Expert System for Automatic Weather Station Instrument Malfunction Diagnosis Using the Certainty Factor Method (BMKG Regional North Sumatra Case Study)

Juliana Sari Kembaren, Muhammad Amin

Abstract

Expert systems are one of the methods that can be used to assist in decision-making, particularly in diagnosing equipment malfunctions. This research aims to design an expert system that can diagnose damage to weather measuring instruments on the Automatic Weather Station (AWS) using the Certainty Factor (CF) method. A case study was conducted at the BMKG Regional Office of North Sumatra, which has various types of weather equipment that require routine maintenance and damage diagnosis. This expert system relies on the knowledge of experts to identify symptoms of damage and provide repair solutions based on the certainty level calculated using the Certainty Factor method. The CF method is used to determine the confidence level in the possible diagnosis provided by the expert system. The results of this study show that the developed expert system can help improve the efficiency in diagnosing weather measuring instrument malfunctions and provide accurate repair recommendations. Thus, it is expected that the use of this expert system can accelerate the maintenance and servicing process of weather measuring instruments at BMKG, as well as reduce errors in diagnosis made by technicians.

Keywords: *Expert system, Certainty Factor, Automatic Weather Station, Damage Diagnosis, BMKG.*

Juliana Sari Kembaren[1]
[1]Information Technology, Universitas Pembangunan Panca Budi, Indonesia
e-mail: juli_kembaren@yahoo.com[1]

Muhammad Amin[2]
[2]Information Technology, Universitas Pembangunan Panca Budi, Indonesia
e-mail: mhdamin@dosen.pancabudi.ac.id[2]

Introduction

Weather measuring equipment, such as Automatic Weather Stations (AWS), plays a very important role in monitoring atmospheric conditions and providing accurate weather information for various needs, ranging from weather forecasting, scientific research, to natural disaster mitigation. In its operation, AWS can experience damage or disruptions that can affect the accuracy of the data produced. Therefore, the maintenance and repair of this equipment become one of the most important aspects to ensure the reliability of the existing weather measurement system. The purpose of the Automatic Weather Station (AWS) is to measure and identify the local climate [1]. The era of digitisation has begun for the international weather parameter observation program. The Automatic Weather Station (AWS) is one of the devices used to measure weather characteristics [2]. An Automatic Weather Station (AWS) was developed to measure the weather using a more cost-effective and superior automatic observation technology. The Automatic Terminal Information Service (ATIS) technology uses weather-related data from the AWS, including temperature, humidity, pressure, wind direction, and wind speed [3].

BMKG (Meteorology, Climatology, and Geophysics Agency) Regional North Sumatra, as one of the institutions responsible for weather observation, has a number of weather measuring instruments at various points scattered throughout the region. Although these instruments are equipped with advanced technology, maintenance and damage diagnosis often require specialised expertise that is only possessed by a few experienced technicians. This causes the maintenance and damage diagnosis process to become slower and more prone to human error, especially in cases where the symptoms of damage are not immediately obvious. The public, as well as government agencies involved in disaster management, can utilise the information provided by BMKG to determine the weather forecast for the upcoming days and modify their operations that rely on weather as an indicator, including agriculture, tourism, fishing, transportation, trade, and government [4].

On the other hand, the development of expert system technology offers solutions that can enhance the efficiency of diagnosing and maintaining weather measuring instruments. Expert systems, which can mimic the way an expert thinks in solving problems, have the potential to assist technicians in diagnosing equipment malfunctions with greater accuracy. One of the methods that can be used in expert systems is the Certainty Factor (CF), which is used to provide a level of certainty in a diagnosis based on the symptoms that appear. Research conducted by Rasim et al.

According to Naive Bayes probability calculations, the research findings demonstrate that the expert system developed correctly diagnoses printer issues automatically. This program has demonstrated the ability to reduce reliance and speed up the process of identifying problems [5]. The Certainty Factor method can provide accurate results from calculations based on the weight of symptoms selected by the user in the system, as demonstrated by the program implemented with the system based on the manual calculations. It can also provide answers to problems with uncertain truth, like the problem in this research, which is the diagnosis of a disease. Expert systems will offer the community the quickest replies, and the Certainty Factor approach will aid in finding answers. [6], [7].

