Developing Effective Crowdsourcing Systems for Medical Diagnosis: Challenges and Recommendations

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Abstract

Diverse medical traditions follow different 'grammar' making encapsulation of varied body of knowledge challenging. However, the advances in information technology in the 21st century provide an opportunity to aggregate knowledge from varied cultures and medical traditions to tackle difficult health issues for which no cure has been developed. In addition to accumulating knowledge from wide-ranging sources, an ideal crowdsourcing system (CS) can benefit from the use of appropriate algorithms to choose the best solution. This conceptual paper examines existing classification of crowdsourcing and the various challenges involved with the capture and transmission of medical knowledge. It proposes the steps involved in developing an effective CS for dealing with medical problems. The ideal CS should involve the crowd and medical experts from all across the world, who together with the help of algorithms and other technology features in the CS could provide a useful solution for hard to solve health problems.

1. Introduction

In today's technology-driven world, opportunity arises to share information or knowledge through internet-enabled systems. Organizations world-wide have crowdsourced problems related to diverse topics (for example, ideas for new products, improving existing products) [1]. In general, crowdsourcing has been employed to accomplish four main categories of tasks: problem solving, data processing, monitoring, and surveying. In the health care domain, crowdsourcing has been used to answer important health-related research questions [10]. Problem solving (generating ideas to solve medical problems) is a more recent phenomenon in crowdsourcing. This is illustrated with the advent of platforms such as CrowdMed.

CrowdMed is a crowdsourcing system that attempts to solve rare medical cases that trained medical experts have not been able to solve. Cases are outsourced to the crowd. Here, the application of the 'Theory of Crowd Capital' [22] may be appropriate. The theory explains the dynamics and mechanisms that enable organizations to engage crowds through use of internet-enabled technology for resource creation purposes.

In this paper we argue that knowledge transactions are fundamentally difficult to conduct. Specifically referring to 'global' (unrestricted by specific culture or tradition) medical knowledge, we contend that capturing knowledge is a challenge. Medical knowledge signifies the body of knowledge or information relevant to the field of medicine. Diverse medical traditions follow different 'grammar' (language rules), and thus the encapsulation of such a varied body of knowledge is difficult. Considering these challenges in encapsulation of global medical knowledge, we propose how medical crowdsourcing systems (comparable to CrowdMed) can be designed to capture 'relevant' knowledge; the knowledge that will cure the individual patient's specific medical problem. We believe that the solution will originate from the aggregate knowledge coming from diverse medical philosophies as well as thoughts from a broad spectrum of medical practice and traditions.

The paper is structured as follows. We begin by discussing crowdsourcing typology [5]. In the next section we go into the discourse on knowledge and issues related to knowledge transfer [11, 13]. We then explore the challenges associated with capturing global medical knowledge. In the subsequent section, we use classification of crowdsourcing based on the method used to analyze the crowd contributions proposed by [16] as a 'spring board' to recommend a step approach to develop a crowdsourcing system for medical diagnosis of health issues for which cure has not been developed. In the concluding section, we present closing arguments on the promise of crowdsourcing systems that rely on bringing together knowledge from diverse sources.

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2. Crowdsourcing typology

There are many types of crowdsourcing with different objectives. Crowd polling systems are often used as a method for getting information from crowds about their opinions, while crowd-solving systems involves the incorporation of numerous individuals in teams undertaking creative work. Crowd processing systems rely on large quantities of contributions. This guideline provides the margins, placement, and print areas. If you hold it and your printed page up to the light, you can easily check your margins to see if your print area fits within the space allowed.

Contributors collectively process tasks in large numbers to minimize the use of traditional organizational resources [5]. *Crowdfunding* is a special type of crowdsourced product that is used as a method for generating funds from many individuals to fund businesses, creative projects, charities and more.

Crowd-solving involves gathering ideas from individuals and the aggregation of 'intangible' 'goods' in the form of the crowds' knowledge or information [14, 17, 19]. On the other hand, crowdsourcing strategies like crowdfunding and crowdpolling involve asking individuals to make 'tangible' contributions in the form of currency (crowdfunding) or votes (crowdpolling).

