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Estimating Time Since Death: A Forward Chaining-Based Expert System Design

D.Noveriyanti[1], E.E Surbakti[1]*, R. Winantyo[2]

[1] *Informatics, Faculty of Engineering and Informatics, Universitas Multimedia Nusantara, Tangerang, 15810, INDONESIA*

[2] *Electrical Engineering, Faculty of Engineering and Informatics, Universitas Multimedia Nusantara, Tangerang, 15810, INDONESIA*

*Corresponding Author: eunike.endariahna@umn.ac.id
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Abstract

The death rate in Indonesia continues to rise each year. Forensic specialists play a crucial role in estimating the time since death by examining the condition of the body. Their responsibilities extend beyond body examinations to various other cases involving biological evidence. However, the increasing death rate and the complexity of cases often exceed the number of dedicated forensic specialists in the country. To address this challenge, advancements in technology can enhance the effectiveness of forensic specialists. An expert system utilizing the forward chaining method has been developed to estimate the time interval since death. This system aims to assist forensic professionals and the courts in determining the time of death more accurately. The estimation system was designed with an inference engine that incorporates 33 characteristics of corpses and categorizes them into 12 intervals of time since death. It produces output that is aligned with predefined rules. The system achieved 100% accuracy when tested with 30 expert-validated corpse cases.

1. Introduction

Every human being must experience a cycle of life that begins with birth and ends with death [1]. Every year, Indonesia experiences an increase in the death rate. According to estimated data from the United Nations Population Fund Indonesia, the death rate in 2019 was 1.6 million people and is expected to continue to increase until 2045, with a total of 3.2 million people [2]. Death itself is the cessation of the body's biological functions in maintaining life. There are two ways of death in forensic medicine, namely natural death caused by a history of illness or aging and unnatural death caused by something unexpected or sudden, such as suicide, accident, murder, etc. [3]. According to data taken from the Indonesian Central Statistics Agency, throughout 2022, there were 139,258 accident cases recorded, with 28,131 cases resulting in death [4]. There were also a total of 971 suicide cases from the National Criminal Information Center as of October 18, 2023 [5].

If an unnatural death is suspected, investigators or authorities can submit expert information or Visum et Repertum. This expert testimony for examining bodies or corpses is based on Article 133 of the Criminal Code (Criminal Procedure Code), which states that investigators for the purposes of justice have the authority to submit expert testimony to doctors, medical judges, and other experts as valid evidence [6]. Visum et repertum is evidence that can be used by investigators to explain to the judge the things found during the examination of living or dead biological objects, which contain the cause of death, time since death, characteristics of the body found,

and so on [7]. Time since death is an estimate of how long the body has been dead, which can be determined by a forensic specialist by looking at the characteristics of the body. Time since death is one of the most important aspects in criminal cases and can be determined from the condition of the corpse's bruising, stiffness of the corpse, temperature of the corpse, signs of decomposition, and other special characteristics [8].

According to data taken by the Indonesian Medical Council until 2023, there are only around 308 forensic specialist doctors in Indonesia spread across various regions in Indonesia [9]. Forensic specialist doctors, as one of the experts who have the task of making a Visum et Repertum, also have other duties such as examining injured victims, abuse, corpses, bodies that have been buried, and so on [10, 11]. According to data taken from the Women and Children Protection Information System (Simfoni PPA) throughout 2023, there were 26,161 cases of violence against women and 6,332 cases of violence against men [12].

In this era of very fast technological development, technology can be utilized to help work become easier and more effective [13]. Seeing the limited number of forensic doctors, few people interested in becoming forensic doctors [14], the large number of cases that need to be handled, and the death rate that continues to increase every year, a website-based expert system was designed and created to help forensic doctors, as well as other parties. The court will determine the estimated time interval since death, which is one of the important factors in Visum et Repertum. The system is also created in the form of a website to make it easier to access on any device as long as it is connected to the internet.

The design and creation of this system are expected to provide conclusions regarding the estimated time interval since death using the characteristics of the corpse as biological evidence obtained from the examination of the corpse by a doctor or authorized medical personnel. This hope is supported by a comparison of several methods from similar research streams in creating expert systems, namely backward chaining, forward chaining, and the certainty factor. In Patmawati et al.'s research using the certainty factor method, the expert system accuracy was 80% [15]. In Retno et al.'s research, the forward chaining method is superior to backward chaining, with user results conforming to 90%, while backward chaining has a percentage of 75% [16]. Another study by Sulindawatya et al. found an accuracy of 83.3% in expert system analysis using the forward chaining [17] method. Looking at the research flow and the accuracy of the three methods, it was decided that the forward chaining method would be used in the design and creation of the system. The application used from previous research is the research steps from data collection to report creation, rule creation with IF-THEN, and accuracy calculations. The forward chaining method is also used because it has a concept that is easy to understand and is in accordance with the concept of collecting research data on several facts, namely the characteristics of the corpse, to obtain results or conclusions, namely the estimated time interval since death.

