Expert System for Diagnosing Gourami Fish Diseases Using the Certainty Factor Approach

Hindayati Mustafidah[1*], Ilham Gunadi[1], Cahyono Purbomartono[2], Suwarsito[2], Eri Zuliarso[3]

[1]*Informatics Engineering, Universitas Muhammadiyah Purwokerto, Indonesia*
[2]*Aquaculture, Universitas Muhammadiyah Purwokerto, Indonesia*
[3]*Information Technology, Universitas STIKUBANK, Indonesia*

*corr-author: h.mustafidah@ump.ac.id

Abstract - Gourami is an economically significant fish in the aquaculture sector due to its high market demand and relatively stable price. However, it is also challenging to cultivate, with disease outbreaks being one of the primary difficulties. Early diagnosis of gourami fish diseases requires expertise from fish health specialists, who are often difficult to find due to their limited availability. With advancements in artificial intelligence-based technology, this study developed an expert system to diagnose gourami fish diseases based on observed symptoms. The system employs the Certainty Factor (CF) approach to estimate the likelihood of a particular disease affecting the fish. The Certainty Factor approach utilizes a knowledge base derived from expert knowledge to address uncertainty in diagnosis. The certainty factor weights are determined based on confidence levels from both experts and users to generate an accurate diagnosis. This expert system was developed using data from 20 types of gourami fish diseases and 38 associated symptoms. The system successfully identified diseases with a certain level of confidence and provided appropriate treatment recommendations based on the confidence level obtained. By implementing this expert system, the risk of disease outbreaks can be minimized, thereby improving efficiency and productivity in gourami fish farming while helping maintain fish health and reducing economic losses caused by disease.

Keywords: certainty factor; disease; expert system; gourami; symptoms.

I. INTRODUCTION

The giant gourami (*Osphronemus gourami*) is a commercially valuable species in aquaculture, especially in freshwater fish farming. Its consistently high demand and stable market price make it one of the 15 priority fish commodities aimed at boosting production and farmer income [1]. According to Indonesia's Ministry of Marine Affairs and Fisheries (KKP), the country's gourami production declined by 2.37% in 2021, decreasing from 180,388.76 tons in the previous year to 176,113.78 tons. However, farming gourami presents considerable challenges due to various risks, particularly frequent disease outbreaks, which lead to high mortality rates and reduced fish quality, resulting in economic losses [2]. Several factors influence fish health, including water quality, feeding practices, and even genetic traits.

Each type of disease affecting gourami requires a specific treatment and management approach. The wide range of diseases attacking gourami complicates the detection process, as some share similar symptoms [3]. This makes it difficult for fish farmers to determine the appropriate control measures, highlighting the need for fisheries experts who can accurately diagnose diseases and provide effective solutions. However, in many areas, such experts are scarce, and hiring a specialist or consultant can be costly. As a result, most fish farmers rely solely on their own experience to manage fish diseases [4] [5].

There are several common types of diseases that affect gourami, including parasitic, bacterial, viral, and fungal infections [6]. Gourami suffering from parasitic diseases typically exhibit symptoms such as body wounds, white spots on the skin and fins, and decreased appetite. Bacterial infections, often caused by *Aeromonas*, *Pseudomonas*, and *Vibrio* species, can lead to body wounds, gill swelling, dull body coloration, and reduced appetite. Viral infections in gourami commonly present with symptoms such as body swelling, dull coloration, and appetite loss. In contrast, fungal infections are characterized by the presence of white filaments on the skin and fins, along with decreased appetite.

Expert systems, a product of rapid advancements in computer technology and Artificial Intelligence (AI) [7] [8], serve as a valuable alternative for fish farmers in diagnosing fish diseases. These systems are designed to

replicate the problem-solving abilities of experts by integrating expert knowledge into a computer-based framework. An expert system operates by analyzing facts or symptoms through a rule-based knowledge base [9]. The application of expert systems in fisheries has been explored for over two decades. Research by [10], [11], and [12] focused on developing expert systems for diagnosing fish diseases and determining appropriate treatments. Additionally, [13] developed an expert system for selecting suitable fish species based on water quality.

