Abstract

In 2013 the number of patients with Diabetes Mellitus (DM) in the world has reached 382 million. It is estimated that the prevalence will increase 55% in 2035. As a form of our efforts to contribute to the prevention of this phenomenon we propose an application of computational intelligence by using fuzzy hierarchical model that has the ability to perform early detection against DM. In order to achieve the success of our propose method, we cooperate with one of the eastern Jakarta hospital laboratory in Indonesia as a facilitator of the data that we need during research and conducting interviews with two medical doctors at the same hospital as a form of knowledge acquisition process. The architecture of our proposed method is designed based on how a medical doctor concluded related to indication that someone has the potential against DM, which is the model has been adjusted with the data we have obtained from the authorities in the laboratory. As a form of evaluation that we do, we did a comparison of the data we have obtained from our method with the medical doctor decision which is equipped with the data from laboratory, and the result is 87.46% of the 311 relevant data is equal to medical doctor’s statement. In interpreting the conclusions that we get with the hospitals that cooperate with us, the results showed that the method we propose has meet the needs of the effectiveness and efficiency in performing early detection against DM and can help people in knowing the potential of DM since early.

1. Introduction

Number of patients with Diabetes Mellitus (DM) in the world has reach 382 million in 2013. It has been predicted that the prevalence will increase 55% in 2035, and claimed to have an impact one death every 6 to 10 seconds. DM is a complex debilitating disease that can lead to serious complications impact with characteristic of high blood glucose level in someone’s body, which is caused by body deficient or resistant to insulin.

The main cause of someone infected by DM has not been identified decidedly. However, it is known from related studies that complex diseases such as DM is mainly caused by a combination of genetic factors, environmental and
lifestyle. Researchers in related fields convey there is possibility that the large amount of data especially related to DM can contribute in order to provide information about someone’s potential against DM since early. Considering that dealing with large amount of data is often caused the measures to take decision with traditional methods run into problems, especially regarding to the high level of complexity and uncertainty factors. In order to overcome that problems, it has been possible to estimating the potential of DM in someone’s body with the application of computational intelligence techniques that demands efficiency and effectiveness in conducting an analysis of the available data.

As part of an effort to address these issues, in this paper we will discuss the application of fuzzy logic with hierarchical model as implementation of computational intelligence techniques in particular to identify and determine the potential for someone related to DM.

The rest of this paper consist as followed, the second section presents the studies that have relevance to the research methods and the primary domain. In the third section will be presented the data used and introduced fuzzy computational modelling with hierarchical model to obtain information related to someone’s potential against DM. The results will be presented and discussed in the fourth section along with the relevant discussion to be delivered and the fifth section in the form of conclusions that can be made of the research question.

2. Related work

This section will discuss some of the research that applying computational intelligence methods either single or combined methods (hybrid) as an effort that was proposed in the early detection of the someone’s potential against DM and other types of diseases.

Jayalakshmi and Santhakumaran propose improvements to the classification accuracy for the diagnosis of DM by using artificial neural network (ANN) which by Thirugnanam et al enhanced the ability of diagnosis with stage approach to early prediction of the DM with a combination of two techniques of computational intelligence in the form of fuzzy logic and artificial neural network and case-based reasoning for knowledge engineering techniques. To improve the accuracy of prediction results on each approach, Thirugnanam et al implements a rule-based algorithm to assist in classifying and predicting specific data. Meng et al conducted a study to perform a comparison between the performance of the three methods, namely artificial neural network prediction, modeling decision tree and logistic regression, to predict DM using the 12 risk factors. In this study suggest that the decision tree modeling produces the highest level of classification accuracy.

Lee and Wang proposed the application of fuzzy expert system for decision support applications against DM. Five-layer fuzzy ontology developed into a fuzzy expert system to describe the knowledge modeling under uncertainty and extend fuzzy domain ontology in DM.

Aribarg et al, Beloufa and Chikh, Ganji and Abadeh, applying the combined (hybrid) fuzzy logic and artificial bee colony algorithm, where the core of the use of Ant Colony-based classification is to extract rules of fuzzy. Aribarg et al proposed the optimization of the modified fuzzy ant-miner for medical diagnosis efficiency with the aim to describe the ability of simulates annealing (SA) to make modified fuzzy ant-miner more accurate. Ganji and Abadeh proposed a classification algorithm for diabetes diagnosis with a combination of Ant Colony optimization and Fuzzy Logic, named FCS-ANTMINER. Beloufa and Chikh proposed the artificial bee colony algorithm that has been modified to perform DM diagnose process. The submission of modifications to this algorithm has been used as part of the evolutionary algorithm with the goal of creating a more optimal fuzzy classifier to assist physicians in decision making.

