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Expert System of Error Tracking Automated Weather Observing System Using Certainty Factor Method Based on Android Application

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Abstract

The limited number of technicians at several BMKG UPT (Task Implementation Units) in Indonesia is the main background of this research. Especially in the field of Aviation Meteorology, which has a significant safety risk for equipment data users. This can be made easier with an expert system. The fault tracking expert system aims to provide information about the symptoms of damage that occur in the Automated Weather Observing System (AWOS) so that it can make it easier for BMKG technicians to repair and handle the equipment. This research stage begins with collecting information data through experts and literature sources regarding AWOS equipment, then calculating the certainty value of the information using the certainty factor method, and produce information that will be displayed through the application. The system uses a Certainty Factor calculation method that presents the calculation of the certainty value of information based on the percentage of information delivery by the source, this method is used in accordance with the type of research that utilizes information from sources or experts in the AWOS field. The resulting system is an android application consisting of several knowledge bases stored in the MySQL database on the server. The results of the data analysis show that the resulting system can be used on the user's smartphone, and users can consult AWOS equipment damage properly. In addition, users can also view the consultation history and damage list. The application user satisfaction questionnaire shows the system has worked and fulfilled the function for users by showing a value of 33.3% Very Good and 66.7% Good.

Keywords: Automated Weather Observing System (AWOS), Certainty Factor, Android

1. Introduction

Providing fast, precise, accurate, and continuous weather information services is essential for flight operations, especially at airports with high flight frequency and rapidly changing weather conditions (Feng & Li, 2019; Halder & Sivakumar, 2017). Many observers have to double as maintenance personnel, which may ultimately reduce the effectiveness of AWOS equipment maintenance (Li & Hai-ping, 2019). Weather information is not only important for flight safety, but also for the overall operational efficiency of the airport. In this context, Automatic Weather Observing System (AWOS) equipment plays an important role (Landolt et al., 2019; McCarthy, 1989; Stough et al., 2005). This equipment must be properly maintained in order to continue providing reliable data. However, the maintenance of such equipment faces considerable challenges mainly related to the limited human resources available in some Technical Implementation Units (UPT) of the Meteorology, Climatology and Geophysics Agency (BMKG) (Brönnimann et al., 2018; Chimani et al., 2022; Saltikoff et al., 2017).

The need for a system that can utilize the knowledge of certified maintenance personnel is becoming increasingly urgent. This knowledge needs to be processed and presented in the form of a system that is easily accessible and used by users who do not necessarily have an in-depth technical background (Coandă et al., 2020;

Márquez & Papaelias, 2020). One emerging solution is the use of expert systems, which are computer-based systems that use knowledge and inference to solve problems that usually require human expertise (Li, 2023; Marlinda et al., 2022; Sianturi & Tarigan, 2019). This expert system is expected to assist in the maintenance of AWOS equipment by providing solutions, suggestions, and decisions based on expert knowledge that has been inputted into the system (Bouhalouan et al., 2020; Georgeff & Firschein, 1985; Quinn & Merolla, 1991).

The main problems faced in the maintenance of AWOS equipment are the limited human resources competent in the field and the absence of a system that can assist the maintenance process efficiently (Tretten & Normark, 2019). A common solution that can be applied to overcome these problems is the development of expert systems that utilize technical knowledge from maintenance experts and apply it in the form of easy-to-use applications (Lopes et al., 2016). These systems would utilize methods such as Certainty Factor to address uncertainty in the information provided, as well as being based on an easily accessible platform, such as a mobile application (Karthik & Kamala, 2021; Sajida, 2023). By incorporating the certainty factor method, this system can measure the level of certainty or uncertainty in the information it processes, thus enabling more informed decision-making (Sajida, 2023). Additionally, the system is designed to be easily accessible through a mobile application platform (Tongkaw & Tongkaw, 2018). This choice is in line with the trend of utilizing mobile technology for instant access to information without the constraints of traditional desktop or notebook computers (Adinugroho et al., 2015). In addition, the use of mobile applications can increase accessibility and user engagement, making the system easier to use and widely available (Fabiyi et al., 2022).