This expert system was developed to assist forensic doctors in estimating the time since death by capturing and formalizing expert knowledge into a rule-based system. Unlike previous studies that focused solely on manual assessments or traditional biological indicators, this research combines validated forensic knowledge with a systematic computational approach. The system integrates information from authoritative sources such as the Textbook of Forensic Medicine and Medicolegal [18], as well as relevant studies by Taufik et al. on forensic roles in homicide cases [8] and by Shrestha et al. on biological methods for estimating postmortem intervals. These sources were reviewed and revalidated through expert interviews to ensure accuracy and relevance[19]. The key innovation lies in the use of the forward chaining method, enabling the system to infer conclusions from user-inputted facts in a logical, data-driven manner. By implementing the system as a web-based platform, it offers enhanced accessibility for forensic practitioners, especially in remote or resource-limited areas. The expert system aims not only to support forensic specialists in preparing Visum et Repertum reports but also to contribute to faster, more objective, and consistent decision-making in judicial processes. This work thus bridges the gap between expert knowledge and practical application through technology, offering both a conceptual and functional advancement in forensic support tools.

2. Theoretical

2.1 Expert System

One information technology that can be used to find answers to questions related to a complex problem is the expert system [20]. An expert system or expert system is an information system in a domain with problem-solving skills equivalent to an expert [21]. The knowledge and experience of an expert related to their field means that experts or experts can decide things better than non-experts in solving more complicated problems, which then can be applied in an expert system [22].

2.2 Forward Chaining

In an expert system, there is an inference engine which is the core or brain of the system. One approach that can be used to organize an inference engine with a knowledge base is forward chaining or forward tracking. The forward chaining method is a forward search that starts from facts to test a hypothesis of truth until concluding

[23]. Tracking facts in forward chaining ends with a conclusion matching the rules that have been created with the IF rules from IF-THEN to test a hypothesis. The system will match the facts with the rules that have been built, if there are facts that match the rules that have been made, the system will display conclusions according to the facts [24].

2.3 Time Since Death

Time since death is an important aspect in the Visum et Repertum to become strong evidence in determining the law against a suspect, which can be measured by looking at the changes in the body that occur after being declared dead (post-mortem). Several aspects used in determining time since death are by looking at bruising, stiffness, body temperature, decomposition, insect activity, and so on [18, 8, 19].

3. Research Methodology

This research followed several steps to develop an expert system. It started with data collection through literature reviews and interviews with experts to understand the topic and gather important information. Then, the system planning phase defined the goals and overall structure of the system. Next, the team identified the features and requirements the system needed. To show how the system would work, it created a flowchart and a data flow diagram (DFD). After that, it designed the user interface to make it easy to use. In the final step, build the inference engine using forward chaining, a method where the system starts from facts given by the user and uses rules to reach a conclusion.

3.1 Data Collection

3.1.1 Study of Literature

A search was carried out and further understanding was carried out regarding the matters that were the main discussion in the research. Especially regarding the time lapse since death and related characteristics of the corpse from books or journals that discuss similar topics. The data collected was taken from several journals and books, for example, 4-6 hours after death, the body temperature of the body had begun to cool (rectal temperature 34-35C), stiffness of the body occurred 2-3 hours after death, and continued for 8-12 hours [18, 8, 19].

3.1.2 Expert Interviews

After carrying out the literature study and data collection stages, an interview was conducted with a forensic specialist doctor to revalidate the time interval data since the death and the characteristics of the corpse that had been collected so that it could be processed and implemented into an expert system. It was found that there were 12 validated time intervals since the death and 33 characteristics of the corpse in question.

3.2 System Planning

3.2.1 Analysis of Feature Requirements

There are two user roles that can later access the system. Users as regular users will later be able to access the time interval test feature since death, view the saved test history table, and consult with a doctor or admin. Users as admins will later be able to manage data on the Website, namely create, read, update and delete data on time since death, characteristics of bodies, rules, users and messages.

3.2.2 Flowchart

Explanation of the flow of features on a website or expert system using a flowchart to explain how each feature works. In Fig. 1 Flowchart for the Expert System Website for Estimating Time Intervals since death, presents the overall flow of the Website.