The application of computational intelligence algorithm with Gini index-Gaussian Fuzzy decision tree to predict the incidence of early stage diabetes has been done by Varma et al. The core of the application of this algorithm to identify the correct split point and build a node of a binary tree with the Gini index. When the split attribute points have been chosen and there is no guarantee that the value of the split is right, then the fuzzification step on fuzzy Gaussian function needs to be executed.

Zhu et al proposed a multiple classification system to detect Type 2 Diabetes Mellitus (T2DM) that works by taking a person’s physiological data as input values and converts it into a vector input values through the process of transforming data with normalized value between 0 and 1. Then, the value of the vector will be used as training data for the classifier to produce a classification model that can identify someone’s potential against DM. Simultaneously,
Nguyen et al. propose the integration between fuzzy standard additive model with a genetic algorithm for medical data diagnosis. The main function of the use of fuzzy is to deal with the noise and complexity of medical data, while the standard additive model has influence in dealing with high dimensional data.

We can conclude that based on the study of related works, we assess that there has been no literature on the same domain that apply fuzzy hierarchical model as the main method of research. As a form of our efforts to contribute to the prevention of this phenomenon we propose an application of computational intelligence by using fuzzy hierarchical model that has the ability to perform early detection against DM.

3. Proposed method

In this section, we present in more detail about the use of data that is relevant with how to do early detection against DM in someone based on our survey activities and knowledge acquisition. More detailed presentation will also be made on description of the architectural design of fuzzy model that we propose as an effort for the early detection of someone’s potential against DM.

3.1. Data and knowledge acquisition

The data that will be used as an input values for the early detection against DM in this study is based on survey activities at one of the eastern Jakarta hospital laboratory in Indonesia and conducting interviews with two medical doctors at the same hospital as a form of knowledge acquisition.

From the hospital laboratory we carry an information and sample data about patients blood glucose tests, which is included patient’s age, fasting blood glucose test, 2-hour postprandial blood glucose test and HbA1c examination. Fasting blood glucose test will measures blood glucose level after someone does not have caloric intake for at least 8 hours but no more than 14 hours. 2-hour postprandial blood glucose test measures blood glucose exactly 2 hours after patient start eating and already had a fasting blood glucose test. HbA1c is an examination to determine the levels of glucose in blood using a high-performance liquid chromatography (HPLC), HbA1c examination can reflects someone’s average of glucose level in last 120 days.

Afterward, based on the medical doctor’s statement as a form of knowledge acquisition process to perform early detection against DM, we were informed that besides using laboratory data there are three symptoms including polyuria, polydipsia and polyphagia which can support medical doctor in order to perform early detection of someone’s potential against DM. Increased urination that resulting in a loss of glucose as well as water and electrolytes in the urine of a person called polyuria, based on the information we get from the medical doctor that polyuria conditions generally perceived someone at night. Polydipsia is a condition whereby someone can quickly feel thirsty and then consume excessive quantities of liquid, while not doing any exercise. Polyphagia is a condition associated with DM symptoms in which a person quickly feel hungry and increased appetite. Based on the interviews conducted with medical doctor has produced information that there are several factors that will become a medical doctor decision support in gaining clarity for the early detection of someone’s potential against DM, a person can be said to have an indication of DM if they felt at least two of the three symptoms (polyuria, polyuria, polyphagia), both of blood glucose level test are high (fasting blood glucose, 2-hour postprandial blood glucose) and has reached more than 40 years old. As a form of accuracy test, the result of HbA1c examination which acts as the real data will be compared with the output of the proposed method.

Based on the result of our knowledge acquisition process to determine whether a person has the potential to have DM or not, if someone is having 2 of 3 symptoms (polyuria, polydipsia and polyphagia) with 1 of the 2 blood glucose tests is high (fasting blood glucose and 2-hour postprandial blood glucose) it can be concluded that the person has the potential to have DM. If the conclusion is equipped with known that a person’s age has exceeded the age of risk, then that person can be said to be high potential against DM.

Furthermore, we are going to present the range value of each input variable as a basis for determining the fuzzy value. This range value is obtained based on the knowledge acquisition process with medical doctor, authorities in laboratory and international reference source. Starting from the information that we get against patient’s age factor. Henceforth, we are going to present the information about range value for blood glucose tests that will be shown in Table 1 and the range value of symptoms related to DM that will be shown in Table 2.
Based on the results of the knowledge acquisition process with the medical doctor, we obtained information that a person has the potential against DM at the age of 40 to 50 years old.

We have conducted an analysis of the data that we have obtained from the laboratory, we get the results that the youngest patient with DM is 43 years old.

Based on international reference source\(^1\), we obtained information that DM’s patients is generally found in the age of 40 to 59 years old.

