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Exploration of the Dempster-Shafer Theory for Diagnosing Hardware Damage: Comparative Study with the Certainty Factor Method

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Abstract

Comparative research is a research method that compares two or more research objects to expand understanding of them. In this context, we compare the Certainty Factor method and the Dempster-Shafer method in diagnosing computer hardware damage. The Certainty Factor method measures an expert's confidence in the solution that will be provided. On the other hand, the Dempster-Shafer method is a useful theory in situations where uncertainty dominates. This research focuses on comparing the effectiveness of the two methods in detecting computer hardware damage. An experimental approach is used to look for causal relationships between variables controlled by the researcher. The research results show that the Certainty Factor method has an average success rate of 14.51 %, while the Dempster-Shafer method reaches 84.27% in terms of error difference. From these results, it can be concluded that the Certainty Factor method is more effective in diagnosing computer hardware damage.

Keywords: Dempster-Shafer, Hardware Damage, Certainty Factor, Decision Support System

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I. INTRODUCTION

THE use of computer technology is rapidly increasing around the world. However, computers are prone to damage[1],[2] which can be categorized into two types: software and hardware. Users usually seek help from computer technicians to analyze and fix the problem, which can take a lot of time. To simplify the process and speed up repair, an expert system technology and inference engine can be utilized to identify the symptoms of computer hardware damage.

An expert system is a type of artificial intelligence program that uses a knowledge base and an inference system to imitate the problem-solving abilities of a human expert[3] – [5]. There are various methods used in expert systems, such as the Dempster-Shafer theory and the Certainty Factor. These systems can be very helpful in research and decision-making.

The Dempster Shafer theory is used to solve problems that cannot be completely and consistently resolved [6] – [8]. The Certainty Factor is a way to determine the level of certainty about facts or rules that describe an expert's confidence in solving the problem [9] – [11]. This research aims to calculate the Dempster Shafer Method and Certainty Factor in finding the error value for hardware damage to computers. As well as comparing the Dempster Shafer and Certainty Factor methods for diagnosing damage to computer hardware.

II. RESEARCH METHOD

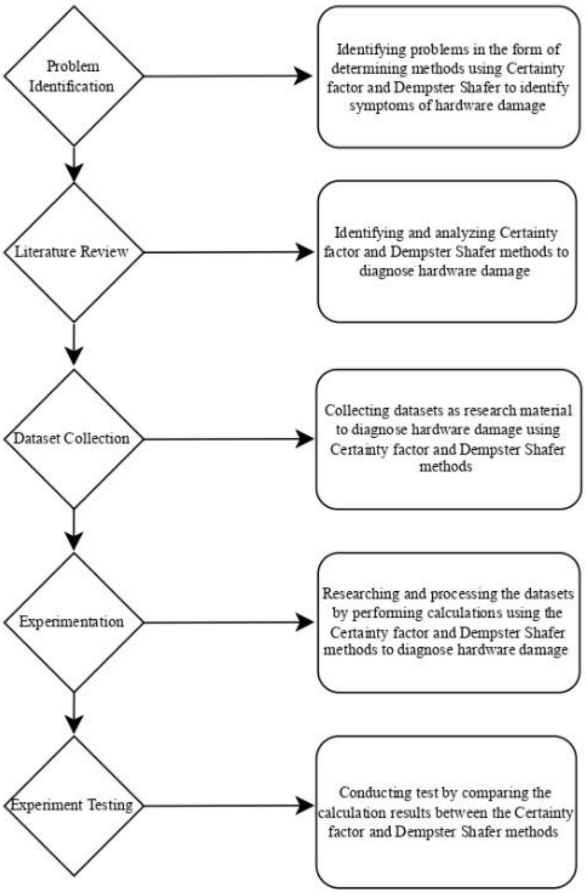

Fig. 1. Research Stages

A. Problem Identification and Literature Review

In this stage, the researcher identifies the problem of how to compare the Dempster Shafer and Certainty Factor methods in diagnosing computer hardware damage and looks for references about the problems that will be discussed in the research. And determine the definition base rule in system expert For identifying damaged device hard use Dempster Shafer and Certainty Factors .

B. Dataset Collection

Dataset collection comes from research papers or articles that have been carried out and then validated by with an expert .

C. Experiment

This stage contains calculations between the Dempster Shafer method and the certainty factor in diagnosing computer hardware damage using data originating from experts and users . Research was also carried out to obtain damage data from users to use as calculation material for the two methods used by researchers.