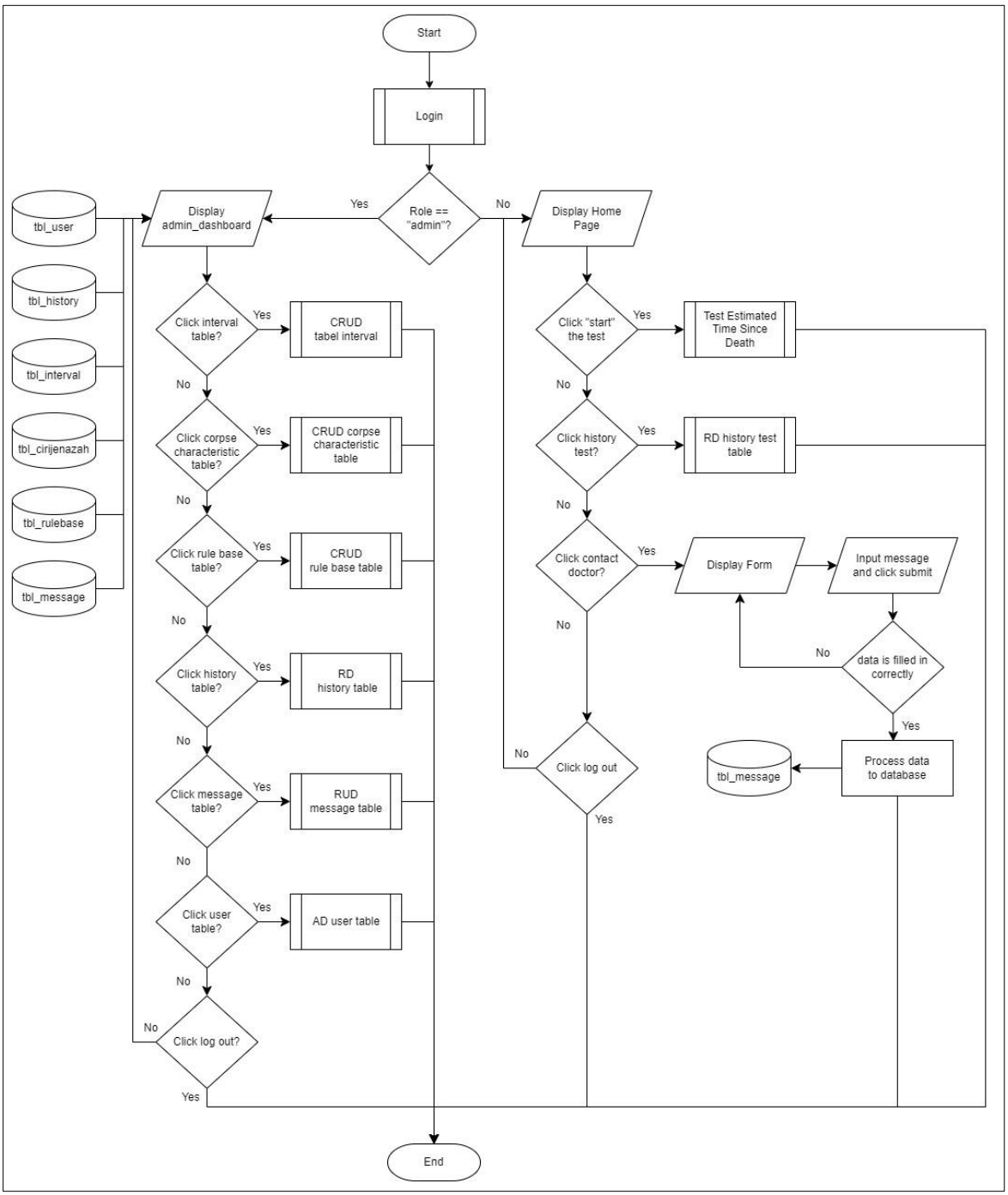

Fig. 1 *Flowchart for estimating time intervals since death*

3.2.3 Data Flow Diagram

Data flow diagrams or DFDs are used to explain further the flow of data on the features on the website later. The data flow diagram used to determine the flow of data entering and exiting each feature uses DFD level 1 in Fig 2.

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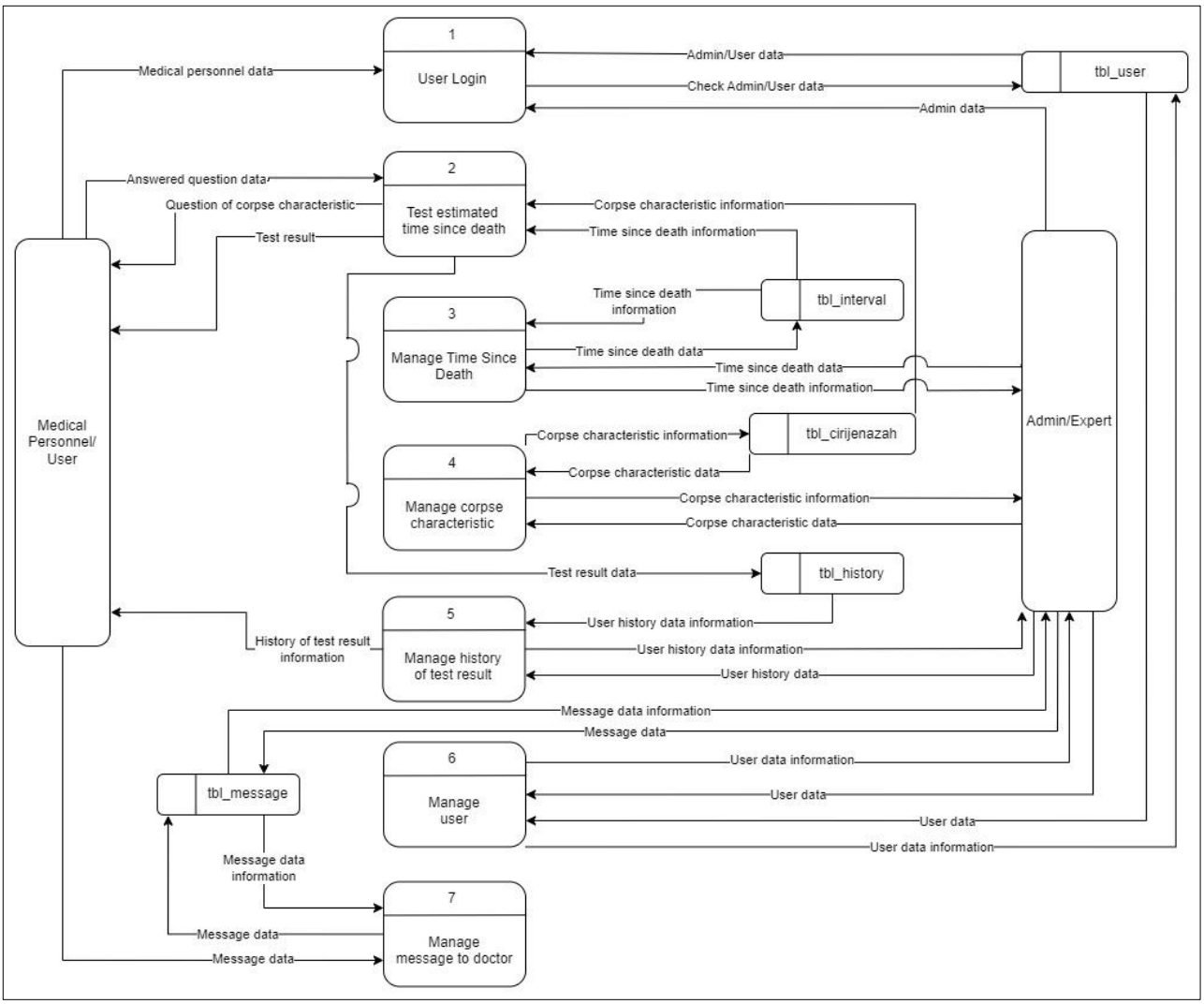

