Journal of Digital Business and Data Science, Vol. 3 No. 1 January-June 2026 I E-ISSN: 3089-1345
DOI: https://doi.org/10.59261/jdbs.v3ix1.34

Journal of Digital Business and Data Science

JOURNAL OF DIGITAL BUSINESS AND DATA SCIENCE

Journal Homepage : https://jdbs.poltekssci.ac.id/index.php/ps/

Diagnostic Expert System Website-Based Stroke Disease Using Forward Chaining and Certainty Factor Methods

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Article received on 11-04-2026 — Final revised on 25-05-2026 — Approved on 09-06-2026

Abstract

Background: Stroke is a neurological condition characterized by the sudden loss of brain function resulting from disruption of blood supply to the brain. It ranks as the second leading cause of death globally, with a mortality rate ranging from 18% to 37%, and constitutes a major cause of neurological disability in Indonesia as well as the third leading cause of death worldwide.
Objective: This study aimed to develop a web-based expert system enabling patients and their families to perform early detection of stroke symptoms.
Method: This study employed a prototype-based development methodology. The knowledge base was constructed through structured interviews with a neurologist and validated through cross-checking with clinical records. The Forward Chaining method served as the inference engine, deriving diagnostic conclusions from symptom-based facts, while the Certainty Factor method quantified diagnostic uncertainty. System testing was conducted using six patient case samples provided by the expert.
Findings and Implications: The system achieved a diagnostic accuracy of 86.68% based on cross-validation with expert knowledge using six clinical case samples. Black-box functional testing confirmed that all system features performed as expected.
Conclusion: These results indicate that the system is capable of supporting preliminary stroke symptom assessment, thereby facilitating early decision-making prior to professional medical consultation. However, given the limited number of test cases, the system's generalizability warrants further validation using a larger clinical dataset.

Keywords: stroke; forward chaining; certainty factor

INTRODUCTION

Stroke is a neurological condition characterized by the sudden disruption of blood supply to the brain, resulting in loss of brain function (Didit, 2019). Stroke ranks second among leading causes of death globally, with a mortality rate ranging from 18% to 37% (Andri, 2012). This stroke disease is one of the from existence reason death and disability the main neurological disease in Indonesia and stroke is also a reason death number 3 in the world and number 1 in Indonesia (Adeniran et al., 2010). Disease This often found at the age of productive (20-64 years) and elderly (60-80 years) become reason death most second in the world and is reason disability main. Total strokes in Indonesia are predicted as many as 500,000 each year and around 2.5% or 25,000 people died, the rest disabled light or heavy . With the 500,000 data show that sufferers *stroke* in Indonesia is very large and is a very heavy load For can handled by the patient himself and family patient (Roosnik, 2011).

Based on interview with Dr. Fadhilah, Sp.N, M.Kes who is a doctor nerves at Agoesdjam Regional Hospital, as for characteristics of stroke such as lost balance and awareness, nerves problems, mental changes, and changes function five senses matter this is what influences family mental burden patients (Theo, 2015). Consequently, healthcare practitioners and families frequently encounter difficulties in obtaining accurate stroke information due to the scarcity of accessible stroke specialists.

In response to this challenge, the development of a computer-based expert system offers a viable solution for assisting in stroke diagnosis without requiring direct consultation with a specialist. An expert system is a computer-based application that utilizes knowledge, facts, and reasoning techniques to solve problems that typically require human expertise. Such systems encode specialist knowledge into a computational program, enabling decision-making processes that replicate expert-level reasoning and have been widely applied in medical diagnosis domains (Casal-Guisande et al., 2023).

Expert systems can further augment professional activities by serving as intelligent assistants that draw upon contextual knowledge to support decision-making. In the domain of stroke diagnosis, the Forward Chaining inference method is particularly well-suited, as it begins with available symptomatic facts and applies production rules to derive diagnostic conclusions. The accuracy of this inference process is further enhanced by incorporating the Certainty Factor method, which assigns numerical confidence values to handle the inherent uncertainty in symptom-based diagnosis (Nuraeni, 2022).

The Forward Chaining method constitutes a data-driven search strategy that initiates from known facts and progressively applies inference rules to reach a conclusion or goal state. The Certainty Factor method complements this process by quantifying diagnostic confidence under conditions of uncertainty, making it appropriate for medical knowledge domains where symptom presentations may be

ambiguous (Febrianto, et.al, 2023). Web-based deployment enables universal access to diagnostic information without temporal or geographic constraints, which is particularly relevant for productive-age populations (20–64 years) and elderly individuals (60–80 years) at elevated risk of stroke.

