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Abstract



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Forward chaining is one of the chaining methods other than backward chaining in the expert system. It starts from an event or fact to produce a solution. Prior to commencing, knowledge of a case must be represented. The case in this research is the problem of skin diseases caused by fungal infections experienced by humans. Knowledge about the type of skin diseases due to fungal infection was obtained from various sources of literature and experts. Then, the knowledge was represented using rules in the form of IF-premise THEN-conclusion. Forward chaining was performed on facts that match the state of the symptoms of skin diseases to make the most likely diagnosis of skin diseases and how to treat it. This system was developed based on computer program. System testing was done by consultation techniques between users and the system. The system asked questions as the premises that must be answered by the user. If the user's answer was in accordance with the rules that had been compiled as a form of knowledge representation, then the solution would be achieved as a conclusion. This solution was the most likely diagnosis of fungal skin disease.

Keywords: Forward Chaining; Fungal Skin Disease; Knowledge; Rule; Solution**Document Type:** Research Article**Affiliations:** 1: Informatics Engineering, Universitas Muhammadiyah Purwokerto, Purwokerto, Central Java, Indonesia 2: Faculty of Medicine, Universitas Gadjah Mada, Sleman, Special Region of Yogyakarta, Indonesia

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Knowledge Representation and Forward Chaining in the Diagnosis of Fungal Skin Diseases

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Forward chaining is one of the chaining methods other than backward chaining in the expert system. It starts from an event or fact to produce a solution. Prior to commencing, knowledge of a case must be represented. The case in this research is the problem of skin diseases caused by fungal infections experienced by humans. Knowledge about the type of skin diseases due to fungal infection was obtained from various sources of literature and experts. Then, the knowledge was represented using rules in the form of IF-premise THEN-conclusion. Forward chaining was performed on facts that match the state of the symptoms of skin diseases to make the most likely diagnosis of skin diseases and how to treat it. This system was developed based on computer program. System testing was done by consultation techniques between users and the system. The system asked questions as the premises that must be answered by the user. If the user's answer was in accordance with the rules that had been compiled as a form of knowledge representation, then the solution would be achieved as a conclusion. This solution was the most likely diagnosis of fungal skin disease.

Keywords: knowledge, rule, forward chaining, fungal skin disease, solution.

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1. INTRODUCTION

Skin diseases are disorders affecting the skin covering the body surface. The etiologies of skin diseases include bacterial and viral infection, fungal infection, parasitic infestation, insect bites, allergic reaction, autoimmunity, immunocompromised state, and poor hygiene. In Indonesia, most skin diseases are caused by bacterial, viral, and fungal infection as well as allergic reaction. This is a contrary of what mostly occur in Western countries where degenerative factors contribute more in skin diseases. Other factors affecting the development of skin diseases are behavior of the society and poor sanitation of the environment.¹

Fungal skin diseases or dermatomycoses are disorders of the skin, nails, hair, and mucous membranes caused by fungal infection.² Fungal skin infections are commonly found in Indonesia since it is a tropical country with hot and humid climate in addition to its hygiene problem. In Jakarta, those serve as second most common group of skin diseases after dermatitis. In other regions such Padang, Bandung, Semarang, Surabaya, and Manado, fungal skin infections are the 2nd to 4th most prevalent diseases compared to other group of diseases. Cutaneous and subcutaneous diseases were the top 10 diseases in hospital outpatient care in year 2010 with a total of 247,179 cases or 60.77%.³ The data showed that skin diseases affect many people in Indonesia which may reflect the low level of society care towards their skin health.

Early detection of the diseases can improve its management and may lead to more appropriate treatment.⁴ However, society still has low level of care towards diseases particularly skin

diseases; one of the causes is due to their poor understanding about the diseases. Therefore, it leads to inappropriateness of the disease treatments. In order to overcome that, it requires a system which has capability to come up with the most likely diagnosis of skin diseases as close to what an expert is able to do, considering that diagnosis of human diseases is a complicated process which demands a high level of expertise.⁵ To identify the most accurate treatment, it depends on the approaches used in the process of diagnosis. System that may be able to do such kind of task is an expert system which is part of an artificial intelligence. Comparing the results of expert system and physician's diagnosis showed an accuracy of 97.1%, sensitivity of 97.5% and specificity of 96.5%.⁶

An expert system works by reasoning or tracing from facts or symptoms to achieve a solution. This is called as chaining. Chaining is a simple method used by most inference engines to produce a line of reasoning. Chaining in expert system consists of 2 types which are forward and backward chaining. In forward chaining, the engine begins with the initial content of the workspace and proceeds toward a final conclusion. Otherwise, in backward chaining, the engine starts with a goal and finds knowledge to support that goal.