D. Experimental Testing

This stage was tested by comparing the two methods, namely Dempster Shafer and the Certainty Factor in diagnosing computer hardware damage . This comparison is carried out by looking for the error difference value of the two methods.

III. RESULTS AND DISCUSSION

The dataset used in this research consists of several data, namely damage data, symptoms, expert interpretation data, an expert measure of belief (MB) and measure of disbelieve (MD) values and user certainty values. This data was obtained from previous research, namely the Expert System for Diagnosing Computer Damage with the Certainty Factor Algorithm in the Budi Luhur ICT Lab [12].

The user certainty value is obtained when the user diagnoses the symptoms he is experiencing. This data was obtained using a questionnaire.

TABLE I. USER CERTAINTY VALUE

Gejala	R1	R2	R3	R4	R5	R6	R7
G1	0.4	0.4	0.6	1.0	0.8	0.4	0.4
G2	0.4	0.6	0.8	1.0	1.0	0.6	0.6
G3	0.4	0.6	0.8	0.8	0.4	0.6	0.4
G4	0.4	0.6	0.6	0.8	0.2	0.8	0.8
G5	0.4	0.8	0.4	0.8	0.2	0.6	0.6
G6	0.4	0.4	0.4	0.8	0.4	0.8	0.6
G7	0.4	0.4	0.6	0.1	0.4	0.6	0.8
G8	0.4	0.4	0.6	0.6	0.4	0.8	0.8
G9	0.4	0.4	0.8	0.8	0.2	0.8	0.8
G10	0.4	0.6	0.8	1.0	0.4	0.6	0.8
G11	0.4	1.0	0.8	0.6	0.6	0.8	0.8
G12	0.4	0.4	0.8	0.8	0.6	0.8	0.8
G13	0.4	0.8	0.2	0.8	0.8	0.8	0.6
G14	0.4	0.6	0.8	0.8	0.4	0.8	0.6
G15	0.4	0.4	0.4	1.0	0.4	0.4	0.8
G16	0.4	0.6	1.0	1.0	0.2	0.4	1.0
G17	0.4	1.0	0.6	1.0	1.0	1.0	0.8
G18	0.4	0.8	0.4	1.0	0.4	0.8	0.8
G19	0.4	1.0	0.4	1.0	0.2	0.6	0.6
G20	0.4	0.4	0.6	1.0	0.4	0.6	0.8
G21	0.4	0.8	0.4	1.0	0.8	0.6	0.6
G22	0.4	1.0	0.6	0.8	0.4	0.6	0.8
G23	0.4	0.4	0.4	1.0	0.6	0.4	0.8
G24	0.4	0.4	0.6	1.0	0.2	0.8	0.8
G25	0.4	0.4	0.8	1.0	0.4	0.6	0.8
G26	0.4	0.4	0.4	1.0	0.2	0.6	0.8
G27	0.4	0.6	1.0	1.0	0.2	0.6	1.0
G28	0.4	0.4	1.0	1.0	0.2	0.6	0.8
G29	0.4	0.4	0.8	1.0	0.4	0.6	0.8
G30	0.4	0.4	0.8	0.8	0.6	0.6	0.8
G31	0.4	0.4	0.6	1.0	0.2	0.6	0.8
G32	0.4	0.4	0.6	1.0	0.2	0.8	0.8
G33	0.4	0.4	0.6	1.0	0.2	0.8	0.8

Table 2 displays the expert's MB and MD values. The MB value represents the level of trust in an expert, while the MD value represents the level of distrust.

