A. Sianturi, "Diagnose Expert System Computer Malfunction Certainty Factor Method," 2020.
- [90] B. Ariyanto, I. Agus Adhi Nugroho, dan S. Farisa, "Perancangan Sistem Pakar Diagnosa Kerusakan Mesin Boiler Miura EH-500F Menggunakan Metode Forward Chaining Berbasis Web," *Jurnal KIMU Teknik Elektro*, 2019.

- [91] A. S. Puspaningrum, S. Rochimah, dan R. J. Akbar, "Functional Suitability Measurement using Goal-Oriented Approach based on ISO/IEC 25010 for Academics Information System," *Journal of Information Systems Engineering and Business Intelligence*, vol. 3, no. 2, hlm. 68, Okt 2017, doi: 10.20473/jisebi.3.2.68-74.
- [92] A. Haslinda dan N. Shiratuddin, "Evaluation of e-Book Applications Using ISO 25010," *International Symposium on Technology Management and Emerging Technologies (ISTMET)*, 2015.
- [93] J. S. Dumas dan J. C. Redish, *A Practical Guide to Usability Testing REVISED EDITION*, Revised Edition. 1999.