Maintenance of Automatic Weather Observing System (AWOS) equipment, especially in the face of limited human resources, can be addressed through the development and implementation of expert systems. Expert systems are computer-based systems that utilize knowledge and inference to solve problems that require human expertise (Sanaei et al., 2014). By integrating technical knowledge from maintenance experts into an expert system, solutions, advice, and decisions can be provided based on the expert knowledge stored in the system (Khan et al., 2014). This approach can help mitigate the challenges posed by the limited availability of human resources competent in the maintenance of AWOS equipment, ensuring the continuous provision of reliable data by such equipment (Martínez, 2019). In addition, expert systems can be designed to be accessible and user-friendly, so that they can be used by users who do not have an in-depth technical background. By incorporating methods such as certainty factors to handle uncertainty in the information processed by the system, more accurate decision-making can be achieved (Ciman & Gaggi, 2017). In addition, utilizing mobile app platforms for expert systems can increase accessibility and user engagement, aligning with the trend of using mobile technology for instant information access (Fabiyi et al., 2022). This solution not only addresses challenges related to limited human resources but also ensures efficient maintenance of AWOS equipment, thereby contributing to the overall operational efficiency and safety of airport operations.

The purpose of this research is to develop and implement an expert system specifically designed for the maintenance of Automatic Weather Observing System (AWOS) equipment. The system is expected to utilize the technical knowledge of maintenance experts and apply it in the form of an application that is easily accessible and usable by users with limited technical backgrounds. This research offers a new approach to overcome the limitations of competent human resources in AWOS equipment maintenance (Sainz & Pérez, 2014; Wang et al., 2021). The novelty of this research lies in the use of the certainty factor method to handle uncertainty in the information processed by the expert system (Islam et al., 2018) (Noroozi et al., 2014). In addition, this study will also develop a mobile application platform that increases accessibility and user engagement, something that has not been widely explored in the context of AWOS care. The main hypothesis to be tested is that the use of a mobile app-based expert system will improve the effectiveness and efficiency of AWOS equipment maintenance. The research will include the development of an expert system that integrates the knowledge of AWOS maintenance experts into an easily accessible platform, specifically a mobile app. The research will involve an empirical evaluation of the effectiveness and efficiency of the system in an operational context at the Technical Implementation Unit (UPT) of the Meteorology, Climatology and Geophysics Agency (BMKG). In addition, the research will examine aspects of usability and user acceptance of the expert system, with a focus on users with limited technical backgrounds. A comprehensive analysis of the impact and effectiveness of the expert system in improving the maintenance process of AWOS equipment will be conducted. bagian integral dari cakupan penelitian ini.

2. Research Methods

2.1. Certainty Factor

The Certainty Factor (CF) method is one of the most useful tools in expert systems for diagnosing uncertain events (Ashidiqi et al., 2023). This method involves calculations based on source information and user-provided certainty values to determine the certainty of a fact or rule (Yuwono et al., 2019). By interviewing experts, CF values can be obtained and converted from expert interpretations, thus helping in the decision-making process (Ashidiqi et al., 2023).

The ability of the CF method to handle uncertain conditions and measure certainty makes it a strong choice for expert systems that address a wide variety of problems (Hamid et al., 2021). Furthermore, modifications to the CF method have been proposed to improve its effectiveness in solving expert system problems (Bligania, 2024). In conclusion, the Certainty Factor method plays an important role in expert systems by providing a structured approach to handling uncertainty and measuring the level of certainty in the decision-making process in various fields.

Table 1. CF Certainty Value

Uncertain Term	CF
Definitely not	-1.0
Almost certainly not	-0.8
Probably not	-0.6
Maybe not	-0.4
Unknown	-0.2 to 0.2
Maybe	0.4
Probably	0.6
Almost certainly	0.8
Definitely	1.0

In the Certainty Factor method, there are many types of calculations that are tailored to existing rules and facts. Calculations for each symptom that causes problems or damage can use the following Certainty Factor combination rules (Chavoshi, 2023; Muntiari & Hanif, 2023):

1. Certainty Factor for rules with single symptoms (single premise rules):
   IF E Then H (CFrule)
   $$CF(H|E) = CF(E) \times CF(H)$$
2. Certainty Factor for rules with similarly concluded rules or more than one symptom:
   $$CFcombine = CF[H,E]_{1,2} = CF[H,E]_1 + CF[H,E]_2 * (1 - CF[H,E]_1)$$
3. Certainty Factor to calculate the conclusion percentage:
   $$CF_{percentage} = CF_{combine} * 100\%$$

Based on the CF value weight table, there is a percentage level of conclusion to describe the expert's level of confidence in a solution to a problem presented in table 2.