Several prior studies have demonstrated the application of expert systems in stroke diagnosis using methods such as Fuzzy Logic, Dempster-Shafer (Kanggeraldo, Sari, & Zul, 2018), and Forward Chaining (Irawan, 2021). Epidemiologically, stroke remains the leading cause of death and disability in Indonesia (Venketasubramanian, & Tugasworo, 2022), and global data confirm that it ranks among the foremost causes of mortality worldwide, with incidence rising substantially over the past three decades (Feigin et al., 2021). The Indonesian Health Survey of 2023 reported a national stroke prevalence of 8.3 per 1,000 people, underscoring the urgent need for accessible diagnostic tools (Kementerian Kesehatan RI, 2023). However, prior studies predominantly employed single inference methods without integrating uncertainty quantification. The present study addresses this gap by developing a web-based expert system for stroke diagnosis that combines Forward Chaining inference with the Certainty Factor method, thereby enabling both structured reasoning and probabilistic confidence estimation in a clinically accessible platfor

RESEARCH METHOD

Stages in study This as shown in Figure 1.

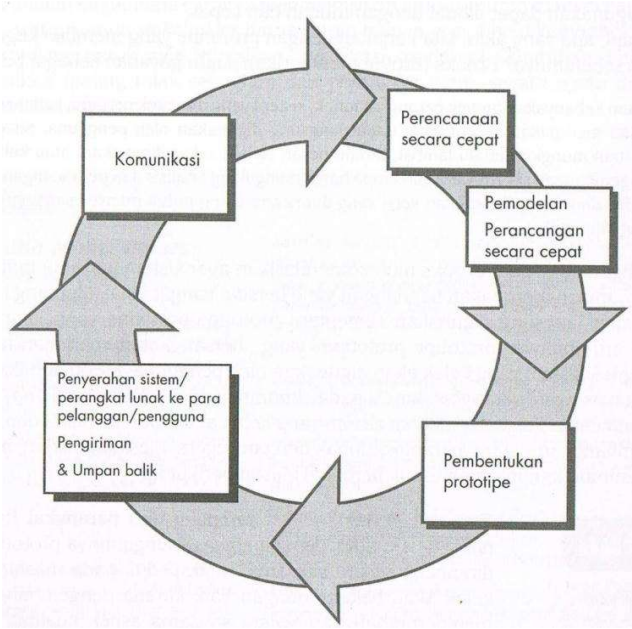


Figure 1. Steps Study

Following stages in the method development the system used in study This :

1. Communication: Communication between researchers and experts For do collection Requirements Gathering & Analysis. Researchers and experts define objective system, symptoms, diseases, solutions and rules expert.
2. Design In a way Fast: Focus on designing knowledge base, flow work (such as forward chaining or certainty factor), and prototype interfaces.
3. Modeling Design In a way Fast: Implementation design to in device soft system experts, as well as create models and quick designs on drawings from software aspect.
4. Formation Prototype: Quick design leads to creation from the prototype.
5. System/Device Handover soft to users/customers sender & feed back: Prototype sent Then evaluated back by experts and researchers, feedback is used for filter need for software. Fix system based on evaluation until reach final product.

Data collection

Steps taken is collect the necessary data for the diagnostic process disease *Stroke*, method data collection carried out in study This that is:

Literature review

Literature review containing description about theories, findings and materials other research which is obtained from material reference for can made into runway activity research. Description in literature *review* This directed for compile framework clear thinking about solution problems that have been described in previously in the formulation problem. Study method library done with look for literature, namely journals on *Google Scholar* and through book related prints with research that done by the author.

Interview

Interview that is condition ask answer researchers with source, both source status as informant and respondents. Conversation That carried out by two parties, namely interviewer *(interviewer)* who submitted questions and interviewees *(interviewee)* who gave answer on question That. Interview methods that can be done is interview structured and interviews not structured interviews structured is interviews conducted if researchers has know with Certain related information you want obtained. In do interview, researcher use method interview structured in the form of instrument study in the form of alternative questions along with the answer that has been prepared.

Interview not structured is interview Where researchers No use guidelines interviews that have been arranged in a way systematic and complete. Guidelines interviews used only in the form of large lines problems that will asked. Interview method can done in a way direct and indirect direct. Interview method direct is methods used in a way face to face with respondents *(face to face)*, but method interview No direct is method interviews conducted with No meet direct with respondents, can in the form of other media like telephone, email, etc. In the research this researchers use method interview No structured and carried out in a way direct to Doctor Fadhila, Sp.S. M.Kes as doctor who treats stroke in Ketapang Regency. In a number of questions asked namely

How symptom beginning Stroke and other diseases. From the results interview said, it was obtained information in the form of type disease, symptoms, treatment and others.

Observation

Observation as technique data collection has characteristics specific compared to other techniques, namely interviews and questionnaires is a complex process, a structured process from various biological and psychological processes. Two of the most important are the processes of observation and memory. In terms of the implementation process data collection, observations made is observation *non-participants,* observation *non- participants* is observation Where researchers No involved direct with the activities of the people being observed and only as observer independent.

Documentation

Documentation is search and collect data regarding things or variables in the form of notes, transcripts, books, magazines, agendas, minutes meetings and so on.

RESULTS AND DISCUSSION

Implementation done with apply methods used in the system that is method *forward chaining* and *certainty factor* in build application system diagnosis disease *stroke* website -based interface application consists of from admin and user interface. Here is explanation interface the system that has been built.