One of the weighting methods for symptoms in expert systems is the **Certainty Factor (CF) method**. CF incorporates confidence values obtained from experts to handle uncertainty [14], [14], [15], alongside confidence values from users. Studies have shown that CF provides higher accuracy compared to other methods [16], [17], [18]. Previous research on CF implementation includes [19], who applied CF for early detection of tuberculosis, and [20], who utilized CF for identifying heart disorders.

Given the accuracy of the Certainty Factor (CF) method in diagnosing diseases, as previously mentioned, this study develops an expert system using the CF method with forward chaining to diagnose gourami diseases. This research builds upon the study conducted by [5].

II. METHOD

Fig. 1 illustrates the stages involved in developing an expert system using the Certainty Factor (CF) method for diagnosing gourami diseases.

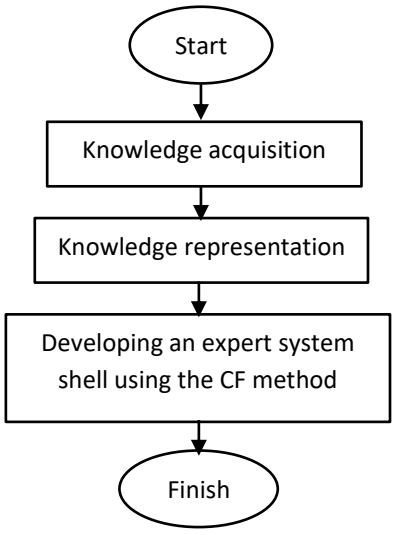

Fig. 1 Research stages

1) Knowledge Acquisition: The knowledge incorporated into the expert system is gathered from books and journal articles related to gourami diseases and their symptoms. Additionally, expert interviews are conducted to determine the CFexpert values for diagnosing diseases. The acquired knowledge is then stored in the knowledge base.

2) Knowledge Representation: The knowledge stored in the knowledge base is represented using IF-THEN rules, which include facts or symptoms along with the corresponding gourami disease types.

3) Expert System Shell Development: The development of the expert system shell involves creating and refining the framework used to build the expert system. This shell serves as a structural foundation that facilitates the integration of expert knowledge and the formulation of rules for inference and problem-solving at a specific confidence level. The confidence level is determined using the **Certainty Factor (CF) method**. The expert system shell is developed using the **Kotlin programming language**, tailored for the **Android platform**, and implemented in **Android Studio**.

The **Certainty Factor (CF) method** serves as the core problem-solving approach in the expert system developed in this study, utilizing the (1) and (2) [21]:

$$CF = CFuser * CFexpert \quad (1)$$

$$CFcombine = CF_1 + CF_2(1 - CF_1) \quad (2)$$

CFuser is the confidence value assigned by the user to a fact or hypothesis.
CFexpert is the confidence value assigned by the expert based on predefined knowledge or established rules.
CF_1 is the **certainty factor** value from the first rule.
CF_2 is the **certainty factor** value from the second rule.

This method helps quantify uncertainty by combining expert and user confidence values to improve the accuracy of disease diagnosis in gourami fish.

CFcombine represents the confidence level in a hypothesis after considering two contributing pieces of evidence. The calculation $(1 - CF_1)$ acts as an adjustment factor to ensure that CF_2 does not fully add to the total value but only contributes to the portion not yet accounted for by CF_1.

III. RESULTS AND DISCUSSION

A. Research Knowledge

The knowledge in this study consists of diseases, their symptoms, and expert-determined **Certainty Factor (CF)**parameter values.

1) Gourami Diseases and Symptoms: This study identifies 20 types of diseases affecting gourami fish, along with their causes and symptoms. The data were gathered from various scientific journals and books. Table I provides a comprehensive summary of these diseases, including their underlying causes and commonly observed symptoms. Besides, this study also identifies 38 symptoms associated with various gourami diseases. The symptoms were compiled from scientific literature and expert consultations. Table II lists these symptoms along with their corresponding codes.