Tabel 2. Tingkat Persentase Kesimpulan

Percentage Rate	Belief Value
0% – 20%	Don't know
21% – 40%	Most Likely
41% – 80%	Almost Certain
81% – 100%	Definitely

2.2. Data Collection Technique

a. The interview method (Moore et al., 2021; Petitmengin, 2006) with resource persons/experts in the field of AWOS BMKG can be supported with demonstrated expertise in expert system implementation. This expertise can help in determining the Certainty Factor value based on insights gained from the experts.
b. Literature Study, taking some reference knowledge about certainty factor, expert system, and AWOS Allweather.inc manual book (Andri et al., 2023; Wintersparv, 2022).
c. A questionnaire used as a user assessment of the use of android applications (Kamilah et al., 2023; Manstein et al., 2023; Sharma, 2022).

2.3. Data Processing

Data obtained from interviews with sources will be processed using an expert system to make information easily accepted by users. The expert system is used with the Certainty Factor method as a method that can allow users to obtain a level of confidence in the information received. In general, the system will be displayed through an android-based application (Epiloksa et al., 2022; Haq et al., 2022; Sari et al., 2021). The design of the android base is done utilizing Android Studio software (Devandroid, 2019; Nasution, 2019; Singh et al., 2016) with JAVA programming language (Ogihara, 2018) and using MySQL database (Manual, 2023) as data storage.

3. Results and Discussion

3.1. Results

This research focuses on developing an expert system to track errors in the Automated Weather Observing System (AWOS) using the Certainty Factor method. The use of this method is guided by the CF calculation value (Table 1) based on the confidence of the information from the source and the certainty value given by the user. Based on the information by the source, it is divided into two different data in the form of damage symptoms (Table 3.) along with the CF value and unique code for each symptom. After that there is a diagnosis of damage that occurs to the equipment (Table 4.) accompanied by its

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relationship to the damage symptom data (Table 3.)

Table 3. Symptoms of Damage

Code	Symptoms of Damage	Expert CF Value
G1	Indication that the data generated by the sensor does not enter the data logger.	0.9
G2	Temperature sensor does not output data.	0.8
G3	Air temperature data is not accurate.	0.7
G4	RH sensor does not output data.	0.8
G5	RH (Humidity) sensor data is not accurate.	0.7
G6	Visibility sensor indication does not output data.	0.8
G7	Visibility sensor visibility is inaccurate.	0.7
G8	The ceilometer sensor indication does not output data.	0.8
G9	The ceilometer sensor failed to read data.	0.7
G10	Lightning detector sensor does not output data.	0.8
G11	Lightning detector sensor reads lightning occurred, when there is no lightning.	0.7
G12	Lightning detector sensor misreads the direction of lightning.	0.8
G13	The barometer sensor reads incorrect data.	0.7
G14	The barometer sensor interface output is off.	0.8

Table 4. Diagnosis of Damage

Code	Diagnosis AWOS malfunction	Symptoms
K1	Fault in the sensor connection to the data logger.	G1
K2	Temperature sensor problem.	G2, G3
K3	RH sensor has a problem.	G4, G5
K4	The sensor lens is dirty.	G7, G9
K5	Physical damage to visibility sensor.	G6
K6	Ceilometer sensor blower is not working.	G8
K7	Lightning detector sensor has a problem.	G10, G11, G12
K8	Barometer sensor has a problem.	G13, G14
K9	Ultrasonic wind sensor problem.	G15, G16
K10	Solar radiation sensor problem.	G17
K11	Tipping bucket problem.	G18, G19
K12	Data communication problem.	G20, G21
K13	Error in radio frequency.	G22