User Interface Implementation

Following is implementation from system user interface design expert diagnosis disease *stroke* use method *forward chaining* and *certainty* web -based *factors*.

Expert System Home Page

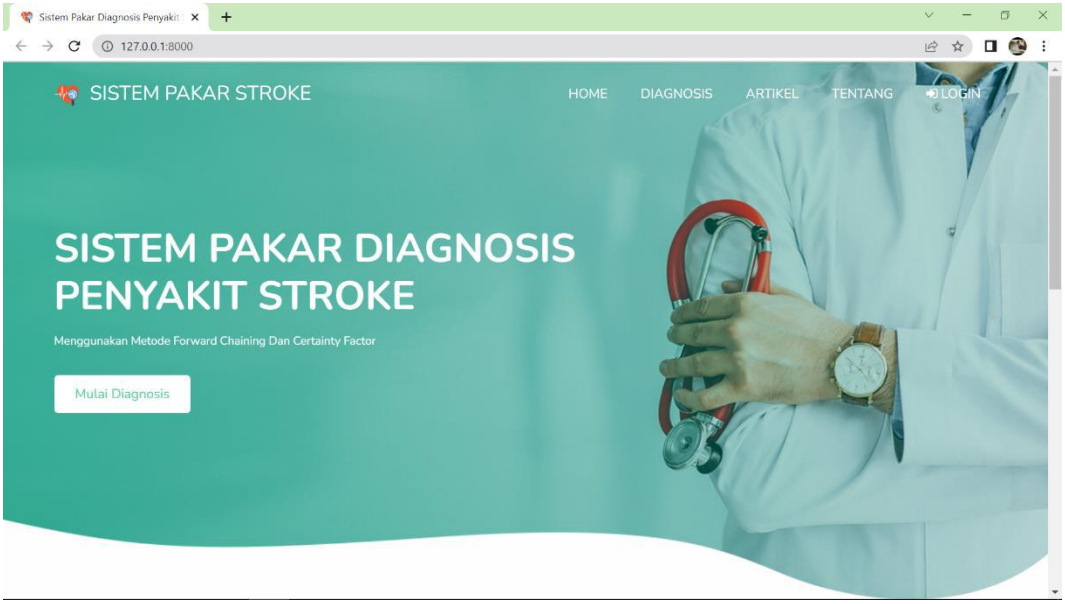


Figure 2. Dashboard Page

In Figure 2 there is page beginning system disease diagnosis expert *stroke* that has the start menu from the diagnosis menu, articles, about and login.

Admin Login Page

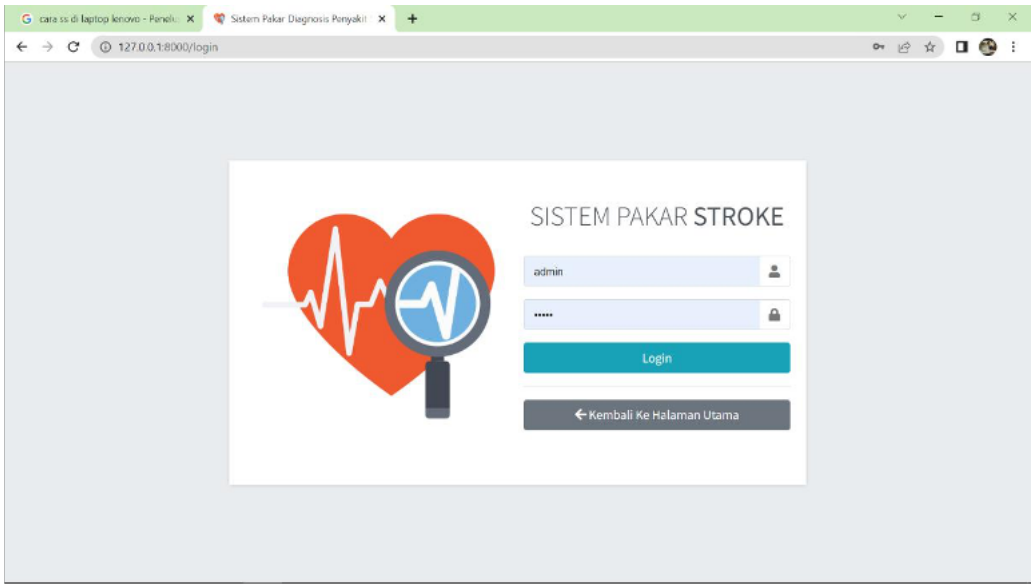


Figure 3. Admin Login Page

The admin page is pages used for do adding data, editing data and deleting data. The admin page only can accessed by doctors specialist and admin user.

