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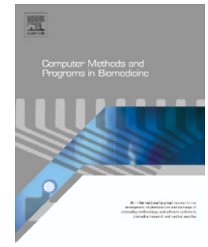

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Fuzzy cognitive map software tool for treatment management of uncomplicated urinary tract infection

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ABSTRACT

Uncomplicated urinary tract infection (uUTI) is a bacterial infection that affects individuals with normal urinary tracts from both structural and functional perspective. The appropriate antibiotics and treatment suggestions to individuals suffer of uUTI is an important and complex task that demands a special attention. How to decrease the unsafely use of antibiotics and their consumption is an important issue in medical treatment. Aiming to model medical decision making for uUTI treatment, an innovative and flexible approach called fuzzy cognitive maps (FCMs) is proposed to handle with uncertainty and missing information. The FCM is a promising technique for modeling knowledge and/or medical guidelines/treatment suggestions and reasoning with it. A software tool, namely FCM-uUTI DSS, is investigated in this work to produce a decision support module for uUTI treatment management. The software tool was tested (evaluated) in a number of 38 patient cases, showing its functionality and demonstrating that the use of the FCMs as dynamic models is reliable and good. The results have shown that the suggested FCM-uUTI tool gives a front-end decision on antibiotics' suggestion for uUTI treatment and are considered as helpful references for physicians and patients. Due to its easy graphical representation and simulation process the proposed FCM formalization could be used to make the medical knowledge widely available through computer consultation systems.

1. Introduction

The most common type of urinary tract infection (UTI) is the inflammation of urinary bladder or *cystitis*. A more serious form of UTI is the inflammation of renal pelvis or *pyelonephritis*. The former belongs to the lower urinary tract whereas the latter to the upper urinary tract. UTIs can be classified as uncomplicated (patients with urinary tracts that are normal from both structural and functional perspective) and complicated (that does not fit the uncomplicated category) [1,2]. Uncomplicated UTIs are most common in young, sexually active women (due to shorter urethra) as well as in hospitalized patients. Because women have a shorter urethra than men, they are 14-times more likely to suffer from an UTI [3]. A number of studies showed that the diagnosis and treatment management of uUTI is a complex and common problem and a special attention is demanded [4,5]. A United States and Canadian study showed that approximately one half of all women will have a UTI caused mainly by *Escherichia coli* in their lifetimes, and one fourth will have recurrent infections [4–6]. Further a number of studies (guidelines) show the amplitude of this problem and the guidelines to be followed [7].

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Escherichia coli (e.coli) is the most common cause of uncomplicated UTI and accounts for approximately 75–95 percent of all infections [4]. *E. coli* is responsible for approximately 90% of community-acquired UTIs seen in individuals with ordinary anatomy (no complicating factors) [8].

The treatment of uUTIs and the appropriate selection of optimal antibiotics is a complex medical task where a number of parameters, signs, symptoms, adverse events and contraindications are present [7,8]. Thus, the management of medical treatment requires the combinatorial analysis of decision variables, most of which are qualitative in nature and due to the complexity and vagueness involved in the decision making process, physicians need some level of decision support.

Medical decision support systems (MDSSs) form a significant part of the field of medical knowledge management technologies through their capacity to support the clinical process and use of knowledge, from diagnosis and investigation through treatment and long-term care. Their role and acceptance in daily clinical practice is increasing. Recent studies [9–13] show that MDSSs can improve physician performance and accuracy, while the quality of each system may depend on the technical approach they use to model medical information. Systems are often built for a predetermined purpose, which usually sets the underlying methodology to be used 0. Artificial intelligence (AI) systems are intended to support healthcare workers with tasks that rely on the manipulation of data and knowledge and where the dynamic learning of new information is necessary 0. Schurink et al. presented in a review article a number of computer-assisted decision support systems for the diagnosis and treatment of infectious diseases in intensive care units [14].

Knowledge-based systems, as the commonest type of DSS technology, were initially used in clinical routine [15]. Also known as expert systems, they contain clinical knowledge, usually about a very specifically defined task, and are able to reason with data from individual patients to come up with reasoned conclusions. Although there are many variations, the expert systems rarely are able to cope with uncertainty, imprecise or incomplete information and the knowledge within them is typically represented in the form of a set of rules 0. Bayesian networks, influence diagrams and fuzzy logic based methodologies are the most widely used knowledge representation and decision models under uncertainty in medical informatics [15]. Fuzzy logic has been considered mainly as a means to model the inherent uncertainty present in real-world medical decision making, with the approaches in [16–18] to be among the most recognized ones.

FCMs are ideal causal knowledge acquiring tools with fuzzy signed graphs which can be presented as an associative single layer neural network [19]. They describe particular domains using nodes (variables, states, inputs, and outputs) and signed fuzzy relationships between them. The fuzzy part allows us to have degrees of causality, represented as links between the nodes of these diagrams, also known as concepts. This structure establishes the forward and backward propagation of causality, admitting the knowledge base to increase when concepts and links between them are increased. FCM represents knowledge in a symbolic manner, encoding the relations between the elements of a mental landscape so that the impact of these elements can be assessed. They also present a number of advantages over conventional fuzzy approaches to reasoning. It has been proved by the literature that it is an efficient, transparent and easy of use tool for medical decision support tasks [20–26].

Evans et al. demonstrated that some nosocomial infections are preventable or minimized with appropriate empiric antibiotic treatment using a computer-based antibiotic assistant program [27]. Furthermore, a computer-based tool for empiric antibiotic decision support, called Q-ID, was conducted by Warner et al. [28]. That tool used a series of infectious disease knowledge bases to make recommendations for empirical treatment or to check the appropriateness of current antibiotic therapy.

To model bacterial infections and make medical diagnosis and treatment suggestions for UTI, probabilistic networks and fuzzy logic based methodologies have been proposed by some researchers [29,30]. Leibovici et al. tried to model bacterial infections by proposing a causal probabilistic network for optimal treatment of these infections [29]. Although, the probabilistic network was a convenient way to combine data from databases collected at different locations and times with published information, its calibration to new sites requires data that is available in most modern hospitals. Kao and Li tried to exceed the above limitations by proposing an optimal treatment model for bacterial infections with fuzzy information using influence diagrams [30]. The influence diagrams were conducted two kinds of reasoning simultaneously: diagnostic reasoning and treatment planning [31,32]. The input information of the reasoning system was conditional probability distributions of the network model, the costs of the candidate antibiotic treatments, the expected effects of the treatments, and extra constraints regarding belief propagation. The output results of the reasoning model that were the likelihood of a bacterial infection, the most likely pathogen(s), the suggestion of optimal treatment, the gain of life expectancy for the patient related to the optimal treatment, and the cost–effect analysis of the treatment prescribed, showed the effectiveness of the proposed approach.

In most medical domains, there is a substantial body of knowledge prescribed by guidelines that can be used to model that domain. A medical guideline is a document with the aim of guiding decisions and criteria regarding diagnosis, management, and treatment in specific areas of healthcare. Guidelines include the description of the various alternatives and of the selector factors that would allow establishing decisions among them. However, because of the sheer volume of one such guideline and the rigid structure of such guidelines it is very difficult for the treating physician to apply and strictly follow the workflow presented by such guidelines. It is our objective to create a computerised system that dynamically guides the physician through the workflow for UTI treatment management.

Thus, in order to solve the problem of modeling medical knowledge from guidelines and to assign antibiotic suggestions for the problem of uUTI by handling uncertainty, the FCM approach is established and formalized. This study, considering the needs of commonsense causality, tries to model the complex problem of UTI, which is a very common medical problem, keeping its main characteristics of uncertainty