Some recent studies about expert system in assisting the process of human diseases diagnosis were an expert system to identify lung diseases and a system to diagnose diseases caused by tropical infections.^{7,8} Further, an expert system was to be developed to diagnose skin diseases using online system and Certainty Factor method.^{9,10} Another expert system about pediatric skin diseases had also been developed.¹¹

This study is an extension from a previous study which developed an expert system to help diagnosing fungal skin diseases in human using backward chaining method.¹² Therefore, further system development was carried out in this study and it aimed to show how the reasoning process using forward chaining works. Forward chaining was also used before in knowledge tracing in the diagnosis of lung and tropical infection diseases.^{7,8} Forward chaining is a data-driven method of deriving a particular goal from a given knowledge base and set of inference rules. In other word, data-driven reasoning is a reasoning which starts from a set of data and ends up at the goal considered as the conclusion. Inference rules are applied by matching facts to the antecedents of consequence relations in the knowledge base. The application of inference rules results in new knowledge (from the consequence of the relations matched), which is then added to the knowledge base.

2. EXPERIMENTAL DETAILS

2.1 Knowledge acquisition

Knowledge in this study was obtained from various sources.^{1, 2, 13, 14} Skin diseases to be included in this study were those caused by fungal infections.

2.2 Knowledge representation

Knowledge in this study was represented using decision table.

2.3 Chaining simulation

This study used forward chaining as in Figure 1. Chaining simulation was done using C++ programming language. This simulation showed how the tracing proceeds in diagnosing fungal skin diseases.

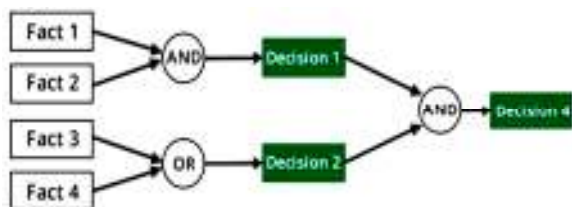


Figure 1. Forward chaining

The system started from a set of facts and a set of rules. It tried to find a way of using those rules and facts to deduce a conclusion or come up with a suitable course of action. Steps of applying forward chaining:

1. Take the facts in the fact database and see if any combination of these matches all the antecedents of one of the rules in the rule database.
2. When all the antecedents of a rule are matched by facts in the database, then this rule is triggered.
3. When a rule is triggered, it is then fired, which means its conclusion is added to the facts database.
4. If the conclusion of the rule that has fired is an action or a recommendation, then the system may cause that action to take place or the recommendation to be made.

3. RESULTS AND DISCUSSION

List of skin diseases caused by fungal infection consisted of 20 entities as shown in Table 1. There were 65 symptoms of fungal skin diseases that had been gathered. Those are enlisted in Table 2. Knowledge in this study was represented in the rule form of *IF premise THEN conclusion* as shown in Table 3. In this

representation, there were 20 rules in total. The premises were the symptoms of fungal skin diseases while the conclusion was a diagnosis of fungal skin disease. In accordance to the numbers of fungal skin diseases mentioned in Table 1, there were 20 rules created in total as presented in Table 3.