The correlation of Table 3 and Table 4 gives a clear picture of how this system works. Taking an example, on calculation diagnosis of damage K7 (If G2&G3 Then K2) symptom G2, which indicates that the temperature sensor does not output data, and symptom G3, which indicates inaccurate air temperature data, are combined to diagnose a malfunction in the temperature sensor with a CF value of 0.94. With the CF calculation stages as follows:

1. Calculation of single premise rules:
   - G2 = $CF[H]_1$ (CF Symptoms 2)
     $CF[H,E]_1 = CF[H]_1$ (CF Symptoms 2)*

     $CF[E]_1$(CF by User) = 0.8 * 1 = 0.8

   - G3 = $CF[H]_2$ (CF Symptoms 3)
     $CF[H,E]_2= CF[H]_2$ (CF Symptoms 3) *

     $CF[E]_2$ (CF by User) = 0.7 * 1 = 0.7

2. Calculation of rules for more than one symptom (similarly concluded rules):
   - $CF_{combine}$ $CF[H,E]_{1,2} = CF[H,E]_1+CF[H,E]_2 * (1 – CF[H,E]_1)$
     = 0.8 + 0.7 * (1 – 0.8) = 0.94

3. Conclusion Percentage Calculation
   - $CF_{percentage}= CF_{combine}$ * 100%
     = 0.94 * 100% = 94 %

4. Belief Value
   The certainty value for solution K2 with a percentage of 94% is certain.

Another example, on calculation diagnosis of damage K7 (If G10&G11&G12 Then K7) symptom G10, which indicates that lightning detector sensor does not output data, symptom G11, which indicates lightning detector sensor reads lightning occurred, when there is no lightning, and symptom G12 that indicates misreads the direction of lightning, three symptoms are combined to diagnose a Lightning detector sensor has a problem with a CF value of 0.93. With the CF calculation stages as follows:

1. Calculation of single premise rules:
   - G10 = $CF[H]_1$ (CF Symptoms 10)
     $CF[H,E]_1 = CF[H]_1$ (CF Symptoms 10)*

     $CF[E]_1$ (CF by User) = 0.6 * 0.8 = 0.54
   - G11 = $CF[H]_2$ (CF Symptoms 11)
     $CF[H,E]_2 = CF[H]_2$ (CF Symptoms 11)*

     $CF[E]_2$ (CF by User) = 0.7 * 0.4 = 0.28
   - G12 = $CF[H]_3$ (CF Symptoms 12)
     $CF[H,E]_3 = CF[H]_3$ (CF Symptoms 12)*

     $CF[E]_3$ (CF by User) = 0.8 * 1 = 0.8
2. Calculation of rules for more than one symptom (similarly concluded rules):
   - $CF_{combine}\ CF[H,E]_{1,2} = CF[H,E]_1 + CF[H,E]_2 * (1 - CF[H,E]_1)$
     $= 0.54 + 0.28 * (1 - 0.54) = 0.67$
   - $CF_{combine}\ CF[H,E]_{old,3} = CF[H,E]_{old} + CF[H,E]_3 * (1 - CF[H,E]_{old})$
     $= 0.67 + 0.8 * (1 - 0.67) = 0.93$
3. Conclusion Percentage Calculation
   - $CF_{percentage} = CF_{combine} * 100\%$
     $= 0.93 * 100\% = 93\ \%$
4. Belief Value
   The certainty value for solution K7 with a percentage of 93% is certain.

This shows that the system is able to handle a combination of symptoms to provide more accurate diagnoses. Where the application of this system in the android application can be seen in Figure 1 and Figure 2 which shows that the information obtained by the user is in accordance with the symptoms of damage that occur in the AWOS equipment owned by the user.