Fig. 2 *Data flow diagram level 1*

3.2.4 Interface Design

Interface design uses low-fidelity prototypes. The placement of text, images and others is designed on each page that will be created.

3.2.5 Interface Engine

Using data that has been collected and validated by experts, a rule was created using the forward chaining technique which uses the IF-THEN rule in the test feature for estimating the time interval since death. The application of this method is carried out using the following facts (Table 1) about the characteristics of the corpse.

Table 1 *List of the corpse characteristics*

Code	Characteristics of the Corpse
C1	Macular opacities (water-filled vesicles).
C2	No decrease in body temperature, still warm (37°C).
C3	Body temperature adjusts to the surrounding temperature.
C4	Body temperature begins to cool (rectal temperature 34-35°C), if the surrounding temperature is cold.
C5	The body temperature of the corpse is cold and is the same as room temperature (28-29°C).
C6	Bleeding spots (Tardieu spots).
C7	Bruises that are pressed the color can still disappear.

C8	Bruises are clear and when pressed do not disappear.
C9	Muscles are still completely relaxed (primary relaxation period).
C10	Stiffness in the small muscles of the face (around orbital, maxillaries and mandibular).
C11	Stiffness in large muscles.
C12	Perfect body rigidity throughout the body.
C13	Body stiffness in small muscles disappears.
C14	Body stiffness in large muscles disappears.
C15	Stiffness throughout the body disappears completely.
C16	Body position (pugilistic attitude), legs and arms in frog position, if straightened they will bend again due to decaying fluid in the joints.
C17	Clear cornea.
C18	The cornea of the eye begins to become cloudy.
C19	Cloudy cornea.
C20	The cornea becomes milky white and the flash on the cornea is no more.
C21	Decreased intraocular pressure (up to 4 mmHg).
C22	The skin on the lowest part of the body is permanently purplish red.
C23	Purplish-red skin color and persistent lividity.
C24	Deposition of fly eggs (blowfly eggs).
C25	Deposition of fly eggs (blowfly eggs) in hollow parts of the body such as the mouth, nose, etc.
C26	Deposition of fly eggs (blowfly eggs) which have hatched into larvae coming out of the hollow parts of the body.
C27	Starting to show signs of decay, especially in the lower right abdominal area, it looks greenish blue (the part of the large intestine because it is closest to the surface of the skin).
C28	Stomach bulging due to putrefactive gases.
C29	There is a smell of putrefaction, and putrefactive fluids coming out of the nose and mouth.
C30	The body of the corpse becomes increasingly bloated, the face swells, and the lips thicken.
C31	Visible image of blood vessels on the surface of the body (marble appearance).
C32	The body of the corpse experiences a process of total blistering and swelling (the effects of decomposition) throughout the body, the scrotum, tongue swells, and eyes bulge out.
C33	Some blisters and bubbles burst, skin becomes easily peeled.

Using previously obtained facts, a premise is created that is based on data and validation that has been carried out by experts and is also used to guide the conclusion. The premises used are as follows:

A. There are bleeding spots (Tardieu's spots) and bruises that are pressed can still disappear.

B. There are bruises that are pressed can still disappear.

C. There is a body temperature of the corpse that is cold and is the same as the room temperature (2829°C) and the bruises that are pressed can still disappear.

D. There is a body temperature of the corpse that is cold and is the same as the room temperature (2829°C).

E. There is a body temperature of the corpse that is cold and is the same as the room temperature (2829°C) and the skin color is reddish-purplish and the fluidity is stable.

F. Macular opacities (water-filled bubbles) were found, there was no decrease in body temperature, still warm (37°C), muscles were still completely relaxed (primary relaxation period), and the cornea was clear.

G. There was no decrease in body temperature, still warm (37C), stiffness in the small facial muscles (around the orbit, maxilla and mandible), and the cornea was clear.

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H. There was body temperature adjusting to the surrounding temperature, stiffness in the small facial muscles (around the orbit, maxilla and mandible), and the cornea began to become cloudy.

I. There was body temperature starting to cool (rectal temperature 34-35 C), if the surrounding temperature was cold, stiffness in the large muscles, and the cornea began to become cloudy.

J. There was stiffness in the large muscles, the cornea was cloudy, and the skin of the lowest part of the body was permanently reddish-purple.

K. Stiffness was found in the large muscles, cloudy corneas, decreased intraocular pressure (reaching 4 mmHg), and the skin of the lowest part of the body was permanently reddish-purple.

