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EXPERT SYSTEM FOR DIAGNOSING DISEASES IN CATTLE USING DEMPSTER-SHAFER METHOD (Case Study: Aek Gareder Farm)

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ABSTRACT
Cattle are a popular livestock species in Indonesia. They are typically used as a source of protein, such as milk and meat, but some farmers also use them for fur and leather production. The number of cattle has been increasing dramatically each year. To obtain good-quality cattle, cattle development must consider legal regulations, proper nutrition, and care for the health of the livestock. One challenge in maintaining cattle quality is the presence of diseases that affect cattle. The lack of knowledge among farmers about cattle diseases is a barrier for them. In this research, an expert system using the Dempster-Shafer method was developed to diagnose diseases in cattle at the Aek Gareder farm. The objectives of this research are to apply the Dempster-Shafer method, build an expert system that facilitates cattle disease diagnosis for farmers, and evaluate the validity and effectiveness of the expert system. The research results show that the accuracy level of the expert system diagnosis reaches 95%. With the presence of this expert system, it is expected to enhance farmers' knowledge, facilitate cattle disease diagnosis, and contribute positively to overall cattle maintenance.

Keywords: Expert System, Dempster-Shafer, Cattle, Cattle Disease.

INTRODUCTION
Cattle farming is one of the most prevalent and developed forms of livestock worldwide, especially in northern regions of the world. Cattle belong to the Bovidae family and the genus Bos. Cattle hold high economic value, particularly in countries with rapid economic growth. Cattle farming also serves as a crucial source of foreign exchange for a country's economy [1]. Cattle are a popular livestock species in Indonesia, primarily used as a source of protein through milk and meat, although some farmers also utilize them for fur and leather production [2].

According to data from the Indonesian Central Statistics Agency (BPS), in 2019, there were 565,001 dairy cattle and 16,930,025 beef cattle. In 2020, these numbers increased to 568,000 dairy cattle and 17,440,393 beef cattle. In 2021, there were 578,579 dairy cattle and 18,053,710 beef cattle. This indicates a significant annual increase in cattle numbers. To ensure good cattle quality, cattle development must comply with legal regulations, proper nutrition, and healthcare practices [3].

In maintaining cattle quality and care, one significant challenge is the presence of diseases that affect cattle. The lack of knowledge among farmers about cattle diseases poses a barrier. The cost of treating cattle diseases is also a burden for farmers as it can reduce their profits. Veterinary expenses can be particularly high, especially when the animal needs to be treated by a veterinarian, and additional medications must be purchased [4]. Additionally, one issue faced by cattle farmers is difficulty accessing quality veterinary services, especially when they are located far from animal health facilities, leading to additional transportation and accommodation expenses during treatment [5].

With advances in science and information technology, particularly in the field of artificial intelligence, various aspects of daily life have been improved. One such application is expert systems, which mimic the problem-solving abilities of experts or specialists, resulting in cost and time efficiency. This is particularly significant given the high cost of cattle healthcare today.

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Expert systems serve as intelligent consultants in specific domains, allowing users to consult with a computer as if they were speaking to an expert. To be efficient, computers must utilize heuristic knowledge presented in an easily understandable format, differentiating between data, knowledge, and control structures. Several methods are used in expert systems to calculate inconsistency, such as Bayesian Networks, Dempster-Shafer, and Certainty Factor. Some prior research has compared the implementation of the Dempster-Shafer method with the Certainty Factor method, with results indicating that the Dempster-Shafer method has a higher accuracy rate than the Certainty Factor method. This is also evident in research comparing the Dempster-Shafer method with Bayesian Network methods. Using the Dempster-Shafer Algorithm, information is combined based on belief functions and plausible reasoning, making it suitable for implementing expert systems for diagnosing diseases in cattle [3].

To help farmers understand the diseases affecting their cattle, the proposed solution is to develop an expert system using the Dempster-Shafer method. Some existing studies using this method include research on cattle diseases [6], diseases in goats and cattle (Aan & Diana, 2018), autism in children [7], diseases caused by the Treponema Pallidum bacterium [8] and others.