TABLE II. EXPERT MB AND MD SCORES

Damage Name	Symptom Name	MB	MD
MONITORS	The CPU turns on but no image is displayed on the screen	0.8	0.3
	Black blocks appear and the image is skewed/random	0.9	0.1
	There is a horizontal/vertical line in the middle of the layer	0.9	0.1
	The screen light is red	0.7	0.3
Mouse	The mouse pointer does not respond to mouse movements	0.9	0.1
	Device driver information was not found in device manager	0.8	0.2
	The mouse light does not turn on	0.9	0.2
	Double click	0.9	0.2
MEMORY	The processor turns on but no image is displayed on the layer	0.8	0.2
	A message appears in Windows, saying Windows is missing	0.9	0.1
	Warehouse	0.7	0.2
	Repeated beeps	0.7	0.3
	Long beep sound when turned on	0.8	0.2
	The application runs slowly	0.7	0.3
	An error message appears in the bios	0.8	0.2
	Frequently crashes/stops when running the application	0.7	0.3
	Slow input response	0.8	0.3
Hard disk	Slow application	0.7	0.3
	Until Windows reloads	0.7	0.3
	The error message appears when the operating system is first loaded from the hard drive	0.7	0.2
	Always scan the disk at startup	0.9	0.1
	There is a strange sound in the hard drive	1	0
	Device not detected in bios	0.8	0.2
Video Graphics Adapter	The processor is on but no image is displayed on the layer	0.8	0.2
	The graphic performance seems very heavy	0.9	0.2
	An error message appears when running a GUI application	0.8	0.2
	Exit the blue screen on the Windows operating system	0.7	0.3
	Slow application	0.7	0.3
	Device driver information was not found in device manager	0.7	0.2
	The screen light is red	0.7	0.3
Operating System	Slow application	0.8	0.3
	Until Windows restarts	0.8	0.2
	Exit the blue screen on the Windows operating system	0.8	0.2
	An error message appears when loading the operating system from the hard drive for the first time	0.7	0.3
	Frequent crashes when running the application	0.8	0.2
	Suddenly the OS reboots automatically	0.8	0.1
Power Supply	really dead	0.9	0.2
	Often die suddenly without knowing the cause	0.7	0.4
	There is no indication that some/all devices are turned on	0.9	0.2
	There is no power indicator light	0.9	0.2
	Suddenly the OS reboots automatically	0.6	0.4
Processor	BIOS alarm sound	0.9	0.3
	There is no native bios screen	0.9	0.1
	An error message appears in the bios	0.8	0.3
	The processor is on but no image is displayed on the layer	0.7	0.3
Motherboards	Only some devices work	0.9	0.1
	really dead	0.8	0.2
	There is no indication that some/all devices are on	0.9	0.2
	There is no sign of power on	0.6	0.2
Keyboards	Some/all typed characters will die	0.9	0.1
	Device driver information was not found in device manager	0.8	0.4
	The device is not detected in the BIOS	0.7	0.4
	Slow input response	0.7	0.3

The Uncertainty Factor is a measure of the level of confidence in an event, fact, or hypothesis, based on evidence or expert judgment. The Certainty Factor assigns a value that reflects the degree of confidence that an expert has in the data. Table III presents the level of expert confidence in the problem itself.

After obtaining the certainty and uncertainty values from experts and users, the next step involved manual testing. This manual testing aimed to prove the effectiveness of the Dempster Shafer method and certainty factor calculations in diagnosing hardware damage to computers. The process required manually calculating the diagnosis using both methods, by determining the symptoms and their corresponding values individually. This calculation relied solely on the user data collected from the 2nd respondent.

TABLE III. EXPERT INTERPRETATION VALUES

Condition	Mark
No Know or No Certain	0.2

Condition	Mark
Possible	0.4
Possibility Big	0.6
Almost Certain	0.8
Certain	1.0

A. Calculations Using The Dempster-Shafer Method

The data used for this calculation was gathered from both experts and computer users. The equation for calculating the data can be seen in Equation (1) and Equation (2)

1. Determine mass initial functions, namely m_1 and m_2 [7],[13].

$$M_1 = 1 - user\ value \quad (1)$$

2. Make a ranking of all mass functions[7][13]

$$M_i(Z) = \frac{\sum_{x \cap y = z} m_1(x).m_2(y)}{1 - \sum_{x \cap y = \theta} m_1(x).m_2(y)} \quad (2)$$

TABLE IV. MONITOR DAMAGE DATA FROM EXPERTS

Name Damage	Name Symptom	Weight
MONITORS	CPU is on but no image is displayed on the screen (G1)	0.8
	Black blocks appear and the image is skewed/random (G24)	0.9
	There is a horizontal/vertical line in the middle of the screen (G2)	0.9
	Display light is red (G31)	0.7

G1: CPU is on but no image is displayed on the screen

$$M1\ (k1.k3, k5, k8) = 0.8$$
$$M1\ (\Theta) = 1 - 0.8 = 0.2$$

G2: There is a horizontal/vertical line in the middle of the screen

$$M2\ (k1) = 0.9$$
$$M2\ (\Theta) = 1 - 0.9 = 0.1$$

Recalculate new density values for each subset using density function m3 according to combination rules m3.

