Expert System for Diagnosing Osteoarthritis with Fuzzy Tsukamoto Method

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Abstract. Osteoarthritis is a degenerative joint disease involving the cartilage, the lining of the joints, ligaments, and bones, causing pain and stiffness in the joints that suffer from these symptoms. People often ignore pain that occurs when moving the shoulder, plate, knee and hand pain when it has great potential are the symptoms of the disease Osteoarthritis. Expert systems can be used as a system to identify disease Osteoarthritis. With Osteoarthritis disease diagnosis expert system then expected to help people to detect diseases early Osteoarthritis and can consult with a doctor before continuing to a more dangerous stage. In this research using Fuzzy Tsukamoto Algorithm method, which method is an extension of the reasoning Tsukamoto monotonous, every consequent formed IF-Then rules should be presented with a fuzzy set. As a result, output inference of each rule is given explicitly by predicate. Result is obtained by using a weighted average (center average defuzzifier). Symptoms of Osteoarthritis serve as fuzzy values which will then be sorted according to a predetermined membership function. After fuzzy value of the calculation has been obtained, then fuzzy value will be converted into firm value using a weighted average. From these results it can be concluded that the accuracy of the expert system that has been built to have an accuracy of 90% that is 18 of the 20 patients who had been tested using an expert system that has been built

1. Introduction
Osteoarthritis or commonly called calcification of joints which can cause major disruptions in daily living activities because joint is part of body that is most often used in various activities. Osteoarthritis is a degenerative disease of the joints in bones such as the joints in the hands, knees, neck and even the waist [5]. Osteoarthritis can cause pain, stiffness, and even deformity in the joints that have Osteoarthritis. Osteoarthritis is classified as the most common disease experienced by people in all corners of the world [1][2]. Starting from children to adults may be able to suffer from Osteoarthritis. Frequent handling of osteo cases is handled late because of people often ignore of early symptoms in knee joint, so needed an application of an expert system that can identify pain of joints in the hands, knees, neck and waist. In this research, expert system implemented using Fuzzy Inference System algorithm is used and the method used is the Tsukamoto method where the Tsukamoto method can provide accurate and dynamic results in accordance with the data provided [3][4].
2. Method
This section explains how Tsukamoto’s fuzzy method works. In Tsukamoto’s method, each rule takes the form of a link between causation or input-output where the antecedent and consequence must be related. Each of the rules is displayed using the fuzzy membership function, with a uniform membership function. Then to look for crisp or crisp results, a defuzzification formula called the "Center Average Defuzzifier Method" is used.

2.1. Data Symptoms of Osteoarthritis
The clinical factors and symptoms of osteoarthritis can be seen in the table 1 below. There are 10 symptoms given id G01-G10.

| gid | Symptoms                                      |
|-----|-----------------------------------------------|
| G01 | Age Range                                     |
| G02 | Body Weight Range                             |
| G03 | Smoker                                        |
| G04 | Trauma to the bone or joint                   |
| G05 | Having heavy work / activities                |
| G06 | Parents Osteoarthritic History                |
| G07 | Lump on shoulder and knee joint               |
| G08 | Pain when moving joints on shoulder and knee  |
| G09 | Stiffness on joint when moving                |
| G10 | Difficulty when moving the joints in long terms |

2.2. Osteoarthritis disease data
Osteoarthritis disease data can be seen in the table below. Based on these table, ostearthritis divided into 2 disease, there are acute and chronic.

| pid | Disease name |
|-----|--------------|
| P01 | Acute Osteoarthritis |
| P02 | Chronic Osteoarthritis |

2.3. Symptoms Membership Function
Here, membership functions for each symptom, there are 11 members function related with osteoarthritis. Below is a graphical image of the function.

2.3.1. Age Membership functions

Value in age symptoms can be seen based on the age range that has been defined in the lifetime membership function image which can be seen in Figure 1 below.
2.3.2. Body Weight Membership functions

Value on weight symptoms can be seen based on the weight range that has been established by the weight membership function, which can be seen in Figure 2 below.

![Body Weight Membership functions](image1.png)

Figure 2. Body Weight Membership functions

2.3.3. Smokers Membership Functions

Value of smoker’s symptoms is determined by knowing whether a user is a smoker or not. Based on symptoms of Smokers Membership Functions can be seen in Figure 3 below.

![Smokers Membership Functions](image2.png)

Figure 3. Smokers Membership Functions

2.3.4. Trauma Membership functions

Value of trauma symptoms is determined by question to the user whether user has suffered trauma to the bone, Trauma Membership functions can be seen in Figure 4 below.

![Trauma Membership functions](image3.png)
2.3.5. Heavy Worker Membership functions

Value of the symptoms of severe activity is determined by giving question to the user whether user has heavy activity such as basketball, rugby, football, or profession as a building labour etc. Heavy Worker Membership functions activity can be seen in Figure 5 below.

![Figure 5. Heavy Worker Membership functions](image)

2.3.6. Parents Disease History Membership Functions

Value of the symptoms from father and mother history is determined by the question to the user whether the user has a father/mother who has suffered from Osteoarthritis Parents Disease History Membership functions can be seen in Figure 6 below.