Based on an interview with Mr. Ali Sahab, the Chairman of Aek Gareder Farm, cattle farmers still struggle to understand cattle diseases, resulting in delayed growth and reproduction, leading to losses for farmers. The economic condition of the farmers further worsens the health of the cattle, which ultimately affects the farmers' income. In Aek Gareder Farm in Padang Sidempuan Tenggara, there is currently no application system to assist cattle farmers in diagnosing cattle diseases. To address this issue, the author has designed an expert system to diagnose diseases in cattle.

METHODS

The Dempster-Shafer method is employed in this research to diagnose diseases in cattle at Aek Gareder Farm. Figure 1 shows a flowchart depicting the steps of the method utilized in the research process for the disease diagnosis system in cattle. The diagram illustrates the stages that must be followed in the research process leading to the creation of the final system.

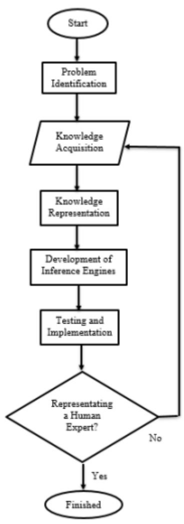

Figure 1. Research Flowchart

Problem Identification

The initial step in the research is to identify the issues related to the diagnosis of diseases in cattle. Therefore, this expert system is limited to handling the diagnosis of diseases in these animals.

Knowledge Acquisition

The source of knowledge for designing this expert system is obtained through observation and interviews. Observation was conducted as preliminary research to identify issues related to diagnosing diseases in cattle at Aek Gareder Farm. From the observation results, the problem of farmers' lack of knowledge about the symptoms of diseases in cattle was identified and formulated in this study. Accurate and reliable data for this research was obtained through interviews with relevant parties, thus obtaining valid disease data and initial treatment solutions for symptoms of diseases in cattle.

Knowledge Representation

After obtaining a suitable database, the next step is knowledge representation. The information collected in this database is transformed into several rules constructed using logical operators in the form of IF-THEN rules that indicate relationships between the information received.

Development of Inference Engines

The development of the inference engine used the Dempster-Shafer technique. In this approach, the foundation is based on the rules created in the knowledge representation section. The process of the Dempster Shafer method can be seen in Figure 2.

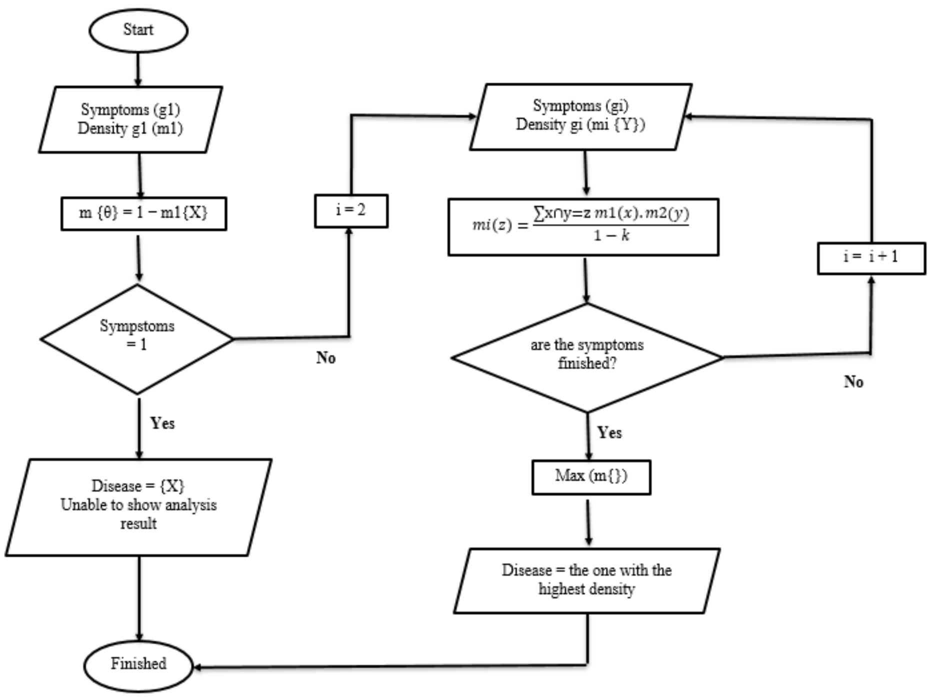

Figure 2. Process Flow Diagram *Dempster Shafer*

Here is the sequence or steps of calculations to be followed when using the Dempster-Shafer method:

1. The user selects the symptoms displayed by the system.
2. The system obtains rules based on user input. The result used is evidence x, which becomes evidence for any hypothesis. For example, symptom 1 has a certainty factor of 0.2 for hypotheses 1, 2, 3, etc.