The Certainty Factor method allows the system to consider various potential damages by assigning weights or confidence levels to each possibility. Thus, the decisions made can be more structured and based on existing data, reducing reliance on subjective interpretation. The purpose of this study is to evaluate the precision and dependability of the Certainty Factor (CF) approach in expert systems for the diagnosis of hypertension. One method for providing certainty about a fact is the Certainty Factor (CF). [8], [9]. The Certainty Factor technique is combined with an expert system model in this study, which was created via a prototyping method. The study's findings demonstrate that using the Certainty Factor approach leads in a precise and successful system. Experts tested the constructed system's viability, and the results showed a 100% viability percentage, or "Very Feasible." Additionally, this system was tested for user feasibility using the PSSUQ questionnaire; the average percentage calculation for all categories was "88.85%," which is considered "Very Feasible." [10].

In the context of BMKG Regional North Sumatra, the use of an expert system with the Certainty Factor method to diagnose damage to weather measuring instruments can provide significant benefits. This system not only increases the efficiency of damage diagnosis but also minimises technical errors that can occur in the maintenance of these instruments. Thus, it is hoped that the quality and accuracy of weather observations conducted by BMKG can be maintained, allowing for better weather information services to be provided to the public.

With that background, this research aims to design and develop an expert system for diagnosing weather instrument malfunctions on the AWS at the North Sumatra Regional BMKG using the Certainty Factor method. This system is expected to significantly contribute to improving the efficiency and accuracy of the maintenance and upkeep of weather instruments at the BMKG.

Literature Review

2.1 Artificial Intelligence

Artificial intelligence comes from the English term "Artificial Intelligence" or the abbreviation AI, where intelligence is an adjective meaning smart, while artificial means man-made. The artificial intelligence referred to here pertains to machines that are capable of thinking, weighing the actions to be taken, and making decisions like humans do [11]. So, artificial intelligence is a branch of computer science that aims to enable a computer to think and reason like a human. Artificial intelligence can assist humans in making decisions, searching for information more accurately, or making computers easier to use with interfaces that utilise natural language, making them easy to understand. One part of the artificial intelligence system is the expert system, where the expert system is a part of artificial intelligence that specifically attempts to adopt someone's expertise in a particular field into a system or computer program [12].

2.2 Expert System

Expert System In their journal [13], the basic concept of an expert system includes expertise, experts, rules, inference expertise transfer, and the ability to explain. Expertise is the superior mastery of knowledge in a specific field obtained through training, reading, or experience. In its construction, an expert system combines inference rules with a specific knowledge base provided by one or more experts in a particular field. the combination is stored in a computer, which is then used in the decision-making process to solve specific problems. Advantages of Expert Systems. Hay dos componentes principales necesarios para crear una aplicación de inteligencia artificial, a sabre, la base de conocimientos y el motor de inferencia [14]. El entorno de desarrollo se incluye para el desarrollo de expertos en el entorno del sistema experto, mientras que el entorno de consulta es utilizado por usuarios no expertos para obtener conocimientos expertos [15].

El término sistema experto se origina del término sistema experto basado en conocimiento. Este término surgió porque, para resolver problemas, un sistema experto utiliza el conocimiento de un experto que se introduce en la computadora. Alguien que no es un experto utiliza un sistema experto para mejorar sus habilidades de resolución de problemas, mientras que un experto utiliza un sistema experto como asistente de conocimiento. El propósito principal de los sistemas expertos no es reemplazar la posición de un experto o especialista, sino difundir el conocimiento y la experiencia de expertos que son competentes en sus campos. Los sistemas expertos se componen de dos partes principales, a sabre, el entorno de desarrollo y el entorno de consulta. Componentes del sistema experto [16].

Existen varias técnicas de representación del conocimiento comúnmente utilizadas en el desarrollo de un sistema experto, a sabre: (1) conocimiento basado en reglas, (2) conocimiento basado en marcos, (3) conocimiento basado en objetos y (4) razonamiento basado en casos. Salah satu metode yang paling umum untuk merepresentasikan pengetahuan adalah dalam bentuk aturan if...then [17].

Basis Pengetahuan adalah hasil dari akuisisi dan representasi pengetahuan dari seorang ahli. Basis pengetahuan mengandung pengetahuan dalam pemecahan masalah. Ada dua bentuk umum basis pengetahuan yang digunakan, yaitu: (1) Penalaran Berbasis Aturan, di mana pengetahuan direpresentasikan menggunakan aturan dalam bentuk: Jika-Maka. Penalaran ini digunakan ketika ada sejumlah pengetahuan ahli tentang masalah tertentu, dan ahli tersebut dapat menyelesaikannya secara berurutan. (2) Penalaran Berbasis Kasus, di mana basis pengetahuan mengandung solusi yang telah dicapai sebelumnya, dan kemudian solusi untuk situasi saat ini diturunkan [18]. Mesin Inferensi (Inference Engine) mengarahkan pencarian melalui basis pengetahuan, sebuah proses yang melibatkan penerapan aturan inferensi yang dikenal sebagai pencocokan pola. El programa de diagnóstico decide qué reglas investigar, qué diagnósticos eliminar y qué atributos ajustar.