TABLE V. DENSITY FUNCTIONS 3

		M2 {k1}	(0.9)	M2 (ϴ)	(0.1)
M1{k1.k3,k5,k8}	(0.8)	{k1}	0.72	{k1.k3,k5,k8}	0.08
M1(ϴ)	(0.2)	{k1}	0.18	ϴ	0.02

$$M3\ \{k1\} = 0.18 + 0.721 - 0 = 0.91 = 0.9$$
$$M3\ \{k1.k3, k5, k8\} = 0.081 - 0 = 0.081 = 0.08$$
$$M\Theta = 0.021 - 0 = 0.02$$

G24: Black blocks appear and image is skewed/random

$$M4(k1) = 0.9$$
$$M4\ (\Theta) = 1 - 0.9 = 0.1$$

Recalculate new density values for each subset of the function with density function m5. M5 combination rules

TABLE VI. DENSITY FUNCTIONS 5

		M4{k1}	(0.9)	(ϴ)	(0.1)
M3 {k1}	(0.9)	{k1}	0.81	{k1}	0.09
M3{k1.k3,k5,k8}	(0.08)	{k1}	0.072	{k1.k3,k5,k8}	0.008

		M4{k1}	(0.9)	(ϴ)	(0.1)
M3 (ϴ)	(0.02)	{k1}	0.018	(ϴ)	0.002

$$M5\ \{k1\} = (0.81 + 0.72 + 0.018 + 0.09)/(1 - 0) = 0.99/1 = 0.99$$
$$M5\ \{k1.k3, k5, k8\} = 0.008/(1 - 0) = 0.008/1 = 0.008$$
$$M5\ \Theta` = 0.002/1 = 0.002$$

G31: Display light is red

$$M6\ (k1.k3, k5) = 0.7$$
$$M6\ (\Theta) = 1 - 0.7 = 0.3$$

Recalculate new density values for each subset of the function with density function m7. M7 combination rules:

TABLE VII. DENSITY FUNCTIONS 7

		M6{k1.k3,k5}	(0.7)	(ϴ)	(0.3)
M5 {k1}	(0.99)	{k1}	0.693	{k1}	0.297
M5{k1.k3,k5,k8}	(0.008)	{k3,k5}	0.0056	{k1.k3,k5,k8}	0.0024
M5 (ϴ)	(0.002)	{k1.k3,k5}	0.0014	(ϴ)	0.0006

$$M7\ \{k1\} = 0.693 + 0.2971 - 0 = 0.991 = 0.99$$
$$M7\{\ k3, k5\ \} = 0.00561 - 0 = 0.0056$$
$$M7\ \{k1.k3, k5\ \} = 0.00141 - 0 = 0.0014$$
$$M7\ \{k1.k3, k5, k8\} = 0.00241 - 0 = 0.0014$$
$$M7\ \Theta = 0.00061 - 0 = 0.0006$$

Based on the four symptoms above, namely G1. G2, G24 and G31. the highest confidence value is obtained, namely 0.99.

TABLE VIII. MONITOR DAMAGE DATA FROM USERS

Name Damage	Name Symptom	Weight
MONITORS	CPU is on but no image is displayed on the screen (G1)	0.4
	Black blocks appear and the image is skewed/random (G24)	0.4
	There is a horizontal/vertical line in the middle of the screen (G2)	0.6
	Display light is red (G31)	0.4

G1: CPU is on but no image is displayed on the screen

$$M1\ (k1.k3, k5, k8) = 0.4$$
$$M1\ (\Theta) = 1 - 0.4 = 0.6$$

G2: There is a horizontal/vertical line in the middle of the screen

$$M2\ (k1) = 0.6$$
$$M2\ (\Theta) = 1 - 0.6 = 0.4$$

Recalculate new density values for each subset of the function with the density function m3. M3 combination rules:

TABLE IX. DENSITY FUNCTIONS 3

		M2{k1}	(0.6)	M2 (ϴ)	(0.4)
M1{k1.k3,k5,k8}	(0.4)	{k1}	0.24	{k1.k3,k5,k8}	0.16
M1(ϴ)	(0.6)	{k1}	0.36	ϴ	0.24

$$M3\ \{k1\} = 0.24 + 0.361 - 0 = 0.61 = 0.6$$
$$M3\ \{k1.k3, k5, k8\} = 0.161 - 0 = 0.161 = 0.16$$
$$M\Theta = 0.241 - 0 = 0.24$$