2) CF Parameter Values: As previously mentioned, expert-derived CF values (CFexpert) are essential to ensure the system provides accurate disease diagnoses for gourami fish. The certainty factor (CF) values represent different levels of confidence assigned by experts when assessing the likelihood of a symptom contributing to a specific disease. These values help improve the accuracy of the expert system's diagnosis, as shown in Table III.

TABLE I
TYPES OF GOURAMI DISEASES, CAUSES, AND COMMON SYMPTOMS

Disease Code	Disease Name	Cause	Common Symptoms
P001	Saprolegniasis	Fungal (*Saprolegnia* sp.)	White cotton-like growth on the skin, fins, and gills
P002	Lernaeosis (*Lernaea* sp.)	Parasitic (*Lernaea* sp.)	Worm-like parasites attached to the body, inflammation
P003	Argulosis	Parasitic (*Argulus* sp.)	Scratching, red sores, irritation, lethargy
P004	White Spot Disease (*Bercak Putih*/ *Ichthyophthiriasis*)	Parasitic (*Ichthyophthirius multifiliis*)	White spots on the skin, rapid gill movement, loss of appetite
P005	Trichodiniasis	Parasitic (*Trichodina* sp.)	Mucus-covered skin, erratic swimming, difficulty breathing
P006	Motile *Aeromonas* Septicemia (MAS)	Bacterial (*Aeromonas* sp.)	Skin ulcers, bloated abdomen, hemorrhages
P007	Columnaris	Bacterial (*Flavobacterium columnare*)	Frayed fins, white patches on the skin and gills
P008	Fish Tuberculosis (TBC)	Bacterial (*Mycobacterium*sp.)	Weight loss, ulcerations, lethargy
P009	Dactylogyriasis	Parasitic (*Dactylogyrus* sp.)	Gill damage, excessive mucus, labored breathing
P010	Gyrodactyliasis	Parasitic (*Gyrodactylus* sp.)	Scraping against objects, frayed fins, irritation
P011	Myxosporiasis	Parasitic (*Myxosporea* sp.)	Cysts in muscles, deformities, weight loss
P012	Ergasilosis	Parasitic (*Ergasilus* sp.)	Gill damage, mucus buildup, respiratory distress
P013	Clinostonumiosis	Parasitic (*Clinostomum* sp.)	Visible cysts in muscles, reduced mobility
P014	Oodiniasis	Parasitic (*Oodinium* sp.)	Golden dust-like appearance on the skin, lethargy
P015	Edwardsielosis	Bacterial (*Edwardsiella* sp.)	Swollen eyes, skin ulcers, hemorrhages
P016	Vibriosis	Bacterial (*Vibrio* sp.)	Red sores, hemorrhages, lethargy
P017	Furunculosis	Bacterial (*Aeromonas salmonicida*)	Boil-like sores, skin necrosis, internal bleeding
P018	Streptococcosis	Bacterial (*Streptococcus* sp.)	Pop-eye, erratic swimming, swollen abdomen
P019	Branchiomycosis	Fungal (*Branchiomyces* sp.)	Gill rot, respiratory distress, suffocation
P020	Megalocytivirus Infection	Viral (*Megalocytivirus*)	Enlarged cells, organ failure, sudden death

TABLE II
SYMPTOMS OF GOURAMI FISH DISEASES STORED IN KNOWLEDGE BASE

Symptom Code	Symptom Description
G001	Presence of white or brownish-white fungal mycelia (*Terdapat miselia (kumpulan hifa) berwarna putih atau putih kecoklatan*)
G002	Fine, cotton-like filaments on the fish's body (*Terdapat benang-benang halus menyerupai kapas di bagian tubuh ikan*)
G003	Anchor worms firmly attached to the body, fins, gills, or eyes (*Terlihat cacing jangkar yang menempel kuat pada bagian badan, sirip, insang, dan mata ikan*)
G004	Hemorrhaging at wound sites (*Pendarahan pada luka*)
…	……
G038	Liver and digestive tract damage (*Kerusakan pada hati dan saluran pencernaan*)

TABLE III
CF PARAMETER VALUES

Confidence Level	CF Value
Not Confident (*Tidak Yakin*)	0.0
Don't Know (*Tidak Tahu*)	0.2
Slightly Confident (*Sedikit Yakin*)	0.4
Fairly Confident (*Cukup Yakin*)	0.6
Confident (*Yakin*)	0.8
Very Confident (*Sangat Yakin*)	1.0

B. Knowledge Representation

Based on the collected data on symptoms and diseases in gourami fish, the information is represented in the form of a decision table (Table IV) and inference rules (Table V). The decision table illustrates the relationship between symptoms and diseases, aiding in the formulation of rules and system validation. Meanwhile, the inference rules enable the expert system to perform reasoning and decision-making based on the structured knowledge representation.