2.3 Certainty Factor

In facing a problem, answers are often found that do not have full certainty. This uncertainty can take the form of probability or likelihood depending on an event. Uncertain results can be caused by two factors, namely uncertain rules and uncertain user responses to the questions posed by the system. Experts cannot define the relationship between symptoms and their causes with certainty, and patients cannot perceive a symptom with certainty either. In the end, several possible diagnoses will be found.

Certainty Factor states the confidence in an event (fact or hypothesis) based on evidence or expert judgement. Certainty Factor uses a value to assume the degree of an expert's confidence in a piece of data. The Certainty Factor (CF) theory was proposed by Shortliffe and Burhanan in 1975 to accommodate the uncertainty in an expert's reasoning. Certainty Factor (CF) is the value of the clinical parameter given by MYCIN to indicate the level of confidence (Giarratano & Riley, 2006).

Certainty Factor is defined as follows:

$CF(HE) = MB\ (H, E) - MD\ (HE)$ ......equation 1

Explanation:

CF (H, E): Certainty Factor

MB (H, E): Measure of increased belief in hypothesis H given evidence E (between 0 and 1)

MD (H, E): Measure of increased disbelief in hypothesis H given evidence E (between 0 and 1)

The basic form of the Certainty Factor formula for a rule IF E THEN H is as shown in the following equation 2:

$CF(H,e) = CF(E,e) * CF\ (H, E)$ ....equation 2

Where:

CF(E,e): Certainty Factor of evidence E influenced by evidence e

CF (H, E): Certainty Factor of the hypothesis assuming evidence is known for sure, that is when CF(E,e) = 1 CF(H,e): Certainty Factor influenced by evidence e.

If all the evidence on the antecedent is known for certain, then the equation will become:

$CF(H,e) = CF\ (H, E)$ ....equation 3

In its application, CF (H, E) is the certainty value given by the expert towards a rule, while CF(E,e) is the trust value given by the user towards the symptoms they experience.

The reason for using this method is that it can provide accurate results obtained from calculations based on the weights of symptoms chosen by the user, capable of providing answers to problems whose truth is uncertain, such as disease diagnosis issues, and with this method, experts illustrate their confidence by assigning confidence weights according to their related knowledge.

The certainty factor was introduced by Shortliffe Buchanan in the development of MYCIN (Wesley, 1984). Certainty Factor (CF) is the value of the clinical parameter given by MYCIN to indicate the level of confidence. Certainty factor is defined as follows (Giarratano

and Riley, 1994):
CF (h, e) = MB[h,e] – MD[h,e]
MB (h, ei v ei) = MB[h,ei]+MB[h,ei]*(1-MB[h,ei)
MD (h, ei v ei) = MD[h,ei]+MD[h,ei]*(1-MD[h,ei])
Explanation: CF(h,e):
Certainty Factor of hypothesis h influenced by evidence e.
MB(h,e): Measure of increased belief towards hypothesis h influenced by evidence e.
MD(h,e): Measure of increased disbelief towards hypothesis h influenced by evidence e.
e: Evidence (Fact/Sign/Clue/Symptom).
i: Number of evidence provided.
To calculate the combination between 2 CF:
$CF\ Combine\ (CF1,\ CF2) = CF1 + CF2 * (1 - CF1)$

The first step in the certainty factor method is to determine the hypothesis. After the hypothesis, the next step is to determine the initial confidence factor, which has a value between -1 and 1, as shown in the table 1.

Table 1. Certainty Factor Interpretation Table

Namber	Certainty Term	CF
1	Definitely Not	-1
2	Almost Certainly Not	-0,8
3	Most Likely Not	-0,6
4	Maybe Not	-0,4
5	Don't know	-0,2 - 0,2
6	Maybe	0,4
7	Highly Likely	0,6
8	Almost Sure	0,8
9	Certain	1

Next, an evaluation is conducted on the evidence related to the hypothesis. The next step is to calculate the CF based on each piece of evidence. After obtaining the CF, the next step is to combine each CF. Based on the combined CF, the belief in the hypothesis can be updated. This new belief represents the level of confidence that the hypothesis is true based on the evaluated evidence.