Table 1. List of skin diseases caused by fungal infection

No.	Diseases
1	Tinea Versicolor
2	Tinea Nigra Palmaris
3	Tinea Capitis Gray Patch Ringworm
4	Tinea Capitis Black Dot Ringworm
5	Tinea Capitis Kerion
6	Tinea Capitis Favosa
7	Tinea Barbae & Sycosis Barbae
8	Tinea Corporis
9	Tinea Imbricata
10	Tinea Pedis (Athlete’s Foot) of the Predilected Areas
11	Tinea Pedis (Athlete’s Foot) Interdigitalis
12	Tinea Manus
13	Tinea Unguium (Onychomycosis)
14	Tinea Cruris
15	Cutaneous Candidiasis
16	Nail Candidiasis
17	Sporotrichosis
18	Actinomycosis
19	Chromomycosis
20	Subcutaneous Phycomycosis

Table 2. Data about symptoms of fungal skin diseases

No.	Symptoms
1	Itchy skin aggravated by sweating
2	Severely itch
3	Mildly painful
4	Painful
5	Skin covered by fine thin squama (scales)
6	Skin covered by coarse thick squama (scales)
7	Tiny lesions as first symptom or insect bite
8	Macule(s) or patch(es) (discoloration of the skin without any elevation or depression)
9	Affecting palm(s) or sole(s)
10	Starting as brownish black spots which extend to the size of a coin
11	Well-demarcated rash(es) and lesion(s)
12	Affecting scalp and hair
13	Miliary papules around the hair follicles
14	Hair loss
15	Broken-off hairs at the scalp surface (moth-eaten hair loss)
16	Loose hair (hair is easily pulled out)
17	Leaving the black discolored macule(s)
18	The surrounding hair becoming dull
19	Scaly small boils
20	Yellowish-red papules covered with crusts (dried blood, debris, pus, or topical medicine)
21	Scaly macule(s)
22	Bad odor
23	Foul smelled
24	Located on the chin
25	Reddish pimples that sometimes suppurate
.	
.	
.	
65	Rubbery lump on palpation

Table 3. Rules

No.	RULES
1	IF Itchy skin aggravated by sweating AND Covered by fine thin squama (scales) AND Macule(s) or patch(es) (discoloration of the skin without any elevation or depression) THEN Tinea Versicolor
2	IF Itchy skin aggravated by sweating AND Macule(s) or patch(es) (discoloration of the skin without any elevation or depression) AND Affecting palm(s) or sole(s) AND Starting as brownish black spots which extend to the size of a coin AND Well-demarcated rash(es) and lesion(s) THEN Tinea Nigra Palmaris
3	IF Itchy skin aggravated by sweating AND Macule(s) or patch(es) (discoloration of the skin without any elevation or depression) AND Affecting scalp and hair AND Miliary papules around the hair follicles AND Hair loss THEN Tinea Capitis Gray Patch Ringworm
4	IF Itchy skin aggravated by sweating AND Affecting scalp and hair AND Broken-off hairs at the scalp surface (moth-eaten hair loss) AND Leaving the black discolored macule(s) AND The surrounding hair becoming dull THEN Tinea Capitis Black Dot Ringworm
5	IF Itchy skin aggravated by sweating AND Affecting scalp and hair AND Hair loss AND Loose hair (hair is easily pulled out) AND Scaly small boils THEN Tinea Capitis Kerion
6	IF Itchy skin aggravated by sweating AND Affecting scalp and hair AND Hair loss AND Loose hair (hair is easily pulled out) AND Yellowish-red papules covered with crusts (dried blood, debris, pus, or topical medicine) AND Scaly macule(s) AND Foul smelled THEN Tinea Capitis Favosa
7	IF Itchy skin aggravated by sweating AND Located on the chin AND Reddish pimples that sometimes suppurate AND Sores AND Inflamed follicle(s) THEN Tinea Barbae & Sycosis Barbae
8	IF Itchy skin aggravated by sweating AND Macule(s) or patch(es) (discoloration of the skin without any elevation or depression) AND Active bordered lesion(s) with the appearance of erythematous papules or vesicles AND Lesion(s) extending with scratching or excoriation AND Affecting the hairless areas of the skin (face, trunk, arm, leg) THEN Tinea Corporis
9	IF Itchy skin aggravated by sweating AND Severely itch AND Skin covered by coarse thick squama (scales) AND Well-demarcated rash(es) and lesion(s) AND Annular multilayered scales THEN Tinea Imbricata
10	IF Itchy skin aggravated by sweating AND Bad odor AND Located on the ankle, sole, and between the toes AND Squama (scales) and pustule(s) on the sole(s) AND Wet THEN Tinea Pedis (Athlete's Foot) of the Predilected Areas
11	IF Itchy skin aggravated by sweating AND Macule(s) or patch(es) (discoloration of the skin without any elevation or depression) AND Bad odor AND Located on the ankle, sole, and between the toes AND Squama and erosion(s) between the toes AND Wet AND Hyperkeratosis THEN Tinea Pedis (Athlete's Foot) Interdigitalis
12	IF Itchy skin aggravated by sweating AND Macule(s) or patch(es) (discoloration of the skin without any elevation or depression) AND Well-demarcated rash(es) and lesion(s) AND Scaly macule(s) AND Located on the hand(s) (from the wrist to the fingertips) AND Erythematous or red macule(s) AND Vesicles (serous fluid-filled sacs or blisters less than 1 cm in diameter) AND Polycyclic (flower-like shaped) lesion(s) THEN Tinea Manus
13	IF Itchy skin aggravated by sweating AND Infection on the nails AND Damaged nails AND Dull, brittle, and moldy nails AND Thickening of the areas adjacent to the nails AND Thickening of the nail surface AND Rough-surfaced nail(s) THEN Tinea Unguium
14	IF Itchy skin aggravated by sweating AND Well-demarcated rash(es) and lesion(s) AND Scaly macule(s) AND Erythematous or red macule(s) AND Located on the crural region and its surrounding (groin, perineum, buttocks, and genitals) AND Consisting of papules (solid elevations with distinct border which are less than 1 cm in diameter) THEN Tinea Cruris