Table V presents the inference rules used to diagnose specific diseases in gourami fish based on observed symptoms. Each rule follows an IF-THEN structure, where a combination of symptoms leads to the identification of a particular disease.

C. Expert System Shell

An expert system shell is a software framework designed for expert systems. It contains a knowledge base, which consists of the essential information needed to understand, formulate, and solve problems. This knowledge base is constructed from expert knowledge, which is then transformed into rules in the form of IF-THEN statements. These rules are utilized within the inference engine, where they are compared against facts stored in the database based on user input. When the IF (condition) part of a rule matches an input fact, the rule is executed, and the THEN (action) part is added to the database as a newly established fact. This process continues iteratively, as each newly added fact in the knowledge base can trigger additional rules within the inference engine.

D. Implementation Results of the Expert System Shell

The implementation of the developed expert system shell is illustrated in Fig. 2, which represents the main interface of the Android-based application. This main page includes key features such as disease diagnosis, a list of diseases and symptoms, diagnosis history, user guidance, and information about the developers. The application is designed in the Indonesian language.

The list of diseases included in the system is displayed on the page shown in Fig. 3. The disease list page contains a compilation of diseases that affect gourami fish. When a user selects a specific disease, the system navigates to the disease detail page (Fig. 4), which provides a description of the disease, its symptoms, and suggested treatments. Users can access this page by tapping the "Disease List" button on the main page.

TABLE IV
DECISION TABLE FOR SELECTED GOURAMI FISH DISEASES

Symptom Code	Disease Code					
	P001	P002	P003	P004	…..	P020
G001	✓				……	
G002	✓				……	
G003		✓			……	
…….	……	……	……	……	……	
G038						

TABLE V
RULES FOR DETERMINING DISEASE TYPES BASED ON SYMPTOMS

Rule Code	Rule
R001	IF white or brownish-white mycelium (clusters of hyphae) is present AND fine, cotton-like filaments appear on the fish's body THEN Saprolegniasis
R002	IF anchor worms are firmly attached to the body, fins, gills, and eyes AND bleeding occurs in the infected area (wounds) THEN Lernaeasis (Lernae sp.)
R003	IF the fish appears emaciated AND rubs its body against the pond walls or bottom AND exhibits bleeding (wounds) AND has visible parasites attached to its body AND is hyperactive THEN Argulosis
R004	IF appetite decreases (loss of appetite) AND the fish frequently rubs against the pond walls or bottom AND struggles to breathe (gasping) AND white spots appear on its body AND the fish swims sluggishly AND its body color appears pale THEN White Spot Disease
. . .	…
R020	IF appetite is lost or reduced AND the fish moves slowly AND its body color darkens AND skin is damaged AND the fish's body swells AND ulcers or sores appear THEN Megalocytivirus

Fig. 3 displays the "Disease List" page within the expert system application. This page provides users with a comprehensive list of fish diseases, including their names, descriptions, and associated symptoms. It serves as a reference to help users identify and understand various diseases affecting gourami fish. Instead, Fig. 4 presents the "Disease Detail" page within the expert system application. This page provides in-depth information about a specific disease, including its symptoms, causes, and recommended treatments. It serves as a valuable resource for users to better understand and manage diseases affecting gourami fish.