G24: Black blocks appear and image is skewed/random

$$M4(k1) = 0.4$$
$$M4\ (\Theta) = 1 - 0.4 = 0.6$$

Recalculate new density values for each subset of the function with density function M5. M5 combination rules:

TABLE X. DENSITY FUNCTIONS 5

		M4{k1}	0.4	(ϴ)	0.6
M3 {k1}	0.6	{k1}	0.24	{k1}	0.36
M3 {k1.k3,k5,k8}	0.16	{k1}	0.064	{k1.k3,k5,k8}	0.096

		M4{k1}	0.4	(Θ)	0.6
M3 (Θ)	0.24	{k1}	0.096	(Θ)	0.144

$$M5\ \{k1\} = 0.24 + 0.064 + 0.096 + 0.361 - 0 = 0.761 = 0.76$$
$$M5\ \{k1.k3,k5,k8\} = 0.0961 - 0 = 0.096$$
$$M5\ \Theta = 0.1441 - 0 = 0.144$$

G31: Display light is red

$$M6\ (k1.k3,k5) = 0.4$$
$$M6\ (\Theta) = 1 - 0.4 = 0.6$$

Recalculate new density values for each subset of the function with density function m7. M7 combination rules:

TABLE XI. DENSITY FUNCTIONS 7

		M6{k1.k3,k5}	0.4	(Θ)	0.6
M5 {k1}	0.76	{k1}	0.304	{k1}	0.456
M5{k1.k3,k5,k8}	0.096	{k1.k3,k5}	0.0384	{k1.k3,k5,k8}	0.0576
M5 (Θ)	0.144	{k1.k3,k5}	0.0576	(Θ)	0.0864

$$M7\ \{k1\} = 0.304 + 0.4561 - 0 = 0.761 = 0.76$$
$$M7\ \{k1.k3,k5\} = 0.0384 + 0.05761 - 0 = 0.0961 = 0.096$$
$$M7\ \{k1.k3,k5,k8\} = 0.05761 - 0 = 0.0576$$
$$M7\ \Theta = 0.08641 - 0 = 0.0864$$

Based on the four symptoms above, namely G1. G2, G24 and G31. the highest confidence value was obtained, namely 0.76.

Based on the calculation results above, the error difference value between *the user* and expert values is obtained.

TABLE XII. DATA FROM DS USER AND EXPERT CALCULATIONS

Damage	User Value	Expert Value	Error difference
Monitors	76%	99%	23%
Mouse	78.4	187.56%	109.16%
Memory	84.97%	216.55%	131.58%
Hard disk	341.53%	633.01%	291.48%
VGA	114.92	99.94%	14.98%
OS Problem	1%	80.16%	79.16%
Power Supplies	68.64%	12.58%	56.06%
Processor	108%	99%	9%
Motherboards	112%	90%	22%
Keyboards	1%	107.28%	106.28%

B. *Certainty Method Calculation Factor*

the certainty factor is calculated using the formula previously explained. This calculation is carried out using data obtained from experts and computer users.

Steps to calculate the *certainty factor method*

1. Determining Parallel CF
$$CFh,e = CFuser * CF[expert] \quad (3)$$
2. Determining the Combined CF
$$CFgabCF1.CF2 = CF1 + CF2 * (1 - CF1) \quad (4)$$
3. Determine CF Percentage
$$CFpercentage = CFcombine * 100\% \quad (5)$$

TABLE XIII. MONITOR DAMAGE DATA FROM USERS

Damage name	Symptom name	Ms. expert	Mb user
MONITORS	CPU is on but no image is displayed on the screen (G1)	0.8	0.4
	Black blocks appear and the image is skewed/random (G24)	0.9	0.4
	There is a horizontal/vertical line in the middle of the screen (G2)	0.9	0.6
	Display light is red (G31)	0.7	0.4