If there is only one symptom, the system cannot provide an analysis result. The number of symptoms determines the number of combination mass functions that need to be calculated.

3. After completing step 2, the next step is to create initial combination calculations. First, determine the initial mass functions, which are m1 and m2. Data m1 and m2 are obtained from the input.
4. Next, determine the combination of the initial mass functions, which is m3, using the formula in the theory. The result of this combination will be the mass function for further calculations.
5. If there are still symptoms that need to be calculated, step 3 will be repeated, but m1 will be obtained from the previous combination mass function. Meanwhile, m2 will be obtained from the next symptom.
6. The calculation process will stop when all symptoms have been calculated.
7. The final step is to rank all mass functions. Take the highest value and identify the hypothesis associated with that mass function. The data obtained will be the final result of the calculation [6].

Testing and Implementation

After the system is developed, it is tested using different test cases to ensure that the expert system can make accurate decisions and align with the specified specifications. If it turns out that the system still does not represent the expert or human expert thoroughly, additional data sources are created, data acquisition, presentation, machine inference, or data validation are explored until the system can comprehensively represent the expert or human expert.

RESULTS AND DISCUSSION

The expert system is implemented in a program that can be used and run by users. The software can be considered suitable if the designed software is free from errors and able to provide benefits in accordance with the set objectives.

Design of the expert system

Here are the fundamental principles and rules that must be followed to operate this expert system as desired. To ensure that the system operates effectively, it needs to meet the following requirements.

1. Determining the Parameters for the Name of the Cattle Disease
   The data used in this study is information about diseases in cattle obtained through interviews with veterinarians at the Department of Agriculture, Livestock, and Animal Health of Padang Sidempuan City. The results of the data regarding the names of cattle diseases can be seen in Table 1.

Table 1. Names of Cattle Diseases and Their Codes

Disease Code	Disease Name
P001	*Chikungunya*
P002	*Helminthiasis*
P003	FMD (Foot and Mouth Disease)
P004	BEF (Bovine Ephemeral Fever)
P005	*Bloat*
P006	Diarrhea
P007	Scabies (Scabies)
P008	*Pinkeye*
P009	LSD (Lumpy Skin Disease)
P010	MCF (Malignant Catarrhal Fever)

2. Determining Parameter Names of Types of Disease Symptoms in Cattle
In this section, the data used are the names of symptoms of cattle disease obtained through interviews with veterinarians at the Department of Agriculture, Livestock and Animal Health, Padang Sidempuan City. The results of the data on the types of symptoms of cattle disease can be seen in Table 2.

Table 2. Disease Symptoms in Cattle and Symptom Weight Values.

Disease Code	Disease Name	Symptom	Etc
P001	*Chikungunya*	No appetite	0.3
		Weak (Lethargic)	0.3
		Fever	1
		Swelling of the feet	0.6
		Limping	0.6
		Rash on the skin	1
		Seizures	1
P002	*Helminthiasis*	No appetite	0.3
		Feathers are dull and stand up	1
		Thin	1
		Loose stools	1
		There are worms in the feces	1
		Weak (Lethargic)	0.3
P003	FMD (Foot and Mouth Disease)	No appetite	0.3
		Lips and gums appear red, dry and hot	1
		Lesions (blisters)	0.6
		Fever	1
		Weak (Lethargic)	0.3
P004	BEF (Bovine Ephemeral Fever)	No appetite	0.3
		Fever	1
		Excessive salivation	1
		Cough	0.6
		Weak (Lethargic)	0.3
		Discharge from the eyes	0.3
		Discharge from the nose	0.6
		Seizures	1
P005	*Bloat*	No appetite	0.3
		Weak (Lethargic)	0.3
		The left side of the stomach is enlarged	0.5
		Fever	1
		Unable to stand	1
		Tongue sticking out	1
P006	Diarrhea	No appetite	0.3
		Loose stools	1