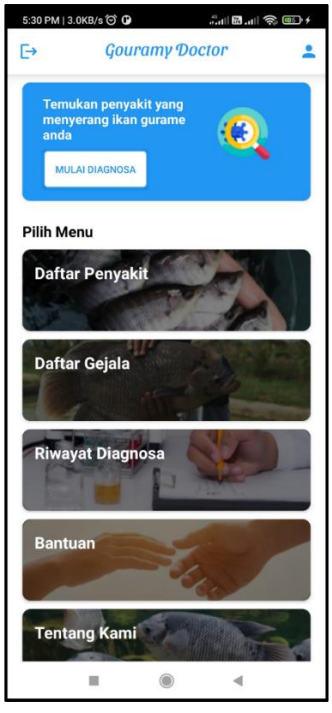

Fig. 2 Main page

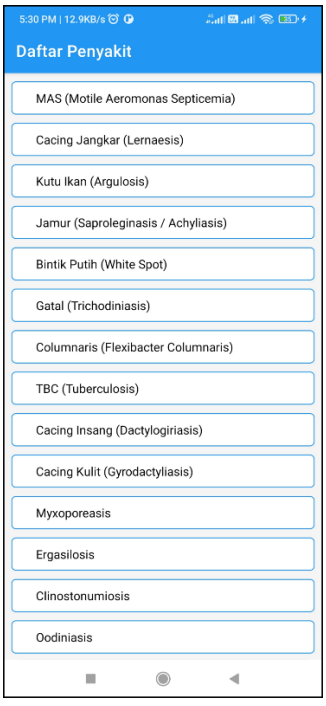

Fig. 3 Disease list page

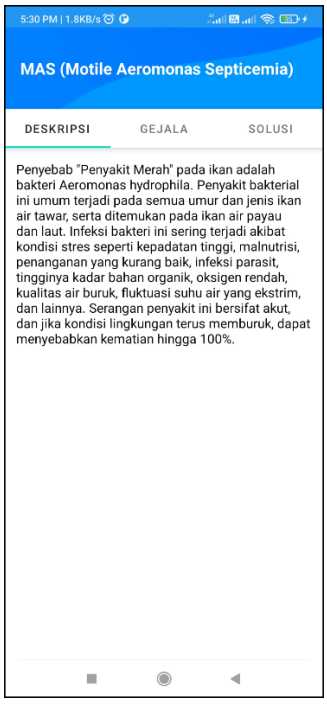

Fig. 4 Disease detail page

In addition to the disease list, the system also includes a symptom list page that provides information about the various symptoms that gourami fish may experience (Fig. 5). When a user selects a specific symptom, the system navigates to a symptom detail page, which may contain photos or videos (Fig. 6). These visual aids are intended to help users accurately identify the symptoms affecting their gourami fish.

The core functionality of an expert system lies in the interaction between the user and the system. Users seek solutions from the system regarding the issues they face. In this case, the user wants a diagnosis of the type of disease affecting farmed gourami fish based on observed symptoms. The system presents a list of potential symptoms for the user to select those that match their fish's condition. Based on the selected symptoms, the system diagnoses the disease affecting the gourami fish. The confidence level of the diagnosis is determined using the Certainty Factor (CF) method.

An example of the gourami disease diagnosis result is shown in Fig. 7. This diagnosis result page displays the detected disease name based on the chosen symptoms, the system's confidence level, the list of selected symptoms, a description of the disease, and recommendations for disease management.

Fig. 7 presents the diagnosis results for fish lice disease (Argulosis) with a confidence level of 94.70%. This confidence level is calculated based on the certainty values provided by the user (Table VI) and verified against the certainty values given by the expert (Table VII).