Table 3. Rules (Cont.)

15	IF Itchy skin aggravated by sweating AND Mildly painful AND Macule(s) or patch(es) (discoloration of the skin without any elevation or depression) AND Hyperkeratosis AND Erythematous or red macule(s) AND Burning sensation on the lesion(s) AND Presence of grayish-white small ulcerations covered with a membrane AND Erosion(s) THEN Cutaneous Candidiasis
16	IF Itchy skin aggravated by sweating AND Mildly painful AND Infection on the nails AND Damaged nails AND Dull, brittle, and moldy nails AND Thickening of the nail surface AND Brownish-black colored nails AND Presence of vesicle(s), erosion(s), and squama on the base of the nails AND Erythema around the nails THEN Nail Candidiasis
17	IF Itchy skin aggravated by sweating AND Consisting of papules (solid elevations with distinct border which are less than 1 cm in diameter) AND Presence of nodule(s) (solid elevations with distinct border which are more than 1 cm in diameter) AND Formation of ulceration(s) and fistule(s) (skin (epidermis and dermis) lesions which have base, wall, border, and content) AND Elevated lesion wall AND Abscess formation (pus-filled sac inside the tissue) THEN Sporotrichosis
18	IF Itchy skin aggravated by sweating AND Blackish-red colored swelling AND Swelling transforming into solid lump AND Lump getting softened AND Crusted fistule (an abnormal passage or communication with dried blood, debris, pus, or topical medicine which may arise from chronic inflammation) THEN Actinomycosis
19	IF Itchy skin aggravated by sweating AND Well-demarcated rash(es) and lesion(s) AND Hyperkeratosis AND Vesicles (serous fluid-filled sacs or blisters less than 1 cm in diameter) AND Rough-surfaced lesion(s) resembling cauliflowers AND Presence of nodule(s) (solid elevations with distinct border which are more than 1 cm in diameter) AND Elevated lesion wall THEN Chromomycosis
20	IF Itchy skin aggravated by sweating AND Painful AND Tiny lesions as first symptom or insect bite AND Well-demarcated rash(es) and lesion(s) AND Formation of ulceration(s) and fistule(s) (skin (epidermis and dermis) lesions which have base, wall, border, and content) AND Swelling under the skin AND Rubbery lump on palpation THEN Subcutaneous Phycomycosis

Forward chaining implementation was simulated by using a computer program builded in C++ language. Based on the knowledge obtained, all the fungal skin diseases present with “itchy skin aggravated by sweating” as the first symptom. If an individual does not experience that symptom, fungal cause of skin disease is unlikely. However, that individual may still have skin disease due to another cause. Chaining was started with a set of facts and a set of rules as seen in Table 3. Based on those rules, a decision tree was built as the first step of forward chaining simulation arrangement. The following symptom asked by the system to a user after the first symptom (“itchy skin aggravated by sweating”) is one of the symptoms presented in Figure 2. Next, chaining was illustrated in a decision tree (Figure 3).