L. Bruises were clearly visible and did not disappear when pressed, perfect body stiffness throughout the body, the cornea became milky white and there was no more flash on the cornea, and the skin of the lowest part of the body was permanently reddish-purple.

M. Stiffness was found in the small muscles disappeared, there was deposition of blowfly eggs, and signs of decay began to appear, especially in the lower right abdomen area which appeared blue green (the large intestine because it is closest to the surface of the skin).

N. Stiffness was found in the large muscles disappeared, there was deposition of blowfly eggs in hollow parts of the body such as the mouth, nose, and others, the stomach was bloated due to putrefying gas and the smell of putrefaction, and putrefactive fluid came out of the nose and mouth.

O. Stiffness was found in the entire body disappeared completely, there was deposition of blowfly eggs that had hatched into larvae that came out of the body with holes, the smell of decay, and decay fluid coming out of the nose and mouth, the body of the corpse is increasingly bloated, the face is swollen, the lips are thickened, and the appearance of blood vessels on the surface of the body (marble appearance).

P. Found the body position starting from pugilistic attitude, the feet and hands are in the position of a frog, if straightened it will bend again because of the decay fluid in the joints, the deposition of fly eggs (blowfly eggs) has hatched into larvae coming out of the body part that has holes, some blisters and bubbles burst, the skin becomes easy to peel off, and the body of the corpse experiences a total blistering and swelling process (effects of decay) throughout the body, the scrotum, tongue are swollen, and the eyes protrude.

The premises that have been established are used to determine the conclusion. The conclusion uses the time intervals since death that have been obtained, which are then represented by codes similar to the previous facts. A list of time intervals since death can be seen in Table 2.

Table 2 *List of time intervals since death*

Code	Time Intervals Since Death
I1	0-30 Minutes
I2	30 Minutes - 1 Hour
I3	1 - 2 Hours
I4	2 - 3 Hours
I5	3 - 4 Hours
I6	5 - 6 Hours
I7	8 - 9 Hours
I8	9 - 12 Hours
I9	16 - 18 Hours
I10	20 - 24 Hours
I11	30 - 36 Hours
I12	40- 48 Hours

4. Result and Implementation

4.1 Decision Tree of Knowledge

Using 33 facts that have been obtained previously, premises are created based on data, and validation carried out by experts is also used to lead to the conclusion. The premises that have been created are used to determine the conclusion. The conclusion uses the twelve time intervals since death that have been obtained, which are then denoted by codes like the previous facts.

The overall visualization of the rules in the inference engine for estimating the time interval since death is depicted with a decision tree, as in Fig. 3, Time Interval Test Decision Tree Since Death. Rules or rulings are based on data that has been validated by experts. Using the premises that have been made previously, several rules are created as follows:

1. Rule 1: IF A ANDF THEN I1 IF there are bleeding spots (tardieu spots) and bruises that are pressed, the color can still disappear (A) AND there is macular opacity (water-filled bubbles), no decrease in body temperature, still warm (37°C), muscles are still completely limp (primary relaxation period), and the cornea is clear (F) THEN the time since death is 0-30 minutes (I1)
2. Rule 2: IF A ANDG THEN I2 IF there are bleeding spots (tardieu spots) and bruises that are pressed, the color can still disappear (A) AND there is no decrease in body temperature, still warm (37C), stiffness in the small muscles of the face (around the orbit, maxilla and mandible), and the cornea is clear (G) THEN the time since death is 30 minutes-1 hour (I2).
3. Rule 3: IF A ANDHTHENI3 IF there are bleeding spots (tardieu spots) and bruises that are pressed, the color can still disappear (A) AND there is a body temperature that adjusts to the surrounding temperature, stiffness in the small facial muscles (around the orbit, maxilla and mandible), and the cornea begins to cloud (H) THEN the time since death is 1-2 hours (I3).
4. Rule 4: IF B ANDHTHENI4 IF there are bruises that are pressed, the color can still disappear (B) AND there is a body temperature that adjusts to the surrounding temperature, stiffness in the small facial muscles (around the orbit, maxilla and mandible), and the cornea begins to cloud (H) THEN the time since death is 2-3 hours (I4).
5. Rule 5: IF B ANDITHENI5 IF bruises are found that when pressed, the color can still disappear (B) AND body temperature is found to be cooling (rectal temperature 34-35 C), if the surrounding temperature is cold, stiffness in the large muscles, and the cornea of the eye is starting to become cloudy (I) THEN time since death is 3-4 hours (I5).
6. Rule 6: IF C ANDJTHENI6 IF body temperature is found to be cold and is the same as room temperature (28-29°C) and bruises that are pressed, the color can still disappear (C) AND stiffness in the large muscles, the cornea of the eye is cloudy, and the skin of the lowest part of the body is permanently reddish-purple (J) THEN time since death is 5-6 hours (I6).
7. Rule 7: IF C ANDKTHENI7 IF the body temperature of the corpse is cold and is the same as room temperature (28-29°C) and bruises can still disappear when pressed (C) AND (K) stiffness is found in large muscles, cloudy corneas, decreased intraocular pressure (reaching 4 mmHg), and the skin of the lowest part of the body is permanently reddish-purple THEN the time since death is 8-9 hours (I7).
8. Rule 8: IF D ANDLTHENI8 IF the body temperature of the corpse is cold and is the same as room temperature (28-29°C) (D) AND bruises are clearly found and do not disappear when pressed, perfect body stiffness throughout the body, the cornea becomes milky white and there is no more flash on the cornea, and the skin of the lowest part of the body is permanently reddish-purple (L) THEN the time since death is 9-12 hours (I8).
9. Rule 9: IF E ANDMTHENI9 IF the body temperature of the corpse is found to be cold and is the same as room temperature (28-29°C) and the skin color is reddish-purple and the lividity remains (E) AND the stiffness of the body in the small muscles disappears, there is deposition of fly eggs (blowfly eggs), and signs of decomposition begin to appear, especially in the lower right abdomen area which appears blue-green (the part of the large intestine because it is closest to the surface of the skin) (M) THEN the time since death is 16-18 hours (I9).
10. Rule 10: IF E ANDNTHENI10 IF the body temperature of the corpse is cold and is the same as room temperature (28-29°C) and the skin color is reddish-purple and the lividity remains (E) AND the stiffness of the body in the large muscles disappears, there is deposition of blowfly eggs in the body parts that have holes such as the mouth, nose, and others, the stomach is bloated due to putrefying gas and there is a smell of