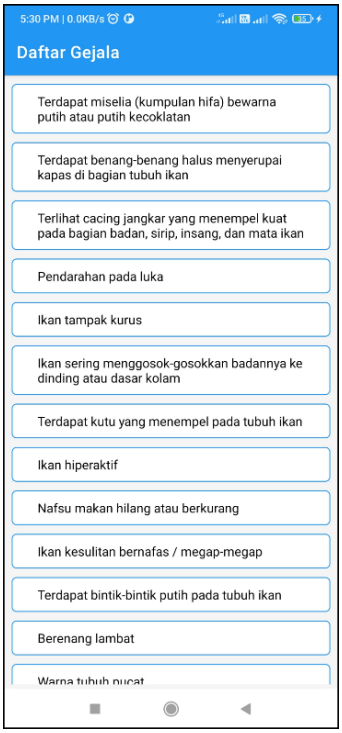

Fig. 5 Symptom list page

Fig. 6 Symptom detail page

Fig. 7 Diagnosis result page

TABLE VI
USER-SELECTED SYMPTOMS

No	Symptom Name	Description	CFuser
1	Fish appears thin (*Ikan tampak kurus*)	Fairly certain	0.6
2	Fish frequently rubs its body against the pond wall or bottom (*Ikan sering menggosokan badan ke dinding atau dasar kolam*)	Fairly certain	0.6
3	Bleeding on wounds (*Pendarahan pada luka*)	Certain	0.8
4	Presence of lice attached to the fish’s body (*Terdapat kutu yang menempel pada tubuh ikan*)	Certain	0.8
5	Fish is hyperactive (*Ikan hiperaktif*)	Slightly certain	0.4

TABLE VII
SYMPTOMS AND EXPERT CF VALUES

No	Symptom Name	CFexpert
1	Fish appears thin (*Ikan tampak kurus*)	0.4
2	Fish frequently rubs its body against the pond wall or bottom (*Ikan sering menggosokan badan ke dinding atau dasar kolam*)	0.6
3	Bleeding on wounds (*Pendarahan pada luka*)	0.8
4	Presence of lice attached to the fish's body (*Terdapat kutu yang menempel pada tubuh ikan*)	0.8
5	Fish is hyperactive (*Ikan hiperaktif*)	0.4

The CFuser value is obtained when the user selects disease symptoms and assigns a confidence level ranging from "Tidak" (Not at all) with a value of 0 to "Sangat Yakin" (Very Certain) with a value of 1. Meanwhile, the CFexpertvalue is determined by experts and stored in the database, using the same value range as CFuser, as shown in Table III.

A value of 0 (Not at all) indicates that a symptom does not appear and is not characteristic of a disease, whereas a value of 1 (Very Certain) signifies that a symptom frequently appears in a disease and strongly characterizes it.

For example, in Table VII, the symptom "Fish is hyperactive" has an expert CF value of 0.4, indicating that it appears occasionally in Argulosis cases. In contrast, the symptom "Presence of lice attached to the fish's body" has an expert CF value of 0.8, meaning it frequently appears and is strongly indicative of Argulosis. Once both CFuser and CFexpert values are determined, the certainty factor calculation is performed using (1) and (2). The **certainty factor (CF)** is calculated by progressively combining the CF values for each selected symptom.

Here is the step-by-step calculation:

1 **Fish appears thin**
$CF_1 = 0.6 * 0.4 = 0.24$
2 **Fish rubs its body against the wall or pond bottom**
$CF_2 = 0.6 * 0.6 = 0.36$
CFcombine1 = 0.24 + 0.36 (1-0.24) = 0.5136
3 **Bleeding wounds**
$CF_3 = 0.8 * 0.8 = 0.64$
Cfcombine2 = 0.5136 + 0.64 (1-0.5136) = 0.824896
4 **Presence of lice attached to the fish's body**
$CF_4 = 0.8 * 0.8 = 0.64$
Cfcombine3 = 0.824896 + 0.64 (1-0.824896) = 0.93696256
5 **Fish is hyperactive**
$CF_5 = 0.4 * 0.4 = 0.16$
Cfcombine4 = 0.93696256 + 0.16 (1-0.93696256) = 0.9470485504
6 **Final CF value**
CF = 0.9470485504 * 100% = **94.70485504%**

This result indicates that the system **diagnoses the disease Argulosis with a certainty of 94.70%** based on the symptoms provided by the user.

B. System Testing

The expert system developed was tested using the **black-box testing method** to ensure that the application functions correctly from a functional perspective. The results of the system testing are presented in Table VIII.

The test results indicate that the developed expert system can provide diagnostic outcomes that align with expectations based on user-inputted symptoms. All test scenarios demonstrate that the system delivers accurate results, both in detecting diseases and in correctly determining when no disease is found due to insufficient confidence levels. Thus, the system has successfully passed the functional testing phase and can be utilized as a tool to assist in diagnosing gourami fish diseases based on observed symptoms.