		More frequent bowel movements than usual	1
		Lips and gums appear red, dry and hot	1
		Weak (Lethargic)	0.3
		Vomit	0.6
		Thin	1
P007	Scabies (Scabies)	No appetite	0.3
		Lumps appear on the skin	0.5
		Rash on the skin	1
		Lesions (blisters)	0.6
		Hard to breathe	0.5
		Cough	0.6
		Fever	1
		Weak (Lethargic)	0.3
P008	*Pinkeye*	No appetite	0.3
		Red and swollen eyes	0.5
		Discharge from the eyes	0.3
		Mucoid (pus) eyes	0.6
		Excessive blinking	0.2
		Fever	1
P009	LSD (Lumpy Skin Disease)	No appetite	0.3
		Rash on the skin	1
		Lumps appear on the skin	0.5
		Hard to breathe	0.5
		Cough	0.6
		Fever	1
		Hair loss	0.3
P010	MCF (Malignant Catarrhal Fever)	No appetite	0.3
		Swollen lymph nodes	0.5
		Seizures	1
		Fever	1
		Hard to breathe	0.5

The weights in Table 2 are obtained based on interviews with veterinarians, the determination which is explained in Table 3.

Table 3. Determination of weight

Symptom	Weight	Information
No appetite (Normally cows consume 3% of their own weight)	1	Taste (3%)
	0.6	Somewhat appetizing (2%)
	0.3	Unappetizing (1%)
	1	Not limp

Weakness (lethargy) (Adapts to the amount of feed consumed)	0.6	A bit weak
	0.3	weak
Fever (The normal temperature of a cow is 38-39.5 degrees Celsius. If > 39.5 degrees Celsius then the cow is declared to have a fever)	1	Fever
	0	No fever
Swelling of the feet	1	Unable to stand
	0.6	The feet are larger (swollen) and turn reddish in color
	0.3	Pain (discomfort), such as difficulty walking
Limping	1	Unable to stand
	0.6	Shifting body weight to the other leg, the affected leg appears bent/slanted (can be seen when the cow stands or walks)
	0.3	Pain (difficulty walking), walking slowly
Rash on the skin	1	There are spots/scratches on the skin, the skin is peeling
	0.6	Itching/cattle rubbing their bodies against the cage, changes in skin color around the skin affected by the rash
	0.3	Hair loss, uncomfortable posture (moving less)
Seizures	1	Ictal Phase (lying on one side or falling, stiff/throbbing muscle movements and unable to stand)
	0.6	Aura Phase (shivering, discomfort)
	0.3	Prodromal Phase (changes in behavior, quieter than usual)
Feathers are dull and stand up	1	Dry and dull fur, standing up more often than usual, won't lie down
	0	Soft and shiny fur
Thin	1	The spine looks very prominent, the hip bones feel wider than usual, the cow's wrists look flatter/concave than usual
	0	Not skinny
Loose stools	1	Liquid consistency, different color, different smell (stronger than usual), more often and more
	0	Normal stool
There are worms in the feces	1	There are worms, slimy feces, changes in color and texture
	0	There are no worms in the feces
Lips and gums appear red, dry and hot	1	Lips and gums appear red, dry and hot
	0	Healthy lips
Lesions (blisters)	1	Swelling of the skin and damage to the layers beneath the wound
	0.6	Red or inflamed patches (irritation)
	0.3	There are bubbles filled with fluid (they can burst and cause open wounds)