Given the above distinction, crowdsourcing for medical diagnosis falls in the first category (crowd-solving), as crowds contribute their ideas to solve medical problems by offering diverse ideas for the treatment of these problems. Medical knowledge is often abstract and complex, a discussion that follows in a later section in the paper. It is a greater challenge to capture this type of knowledge, than, for example, collecting ideas on improving the physical design for a product or gathering inputs on how to market a new product.

Successfully engaging a crowd, and effectively acquiring the desired contributions from it, are necessary, but not sufficient alone to generate important knowledge from the crowd. Procedural rules and associated algorithms used by the crowdsourcing system are critical in achieving the desired objective of effectively organizing, filtering and integrating the incoming crowd contributions. The procedures employed by the crowdsourcing system must incorporate a diversity of opinions from the crowd. As well, successful implementations of crowdsourcing systems should focus on fostering diversity of opinions. This may be achieved by selecting judges (experts) with different backgrounds, eliciting their inputs independently, and injecting diverse thoughts (perhaps, from crowd inputs) to affect their original ideas [12].

3. The discourse on knowledge

Knowledge accumulation is a basic function of technology-enabled crowdsourcing systems. Once knowledge is accrued, the system needs to filter the knowledge that is useful to solving the problem. This filtering process can be complex, as it needs to recognize and identify portions of amassed knowledge that is 'relevant' knowledge. The following discussion explains the concept of relevant knowledge and its sources.

3.1. Relevant knowledge

There are different types of knowledge based on its characteristics that interests the knowledge seeker [13]. These can be termed as either specific (relevant) knowledge or general knowledge. Specific (relevant) knowledge is 'private' knowledge that an individual has, in relation to others, while general knowledge is 'commonplace' knowledge known to a large number of individuals.

Further, relevant knowledge is the knowledge of "…particular circumstances of time and place…" [13, p.19] and the knowledge which is likely to bring about the most desired outcome. Sometimes, this type of knowledge can be termed as "important" knowledge. Relevant knowledge or important knowledge can be accessed from a combination of resources that are widely dispersed and fragmented. As such, "…this [relevant] kind of information is not readily rolled up into statistical summaries …" [13, p.23]. Relevant knowledge does not exists in 'concentrated or integrated form', but "…solely as the dispersed bits of incomplete and frequently contradictory knowledge…" [11, p.5].

To capture relevant knowledge, it is essential to include a broad-range of knowledge sources. Unless an all-inclusive procedure is followed, obtaining relevant knowledge from a small group of individuals may limit the 'scope', that is the 'breadth' of the knowledge.

For crowdsourcing systems, while securing the key elements of relevant knowledge is a challenge, once this challenge is overcome, transferring knowledge to secure its 'integrity', or ensuring that the 'true' meaning of the knowledge is conveyed to the recipient of the knowledge is also a significant hurdle. The section below provides an overview on the challenges relevant to transfer of knowledge.

3.2. Issues with knowledge transfer

Successful dyadic knowledge transfer necessitates that both parties involved in the knowledge handover process develop an understanding of where the desired knowledge resides within the source. Further, both parties must participate in the processes by which the knowledge is made accessible [9]. Otherwise, in all likelihood, a recipient may ignore collection of a key knowledge component if there is a lack of understanding of where the knowledge resides within the source.

The role of cultural factors in knowledge transfer must be taken into consideration. Type of culture influences how its members process, interpret, and make use of a body of information and knowledge [23]. Paying attention to the cultural background provides a better understanding of the relationships between the various domains of messages. Furthermore, it is important to have a-priori knowledge of what pieces of information to sample and what kind of associations already exist with the items and domains of knowledge [3]. In light of these factors, situations when cultural paradigms of agents are removed from one another, transfer of knowledge between the agents may be difficult because articulating particular knowledge or ideas may not be legitimized.

From the standpoint of crowdsourcing systems that involves transfer of medical knowledge, understanding cultural factors that contextualize the residual knowledge becomes imperative. Unless this is achieved, transfer of knowledge that will enable the health care provider (or entity providing consultation) to correctly interpret the information provided by the source (the patient in most cases), becomes problematic. In the following section, we present ideas that are particularly associated with medical knowledge, the context being deliberated in this study.

4. Medical knowledge

4.1. Collective knowledge

Citing the example of the disease syphilis, [8] advances the idea that medical knowledge is the outcome of a collective process of interaction and communication amongst distinct thought ‘collectives'. A key implication of this perspective is that medical knowledge is not 'discovered' by technical experts and then disseminated to a wider public. In contrast, the experts and public alike, participate in verifying this type of knowledge. This idea is consistent with the view from actor-network theory in sociology of scientific knowledge [15]. The theory proposes that facts are generated by networks of scientists and surrounding social groups [2].