Research Methodology

This research aims to design and develop an expert system for diagnosing damage to the Automatic Weather Station (AWS) using the Certainty Factor (CF) method at BMKG Regional North Sumatra. To achieve this goal, this research uses a software engineering research approach by adopting the Waterfall methodology-based system development model. This methodology consists of several stages carried out sequentially and structured, starting from requirements analysis to system testing.

The first stage of this research is a literature review aimed at identifying and understanding various theories, concepts, and applications relevant to the development of expert systems, the Certainty Factor, and fault diagnosis in weather measuring instruments. The literature used includes journals, books, and references related to expert systems, the Certainty Factor method, and the application of information technology in the maintenance of weather equipment. The results of this literature review will serve as the theoretical foundation for designing the expert system to be developed.

At this stage, a system needs analysis is conducted to determine the functions and features required by the expert system in diagnosing faults in AWS. The needs analysis is carried out through interviews with BMKG Regional Sumatera Utara technicians and observations of the existing maintenance processes. The information obtained is used to formulate the symptoms of damage that can occur in AWS, as well as the rules or knowledge base needed for diagnosis. System testing to ensure that the expert system functions as expected. The testing was conducted using damage data obtained from the BMKG Regional North Sumatra and compared with the diagnosis results provided by experienced technicians. The testing aims to measure the accuracy, speed, and reliability of the system in diagnosing weather measurement instrument malfunctions.

Results

In the fact consultation session, the user is only given 2 answer options: if they experience or choose that fact (v), then the CF value = 1; if the fact is not experienced or not chosen, then the CF value = 0. Meanwhile, in the symptom consultation session, the user is given the option to choose what damage occurs to the Automatic Weather Station. Each symptom has a CF weight. The CF (Rule) value is obtained from the expert's interpretation of the "term," which is converted into a specific CF value according to the following table:

Table 2. Certain Term MB/MD

Certain Term	**CF**
Don't know	0 – 0,2
Maybe	0,21 – 0,4
Highly Likely	0,41 – 0,6
Almost Certain	0,61 – 0,8
Certain	0,81 – 1

The Certainty Factor method can also be applied in diagnosing the malfunction of the Automatic Weather Station weather measuring instrument. Here is an example of CF calculation for AWS damage.
Rule 1: IF AWS cannot Sensor Drift THEN damage = Environmental Factor (CF = 0.9)
Rule 2: IF Covered with Dew THEN damage = Humidity Sensor (CF = 0.8)
Rule 3: IF Dirty Bearings THEN damage = Stuck Anemometer (CF = 0.8)
Calculate the combined CF if:
CF (AWS cannot Sensor Drift) = 1 and CF (Environmental Factor) = 1 and CF (Measurement Deviation) = 1
CF1 = C (AWS cannot Sensor Drift) x CF(Rule1) = 1 x 0.9 = 0.9
CF2 = C (Environmental Factor) x CF(Rule2) = 1 x 0.8 = 0.8
CF3 = C (Measurement Deviation) x CF(Rule3) = 1 x 0.8 = 0.8
Answer:
CFA = CF1 + CF2 (1 – CF1) = 0.9 + 0.8 (1 – 0.9) = 0.98
CFB = CF3 + CFA (1 – CF3) = 0,8 + 0,98 (1 – 0,8) = 0,996 = 1
From the manual calculations above, it was found that the certainty factor value from the input symptoms leading to damage to the Environmental Factor is 0.95.

Some of the common damages that occur in each AWS tool are approximately 10 types of damages, which can be seen in the following table:

Table 3. Damage Analysis on AWS

Code	**Type of Damage**
P01	Damage Sensor Drift
P02	Damage to Humidity Sensor
P03	Damage to Anemometer Traffic jam

P04	Damage to Rainfall Sensor Blocked
P05	Damage to Radiometer
P06	Damage to Battery Dead
P07	Damage to Dirty Solar Panels
P08	Damage to Charging System
P09	Damage to Data Logger Error
P10	Damage to Broken or Corroded Cable

The success of an expert system lies in the knowledge and how to process that knowledge to draw a conclusion. The knowledge obtained from the interview results is converted into a table of types of damage that occur in AWS and their symptoms to facilitate the process of finding solutions. The symptoms of damage in AWS can be seen in the following table:

Table 4. Symptoms of Damage in AWS

No	**Code**	**Symptoms / Damage**	**P 01**	**P 02**	**P 03**	**P 04**	**P 05**	**P 06**	**P 07**	**P 08**	**P 09**	**P 10**
1	G01	The sensor is no longer accurate due to age or environmental factors, causing the measurement values to deviate from the actual conditions.	v				v				v	v
2	G02	The sensor is often covered with dew/dust or gets water inside.					v		v		v	v
3	G03	The anemometer bearing is dirty or rusty							v			
4	G04	Rain gauge (penakar hujan) is clogged with dirt, leaves, or insects.				v						
5	G05	Covered in dirt or water					v					v
6	G06	Due to continuous load or the battery being old.		v	v						v	
7	G07	Solar panels covered in dust or bird droppings		v			v				v	v
8	G08	Damage to the power controller		v	v							
9	G09	Data was not sent to the central server.	v									
10	G10	The data collection tool failed to process.		v	v							
11	G11	The sensor connector is rusted.	v									
12	G12	Lightning strikes can damage circuit boards.				v			v			
13	G13	Animals like birds or insects that nest inside sensors or chew on cables						v				

The conclusion of the damage symptoms is a table that summarises where each damage symptom on AWS has the same analyses as other damage symptoms. As shown in the table below:

Table 5. Conclusion of Damage Symptoms on AWS

Rule	IF	THEN	Explanation
1	G01, G09, G11, G13	P01	The sensor is often covered with dew/dust or gets water inside.
2	G06, G07, G08, G10,	P02	The anemometer bearing is dirty or rusty
3	G06, G08, G10, G12, G13	P03	Covered in dirt or water
4	G04, G12, G13	P04	Due to continuous load or the battery being old
5	G01, G02, G05, G07, G17, G11, G13	P05	Damage to the power controller
6	G8, G11, G13	P06	Data was not sent to the central server.
7	G02, G03, G12, G13	P07	The data collection tool failed to process.
8	G6, G9, G12	P08	The sensor connector is rusted.
9	G01, G02, G04, G07, G8, G9, G12, G13	P09	Lightning strikes can damage circuit boards.
10	G01, G02, G05, G07, G11, G12, G13	P10	Animals like birds or insects that nest inside sensors or chew on cables

Conclusion

Based on the research design results that have been outlined, it can be concluded that the application of an expert system to diagnose damage to the Automatic Weather Station at BMKG Regional Sumatera Utara is a relevant, rational, and applicable approach in supporting meteorological device maintenance activities. This system is designed to assist in the process of identifying damage based on the symptoms that appear, so the diagnosis process does not only rely on the technician's experience but can also be supported by a structured system based on expert knowledge. The use of the Certainty Factor method in expert systems is deemed appropriate because this method can accommodate elements of uncertainty in the diagnostic process. In the context of AWS damage, a single symptom can lead to more than one possible malfunction, so a mechanism is needed to calculate the confidence level for each possibility. Thus, the Certainty Factor method provides a logical basis for determining the diagnosis that most closely matches the actual condition and produces more accurate handling recommendations.

Conceptually, the development of this expert system is expected to improve efficiency, consistency, and accuracy in diagnosing weather measurement instrument malfunctions. The presence of this system also has the potential to accelerate the technical decision-making process, reduce the likelihood of manual diagnosis errors, and serve as a medium for documenting the knowledge of expert technicians that can be utilised sustainably. With the presence of this system, the maintenance process of the equipment can be carried out more systematically, thereby supporting the continuity of weather observation operations in the BMKG Regional North Sumatra environment. Therefore, this research emphasises that the Certainty Factor-based expert system can be used as an alternative solution in the management and diagnosis of AWS damage. In addition to contributing to the development of knowledge in the field of expert systems, this research also has practical value for institutions, particularly in supporting the reliability of tools, the quality of weather data, and the effectiveness of field technicians' work.

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References

[1] B. Zamili, "Rancang Bangun Alat Ukur Data Iklim Automatic Weather Station (AWS)," vol. 2, no. 01, pp. 28–36, 2024, doi: 10.55180/aei.v2i1.766.

[2] H. S. Wicaksana *et al.*, "Evaluasi Kinerja Automatic Weather Station Berdasarkan Pengamatan Paralel di Stasiun Meteorologi Kemayoran Prosiding Seminar Nasional Teknik Elektro Volume 6 Tahun 2021," vol. 6, no. 2, 2021.