### Table 1. The range value of blood glucose test.

<table>
<thead>
<tr>
<th>Blood glucose test</th>
<th>Normal (mg/dl)</th>
<th>High (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting blood glucose (based on hospital laboratory)</td>
<td>between 70 and 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>Fasting blood glucose (based on the medical doctor’s statement)</td>
<td>between 80 and 126</td>
<td>&gt; 126</td>
</tr>
<tr>
<td>2-hour postprandial blood glucose (based on hospital laboratory)</td>
<td>between 70 and 140</td>
<td>&gt; 140</td>
</tr>
<tr>
<td>2-hour postprandial blood glucose (based on the medical doctor’s statement)</td>
<td>between 100 and 150</td>
<td>&gt; 150</td>
</tr>
</tbody>
</table>

### Table 2. The range value of symptom by medical doctor’s statement.

<table>
<thead>
<tr>
<th>Types of symptoms</th>
<th>Normal value (times)</th>
<th>Potential value (times)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polydipsia (not doing any exercise)</td>
<td>between 5 and 9 (8 ounces)</td>
<td>more than 9 (8 ounces)</td>
</tr>
<tr>
<td>Polyphagia (within a day)</td>
<td>between 4 and 6</td>
<td>more than 6</td>
</tr>
<tr>
<td>Polyuria (perceived at night)</td>
<td>between 2 and 4</td>
<td>more than 4</td>
</tr>
</tbody>
</table>

### 3.2. Fuzzy hierarchical model

Henceforth, we propose the implementation of computational intelligence technique with fuzzy hierarchical model to illustrate the method that medical doctor use to perform early detection against DM based on our survey activities. The model that has been established based on these needs are presented in Fig. 1 and has been adapted to the relevant data with based on our knowledge acquisition activities.

In Fig. 1 presents the flow process of our proposed method that can be used for early detection of a person against DM. The model variables are classified into 3 types: input variable, temporary variable and output variable.

- **Input variable**, consisting of the value of polydipsia, polyphagia, polyuria, fasting blood glucose, 2-hour postprandial blood glucose and age. The value of the input variable is obtained directly from the user.
- **Temporary variable**, consisting of the value of oral risk that obtained from the fuzzy inference process between polydipsia and polyphagia. Symptom risk that obtained from the fuzzy inference process between oral risk and polydipsia. Blood glucose risk that obtained from the fuzzy inference process between fasting blood glucose and 2-hour postprandial blood glucose. All risk that obtained from the fuzzy inference process between symptom risk and blood glucose risk.
- **Output variable**, is a variable that provide information about the final result. The outcome of output variable contains information about whether someone has no potential against DM, someone has the potential against DM and someone has a high potential against DM.

In generating value for temporary variable and output variable, we use the rules that will be a basis for determining the final outcome of each fuzzy inference process. In the process of laying down the rules, we are guided by the medical doctor’s statement that we have acquired in the interview process. Each fuzzy inference process (5 process) consists of 9 rules to be able to determine the value of temporary variable and output variable, it can be concluded that by using this model requires 45 rules to obtain the final result related to someone’s early detection against DM.

As an example Fig. 2 illustrates the fuzzy inference process between age factor as input variable and all risk as temporary variable to produce the final result, (a) starting with the inclusion of the value of age factor directly from
Fig. 1. Fuzzy hierarchical model architecture for early detection against DM

<table>
<thead>
<tr>
<th>Rule No.</th>
<th>Rule Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule 1</td>
<td>if (AllRisk is Negative) and (Age is NoRisk) then (Result is NoPotential)</td>
</tr>
<tr>
<td>Rule 2</td>
<td>if (AllRisk is Potential) and (Age is NoRisk) then (Result is Potential)</td>
</tr>
<tr>
<td>Rule 3</td>
<td>if (AllRisk is Positive) and (Age is NoRisk) then (Result is Potential)</td>
</tr>
<tr>
<td>Rule 4</td>
<td>if (AllRisk is Negative) and (Age is Risk) then (Result is NoPotential)</td>
</tr>
<tr>
<td>Rule 5</td>
<td>if (AllRisk is Potential) and (Age is Risk) then (Result is Potential)</td>
</tr>
<tr>
<td>Rule 6</td>
<td>if (AllRisk is Positive) and (Age is Risk) then (Result is HighPotential)</td>
</tr>
<tr>
<td>Rule 7</td>
<td>if (AllRisk is Negative) and (Age is HighRisk) then (Result is NoPotential)</td>
</tr>
<tr>
<td>Rule 8</td>
<td>if (AllRisk is Potential) and (Age is HighRisk) then (Result is HighPotential)</td>
</tr>
<tr>
<td>Rule 9</td>
<td>if (AllRisk is Positive) and (Age is HighRisk) then (Result is HighPotential)</td>
</tr>
</tbody>
</table>

Table 3 show 1 of 5 packages of rules that use to operate fuzzy hierarchical model for early detection against DM. In that case 1 package of rules in our method which have 9 items will produce the final result after our method execute 4 earlier rules to produce Oral risk, Blood glucose risk, Symptom risk and All risk with different composition of rules.
4. Results and discussion

In this section will be reviewed on the use of data and proposed method based on the result that we obtained. As an illustration of the use of data and enforcement of knowledge acquisition into the method that we propose, we will present the stages of how the data can be processed to be a final result in the form of early detection of DM. As an example of the input data will be presented in Table 3 and will be continued with an overview of the processes that occur in the method we propose.

