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Collective intelligence in medical diagnosis systems: A case study

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ABSTRACT

Diagnosing a patient's condition is one of the most important and challenging tasks in medicine. We present a study of the application of collective intelligence in medical diagnosis by applying consensus methods. We compared the accuracy obtained with this method against the diagnostics accuracy reached through the knowledge of a single expert. We used the ontological structures of ten diseases. Two knowledge bases were created by placing five diseases into each knowledge base. We conducted two experiments, one with an empty knowledge base and the other with a populated knowledge base. For both experiments, five experts added and/or eliminated signs/symptoms and diagnostic tests for each disease. After this process, the individual knowledge bases were built based on the output of the consensus methods. In order to perform the evaluation, we compared the number of items for each disease in the agreed knowledge bases against the number of items in the GS (Gold Standard). We identified that, while the number of items in each knowledge base is higher, the consensus level is lower. In all cases, the lowest level of agreement (20%) exceeded the number of signs that are in the GS. In addition, when all experts agreed, the number of items decreased. The use of collective intelligence can be used to increase the consensus of physicians. This is because, by using consensus, physicians can gather more information and knowledge than when obtaining information and knowledge from knowledge bases fed or populated from the knowledge found in the literature, and, at the same time, they can keep updated and collaborate dynamically.

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1. Introduction

In medical practice, first-contact medical care is the main entrance to health services, providing continuous and comprehensive personal attention to patients. Therefore, a proper communication channel between the first and second level of medical care is needed. Physicians use interconsulting as the main element to build this communication channel [1,2,3]. Mainly, this practice allows them to share information to reach a consensus about a diagnosis or treatment [4]. The ability of a physician to diagnose a patient's condition depends on several factors, such as knowledge, training, experience, available resources, communication skills and, often, instinct [5–9]. Sharing information is the act of disseminating valuable knowledge gained with other members within an organisation. This activity of physicians in hospitals can potentially generate huge profits and is essential to succeed and survive in competitive environments [10].

This research is based on two concepts closely related to medicine and health care: consensus methods and collective intelligence. The use of consensus methods to solve problems related to health and medicine has been increasing. These methods define levels of agreement between individuals, and, if they are used properly, it is possible to create structured environments that provide the best information that allows experts to solve problems in a more conclusive manner [11]. In [12], Heylighen defines collective intelligence as the ability of a group to solve more problems than its individual members can separately. The basic idea is that a group of individuals can be smarter together than separated. In the same manner, Lévy explains that the term Collaborative Intelligence encompasses Collective Intelligence, defined as a form of universally distributed intelligence, constantly enhanced, coordinated in real time and employing effective mobilisation skills

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[16].

Collaborative intelligence comes from the synergy created when individuals interact with each other following simple rules. However, collective intelligence also has some limitations. One of the main problems is that an expert may incorrectly interpret the ideas of another expert due to differences in experience, knowledge or terms used. In medicine, this problem is known as overlapping [12–15].

We present a case study where physicians employed consensus methods and collective intelligence in order to obtain a medical diagnosis. We compared the diagnosis accuracy that was reached by applying collective intelligence against the diagnosis accuracy reached through the knowledge of a single expert. The experiment was supported by a Diagnosis Decision Support System (DDSS). In addition, based on the information collected, we analysed the way in which medical diagnosis was influenced by the physicians' different opinions. All this work helped us to test the hypothesis that different levels of intelligence between a group of people and its individual members exist. Additionally, we found that these intelligence levels can be measured and used to predict the performance of groups in a variety of tasks.

The rest of this paper is structured as follows. Section 2 presents the state of the art focusing on consensus methods, which are traditionally used in the medical field. In Section 3, we outline the research description and methods used. In Section 4, we show the main results obtained. Finally, in Section 5, we present our conclusions about the results and suggest future research directions and challenges.

2. State of the art

Health care providers often face the problem of trying to make decisions in situations where there is insufficient information or where there is too much or contradictory information [17]. Medical professionals apply consensus methods to solve problems related to the use of medical knowledge and technologies. The diversity of problems is vast; for example, consensus methods can be used in intraocular lens implantation, coronary artery surgery or for treatment of breast cancer [11]. The two consensus methods most commonly used in medicine are the Delphi method and the Nominal Group method. In addition, in [17,21], the authors propose a conference as a third method. These methods provide the means to leverage the knowledge of experts in decision-making.