Admin Home Page

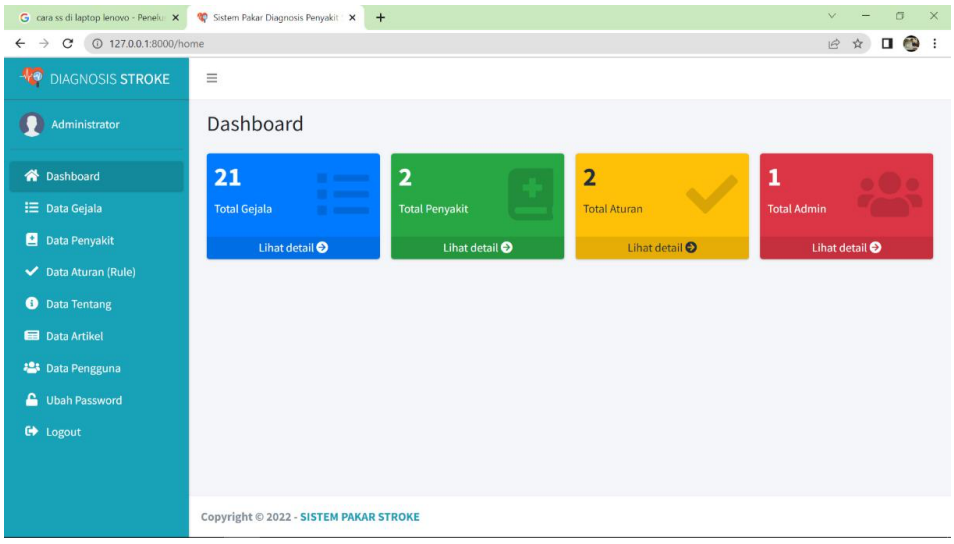


Figure 4. Admin Main Page

In Figure 4. Main admin page, admin can access various menus that only can accessed by admin.

Symptom Data Page

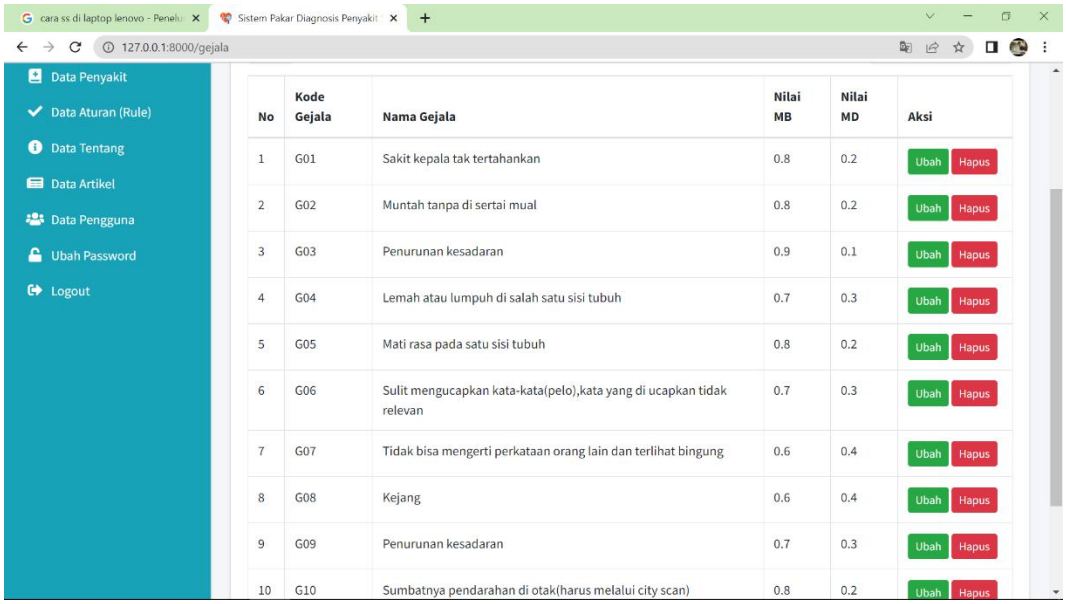


Figure 5. Symptoms Page

Symptom data page for display all type symptoms that have admin entered into *database*. Symptom data page there is also a menu for add symptom new, disease data page can seen in figure 5 above.

Consultation Results Page

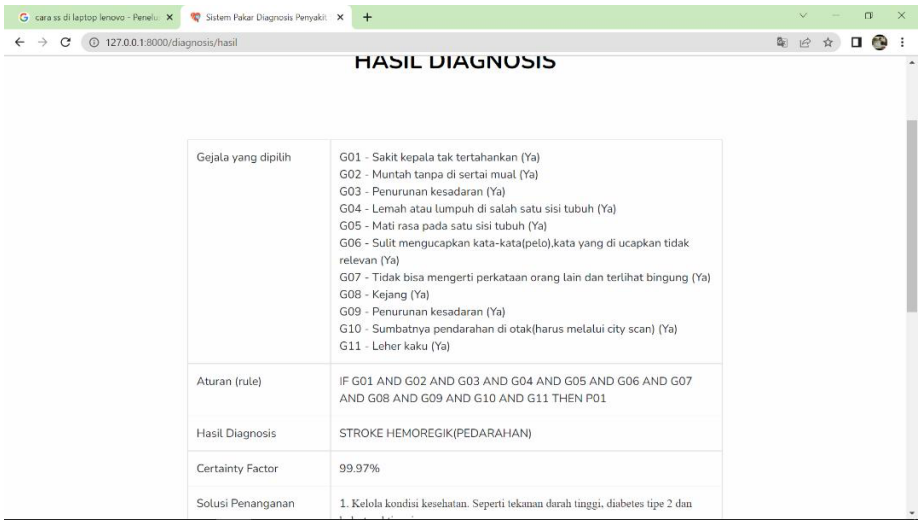


Figure 6. Consultation Results Page

Consultation page display possibility of user suffering disease *strokes* shown in the table results analysis. Results page consultation can seen in figure 6 above.