![Figure 6. Parents Disease History Membership Functions](image)
2.3.7. Lumps Membership functions

Value of the lump symptoms is determined by direction to user to touch the joint area on shoulder and knee. Then give question to the user, whether user feels the bump/swelling in area of the touched joints. Membership function lump can be seen in Figure 7 below.

![Figure 7. Lumps Membership functions](image)

2.3.8. Pain Membership functions

Value of pain symptoms is determined by giving question to user, whether user having experiences pain in shoulder/leg joints when moved. Pain Membership functions can be seen in Figure 8 below.

![Figure 8. Pain Membership functions](image)

2.3.9. Rigid Movement Membership Functions

Value of rigid symptoms is determined from question to user, whether user feels stiffness in joints when they try to move the joints Rigid Movement Membership functions can be seen in Figure 9 below.

![Figure 9. Rigid Movement Membership Functions](image)
2.3.10. Difficulty in Moving Joints Membership functions

Value of difficulty in moving symptoms is determined by question to user, whether user is
difficult to mobilize joints in user body, such as shoulders and knees. Difficulty in moving joints
Membership Function can be seen in Figure 10 below.

![Difficulty in Moving Joints Membership functions](image)

**Figure 10.** Difficulty in Moving Joints Membership functions

2.3.11. Diagnostic Results Membership functions

Membership function of diagnosis is the membership function used during the defuzzification
process. Diagnostic Results Membership Function can be seen in Figure 11 below.

![Diagnostic Results Membership functions](image)

**Figure 11.** Diagnostic Results Membership functions

3. Result and Discussion

Study case, patient X is 55 years old and has a body weight of 87kg wants to make a diagnosis
of himself whether he has Osteoarthritis. He is a smoker, and has experienced trauma to his
bones. He is a construction worker. His father and mother had never experienced osteoarthritis.
He felt swelling in the shoulder and knee joints, and pain when moving the shoulders and legs.
He felt a little stiff when moving his knee. Patient feels that joints in his body are difficult to
move when left in place for a long time.

1. First step, determine Membership Function from symptoms experienced by patient x. Mem-
bership function for each symptom is determined in Section 2 Symptom Membership Func-
tion. Based on answers given are crisp, value of membership function will be firm in accordance
with membership function of each symptom at the system design stage. Following table of
symptoms experienced by patients x.
Table 3. Data Input CF Value Symptoms.

| Symptoms          | Answer            | Membership Function | Value |
|-------------------|-------------------|---------------------|-------|
| Age               | 55 year           | 41-60 year          | 30    |
| Body Weight       | 87 kg             | 86-95 kg            | 40    |
| Perokok           | Smoker Yes        |                     | 30    |
| Trauma            | On Bones Ever     |                     | 50    |
| Heavy Activity    | Construction Worker Yes |                 | 30    |
| Parents OA History| none None None None |                    | 0     |
| Lump on joints    | Shoulder and knee 2 area |                | 80    |
| Pain when moving shoulder / knee | Shoulder and knee Both |         | 90    |
| Stiffness when moving | A little bit stiff when Moving Less |     | 25    |
| Difficulty when moving in long terms | Difficult to move Mid |              | 5     |

2. Second step is determine value of z. z value is result from Tsukamoto method’s fuzzy inference obtained by arranging all the symptoms given by patient X into the membership function of each symptom, then each membership function contains a value that can be used to find the value of z. The formula used is: $z = \frac{\sum(a * z)}{\sum(a)}$

\[
\begin{align*}
    z &= \frac{\sum(a * z)}{\sum(a)} \\
    &= \frac{a_1z_1 + a_2z_2 + a_3z_3 + a_4z_4 + a_5z_5 + a_6z_6 + a_7z_7 + a_8z_8 + a_9z_9 + a_{10}z_{10}}{\sum(a)} \\
    &= \frac{30 + 40 + 30 + 50 + 30 + 0 + 80 + 90 + 25 + 55}{10} \\
    &= \frac{430}{10} = 43
\end{align*}
\]

3. Final step is defuzzification where value of z is still a fuzzy has to be converted into crisp values based on the membership function of Osteoarthritis disease at stage of system design

| Membership function | Crisp             |
|---------------------|-------------------|
| 0 ~ 22              | Healthy           |
| 23 ~ 44             | Acute osteoarthritis |
| 45 ~ 60             | Chronic osteoarthritis |

According to the table above, value of z belongs to membership function Acute Osteoarthritis. Then diagnosis by Patient X is: Acute Osteoarthritis.

4. Conclusion

Conclusion of this research using Tsukamoto method’s fuzzy algorithm can be implemented in expert system of diagnosing Osteoarthritis. Testing expert system for diagnosing osteoarthritis Tsukamoto Method using data patients with osteoarthritis symptoms in referenced hospital produces an accuracy of 90%, 18 patients from 20 data of patients has diagnosis and results
from expert system match with diagnosis results made by doctors at the referenced hospital. The diagnosis results from application of this expert system can be used as reference material for further examination to the hospital or doctor specialist. For further research, needed for addition more than one expert Osteoarthritis so that symptoms as input data can be comparing for getting more accurate result and combining more than one method reference.

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