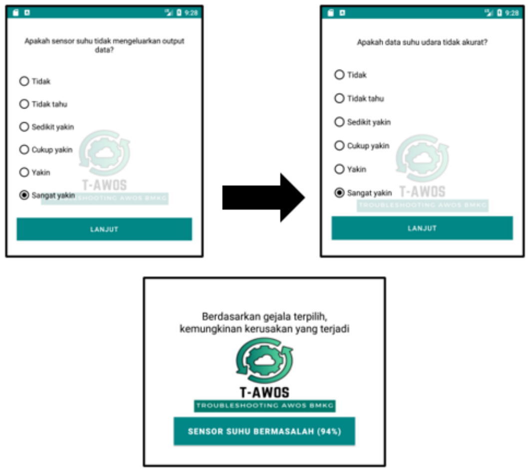

Figure 1. Android System Testing K2

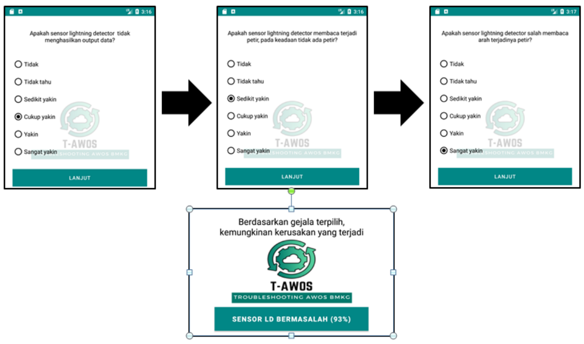

Figure 2. Android System Testing K7

This expert system uses a MySQL database to store a knowledge base that can be accessed through an Android application. This expert system is implemented using Android Studio and JAVA programming language. System testing was conducted through two methods: black box testing to test each feature in the application and a questionnaire to measure user satisfaction. The results of the questionnaire (Table 5.) showed that 38.5% of users rated the application as "Very Good" and 61.5% as "Good", indicating that the application meets the needs of users in identifying and repairing damage to AWOS.

Table 5. Questionnaire Testing Results

Question	Very Good	Good	Standard
1. Is the system appropriate in displaying an attractive and user friendly application interface?	46.2%	46.2%	7.7%

Question	Very Good	Good	Standard
2. Is the system appropriate in meeting the information needs required by users clearly?	38.5%	53.8%	7.7%
3. Is the system appropriate in helping to identify damage to the symptoms of damage that occur in the BMKG AWOS?	46.2%	23.1%	30.8%
4. Is the system appropriate in making it easier for users to troubleshoot AWOS equipment in the BMKG environment?	38.5%	61.5%	-
5. Is the system appropriate in providing analysis and solutions to the symptoms of damage that occur?	30.8%	53.8%	15.4%
6. Do the system functions fulfill the user's wishes?	38.5%	61.5%	-

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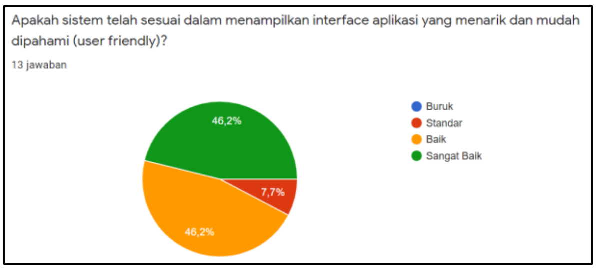