Excessive salivation	1	Continuous discharge from the mouth
	0	Normal
Cough	1	Severe (prolonged)
	0.6	Medium (more often)
	0.3	Light (occasional)
Discharge from the eyes	1	Pus (bacterial infection)
	0.6	Thick mucus/fluid (inflammation)
	0.3	Excessive tears (irritation)
Discharge from the nose	1	Severe (abnormal and unusual color)
	0.6	Medium (more often/more)
	0.3	Light (occasional/small amounts)
The left side of the stomach is enlarged	1	Very severe (difficulty moving, difficulty breathing)
	0.5	Severe (the swelling is large, firm and feels hard to the touch)
Tongue sticking out	1	Tongue sticking out
	0	Normal
More frequent bowel movements than usual	1	More frequent bowel movements than usual
	0	Normal
Vomit	1	Critical
	0.6	Currently
	0.3	Light
Lumps appear on the skin	1	Very Severe (The lump grows quickly, changes in behavior in livestock such as avoiding the area around the lump)
	0.5	Severe (Abnormal color around the skin which will be lumpy and have a hard texture)
Hard to breathe	1	Critical (critical shortness of breath as if food is stuck in the throat)
	0.7	Severe (significant difficulty breathing, labored breath sounds)
	0.5	Moderate (infection of the respiratory tract, rapid breathing)
	0.2	Mild (temporary, fatigue due to heavy activity, hot weather)
Red and swollen eyes	1	Critical (red and swollen eyes due to injury to the eye)
	0.7	Severe (red, swollen, sensitive to light, avoids light)
	0.5	Moderate (red, swollen, more tears)
	0.2	Mild (blinks more often and has few tears)
Swollen lymph nodes	1	Critical (caused by the spread of cancer)
	0.7	Severe (severe infection, significantly enlarged lymph nodes)
	0.5	Moderate (enlarged lymph nodes, feel soft or slightly hard)
	0.2	Mild (slightly enlarged and can recover on its own after the infection heals)

System Testing on Livestock

In this study, 3 livestock were found to be infected with the disease. The owner of the livestock is Mr. Iman Harahap. Table 4 represents the symptoms of the disease obtained through interviews with relevant parties. These symptoms are tested on the system and validated by experts.

Table 4. System Testing on Livestock

No.	Symptom	System Results	Expert Results
1	No appetite Lumps appear on the skin Lesions (blisters) Lips and gums appear red, dry and hot	FMD	FMD
2	No appetite Weak (tired) Cough Discharge from the nose Hard to breathe	BEF	BEF
3	No appetite Loose stools There are worms in the feces Thin Feathers are dull and stand up	*Helminthiasis*	*Helminthiasis*

Number tested	3
Number of appropriate answers	3
Number of inappropriate answers	0

$$Accuracy\ value = \frac{Number\ of\ appropriate\ answers}{Number\ tested}\ x\ 100\%$$
$$= \frac{3}{3}\ x\ 100\% = 100\%$$

Based on the results of tests carried out by comparing the accuracy of diagnoses between experts and systems, it was obtained *percentage* by 100%. This shows that the system obtains a decent classification and can be used effectively [3].

Implementation of the Dempster Shafer Method

From the results of interviews with veterinarians at the Department of Agriculture, Livestock and Animal Health, Padang Sidempuan City, data was obtained to create a disease diagnosis system in cattle using the Dempster Shafer method. The following is the working principle of the Dempster Shafer method for diagnosing diseases in cattle.

1. Selecting symptoms of disease in cattle.
   Disease symptoms can be seen in Table 4 which will be implemented into the Dempster Shafer method.
   a. No appetite
   b. Lumps appear on the skin
   c. Lesions (blisters)
   d. Lips and gums appear red, dry and hot

2. Create rules according to the selected symptoms
   Creating rules based on symptom inputs can be seen in Table 5.

Table 5. Hypothesis Rule

No.	**Hypothesis**	**DF**
1	No appetite (P001, P002, P003, P004, P005, P006, P007, P008, P009, P010)	0.3
2	Lumps appear on the skin (P007, P009)	0.5
3	Lesions (blisters) (P003, P007)	0.6
4	Lips and gums appear red, dry and hot (P003, P006)	1

3. Create the first Combination.

   Determining the initial mass function, namely M1 and M2. Data for M1 and M2 are obtained from the input, can be seen in Table 6.

Table 6. First combination

Density	**Symptom**	**Disease**	**Belief**	**Plau**
M1	No appetite	1,2,3,4,5,6,7,8,9,10	0.3	0.7
M2	Lumps appear on the skin	7.9	0.5	0.5

4. Calculate combination densities
   In Table 7, determine the combination of the initial mass functions, which is M3. Use the formula from the theory.