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putrefaction, and putrefying fluid comes out of the nose and mouth (N) THEN the time since death is 20-24 hours (I10).

11. Rule 11: IF E ANDOTHENI11 IF the body temperature of the corpse is cold and is the same as room temperature (28-29°C) and the skin color is reddish-purple and the lividity remains (E) AND the stiffness throughout the body has disappeared completely, the deposition of blowfly eggs has hatched into larvae coming out of the body parts that have holes, there is a smell of decay, and putrefying fluid comes out of the nose and mouth, the body of the corpse is increasingly bloated, the face is swollen, the lips are thickened, and the appearance of blood vessels on the surface of the body (marble appearance) (O) THEN the time since death is 30-36 hours (I11).
12. Rule 12: IF D ANDPTHENI12 IF the body temperature of the corpse is cold and is the same as room temperature (28-29°C) (D) AND The body position is found to be pugilistic attitude, the legs and hands are in a frog position, if straightened they will bend again due to putrefaction fluid in the joints, the presence of fly egg deposits (blowfly eggs) have hatched into larvae coming out of the body parts that have holes, some blisters and bubbles burst, the skin becomes easy to peel off, and the corpse experiences a total blistering and swelling process (effects of putrefaction) throughout the body, the scrotum, tongue are swollen, and the eyes protrude (P) THEN the time since death is 40-48 hours (I12).