Some scholars have pointed to the idea that the knowledge base changes and develops with experience. The interactions between shepherds living close to a nuclear reprocessing plant in north-west of England and the numerous specialists responsible for monitoring of its functions and evaluating its impact were analyzed [24]. Results showed that the world in which the shepherds and their sheep live is so complex and changing, that specialized knowledge never manages to work. First the experts’ models were undermined by unexpected geological abnormalities. The shepherds knew far more than the researchers. The hypothesis that the forms of food and metabolism of sheep grazing in an enclosure are identical to those of sheep grazing freely, was effectively disproved. The experts acknowledged that their skills were incomplete and needed to be complemented by the observations and knowledge of the ‘natives’ [24].

4.2. Culture (tradition) as context

Medical knowledge is inextricably linked to traditions and culture [6]. Finding cure for medical cases through the application of specialized knowledge may not always be the ‘best’ approach. Incorporating local knowledge embedded in the tradition and culture of the geographic boundary that the patient is located may be necessary. Many suggest that medical practice is an interpretive endeavor where the practitioner’s subjective understanding (in addition to scientific knowledge) about the patient is the key to successful treatment. Every element of knowledge has its roots in specific culture (tradition). There are, for example the Chinese culture, which in important fields such as medicine, arrived at quite different realities from western medicine [2]. The point is that, scientific knowledge is implicitly structured to be 'consistent with' wider cultural ideas; thus challenging commonly held beliefs of it being independent of such factors. Further, medical knowledge is constantly evolving, yet medical practitioners are often not up-to speed with these advances. For issues concerning health, there should be active contribution by lay people to ‘boost’ scientific knowledge or to participate directly in its production [6].

In sum, medicine is an interpretive activity, a learned inquiry and far from being objective or a matter of hard facts. It is grounded in subjective knowledge. In discussion involving medical knowledge, boundaries between specialists and non-specialists seem to be confounding. Such notions lend credence to the belief that in cases involving treatment of diseases that are rare, the management of disease condition may not be based on the scientific knowledge of the medical specialist. Rather, it will be grounded in collaborative ideas that are based on the opinions and knowledge of non-experts who lack the formal specialized knowledge of medical specialists.

The ‘grammar’ or the knowledge base of the field of medicine is vast and varies from one culture to the other. Only 10-20% of medical decisions are based on evidence [20]. Crowdsourcing knowledge discovery in medicine can be approached by lowering the barriers of participation to traditional providers (physicians, nurses). At the same time, the crowdsourcing service should extend an input role to non-traditional (such as individuals with no background in medicine), but interested contributors. The crowdsourcing and open data movements should present an opportunity to involve traditional providers and non-traditional resources of medical knowledge in knowledge creation efforts. They should also incorporate individuals from different cultural traditions, to maintain the sanctity of ideas that originate from individuals representing different cultural backgrounds. In the following section, we propose ideas to construct a crowdsourcing system for medical diagnosis of health issues for which cure has not been determined.

5. Crowdsourcing system for medical diagnosis

We propose a crowdsourcing model based on a ‘step approach’ to solve health problems for which cure is still undiscovered. This step approach attempts to identify and then ‘tap’ different pools of medical knowledge (e.g. Ayurveda, Chinese, Greek) and different approaches to medicine (for example, Western medicine, Homeopathy, Acupuncture). To provide a structure to the step approach, we adopt classification of crowdsourcing based on the method used to analyze the crowd contributions [16]. This is one of the first attempts to categorize crowdsourcing based on the basis of process dimension of crowd capability construct. The process dimension refers to the internal procedures that a crowdsourcing system uses to organize, filter, and integrate crowd contributions.

Crowdsourcing applied for solving health problems for which cure is unfounded, presents unique challenges. Among them is that not many individuals have the knowledge or solution for treating a condition that is rare. The medical problems are not easy to solve. They represent a subset of problems that are highly complex and have high degree of ‘intricacies’ associated with them. Thus, we strive to reconstruct classification outlined by [16], while applying it’s the fundamental tenets to develop our crowdsourcing model.