Table 7. Density combination

	M2 (P007, P009) 0.5	M2 (teta) 0.5
M1 (P001, P002, P003, P004, P005, P006, P007, P008, P009, P010) 0.3	7.9 0.15	1,2,3,4,5,6,7,8,9,10 0.15
M1 (teta) 0.7	7.9 0.35	teta 0.35

$M3\ (P007, P009) = \frac{0,5}{1-k} = \frac{0,5}{1-0} = 0,5$

$M3\ (P001, P002, P003, P004, P005, P006, P007, P008, P009, P010) = \frac{0,15}{1-k} = \frac{0,15}{1-0} = 0,15$

$M3\ (teta) = \frac{0,35}{1-k} = \frac{0,35}{1-0} = 0,35$

5. Make a second combination
   Table 8 is the second combination, containing data from both M3 and M4. M4 is obtained from the input of the subsequent symptoms.

Table 8. Second combination

Density	**Symptom**	**Disease**	**Belief**	**Plau**
M3	-	7.9	0.5	0.35
		1,2,3,4,5,6,7,8,9,10	0.15	
M4	Lesions (blisters)	3.7	0.6	0.4

6. Calculate the second density combination

Just like in step 4, Table 9 is the second combination of mass function, namely M5. Use the formula from theory.

Table 9. Combination of second density

	M4 (3.7)	M4 (teta)
	0.8	0.2
M3 (7.9)	7	7.9
0.8	0.3	0.2
M3 (1,2,3,4,5,6,7,8,9,10)	3.7	1,2,3,4,5,6,7,8,9,10
0.04	0.09	0.06
M3 (teta)	3.7	teta
0.16	0.21	0.14

$M5\ (P007) = \frac{0,3}{1-k} = \frac{0,3}{1-0} = 0,3$
$M5\ (P003, P007) = \frac{0,3}{1-k} = \frac{0,3}{1-0} = 0,3$
$M5\ (P007, P009) = \frac{0,2}{1-k} = \frac{0,2}{1-0} = 0,2$
$M5\ (P001, P002, P003, P004, P005, P006, P007, P008, P009, P010) = \frac{0,06}{1-k} = \frac{0,06}{1-0} = 0,06$
$M5\ (teta) = \frac{0,14}{1-k} = \frac{0,14}{1-0} = 0,14$

7. Make a third combination
   Table 10 is the third combination, which contains data from M5 and M6. M6 is obtained from the input of the next symptoms.

Table 10. Third combination

Density	Symptom	Disease	Belief	Plau
M5		7	0.3	0.14
		3.7	0.3	
		7.9	0.2	
		1,2,3,4,5,6,7,8,9,10	0.06	
M6	Lips and gums appear red, dry and hot	3.6	1	0

8. Calculate the third density combination
   Table 11 is the third combination of mass function, namely M7. Use the formula from theory.

Table 11. Third density combination

	M6 (3.6)	M6 (teta)
	1	0
M5 (7)	k	7
0.3	0.3	0
M5 (3.7)	3	3.7
0.3	0.3	0
M5 (7.9)	k	7.9
0.2	0.2	0
M5 (1,2,3,4,5,6,7,8,9,10)	3.6	1,2,3,4,5,6,7,8,9,10
0.06	0.018	0

M5 (teta)	1	teta
0.14	0.14	0

$M7\ (P003) = \frac{0,3}{1-k} = \frac{0,3}{1-0,5} = 0,6$
$M7\ (P003, P006) = \frac{0,018}{1-k} = \frac{0,018}{1-0,5} = 0,036$
$M7\ (P001) = \frac{0,14}{1-k} = \frac{0,14}{1-0,5} = 0,28$
$M7\ (P007) = \frac{0}{1-k} = \frac{0}{1-0,5} = 0$
$M7\ (P003, P007) = \frac{0}{1-k} = \frac{0}{1-0,5} = 0$
$M7\ (P007, P009) = \frac{0}{1-k} = \frac{0}{1-0,5} = 0$
$M7\ (P001, P002, P003, P004, P005, P006, P007, P008, P009, P010) = \frac{0}{1-k} = \frac{0}{1-0,5} = 0$
$M7\ (teta) = \frac{0}{1-k} = \frac{0}{1-0,5} = 0$

9. The final result
   Based on the calculations above, the hypothesis result based on the input symptoms is FMD (Foot and Mouth Disease).

CONCLUSION

Based on the discussion in the previous chapters and the stages that have been carried out, a conclusion is obtained, namely that an expert system using the Dempster Shafer method has been designed to diagnose diseases in cattle quickly, so that it can make it easier for the public, especially farmers, to diagnose diseases in cattle.

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