User Interface Coding

Following is coding from system user interface design expert diagnosis stroke disease using method *forward chaining* and *certainty* web -based *factors*.

AuthController.php — Login Script (Script code 1.1) PHP

```
1  public function authenticate( Request $request)
2  {
3      $credentials = $request->validate( [
4          'username' => ['required'],
5          'password' => ['required'],
6      ]);
7
8      if ( Auth::attempt($credentials)) {
9          $request->session()->regenerate( );
10
11         return redirect()->intended('home');
12     }
13
14     return back()->withInput()->with( ['error' =>
15         'Incorrect username and password']);
16 }
17
18 public function logout( )
19 {
20     Auth::logout( );
21     return redirect('login');
22 }
```

Figure 7. Script code Login page

Above program is a checking program Are the username and password entered in the login form correct (lines 3, 4, 5)? If correct so will be directed to home form (11). If the username and password are incorrect then notification error will be displayed (14). If it is lagout so will be directed to the login form (21).

Appearance Symptom

SymptomController.php — View Symptom (Script code 1.2) PHP

```
1  // SymptomController.php – View Symptom
2
3  public function index( )
4  {
5      $symptoms = Symptoms::all( ) ;
6      return view( 'symptom.index', compact('symptom') );
7  }
```

Description: index() retrieves all symptom records from the database via Symptoms::all() and passes them to the 'symptom.inde

Figure 8. Script code View symptom

Above program is a program for display symptom list page disease.

Add Symptom Data

SymptomController.php — Add Symptom Data (Script code 1.3) PHP

```php
// SymptomController.php — Add Symptom Data

public function create( )
{
    return view('gejala.create');
}

public function store( Request $request)
{
    $message = [
        'required' => ':attribute must filled',
        'unique'   => ':attribute Already used',
    ];

    $validated = $request->validate( [
        'symptom_code' => 'required|unique:symptom',
        'symptom_name' => 'required',
        'mb'           => 'required',
        'md'           => 'required',
    ], $message);

    $result = Symptom::create($validated);

    if ($result) {
        return redirect()->route('symptoms.index')
                         ->with(['success' => 'Data successfully saved']);
    } else {
        return redirect()->route('symptoms.index')
                         ->with(['error' => 'Data failed saved']);
    }
}
```

Description: create() returns the add-symptom form view. store() validates the request, saves via Symptom::create(), and redirects with

Figure 9. Script code Add symptom data

This program is a program for operate order add symptom disease.

Edit Symptom Data Disease

SymptomController.php — Edit Symptom Data (Code script 1.4) PHP

```php
// SymptomController.php — Edit Symptom Data

public function edit( Symptoms $symptoms )
{
    return view( 'symptom.edit', compact('symptom') );
}

public function update( Request $request, Symptom $symptom )
{
    $message = [
        'required' => ':attribute must filled',
        'unique'   => ':attribute Already used',
    ];

    $validated = $request->validate( [
        'symptom_code' => 'required|unique:symptom,symptom_code,'
                          . $symptom->id,
        'symptom_name' => 'required',
        'mb'           => 'required',
        'md'           => 'required',
    ], $message);

    $result = $symptoms->update($validated);

    if ($result) {
        return redirect()->route('gejala.index')
                         ->with(['success' => 'Data successful changed']);
    } else {
        return redirect()->route('symptoms.index')
                         ->with(['error' => 'Data failed changed']);
    }
}
```

Description: edit() displays the symptom edit form. update() validates and applies changes via $symptoms->update(), then redirects w

Figure 10. Code Script Edit Symptom Data Disease

This program is a program for operate order displays the edit form and commands for edit symptom data.

Delete Symptom Data

SymptomController.php — Delete Symptom Data (Code script 1.5) PHP

```php
// SymptomController.php – Delete Symptom Data

public function destroy( Symptom $symptom )
{
    $result = $symptom->delete();

    if ($result) {
        return redirect()->route('gejala.index')
                         ->with(['success' => 'Data successful deleted']);
    } else {
        return redirect()->route('symptoms.index')
                         ->with(['error' => 'Data failed deleted']);
    }
}
```

Description: destroy() deletes a symptom record via $symptom->delete() and redirects to the symptom list with a success or error flash

Figure 11. Code Script Delete Symptom Data

This program is for delete symptom data disease.

