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Esophageal cancer prediction based on qualitative features using adaptive fuzzy reasoning method

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KEYWORDS

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Risk degrees

Abstract Esophageal cancer is one of the most common cancers world-wide and also the most common cause of cancer death. In this paper, we present an adaptive fuzzy reasoning algorithm for rule-based systems using fuzzy Petri nets (FPNs), where the fuzzy production rules are represented by FPN. We developed an adaptive fuzzy Petri net (AFPN) reasoning algorithm as a prognostic system to predict the outcome for esophageal cancer based on the serum concentrations of C-reactive protein and albumin as a set of input variables. The system can perform fuzzy reasoning automatically to evaluate the degree of truth of the proposition representing the risk degree value with a weight value to be optimally tuned based on the observed data. In addition, the implementation process for esophageal cancer prediction is fuzzily deducted by the AFPN algorithm. Performance of the composite model is evaluated through a set of experiments. Simulations and experimental results demonstrate the effectiveness and performance of the proposed algorithms. A comparison of the predictive performance of AFPN models with other methods and the analysis of the curve showed the same results with an intuitive behavior of AFPN models.

1. Introduction

Expert systems can be represented as a system with knowledge base of rules, and inference engine. The main concept of an expert system is the rule based systems, where the facts and rules represent the main referencing part of domain experts (Yang et al., 2003; Kuo and Chen, 2013).

The graphics as a model is easy for scientists to represent in their application domain. Most current scientists related to studying under the concept of FPNs (Li et al., 2000; Shen, 2003; Wai and Chu, 2007) are focusing on applying fuzzy reasoning mechanism over the adaptive FPN structure rather than utilizing fuzzy Petri net formalism to improve reasoning. Accurate algorithm AFPNs were thus proposed to estimate a risk degree of esophageal cancer problems with high performance. In this paper, our technique employed to model esophageal cancer problem is based on an AFPN. The technique uses 9 fuzzy rules which include the C-reactive protein (CRP) and albumin as two fuzzy input variables, and the risk degree as the output from the defuzzification stage.

Esophageal cancer is one of the most killer malignancies, and all survival rates are still unclear. All signs of the disease

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of esophageal cancer which are often insidious at the onset, exclude early diagnosis (Schneider and Urba, 2007). It is known that the patients, after undergoing surgery for esophageal cancer, suffer from several problems that affect most aspects of quality of life for a long time (Djärv et al., 2008). Most of the patients present with cancer related problems and very few with early stage disease. The only real prospect of cure for early stage disease of cancer lies in surgical resection (Wang et al., 2009). With the high tumor-free survival rates, esophagectomy has been the standard treatment for patients with early esophageal cancer, with which all other therapies are considered (Chang et al., 2012).

More researches in the field of the esophageal cancer are presented. A Chang et al. Chang et al. (2012) proposed a process model for a fuzzy logic to improve the predictive performance of a risk score based on the C-reactive protein and albumin. Bhaskar et al. Bhaskar et al. (2012) presented and studied the fluorescence of the essential amino acid tryptophan in dissociated cells of the esophagus as well as in the esophageal tissue. Naoto et al. Naoto et al. (2009) introduced a weight tuning method for constructing multiclass classifier problems including a synthesized data set and some cancer diagnosis data sets from gene expression profiling. Mathe et al. Mathé et al. (2009) discovered that the low miR-375 expression was associated with poor prognosis in esophageal cancer, and then looked at the inflammatory risk score of adenocarcinoma. Yue et al. Yue et al. (2013) presented a HSCORE method to evaluate the predictive value of SIRT3 expression levels on esophageal cancer outcome. Some studies have focused on this problem in the diagnosis of esophageal cancer (Deans et al., 2007; Hamdan et al., 2010; Ramsey et al., 2007; McMillan et al., 2007). In this study, we determined the predictive value of risk degree for esophageal cancer prognosis.