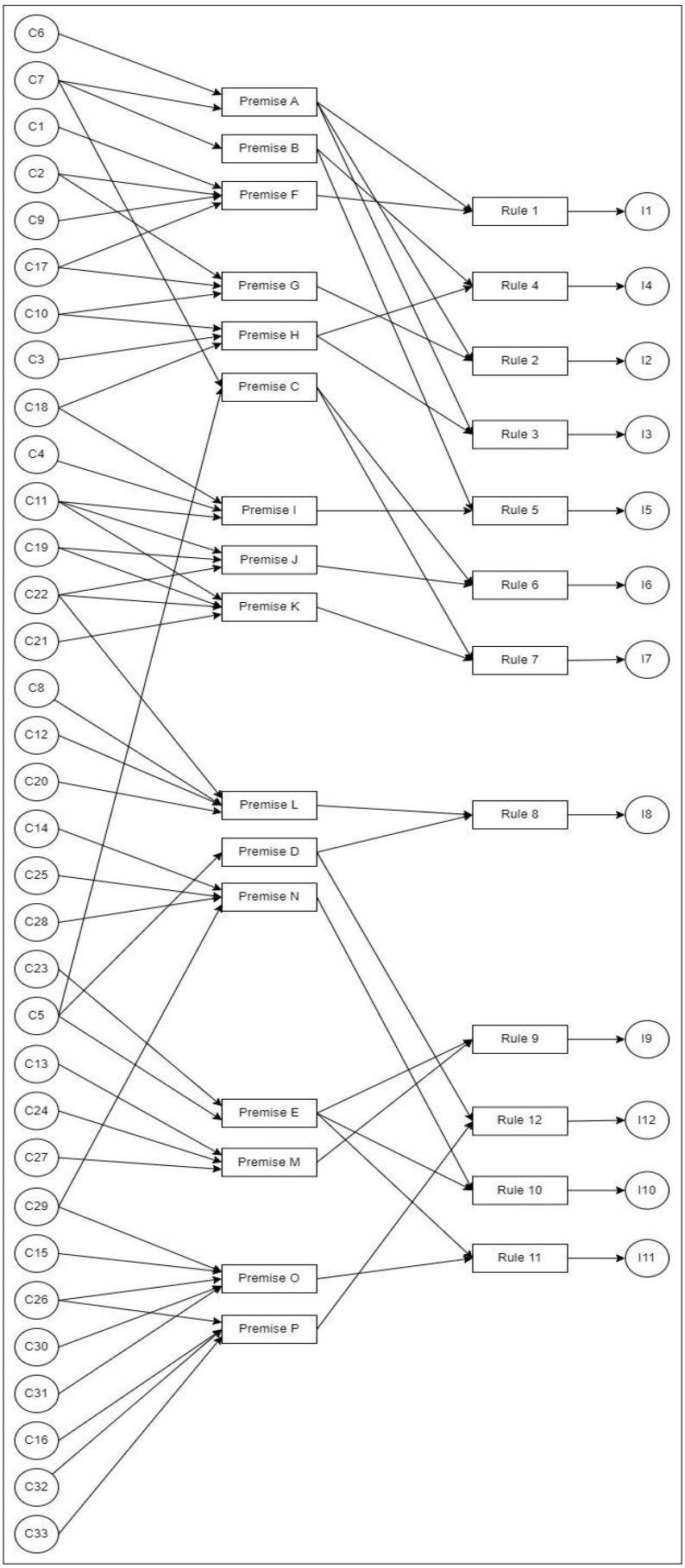

Fig. 3 *Decision tree estimation of time interval since death*

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4.2 Website Implementation

The test results page will be displayed after the user has answered all the questions on the questions page. The corpse data that the user has previously entered is displayed, the questions and answers that the user answered on the question page, the results of the estimated time interval since death that have been executed by the system.

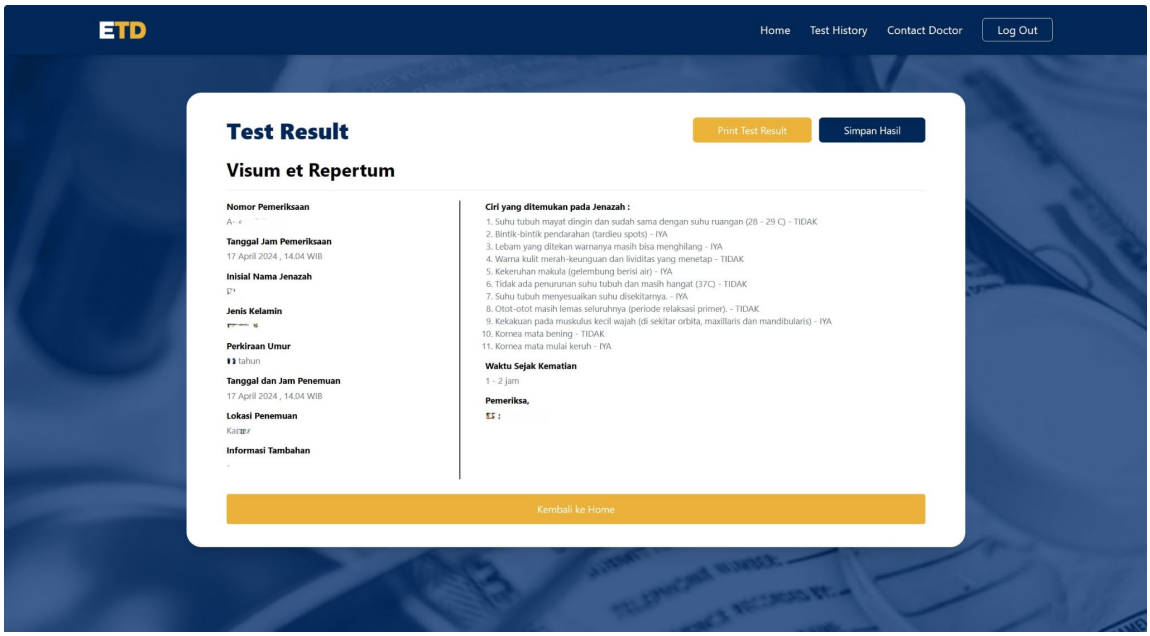

Fig. 4 *Test result page*

Most of the tables on the admin page will be like tables of corpse characteristics, such as Fig. 5, admin page characteristics of corpses. There is a list of table data, an add data button to add new data to the database, and an export CSV button to convert the data to CSV. The edit data button displays the data settings modal, and finally, the delete button to delete data in the database.