Diagnostic Results

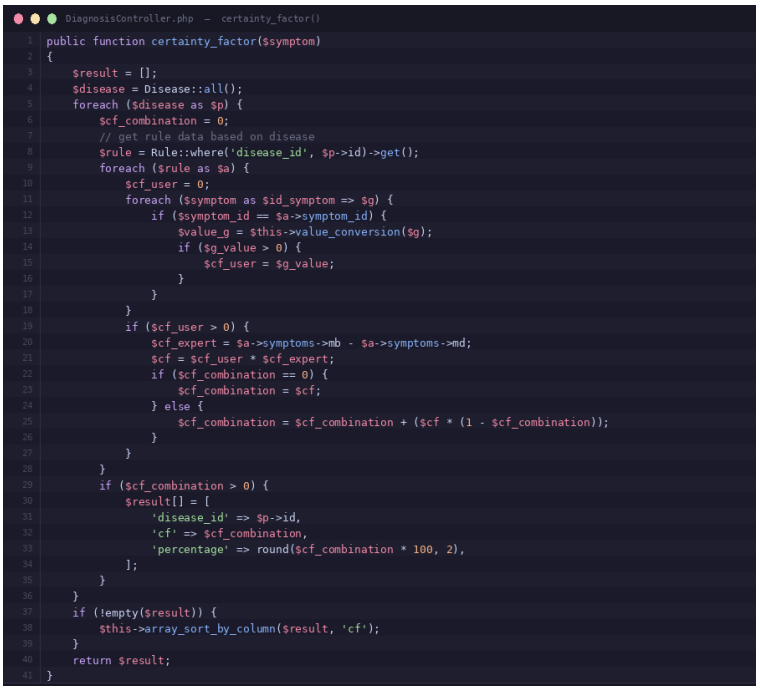
DiagnosisController.php

```php
public function result( Request $request)
{
    $selected_symptoms = $request->symptoms;
    // call function CF method
    $result = $this->certainty_factor($selected_symptoms);
    $symptoms = [];
    foreach ($symptom_selected as $symptom_id => $g) {
        $value = $this->convert_value($g);
        if ($value > 0) {
            $gej = Symptom::find($id_symptom);
            $symptoms[] = $gej->symptom_code . ' - ' . $gej->symptom_name . ' (' . $g . ')';
        }
    }
    // default value of disease not diagnosed
    $disease_name = 'Disease No known';
    $solution = '';
    $cf_value = 0;
    $rule = 'No matching rule';
    $disease_id = null;
    // If disease diagnosed
    if (!empty($result)) {
        $disease_id = $results[0]['disease_id'];
        $disease = Disease::find($disease_id);
        $disease_name = $disease->disease_name;
        $solution = $disease->solution;
        $cf_value = $result[0]['percentage'];
        $result = Rule::where('disease_id', $disease_id)->get();
        $rule = [];
        foreach ($result as $row) {
            $rule[] = $row->symptom->symptom_code;
        }
        $rule = 'IF ' . implode(' AND ', $rule) . 'THEN' . $disease->disease_code;
    }
    $data_diri = session('data_diri');
    $data_diri['symptoms'] = serialize($symptoms);
    $data_diri['rule'] = $rule;
    $data_diri['disease_id'] = $disease_id;
    $data_diri['cf'] = $nilai_cf;
    Result::create($data_diri);
    return view('diagnosis_result', compact('disease_name', 'solution', 'rule', 'symptom', 'cf_value', 'pers
}
```

Figure 12. Script Code Diagnosis Results

This program is results from the overall diagnosis

Certainty Factor




```php
public function certainty_factor($symptom)
{
    $result = [];
    $disease = Disease::all();
    foreach ($disease as $p) {
        $cf_combination = 0;
        // get rule data based on disease
        $rule = Rule::where('disease_id', $p->id)->get();
        foreach ($rule as $a) {
            $cf_user = 0;
            foreach ($symptom as $id_symptom => $g) {
                if ($symptom_id == $a->symptom_id) {
                    $value_g = $this->value_conversion($g);
                    if ($g_value > 0) {
                        $cf_user = $g_value;
                    }
                }
            }
            if ($cf_user > 0) {
                $cf_expert = $a->symptoms->mb - $a->symptoms->md;
                $cf = $cf_user * $cf_expert;
                if ($cf_combination == 0) {
                    $cf_combination = $cf;
                } else {
                    $cf_combination = $cf_combination + ($cf * (1 - $cf_combination));
                }
            }
        }
        if ($cf_combination > 0) {
            $result[] = [
                'disease_id' => $p->id,
                'cf' => $cf_combination,
                'percentage' => round($cf_combination * 100, 2),
            ];
        }
    }
    if (!empty($result)) {
        $this->array_sort_by_column($result, 'cf');
    }
    return $result;
}
```

Figure 13. Script code Certanity factor

This program is method from the *certainty factor*

Conversion Mark


```php
// function For convert information become mark cf user
public function convert_value($description)
{
    $value = '';
    switch ($description) {
        case 'Not Sure':
            $value = 0;
            break;
        case 'Less Sure':
            $value = 0.2;
            break;
        case 'A Little Sure':
            $value = 0.4;
            break;
        case 'Quite Sure':
            $value = 0.6;
            break;
        case 'Sure':
            $value = 0.8;
            break;
        case 'Very Confident':
            $value = 1;
            break;
    }
    return $value;
}
```

