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A fuzzy information-based approach for breast cancer risk factors assessment

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A B S T R A C T

The aim of this study is to define the risk factors that are effective in Breast Cancer (BC) occurrence, and to construct a supportive model that will promote the cause-and-effect relationships among the factors that are crucial to public health. In this study, we utilize Rule-Based Fuzzy Cognitive Map (RBFCM) approach that can successfully represent knowledge and human experience, introducing concepts to represent the essential elements and the cause-and-effect relationships among the concepts to model the behavior of any system. In this study, a decision-making system is constructed to evaluate risk factors of BC based on the information from oncologists. To construct causal relationship, the weight matrix of RBFCM is determined with the combination of the experts' experience, expertise and views. The results of the proposed methodology will allow better understanding into several root causes, with the help of which, oncologists can improve their prevention and protection recommendation. The results showed that Social Class and Late Maternal Age can be seen as important modifiable factors; on the other hand, Benign Breast Disease, Family History and Breast Density can be considered as important factors as non-modifiable risk factors. This study is somehow weighing the interrelations of the BC risk factors and is enabling us to make a sensitivity analysis between the scenario studies and BC risk factors. A soft computing method is used to simulate the changes of a system over time and address "what if" questions to compare between different case studies.

1. Introduction

Cancer has been among the most important health problems recently. Due to frequent occurrence rates and high mortality, cancer was ranked fourth among the known-cause of death in 1970s but now it comes second after the cardiovascular disease, which is the leading cause of death. Breast cancer (BC) has the second highest incidence rate in the world after the lung cancer and it is the leading cause of death in terms of cancer in women [1]. BC incidence and mortality may have conversion in different geographical areas. Though developed countries report higher rates of BC incidence and mortality, changes in the incidence of BC are most dramatic in low–middle income countries (LMC) including Turkey [2]. Overall, BC mortality declined thanks to higher-awareness and advances in detection, protection and treatment. However, it is well known that BC requires an expensive treatment as well as the use of limited resources. All of these bring burden on not only patients but also governments. Thus, originating strategies against BC prevention, protection and treatment have crucial value.

Medical decision systems are complex systems that can be decomposed to non-related and related subsystems and elements, where many factors have to be taken into consideration that may be complementary, contradictory and competitive. These factors have a bilateral influence on each other and determine the overall clinical decision within a different angle. Building a mathematical model to identify the illness had previously been advocated using statistical model [3], generalized linear models [4] and so on.

In this paper, a fuzzy cognitive maps (FCMs) approach is presented in order to explore the importance of these factors in medical decision making. To this purpose, a framework is formalized, based on the critical analysis of literature and experts opinions, in terms of factors affecting breast cancer and the causal relationship between them. After that, an application of FCMs approach is developed for the assessment of such factors in terms of influence on BC.

Fuzzy Cognitive Maps (FCMs) can successfully represent knowledge and human experience, introducing concepts to represent the essential elements and the cause-and-effect relationships among the concepts to model the behavior of any system. In this study, we

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propose Fuzzy Cognitive Map (FCM) model that can help BC oncologists to better identify and evaluate the weights of modifiable and non-modifiable factors that are contributing to the occurrence of BC in their patients. FCM is a relatively new soft computing approach that makes use of the existing experience in the operation of a complex system and compound fuzzy logic and neural networks. Another very useful property of FCM is enabling the use several expert opinions and providing the opportunity to predict the degradation of a product. Thus, FCMs are compatible with medical decision support systems. In this study for the construction of FCM, fuzzy inference system (FIS) is used. FIS is a rule-based method and uses fuzzy weights by using linguistic representation with an associated fuzzy set, instead of binary variables. In this paper, the opinions of the BC experts are combined with the help of Rule-Based FCM (RBFCM), main risk factors are organized in order, eventually, and the relations among the factors are brought into light. RBFMC is an efficient knowledge representation and reasoning method, which is based on human knowledge and experience. It accommodates the knowledge-based building property and can be constructed by experts and/or historical data. The advantageous characteristics of this approach such as simplicity, supporting of inconsistent knowledge, and circle causalities for knowledge make it applicable to many diverse scientific areas from knowledge modeling, prediction and decision making. The results of the proposed methodology will allow better understanding into several root causes, with the help of which, oncologists can improve their prevention and protection recommendation.