Figure 3. Questionnaire Testing Results 1

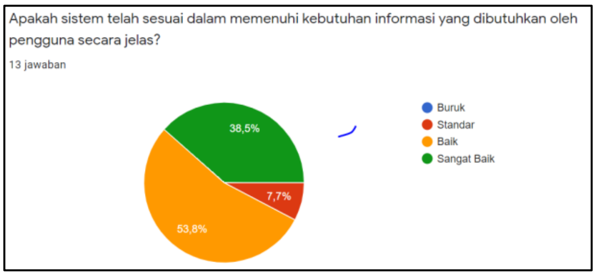

Figure 4. Questionnaire Testing Results 2

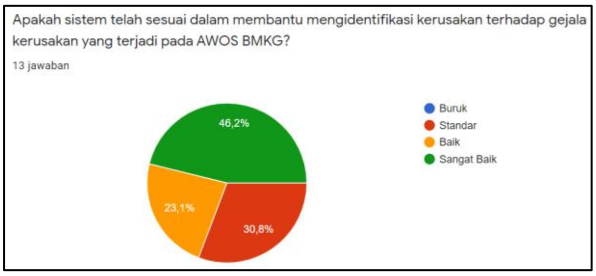

Figure 5. Questionnaire Testing Results 3

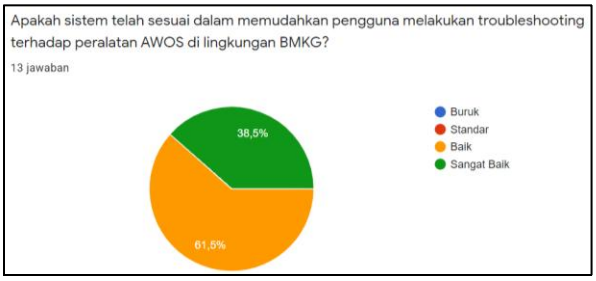

Figure 6. Questionnaire Testing Results 4

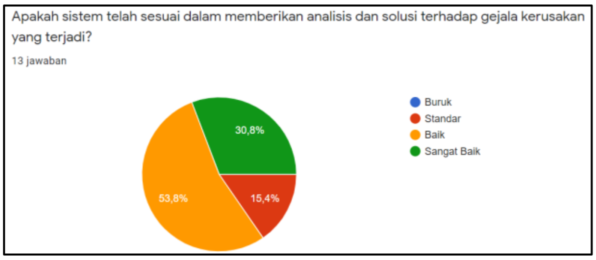

Figure 7. Questionnaire Testing Results 5

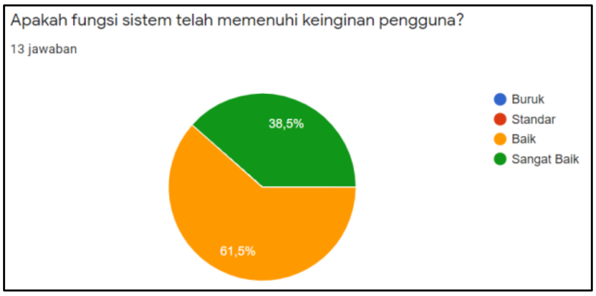

Figure 8. Questionnaire Testing Results 6

3.2. Discussion

The advantage of this research is its implementation in the form of an Android application that facilitates user access and integration with the MySQL database, making it more user-friendly and easily accessible in the field.

The findings of this research are very important because they provide a practical solution to overcome the limited number of technicians at BMKG. With this expert system, technicians can quickly identify and repair damage to AWOS, thus maintaining the smooth operation of airports that rely heavily on accurate and real-time weather data. In addition, the application also allows users to view consultation history and damage lists, thereby improving efficiency in equipment maintenance.

The developed expert system has successfully answered the research question by providing an effective tool for BMKG technicians. The implementation of the Certainty Factor method allows the system to provide accurate diagnoses based on data obtained from experts. The test results show that the system works as expected and fulfills the research objectives. No unexpected or unexplained results were found, indicating that the system has been designed and implemented well. Comparison with other scientific works shows that this system offers advantages in terms of accessibility and ease of use, which have not been found in many previous studies.

Overall, this research successfully made a significant contribution to the field of aviation meteorology by developing an effective and accessible expert system. This shows that the research objectives have been achieved and the results can be practically applied in the field.

4. Conclusion

This research successfully developed an expert system to track faults in the Automated Weather Observing System (AWOS) using the Certainty Factor method based on Android applications. This system is designed to assist technicians at BMKG in identifying and repairing damage to AWOS equipment, especially in the context of limited technician manpower in several BMKG UPTs. The results show that this application can be installed on the user's smartphone and functions well in providing information about the symptoms of damage and the appropriate solution.

The findings of this research have significant implications in the field of aviation meteorology. The application not only makes it easier for technicians to make repairs, but also improves the efficiency of airport operations that rely heavily on accurate weather data. The implementation of the Certainty Factor method allows the system to provide accurate diagnoses based on expert information, which is crucial for maintaining safe and smooth flights.

This research adds knowledge in the field of expert systems and meteorological equipment maintenance. The main advantage of this research is the development of a user-friendly and accessible application, which has not been found in previous research. The system also demonstrates how the Certainty Factor method can be effectively applied in the diagnosis of technical equipment malfunctions.

Although this research was successful in achieving its objectives, there are some limitations that need to be noted. This research was limited to the damage symptoms identified from the interviewees and the manual book, so it may not have covered all possible damage that could occur to the AWOS. In addition, the quality of the interviewees also affects the accuracy of the information obtained. For future research, it is recommended to add more symptoms and more specific damage solutions based on field data.

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