Figure 14. Script Code Conversion Mark

This program is a conversion program mark from disease diagnosis results

Calculation Results *Certainty Factor*

For determine results symptom data required as example user has choose a number of symptoms. The symptom data selected by the user has mark *certainty* combination *factor* as following:

Symptoms selected by the *user:*

a. Weakness or paralyzed in one side body :0.6
b. Numbness in one side body (tingling / numbness) : 0.8
c. Smile No symmetrical : 1

***Certainty Factor* Value Expert**

Table 1. Factor Value Expert

Symptom	hemorrhagic stroke (bleeding)	CF Value of Non-hemorrhagic Stroke
Weakness or paralyzed in one side body	0.6	0.4
Numbness in one side body (tingling/ numbness)	0.6	0.4
Smile No symmetrical	0.6	0.4

Source: Data Processed

The table above shows the diseases associated with the user's selected symptoms and their respective percentages in the system. The system will display the diseases in order, starting with the highest percentage. The manual calculation for each pest is outlined below.

Formula to find the percentage of the CF value of each symptom.

CFcombinedCF[H,E]1,2= CF[H,E]1 + CF[H,E]2 * [1 – CF[H,E]1]

1. Hemorrhagic stroke
2. Expert value x user value

   G 1 : 0.6 x 0.6 = 0.36

   G 2 : 0.6 x 0.8 = 0.48

   G 3 : 0.6 x 1 = 0.4
3. Combined Cf

   CFcombinedCF[H,E]1,2= CF[H,E]1 + CF[H,E]2 * [1 – CF[H,E]1]

   a. 0.36 + 0.48 x (1-0.36) = 0.3328

   b. 0.3328 +0.6 x (1-0.3328) = 0.86688
4. Cf percentage

   0.86688 x 100% = 86.686%

1. Hemorrhagic stroke
   Expert value x user value
   G 1 : 0.4 x 0.6 = 0.24
   G 2 : 0.4 x 0.8 = 0.32
   G 3 : 0.4 x 1 = 0.4
2. Combined Cf
   CFcombinedCF[H,E]1,2= CF[H,E]1 + CF[H,E]2 * [1 – CF[H,E]1]
   a. 0.24 + 0.32 x (1-0.24) = 0.4832
   b. 0.4832 +0.6 x (1-0.4832) = 0.68992
3. Cf percentage
   0.68992 x 100% = 68.992

Testing Accuracy System

Testing accuracy system expert is testing with method compare results diagnosis from expert in a way direct with results diagnosis from system expert with objective know accuracy from system expert diagnosis disease *stroke.*

Tab Testing

Table 2. Tab Testing

Name case	Symptom	System	Expert	Information
Case 1	G01, G02	Stroe (bleeding) hemorrhagic	Stroke (bleeding) hemorrhagic	Correct
Case 2	G 02 , G07, G08	Stroe (bleeding) hemorrhagic	Stroke (bleeding) hemorrhagic	Correct
Case 3	G11, G012, G013	Stroe (blockage) hemorrhagic	Stroke (blockage) hemorrhagic	Correct
Case 4	G 06, G 07, G 012	hemorrhagic stroke (blockage)	Strokenn hemorrhage (blockage)	Correct

Name case	Symptom	System	Expert	Information
Case 5	G 04, G05, G 06	hemorrhagic stroke (blockage)	Stroke non (blockage)	hemorrhagic	Correct
Case 6	G 02, G05, G 08	Stroe hemorrhagic (blockage)	Stroke (blockage)	hemorrhagic	Correct

Source: Data Processed

From the results *cross check* on December 27, 2022 between system with expert knowledge obtained record medical patient mark match obtained as many as 6 out of 6 different cases so that percentage its accuracy can counted use formula as following:

6 X 100% = 100%

6

With Thus, the results accuracy system using 6 data of 100%. Based on results said, then given interpretation and retrieval decision about quality system use qualification percentage in the table following:

Table 3. Qualification Values

No	Percentage	Qualification
1	80% - 100%	Very good
2	60% - 79%	Pretty good
3	50% - 59%	Not good
4	<49%	Not good

Source: Data Processed

Can seen from table qualification so system expert diagnosis *stroke* can walk and have accuracy with mark Enough Good.

Testing *Black Box*

Testing *Blackbox* is Testing done with method *black box* For test functional system.