Table 4. An example of the input data.

<table>
<thead>
<tr>
<th>Input variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polydipsia</td>
<td>11 times to drink</td>
</tr>
<tr>
<td>Polyphagia</td>
<td>6 times to eat</td>
</tr>
<tr>
<td>Polyuria</td>
<td>3 times at night</td>
</tr>
<tr>
<td>Fasting blood glucose level</td>
<td>135 mg/dL</td>
</tr>
<tr>
<td>2-hour postprandial blood glucose level</td>
<td>147 mg/dL</td>
</tr>
<tr>
<td>Age factor</td>
<td>53 years old</td>
</tr>
</tbody>
</table>

All the input value that has been accepted in the form of crisp values will be converted into fuzzy values through the process of fuzzification. The fuzzy inference process will be divided into five stages as stated in Fig. 1, after that each of inference process will be executed based on the placement of variables that have been determined and will be end with a defuzzification process.

As shown in Fig. 3 is the appearance of the surface that is generated based on each fuzzy inference process in processing the input data into a final result or temporary results. Based on data in Table 4, in the early stages of inference process will process polydipsia and polyphagia as input variable in order to generating oral risk as temporary variable. With reference to the surface in (Fig. 3: part a), it can be concluded that from the data sample as shown in Table 3, has the possibility of having 2 of 3 symptoms. Followed by a process of inference (Fig. 3: part b) to obtain the value of symptom risk by using polyuria and oral risk, the results of these variables still declared 2 of 3 symptoms have occured in the data. Meanwhile, in the third stage of inference process (Fig. 3: part c) will process the input variables of fasting blood glucose and 2-hour postprandial blood glucose to generate blood glucose risk value. The results that obtained from this computation found that 2 of 2 blood glucose checks is high. In (Fig. 3: part d) describe the surface of inference process between blood glucose risk and symptom risk to generate the value of all risk variable, until reaching the variable of all risk we get the conclusion that based on the data provided from Table 3
that was found 2 symptoms with 2 high blood glucose level. If we refer to the medical doctor’s statement, the results can already be concluded that the input data shows that someone has the potential against DM has occured, but the data can still be reinforced by the age factor that can conclude whether a person just has the potential against DM or has a high potential which meant almost positive to DM. In this case it has been found that someone had entered the age of risk for DM. Based on (Fig. 3: part e) it can be concluded that the data which presented as examples of cases has the result that a person has a high risk potential of DM.

Henceforth, we will discuss about how this method is evaluated. The evaluation process conducted by comparing the results issued by the method that we propose with the medical doctor’s assessment based on the degree of similarity to his opinion. Performing the comparison of the data related to the field of health research is also carried out by Castanho et al\textsuperscript{20} to predicting pathological stage of prostate cancer and Kelecs et al\textsuperscript{21} for diagnosis breast cancer. With 311 numbers of relevant data we find that the results that have been launched by the architecture of fuzzy model that we propose is 87.46\% equal to medical doctor’s statement which also uses the data from the laboratory related to whether someone has no potential against DM or someone has the potential against DM. However, there is 12.54\% difference between our results with the medical doctor’s statement. If there is a real data shown that someone got a positive with DM but the there is no potential against the age, our architectural of fuzzy model will conclude that it is only potential against DM not high potential against DM. The matching process is done between our final result with HbA1c examination which acts as the real data are used by medical doctors as a source. In this paper we use Matlab as software to perform computation of fuzzy hierarchical model with centroid as defuzzification technique.

5. Conclusion

In this paper, we present an application of computational intelligence by using fuzzy hierarchical model that has the ability to perform early detection and identify someone’s potential against DM. Determination of the use of the method that we propose is based on the knowledge acquisition process with medical doctors, where is the architectural design of the model has been adjusted with the data acquisition based on our survey activities at one of the eastern Jakarta hospital laboratory in Indonesia. It can be concluded that the measures for early detection against DM can be done by using fuzzy hierarchical model as a form of early prevention of positive DM, this is evidenced by the 87.46\% of the 311 relevant data is equal to medical doctor’s statement. However, this method needs further development for the sake of a better functioning.
References