The Delphi method is an attempt to obtain an expert opinion on a systematic basis. In the first step of this method, all participants are interviewed individually and anonymously. Next, the interviews are carried out in three or four rounds. After each round, the results are presented in a tabular form to the group. Finally, the consensus is considered complete when there is a convergence of opinions or when a point of diminishing returns is reached. This method was used at the Centres for Disease Control to select preventive treatments for isoniazid-resistant tuberculosis infection [18]. Another example is presented in [19] where Delphi technique was used to identify performance indicators thought to reflect the quality of patient care in the emergency department. Similarly, in [20], the authors present a modified Delphi approach that was used to develop a consensus-based practice guideline for the diagnosis and treatment of Behçet's intestinal disease. However, despite its usefulness, the Delphi method has limitations. First, on some occasions, participants become fatigued after two or three survey rounds. Second, coordinating large groups and several rounds can be complicated and costly. Third, the Delphi method may not be appropriate if personal contact between participants is desired [10,22,23].

On the other hand, the nominal group method is a structured set of steps aimed at obtaining ideas from groups of experts and then evaluating those ideas within the problem area [24,25]. In medicine, this method has been used in research projects to define consumer and professional roles; it also has been used to define qualities for primary health care organisations. However, the success of a nominal group depends on the skills of a highly trained leader and the organisation of a group that can work well in a highly structured environment [11].

Despite the usefulness of these methods, there are risks in their use. For example, there is the risk of achieving collective ignorance rather than collective knowledge. To avoid this problem, the software Galeno, which uses the SNOMED-CT terminology, can be used to ensure that experts do not use different terms for the same concept [26–28]. Another common problem is that people tend to play power games and want to be recognised as the most important or smartest people in the group and, therefore, tend to reject any different opinion. This problem can be reduced by working with small groups and by working in parallel rather than by waiting in line to participate [12]. In medicine, there are many cases in which collective intelligence is used. For example, in [29], the authors present a system called DITIS, which helps dynamic Virtual Collaborative Healthcare Teams dealing with home care for cancer patients. The system uses dynamic creation and the management and coordination of virtual medical equipment for the continuous treatment of patients at home. In this case, the physicians and nurses collaborate with the patients and their families in order to provide a better medical service. Another example is shown in [30], in which the authors argue that the expansion of digital medical records and recent developments in networking and computer technology have allowed for the possibility of online collaboration among geographically distributed medical staff. In their paper, the authors present a Web-based application that implements a collaborative work environment for physicians that allows for the exchange of digital medical records from person to person. In [31], the authors found evidence of collective intelligence while working with groups composed of two to five members. Their study involved 699 people and explains the performance of groups in a variety of tasks. iPixel [32,33] is a Web 2.0 application that helps the medical community in differential diagnoses related to breast diseases. The system helps in the process of differential diagnosis in mammographic evaluations. Collective intelligence is obtained when each mammogram is semantically tagged by a community of physicians. Khayati and Chaari [34] present a distributed collaborative system that assists physicians in osteoporosis diagnosis through the medical imaging of bone radiographs. They developed a Web solution that uses a knowledge base, an inference engine and ontologies so that physicians, radiologists, designers and programmers who were in different sites could work collaboratively to strengthen the quality of diagnostic results.

Kaplan [35] focused on reviewing the Clinical Decision Support Systems (CDSS) literature in order to have a clearer idea about the impact that the use of informatics applications, especially the ones that aid physicians with diagnosis, can have on the improvement of health care and health processes. By evaluating the results of different studies, he noticed that, even when there is evidence of the benefits that a variety of systems can provide to medical practice, the implementation and use of these systems are not usually common or easy. The author argues that this is usually because the kind of evaluation performed to prove the efficiency of CDSS tends to focus more on the accuracy of the system instead of on the way in which this helps to improve the clinical performance of doctors. Consequently, he states that this lack of information will only be overcome by applying a plurality of methodological approaches in evaluation. Just by doing this, we will broaden our understanding of the clinical use and acceptance of informatics

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