Table 4. Admin Black Box Testing

No	Tested Process	Expected results	Succeed	
			Yes	No
1	*Login*	Displaying the Admin *Login* Page	√	
2	Admin *Dashboard*	Showing Admin *Dashboard*	√	
3	View User Data	Displaying User Data	√	
4	View Disease Data	Displaying Disease Data	√	
5	Add Disease Data	Showing *Add Form*	√	
6	Edit Disease	Showing Edit *Form*	√	
7	Remove Disease	Deleting Disease Data	√	
8	View Symptom Data	Displaying Symptom Data	√	
9	Add Symptom Data	Showing *Form* Add Symptom Data	√	
10	Edit Symptom Data	Showing Symptom Data Edit *Form*	√	
11	Delete Symptom Data	Deleting Symptom Data	√	
12	Look Data Base Knowledge	Displaying Knowledge Base Data	√	
13	Add Knowledge Base	Displaying the AddBase *Form* Knowledge	√	
14	Knowledge Base	Showing Knowledge Base Edit *Form*	√	
15	Delete Knowledge Base	Deleting Knowledge Base Data	√	
16	*Logout*	Exit Admin Page	√	

Source: Data Processed

Can seen from table 4 testing *blackbox* admin that all processes on the admin side are running with as should be in accordance with what is expected in the design process system.

Table 5. Black Box User Testing

No	The Process That Tested	Expected results	Succeed	
			Yes	No
1	*Dashboard*	Displaying the *User Home* Page	√	
2	Diagnosis Disease	Displaying the User's Personal Data Form	√	
3	Diagnosis	Showing Questions and Symptom Options	√	
6	Submit Symptoms	Showing Results Diagnosis , Solution and Recommendations Consumption	√	
7	Print Symptom	Showing Print Diagnostic Results	√	
7	*Logout*	Exit From *Dashboard Page* Users	√	

Source: Data Processed

Can seen from Table 5 Testing *Blackbox user* that all processes on the side users walk in accordance with what is expected in the design process system.

Decision Tree

Making tree decision aim for help simplify in the acquisition process knowledge. Tree decision designed in objective for know attributes (conditions) that can reduced so that make things easier in the search process decision. Tree image decision system expert diagnosis disease *stroke* using method *forward chaining and certainty factor* can seen in Figure 5.

Tree the above decision explain method *forward chaining* that is tracking to front that starts from a group facts with look for suitable rules with existing assumptions / hypotheses going to conclusion, example For look for conclusion P01 is needed facts with look for suitable rules with hypothesis in the form of G01, G02, G03, G04, G05, G06, G07, G08, G09, G10, G11, G12 and G013 for get conclusion in the form of P01.

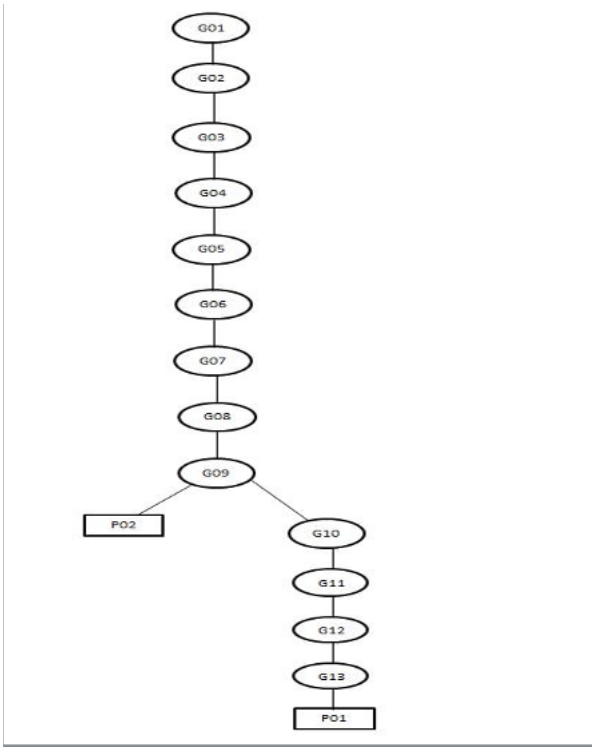


Figure 15. Tree decision

CONCLUSION

This study successfully developed a web-based expert system for stroke diagnosis integrating the Forward Chaining and Certainty Factor methods through a systematic development process encompassing requirements analysis, knowledge base construction, system design, implementation, and black-box functional testing. The system is capable of identifying stroke types along with associated symptoms and achieved a diagnostic accuracy of 86.68% based on cross-validation against expert clinical knowledge using six patient cases. This accuracy level is consistent with prior expert systems using combined inference methods in comparable medical domains. Black-box testing confirmed that all administrative and user-facing functionalities performed as intended.

The system demonstrates potential as a complementary tool for early stroke symptom detection and public health education, particularly given the growing burden of stroke in Indonesia and the limited availability of neurological specialists in many regions. The integration of rule-based inference with probabilistic confidence estimation aligns with contemporary approaches in clinical decision support systems that prioritize interpretability alongside diagnostic reliability. Furthermore, the web-based platform addresses accessibility barriers that are especially relevant for productive-age populations at elevated stroke risk. Future research should focus on expanding the testing dataset, incorporating a broader range of neurological conditions, and conducting user acceptance testing within hospital settings to assess practical feasibility and reliability.

ACKNOWLEDGEMENTS

The authors also acknowledge the support of the institution and research supervisor for their continued encouragement and constructive feedback throughout the development and writing process. Appreciation is likewise extended to the colleagues and peers who participated in system testing and provided valuable input during the evaluation phase.

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