This paper is organized as follows: The next section presents an overview to BC and reviews risk factors for BC. In Section 3, the base concepts and the construction process of FCM are defined. In Section 4, the application of RBFCM to BC risk factors is done to indicate causal relationship. This section generates the weights of factors and presents a scenario analysis to propose the preventive actions against BC. The study is concluded in Section 5.

2. An overview to BC

BC emerges in breast tissues, usually the ducts (tubes that carry milk to the nipple) and lobules (glands that make milk). BS is the most common female cancer and the first most common cause of cancer in women mortality. The etiology of BC has great number of factors [5]. The risk factors for BC can be divided into “factors that cannot be modified” and “life style related factors that can be modified”.

3. Fuzzy Cognitive Maps (FCMs) and fuzzy inference systems(FIS)

3.1. Methodology of FCM

FCM is a causal knowledge-driven methodology for modeling complex decision systems, coming out from the combination of fuzzy logic and neural networks [32]. Extensions by Taber and Kosko [32–34] allow fuzzy numbers or linguistic terms to be used to describe the degree of the relationship between concepts in the FCM. FCM has been widely used in modeling and preparing decision supportive systems tool in different scientific and managerial problems. The medical decision process is complex because data collection is demanding and the combination of these data is vague, confusing or tough to interpret. At this point, FCM helps to overcome these difficulties and it has been used in many different medical research areas [35–39].

A FCM describes the behavior of a knowledge-based system in terms of concepts: each concept represents an entity, a state, a variable, or a characteristic of the system [33]. FCMs include concept

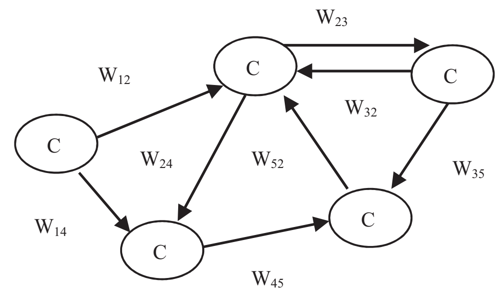

Fig. 1. Graphical representation of a FCM.

nodes and weighted arcs that are graphically showed as a signed weighted graph with feedback. Signed weighted arcs, connecting the concept nodes, display the causal relationship that exists among concepts. Generally, concepts of a FCM represent key-factors and characteristics of the modeled complex system and stand for events, goals, inputs, outputs, states, variables and trends of the complex system taken as model [40]. Concepts variables are represented by nodes and this set can be shown like $C=\{C_1,C_2,...,C_n\}$. Arcs (C_j,C_i) are used to define causal links between concepts; that is how concept C_j causes concept C_i. Causality between concepts allows degrees of causality and not the usual binary logic, so the weights of the interconnections can range in the interval [−1,1] or linguistic terms, such as “negatively very strong”, “zero”, “positively weak”, etc. Fig. 1 illustrates the graphical representation of a simple FCM. (Fig. 2.)

The sign of w_{ij} indicates whether there is a relationship between concepts C_i and C_j, or not. If $w_{ij}>0$, positive causality, if $w_{ij}<0$, negative causality and if $w_{ij}=0$, no relationship between concepts C_i and C_j. The direction of causality indicates whether concept C_i causes concept C_j, or not, or vice versa. These parameters have to be considered when a value is assigned to weight w_{ij}. So, for example, a decision of the example to create C_4 will cause an increase in C_5 to a degree w_{45}. The value of each concept is calculated, computing the influence of other concepts to the specific concept, by applying the following calculation rule:

$$A_i^{(k+1)} = f\left(A_i^k + \sum_{\substack{J \neq I \\ J=1}}^{N} A_j^{(k)w_{ji}} \right) \quad (1)$$

where $A_i^{(k)}$ is the value of concept C_i at iteration step k, $A_j^{(k+1)}$ is the value of the concept C_j at iteration $k+1$, w_{ji} is the weight of the connection from C_j to C_i and f is a threshold function.

3.2. Overview of fuzzy inference system (FIS) and rule base reasoning

In order to be able to use the linguistic model, we need an algorithm that allows us to compute the output value, given some input value. This algorithm is called the *fuzzy inference* algorithm (or system). A FIS is a rule base reasoning way of mapping an input space to an output space using fuzzy logic. The set of rules in a fuzzy expert system is known as *knowledge base*. The functional operations in FIS proceed in the following four steps; evaluate the input for each rule, obtain each rule’s conclusion, aggregate conclusions and defuzzification.