[3] M. E. Millianda *et al.*, "RANCANGAN AUTOMATIC WEATHER STATION (AWS) MENGGUNAKAN ARDUINO MEGA PADA BANDARA," vol. 4, no. 3, 2025.

[4] B. Hartanto *et al.*, "Pencarian dan Pemanfaatan Informasi Data Badan Meteorologi , Klimatologi , dan Geofisika (BMKG)," vol. 1, no. 5, pp. 553–564, 2022, doi: 10.55123/insologi.v1i5.906.

[5] D. Handayani, I. Rawinto, and H. Lubis, "SISTEM PAKAR BERBASIS WEB DIAGNOSIS KERUSAKAN PRINTER MENGGUNAKAN," vol. 5, pp. 275–287, 2025.

[6] D. Deslianti, U. M. Bengkulu, U. M. Bengkulu, and C. Factor, "PENERAPAN METODE CERTAINTY FACTOR DALAM Pendahuluan Studi Literatur," vol. 3, pp. 456–465, 2020.

[7] D. Maulina, A. M. Wulanningsih, F. I. Komputer, and U. A. Yogyakarta, "METODE CERTAINTY FACTOR DALAM PENERAPAN SISTEM PAKAR DIAGNOSA PENYAKIT ANAK Abstraksi Pendahuluan Tinjauan Pustaka Metode Penelitian," vol. 1, no. 2, pp. 23–32, 2020.

[8] D. Kurnia and M. Irfan, "SISTEM PAKAR DIAGNOSIS KERUSAKAN PADA KOMPUTER MENGGUNAKAN," pp. 98–104, 2024.

[9] I. Maria, S. Br, C. Rizal, and H. Kurniawan, "Analisis Akurasi Dan Keandalan Metode Certainty Factor Pada Sistem Pakar Diagnostik Medis," vol. 07, no. 03, pp. 702–707, 2025.

[10] U. Diagnosa and G. Belajar, "Penerapan metode," pp. 12–21.

[11] A. Fitri and W. F. Mahmudy, "Optimasi Keanggotaan Fuzzy Tsukamoto Menggunakan Algoritma Genetika pada Penentuan Prioritas Penerima Zakat," vol. 1, no. 2, pp. 125–138, 2017.

[12] A. Handojo *et al.*, "PERANCANGAN DAN PEMBUATAN APLIKASI SISTEM PAKAR TERHADAP HARTA KEKAYAAN Fendhy Ongko Indonesia sebagai sebuah negara hukum sudah memiliki peraturan-peraturan hukum dibatasi pada jenis-jenis tindak pidana yang Windows XP Profesional , bahasa pemro- Arsitektur Sistem Pakar pada gambar 1 di bawah ini dimana sebuah," vol. 5, no. 1, pp. 32–38, 2004.

[13] S. N. Yanti and E. Budiyati, "Aplikasi Sistem Pakar untuk Mendiagnosa Virus Covid-19 pada Manusia Berbasis Web Menggunakan Metode Forward Chaining," vol. 5, no. 4, pp. 451–458, 2020.

[14] F. Puspita, S. I. Saputra, and J. Merini, "Uji Beberapa Konsentrasi Bakteri Bacillus sp . Endofit untuk Meningkatkan Pertumbuhan Bibit Kakao (Theobroma cacao L .) Various Concentration of Endophytic Bacillus sp . to Improve Growth of Cocoa (Theobroma cacao L .) Seedling," vol. 46, no. 3, pp. 322–327, 2018.

[15] M. Arrosty and J. R. Sagala, "IQ Test Expert System for Selecting Candidates for New Students," vol. 2, no. 1, pp. 94–98, 2020.

[16] L. E. Pradita, M. Ulyan, and R. Sotlikova, "THE IMPLEMENTATION OF PROJECT-BASED LEARNING IN HIGHER EDUCATION : A CASE STUDY IN THE INDONESIAN CONTEXT," vol. 12, no. 1, pp. 475–486, 2024.

[17] C. N. Culture *et al.*, "Android-Based Intangible Cultural Heritage Expert System In Banten Province Using Backward Chaining Method Android-Based Intangible Cultural Heritage Expert System In Banten Province Using Backward Chaining Method", doi: 10.1088/1757-899X/1115/1/012008.

[18] S. Pakar and D. A. N. Pengembangannya, "No Title".