1. Calculations using one premise or by multiplying the expert CF and user CF values with the formula:
$CFh,e = CFuser * CF[expert]$
$G1 = 0.4 * 0.8 = 0.32$
$G24 = 0.4 * 0.9 = 0.36$
$G2 = 0.6 * 0.9 = 0.54$
$G31 = 0.4 * 0.7 = 0.28$
2. From the calculation to determine CF1 to CF5 above, the combined CF is calculated using the formula:
$\boldsymbol{CFgab[CF1.CF2] = CF1 + CF2 * (1 - CF1)}$
$= 0.32 + 0.36 * (1 - 0.32)$
$= \mathbf{0.5648}$
$CFgab\ (H,E)3 = CF(h,e)old + CF(h,e)old3 * (1 - CF\ (h,e)old)$
$= 0.5648 + 0.54 * (1 - 0.5648)$
$= \mathbf{0.799808}$
$CFgab\ (H,E)old4 = CF\ (h,e)old + CF\ (h,e)old4 * (1 - CF\ (h,e)old)$
$= 0.799808 + 0.28 * (1 - 0.79808)$
$= \mathbf{0.8546176}$
3. CF calculation to determine the percentage using the formula:
CF Percentage = CF combine * 100%
= 0.8546176 * 100 %
= 85.46%

TABLE XIV. MONITOR DAMAGE DATA FROM EXPERTS

Name Damage	Name Symptom	MB	MD
Monitors	CPU is on but no image is displayed on the screen (G1)	0.8	0.3
	Black blocks appear and the image is skewed/random (G24)	0.9	0.1
	There is a horizontal/vertical line in the middle of the screen (G2)	0.9	0.1
	Display light is red (G31)	0.7	0.3

This calculation uses the formula:
$CFh,e = MBH,E - MD[H,E]$
$G1 = 0.8 - 0.3 = 0.3$
$G24 = 0.9 - 0.1 = 0.8$
$G2 = 0.9 - 0.1 = 0.8$
$G31 = 0.7 - 0.3 = 0.4$
$\boldsymbol{CFg\ (CF1.CF2) = CF\ 1 + CF2 * (1 - CF1)}$
$= 0.3 + 0.8 * (1 - 0.3) = \mathbf{0.86}$
$CFgab\ (H,E)old3 = CF\ (h,e)old + CF\ (h,e)old3 * (1 - CF\ (h,e)old)$
$= 0.86 + 0.8 * (1 - 0.86)$
$= 0.972$
$CFgab\ (H,E)old4 = CF\ (h,e)old + CF\ (h,e)old4 * (1 - CF\ (h,e)old)$
$= 0.972 + 0.4 * (1 - 0.972)$
$= 0.9832$
$CFpercentage = CFcombine * 100\%$
$= 0.9832 * 100\%$
$= \mathbf{98.32}\ \%$

Based on the calculation results above, the error difference value between *the user* and expert values is obtained.

TABLE XV. DATA FROM USER AND EXPERT CF CALCULATIONS

Damage	CF User	Expert CF	Error Difference
Monitors	85.46%	98.32%	7.86%
Mouse	86.36%	99.28%	12.92%
Memory	103.35%	99.93%	3.57%
Hard disk	98.57%	0%	98.57%
VGA	108.80%	99.48%	9.32%
OS Problem	99.94%	99.48%	0.46%
Power Supplies	96.1%	98.48%	2.38%
Processor	95.17%	97.6%	2.43%
Motherboards	94.90%	98.54%	3.64%
Keyboards	98.87%	94.96%	3.91%

Based on the calculation results between the *Dempster Shafer method and the certainty factor*, the average error value for both is produced. It can be concluded that the CF <DS value means the *certainty method factor* is better compared to *dempster Shafer* in diagnosing computer *hardware damage* . Because the smaller the error value, the better the value.

TABLE XVI. DATA FROM COMPARISON OF DS AND CF

Damage	DS	CF
Monitors	74.17%	7.86%
Mouse	109.16%	12.92%
Memory	131.58%	3.57%
Hard disk	291.48%	98.57%
VGA	14.98%	9.32%
OS	79.16%	0.46%
Power Supplies	56.06%	2.38%
Processor	9%	2.43%
Motherboards	22%	3.64%
Keyboards	106.28%	3.91%
Average error	**84.27%**	**14.51%**

IV. CONCLUSION

The conclusion from the results of this research is that the Certainty Factor method is better used in diagnosing hardware damage to computers, with an average value calculated by the Dempster Shafer method of 84.27% and the Certainty Factor of 14.51% in terms of error difference. This can be taken as a basis for selecting a more effective diagnostic method for cases of computer hardware damage.

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