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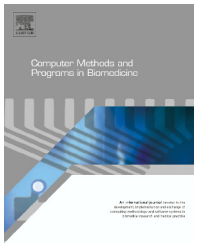

Multi-period medical diagnosis method using a single valued neutrosophic similarity measure based on tangent function

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ABSTRACT

Because of the increased volume of information available to physicians from advanced medical technology, the obtained information of each symptom with respect to a disease may contain truth, falsity and indeterminacy information. Since a single-valued neutrosophic set (SVNS) consists of the three terms like the truth-membership, indeterminacy-membership and falsity-membership functions, it is very suitable for representing indeterminate and inconsistent information. Then, similarity measure plays an important role in pattern recognition and medical diagnosis. However, existing medical diagnosis methods can only handle the single period medical diagnosis problem, but cannot deal with the multi-period medical diagnosis problems with neutrosophic information. Hence, the purpose of this paper was to propose similarity measures between SVNSs based on tangent function and a multi-period medical diagnosis method based on the similarity measure and the weighted aggregation of multi-period information to solve multi-period medical diagnosis problems with single-valued neutrosophic information. Then, we compared the tangent similarity measures of SVNSs with existing similarity measures of SVNSs by a numerical example about pattern recognitions to indicate the effectiveness and rationality of the proposed similarity measures. In the multi-period medical diagnosis method, we can find a proper diagnosis for a patient by the proposed similarity measure between the symptoms and the considered diseases represented by SVNSs and the weighted aggregation of multi-period information. Then, a multi-period medical diagnosis example was presented to demonstrate the application of the proposed diagnosis method and to indicate the effectiveness of the proposed diagnosis method by the comparative analysis. The diagnosis results showed that the developed multi-period medical diagnosis method can help doctors make a proper diagnosis by the comprehensive information of multi-periods.

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1. Introduction

In medical diagnosis problems, due to the complexity of various diseases and the lack of knowledge or data about the problem domain, crisp data are sometimes unavailable as medical diagnosis contains lots of uncertainties. Uncertainty is an important phenomenon of medical diagnosis problems. A symptom is an uncertain indication of a disease. Hence, the uncertainty characterizes a relation between symptoms and diseases. Thus, working with the uncertainties leads us to accurate decision making in medical diagnosis problems. In most of the medical diagnosis problems, there exist some patterns, and then experts make decision according to the similarity between an unknown sample and the basic patterns. However, the arguments introduced from an unknown sample may be vague or fuzzy in nature. To represent incomplete and uncertainty information, Zadeh [1] firstly proposed fuzzy set theory. Its characteristic is that a membership degree is assigned to each element in the set. Since then, various extensions of this concept have been introduced by many researchers. For example, Atanassov [2] extended fuzzy sets to intuitionistic fuzzy sets (IFSs). The prominent characteristic of IFS is that a membership degree and a non-membership degree are assigned to each element in the set. Since there is a number of uncertainties in medical diagnoses, they are the most interesting and fruitful areas of applications in intuitionistic fuzzy set theory. Hence, various medical diagnosis methods have been presented under the general framework of IFSs [3,4]. Recently, Ye [5] put forward cosine similarity measures for IFSs and applied them to pattern recognition and medical diagnosis. Hung [6] introduced an intuitionistic fuzzy likelihood-based measurement and applied it to medical diagnosis and bacteria classification problems. Tian [7] developed the cotangent similarity measure of IFSs and applied it to medical diagnosis.

However, IFSs can handle only incomplete and uncertainty information but not indeterminate and inconsistent information which exists usually in real situations. To deal with this kind of indeterminate and inconsistent information, Smarandache [8] originally proposed the concept of a neutrosophic set from a philosophical point of view. A neutrosophic set A in a universal set X is characterized independently by a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$ and a falsity-membership function $F_A(x)$. The functions $T_A(x)$, $I_A(x)$, $F_A(x)$ in X are real standard or nonstandard subsets of $]^-0, 1^+[$, such that $T_A(x)$: $X \to]^-0, 1^+[$, $I_A(x)$: $X \to]^-0, 1^+[$, and $F_A(x)$: $X \to]^-0, 1^+[$. However, since the defined range of the functions $T_A(x)$, $I_A(x)$ and $F_A(x)$ in a neutrosophic set A is the non-standard unit interval $]^-0, 1^+[$, the neutrosophic set is only used for philosophical applications, but it is difficult to apply it to science and engineering areas. To use it easily, the defined range of its functions $T_A(x)$, $I_A(x)$ and $F_A(x)$ can be restrained to the normal standard real unit interval [0, 1]. For this purpose, Wang et al. [9] introduced the concept of a single valued neutrosophic set (SVNS), which is a subclass of the neutrosophic set and a generalization of IFS. Because of the increased volume of information available to physicians from advanced medical technology, the obtained information of each symptom with respect to a disease may contain truth, falsity and indeterminacy information. Since a SVNS consists of the three terms like the truth-membership, indeterminacy-membership and falsity-membership functions, it is very suitable for representing indeterminate and inconsistent information. However, similarity measure is a key role in the analysis and research of medical diagnosis, pattern recognition, machine learning, decision making, and clustering analysis in uncertainty environment. Therefore, some researchers have proposed various similarity measures of SVNSs and mainly applied them to decision making. For instance, Majumdar and Samanta [10] introduced several similarity measures of SVNSs based on distances, a matching function, membership grades, and then proposed an entropy measure for a SVNS. Ye [11] further proposed the distance-based similarity measure of SVNSs and applied it to group decision making problems with single valued neutrosophic information. Furthermore, Ye [12] proposed three vector similarity measures for simplified neutrosophic sets (SNSs), including the Jaccard, Dice and cosine similarity measures for SVNSs and interval neutrosophic sets (INSs), and applied them to multicriteria decision-making problems with simplified neutrosophic information, which contains single-valued and interval neutrosophic information. Although simplified neutrosophic sets (SVNSs and INSs) have been successfully applied to decision making [11–18], they are scarcely applied to medical diagnosis problems.

In medical diagnosis, recently, Ye [19] proposed the improved cosine similarity measures of SVNSs and INSs based on cosine function and applied them to medical diagnosis problems. Because the symptoms and inspecting data of some disease may be changed in different time intervals, one of the medical diagnosis questions is whether only by taking a single period inspection we can reach a proper conclusion for a particular patient with a particular decease or not. Sometimes he or she may show symptoms of different diseases also. Then, how can we reach a proper diagnosis for the particular patient by taking one inspection? One solution may be to examine the patient through multi-periods (dynamic inspection in different time intervals) and to realize comprehensive diagnosis for the patient corresponding to the dynamic inspecting information. In this case, multi-period medical diagnosis (i.e. dynamic medical diagnosis) needs a comprehensive diagnosis method. However, the existing medical diagnosis methods [3–7,19] can only handle single period diagnosis problems, but cannot deal with comprehensive medical diagnosis problems in the multi-periods (dynamic diagnosis problems). To handle the multi-period medical diagnosis problem, this paper proposes new similarity measures of SVNSs based on tangent function and a multi-period medical diagnosis method based on the proposed similarity measure and the weighted aggregation of multi-period information to help doctors make a proper diagnosis for a patient.

The rest of the article is organized as follows. Section 2 introduces some basic concepts of SVNSs and similarity measures for SVNSs. Section 3 puts forward similarity measures of SVNSs based on tangent function and weighted similarity measures of SVNSs and investigates their properties. In Section 4, we propose a multi-period medical diagnosis method based on the proposed similarity measure and the weighted aggregation of