- Choose one of these symptoms according to your condition:

 1. Macule(s) or patch(es) (discoloration of the skin without any elevation or depression)
 2. Well-demarcated rash(es) and lesion(s)
 3. Affecting scalp and hair
 4. Mildly painful
 5. Bad odor
 6. Located on the chin
 7. Infection on the nails
 8. Consisting of papules (solid elevations with distinct border which are less than 1 cm in diameter)
 9. Blackish-red colored swelling

Figure 2. Initial questions asked by the system to a user

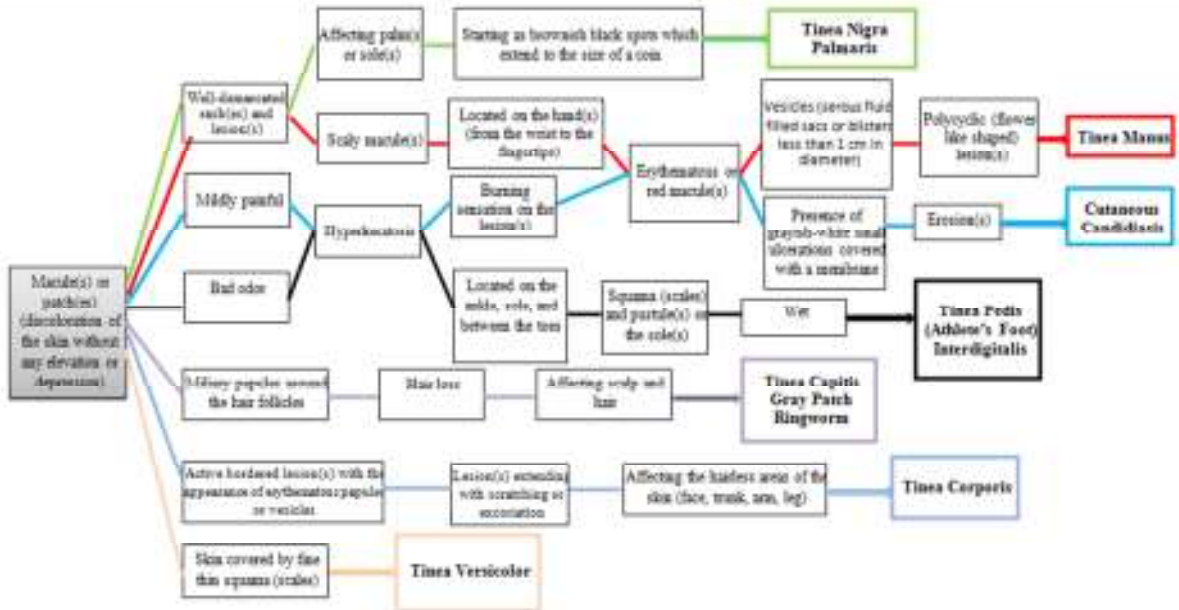


Figure 3. Decision tree of fungal skin disease diagnoses

Based on Figure 3, if an individual experiences symptom of “well-demarcated rash(es) and lesion(s)”, system will ask the next 2 symptoms which are “affecting palm(s) or sole(s)” and “scaly macule(s)”. If both are not experienced by that individual, system will not produce a solution. This occurs because of the lack of facts or symptoms that match the rule hence no diagnosis can be made. Otherwise, if a user presents with symptom of “affecting palm(s) or sole(s)”, the system will ask further about the next symptom whether it is “starting as brownish black spots which extend to the size of a coin”. If this symptom is present, the most likely diagnosis is “Tinea Nigra Palmaris”. The system will not make any solution if the individual does not have symptom of “starting as brownish black spots which extend to the size of a coin”.

4. CONCLUSIONS

Implementation of forward chaining has properties as the following:

- it applies the rules sequentially
- it randomly selects a rule
- it applies more specific rules first
- it prefers rules where conditions match a recently derived fact
- it derives consequences of a set of starting facts: only applying rules where at least one condition matches either with a starting fact or a derived fact
- fact base contains facts that are generally true. e.g. affecting palm(s) or sole(s)

- starting facts describe a concrete situation, e.g. one of fungal skin diseases.

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