CONCLUSION

The Android-based expert system application has been successfully developed by implementing the Certainty Factor method to determine the confidence level of disease diagnosis in gourami fish. The diagnosis is provided based on the symptoms selected by the user, along with their confidence level, which is then combined with expert confidence levels for corresponding symptoms in supporting disease identification. Since there are several varieties of gourami fish, future research can further specify the system to identify diseases affecting specific gourami species. Additionally, this study can be expanded by integrating geospatial data features, such as aquaculture pond locations and climate data, to better understand the relationship between environmental conditions and disease occurrence in gourami fish. The use of geospatial data can also help identify regions prone to specific fish diseases.

TABLE VIII
SYSTEM TESTING RESULTS USING THE BLACK-BOX METHOD

No	User-Selected Symptom Scenario	Expected Result	System Output	Status
1	G001 : Fairly Certain G002 : Certain	Disease : Saproleginasis Confidence Level : 81.28%	Disease : Saproleginasis Confidence Level : 81.28%	Correct
2	G001 : Fairly Certain G002 : Slightly Certain G003 : Slightly Certain	No disease detected	No disease detected	Correct
3	G003 : Certain G004 : Certain	Disease : Lernaesis Confidence Level : 81.28%	Disease : Lernaesis Confidence Level : 81.28%	Correct
4	G010 : Fairly Certain G012 : Slightly Certain G035 : Slightly Certain G015 : Slightly Certain	Disease : Branchiomycosis Confidence Level : 75.14%	Disease : Branchiomycosis Confidence Level : 75.14%	Correct
5	G005 : Slightly Certain G009 : Fairly Certain G010 : Certain G011 : Certain G013 : Certain G020 : Fairly Certain	No disease detected	No disease detected	Correct

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to RISETMU for providing funding and support for this research through the *Hibah Riset Nasional Muhammadiyah* Batch VII Year 2024 under contract number 0258.665/I.3/D/2024. This support has been essential to the successful development of the expert system for diagnosing gourami fish diseases.

REFERENCES

[1] A. S. Ma'arif, *Cara sukses budidaya ikan gurami*. Penerbit Bio Genesis, 2017.

[2] A. Wantoro, H. Sulistiyani, Y. Yuniarthe, A. Setya Putra, A. Candra Widyawati, and N. Putra Wicaksono, 'Sistem Pakar Diagnosis Penyakit Kutu Ikan Gurami (Argunus Indicus) Menggunakan Metode Naive Bayes 1', 2022.

[3] M. Y. Nesi, Y. R. Kaesmetan, and M. O. Meo, 'Sistem Pakar Diagnosa Penyakit Ikan Gurame Dengan Menggunakan FIS Mamdani', *HOAQ (High Education of Organization Archive Quality): Jurnal Teknologi Informasi*, vol. 11, no. 2, pp. 73–80, 2020.

[4] P. Lestari, 'Sistem Pakar Diagnosa Penyakit Ikan Nila pada Dinas Perikanan Teluk Kuantan', *JURNAL PERENCANAAN, SAINS DAN TEKNOLOGI (JUPERSATEK)*, vol. 2, no. 1, pp. 144–150, 2019.

[5] H. N. Suhardjito, 'SISTEM PAKAR PENYAKIT IKAN GURAME PADA PEMBUDIDAYAAN MENGUNAKAN METODE FORWARD CHAINING', *JATI (Jurnal Mahasiswa Teknik Informatika)*, vol. 3, no. 1, pp. 123–128, 2019.

[6] S. Rahmaningsih, *Hama & Penyakit Ikan*. Yogyakarta: Deepublish, 2018.

[7] M. E. Auer, D. Guralnick, and I. Simonics, *Teaching and Learning in a Digital World: Proceedings of the 20th International Conference on Interactive Collaborative Learning – Volume 2*. Switzerland: Springer International Publishing, 2018.