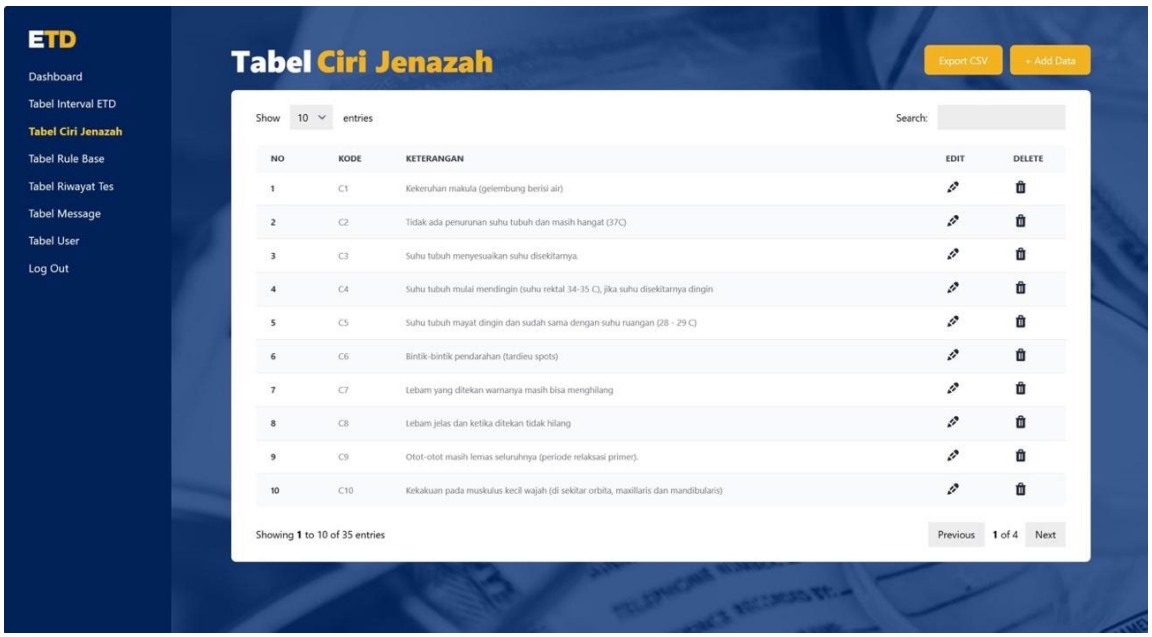

Fig. 5 *Admin page characteristics of bodies*

4.3 Testing of Accuracy

After implementing the entire system, testing is carried out on each rule that has been created by inputting or entering answers according to the twelve rules. The overall test results of the twelve rules were found to be in accordance with the design. Accuracy testing uses 30 real cases of corpses whose biographical data cannot be identified as having died and have been approved by experts as cases that can be used to test system accuracy. The characteristics of the bodies entered are carried out by experts into the system. Then, after the system displays the test results, the expert will analyze whether the case being studied matches the time since death results displayed by the system. If the system display and expert analysis are the same, it can be concluded that the conclusions are appropriate. The calculation of the accuracy percentage is as follows.

Table 3 *System accuracy testing table*

Characteristics of corpses with the answer "Yes"	System Test Results	Expert Analysis Results	Conclusions
C6, C7, C1, C2, C9, C17	I1	I1	Pass
C5, C23, C15, C26, C29, C30, C31	I11	I11	Pass
C6, C7, C1, C2, C9, C17	I1	I1	Pass
C6, C7, C2, C10, C17	I2	I2	Pass
C6, C7, C1, C2, C9, C17	I1	I1	Pass
C5, C8, C12, C20, C22	I8	I8	Pass
C7, C3, C10, C18	I4	I4	Pass
C6, C7, C2, C10, C17	I2	I2	Pass
C5, C23, C14, C25, C28, C29	I10	I10	Pass
C7, C4, C11, C18	I5	I5	Pass
C5, C7, C11, C19, C22	I7	I7	Pass
C5, C16, C26, C32, C33	I12	I12	Pass
C6, C7, C1, C2, C9, C17	I1	I1	Pass
C6, C7, C2, C10, C17	I2	I2	Pass
C7, C4, C11, C18	I5	I5	Pass
C6, C7, C1, C2, C9, C17	I1	I1	Pass
C6, C7, C1, C2, C9, C17	I1	I1	Pass
C7, C3, C10, C18	I4	I4	Pass
C5, C16, C26, C32, C33	I12	I12	Pass
C6, C7, C3, C10, C18	I3	I3	Pass
C6, C7, C1, C2, C9, C17	I1	I1	Pass
C7, C4, C11, C18	I5	I5	Pass
C6, C7, C1, C2, C9, C17	I1	I1	Pass
C6, C7, C3, C10, C18	I3	I3	Pass
C5, C23, C13, C24, C27	I9	I9	Pass
C5, C7, C11, C19, C21, C22	I6	I6	Pass
C6, C7, C2, C10, C17	I2	I2	Pass
C5, C16, C26, C32, C33	I12	I12	Pass
C7, C4, C11, C18	I5	I5	Pass
C5, C16, C26, C32, C33	I12	I12	Pass

The accuracy percentage is found by dividing the total number of appropriate conclusions, which is 30, by the total number of cases tested, which is 30. The results are multiplied by the total percentage of 100 percent so that the system accuracy percentage is 100 percent. Looking at the overall results of the accuracy testing and the percentage results, the expert also believes that the system is accurate in determining the estimated time interval since death.

The entire page and its features have been tested using black box testing a minimum of three times, then the errors found have also been successfully corrected so that the overall test results are in accordance as a whole and run according to the plans that have been made previously.

5. Conclusion

Based on the research that has been carried out from data collection and system design until complete implementation, several things can be concluded as follows.

1. The expert system website for estimating the time interval since death was successfully implemented using the forward chaining method and succeeded in providing output by 12 rules that had been created from 33 characteristics of corpses that had been collected and validated by experts, other related features were also successfully implemented according to the design that had been made.

2. Using 30 real cases that have been approved by experts, the expert system accuracy is 100%, so it can be concluded that the expert system for estimating the time interval since death can provide accurate results and is expected to help forensic specialists doctors, especially the judiciary, to determine the time since death at the initial examination of the body.

For future research, this limitation may hinder the system's ability to handle more varied or unexpected cases. Firstly, it is recommended to explore more advanced or adaptive decision-making methods, such as machine learning models (e.g., decision trees, neural networks, or reinforcement learning), to enhance the system's depth and flexibility in handling complex scenarios. Secondly, the current system's scope is limited to estimating the time of death within a 48-hour range, restricting its applicability to cases with longer intervals. To overcome this limitation, consider expanding the knowledge base of the expert system by incorporating Bayesian inference or data-driven temporal modeling techniques, enabling accurate estimations beyond the 48-hour range and increasing its utility across diverse

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *D. Noveriyanti;* ***data collection:*** *D. Noveriyanti, E.E. Surbakti;* ***analysis and interpretation of results****: D. Noveriyanti;* ***draft manuscript preparation:*** *E.E. Surbakti, R. Winantyo. All authors reviewed the results and approved the final version of the manuscript.*

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