We examined the values between the serum concentrations of C-reactive protein (CRP) and albumin as a set of input data of esophageal cancer. Our algorithm of the AFPN model can obtain a better or the same set of grades of risk degree than the conventional fuzzy logic as in Chang et al. (2012) by using the weight values specified for each place to be optimally tuned based on the observed data. The results demonstrate that, in most situations, our method can improve risk degree accuracy over CRP and albumin as input values. This illustrates that the AFPN model is able to perform as well as (Chang et al., 2012). Noting that the AFPNs approach could be a very good alternative to other methods of biological processes.

The rest of the paper is organized as follows: Section 2 presents brief introductions of esophageal cancer. Section 3 presents our FPN approach to creating the AFPN model of the esophageal cancer with the reasoning Algorithm. Section 4 presents the modeling and description of reasoning process and a five-layer fuzzy model of petri net. Section 5 presents fuzzy rules denoted as certainty factors, fuzzy sets, and rule verification. An execution of the AFPN model of the esophageal cancer and utilizing the algorithm is given in Section 6. In Section 7 we conclude the paper.

2. Brief introductions of esophageal cancer

Esophageal cancer is one of the most killer malignancies, and all survival rates are still unclear. All signs of the disease of esophageal cancer which are often insidious at the onset,

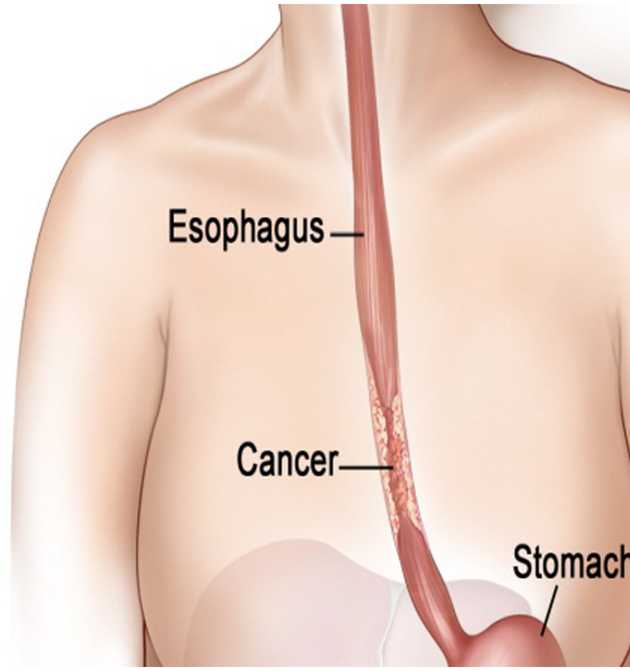

Figure 1 Illustration of the esophageal cancer (Brown et al., 2008).

exclude early diagnosis (Schneider and Urba, 2007). It is known that the patients, after undergoing surgery for esophageal cancer, suffer from several problems that affect most aspects of quality of life for a long time (Djärv et al., 2008). Despite technological advances of improved diagnosis and therapeutics the prognosis for esophageal cancer remains inadequate.

The risk is real and we can describe the risk factors of esophageal cancer as a set of factors such as, exposure of esophageal tissue to acid, alcohol consumption, possibly hot liquids, tobacco smoke, and, unhealthy diet (Jagannath et al., 2013). The diagnosis of esophageal cancer at an advanced stage, making by surgical excision feasible for only 30–40% of patients (Schneider and Urba, 2007; Brown et al., 2008). Fig. 1 illustrates the well-known esophageal cancer with the organ that connects the mouth to the stomach.

3. Adaptive of fuzzy reasoning algorithm

3.1. Formal basis of adaptive fuzzy Petri net

In this section, we present an adaptive fuzzy Petri net model to solve the problem of esophageal cancer. Following are a few definitions of FPN that are needed to comprehend the modeling capability of AFPN. Fig. 2 shows an example of the AFPN model. We can use AFPN to represent the fuzzy production rules. For example, the following fuzzy production rule can be modeled by a FPN as shown in Fig. 2.

R_i : IF d_i THEN $d_k(\lambda_1, \mathrm{CF} = \mu_1, w_1)$

where μ_i is the value of the certainty factor (CF) which indicates the degree of belief of the rule R_i, and $\mu_i \in [0,1]$. If the antecedent portion or consequence portion of a fuzzy production rule contains "and" or "or" connectors, then it is called a