[8] A. D. Syafaati, 'Revolusi Industri dari Generasi 1.0 hingga 4.0', *https://www.academia.edu/37491240/REVOLUSI_INDUSTRI_DARI_GENERASI_1.0_HINGGA_4.0*. Accessed: Feb. 19, 2019. [Online].

[9] B. H. Hayadi, *Sistem pakar*. Yogyakarta: Deepublish, 2018.

[10] H. Mustafidah and S. Suwarsito, 'Penyusunan Formula Pakan dengan Metode Komputasi', Purwokerto, 2004.

[11] H. Mustafidah and S. Suwarsito, 'Sistem Pakar Sebagai Penasehat Cara Mendiagnosa Penyakit Ikan', *SAINS AKUATIK*, vol. 11, no. 2, pp. 209 – 218, 2008.

[12] S. Suwarsito and H. Mustafidah, 'Diagnosa Penyakit Ikan Menggunakan Sistem Pakar (Diagnosis of Fish Diseases Using Expert Systems)', *JUITA (Jurnal Informatika)*, vol. I, no. 4, pp. 123 – 131, 2011.

[13] S. Suwarsito and H. Mustafidah, 'Determination of Appropriate Fish Culture Method Based on Water Quality Using Expert System', *Adv Sci Lett*, vol. 24, no. 12, pp. 9178–9181, 2018.

[14] P. S. Ramadhan and U. F. S. S. Pane, 'Analisis Perbandingan Metode (Certainty Factor, Dempster Shafer dan Teorema Bayes) untuk Mendiagnosa Penyakit Inflamasi Dermatitis Imun pada Anak', *Jurnal SAINTIKOM (Jurnal Sains Manajemen Informatika dan Komputer)*, vol. 17, no. 2, pp. 151–157, 2018.

[15] U. Khaira, B. Aulia, and D. Musfiroh, 'Sistem Pakar Rekomendasi Tanaman Herbal Berdasarkan Faktor Lingkungan Menggunakan Metode Certainty Factor', *SATIN-Sains dan Teknologi Informasi*, vol. 8, no. 2, pp. 101–111, 2022.

[16] S. R. Puji and F. S. P. Usti, 'Analisis Perbandingan Metode (Certainty Factor, Dempster Shafer dan Teorema Bayes) untuk Mendiagnosa Penyakit Inflamasi Dermatitis Imun pada Anak', *Jurnal Sains dan Komputer (SAINTIKOM)*, vol. 17, no. 2, pp. 151–157, 2018.

[17] R. Ginting, M. Zarlis, and R. Rosnelly, 'Analisis Perbandingan Metode Certainty Factor dan Teorema Bayes untuk Mendiagnosa Penyakit Autis Pada Anak', *JURNAL MEDIA INFORMATIKA BUDIDARMA*, vol. 5, no. 2, pp. 583–589, Apr. 2021, doi: 10.30865/mib.v5i2.2930.

[18] R. A. D. Yunas, A. Triayudi, and I. D. Sholihati, 'Implementasi Sistem Pakar untuk Mendeteksi Virus Covid-19 dengan Perbandingan Metode Naïve Bayes dan Certainty Factor', *Jurnal Teknologi Informasi dan Komunikasi)*, vol. 5, no. 3, pp. 338–345, 2021, doi: 10.35870/jti.

[19] N. D. Wirasbawa, C. T. P. Widjaja, C. I. Wenji, and S. Hansun, 'Expert API for Early Detection of TB Disease with Forward Chaining and Certainty Factor Algorithms', *Informatica (Slovenia)*, vol. 46, no. 6, pp. 117–124, 2022, doi: 10.31449/inf.v46i6.3947.

[20] Sumiati, H. Saragih, T. K. A. Rahman, and A. Triayudi, 'Expert system for heart disease based on electrocardiogram data using certainty factor with multiple rule', *IAES International Journal of Artificial Intelligence*, vol. 10, no. 1, pp. 43–50, 2021, doi: 10.11591/ijai.v10.i1.pp43-50.

[21] D. Heckerman, 'Probabilistic interpretations for MYCIN's certainty factors', *arXiv preprint arXiv:1304.3419*, 2013.