Our modified taxonomy for crowdsourcing consists of four steps detailed in the following sections. We believe this classification is among the first attempts to elucidate crowdsourcing process in the context of health care, specifically targeted towards medical diagnosis of health conditions for which remedies are unknown.

5.1. Step one: Analogous crowd voting

Drawing on [16], we posit that a method similar to crowd voting will be the first step in crowdsourcing for diagnosis of rare medical conditions. We begin with crowdsourcing the medical case to the crowd. Specifically, we are requesting the crowd’s input in identifying the disease. Once the crowd consisting of individuals from diverse backgrounds provide their inputs on the type of disease (by specifying the name, symptoms, diagnosis, prognosis), the crowd voting mechanism can be applied were input from the crowd is aggregated.

The aggregation method should be designed such that equal weights are assigned to individuals in the crowd, without distinguishing any level of expertise. The outcome of such an approach may be optimum when it considers external information and, reinforces the implicit wisdom to be found in the crowd. As is customary in crowd voting, contributions are taken at face value without any validation. The ‘top’ choices for the disease names are selected from the inputs provided by the crowd. Once the top disease names have been identified, algorithms are used to select the ‘one’ disease that is most likely. A logic within the algorithm that should drive this selection is to choose the disease (from the set of diseases ascertained by the crowd) based on the degree to which its characteristics (symptoms, diagnosis, and prognosis) matches that of a known or well established disease condition.

5.2. Step two: Expert panel recommendations

The second step in the process is comparable to crowd idea sourcing proposed by [16], but slightly distinct in certain aspects. In this step, an eclectic group of medical experts will represent the crowd. It is important to avoid a monopoly of any particular medical tradition when selecting this pool of experts. This group must represent various cultural contexts, different medical backgrounds, and should comprise of individuals that are open to the idea of offering credence to medical solutions that are derived from backgrounds that is substantively different from their own.

Since a pool of experts serve as the alternative to a typical crowd, this approach is a deviation from the fundamental tenet that 'wisdom of crowd' or collective intelligence has immense potential to solve problems. A justification of this departure is that the crowd may not have the capability to provide solution to highly complex problem – a health condition or disease for which cure is yet to be established, and may also not possess the 'depth' and 'breadth' of medical knowledge required to solve such complex medical problems.

This eclectic group of medical experts serving as the 'crowd' will provide a set of solutions to cure the rare health condition identified in step one. Since the group represents medical experts from a variety of cultural and medical traditions, it is expected that the set of proposed ideas from this group will embody a wide-ranging set of solutions that cover the 'breadth' as well as 'depth'. This entails that the solutions proposed will include traditional and non-traditional remedies, as well as those that are rooted in rigorously 'vetted' medical knowledge systems.

While offering their inputs, the medical experts should consciously or sub-consciously avoid any personal bias to influence their judgment. Also, they should keep in mind that proposing 'personalized' cure, rather than a generic remedy to a medical problem should be important criteria when offering their medical advice. Here, personalized care refers to a concept of medical attention that is individualized to the needs and personal preferences of the person/patient seeking inputs from the crowd.

Once these medical experts create a pool of solutions, an algorithm should be applied to select and rank the top solutions. The algorithm's logic should consider both quantitative and qualitative aspect of each solution included in the pool created by the medical experts. For instance, the quantitative attribute of a solution may be a function of how many times (objective measure) the solution has proved to be successful in the past when treating a health condition. While the qualitative facet of a solution characterizes how satisfied (emotional response) a patient has been after being treated with the solution. Here, algorithms should find the appropriate balance between the quantitative and qualitative traits of a solution ensuring satisfaction on both the rational and emotional dimensions. This will confirm the incorporation of both (the rational and emotional dimensions) in the proposed solution.

5.3. Step three: Analogous solution crowdsourcing

Once the top solutions have been selected and ranked relevant to the health condition, the stage is set for the third phase in our step-approach. This phase is similar to the concept of solution crowdsourcing proposed by [16]. The crowd will be invited to provide their opinions to select the final solution from the set of ranked (top) solutions. They will be asked to submit their choice based on their cognizance of factors linked to the following; (a) whether the solution, once applied to an individual patient can be tested for its efficacy and effectiveness (b) whether the patient has had a positive experience after receiving the solution/treatment, and (c) whether the solution is merely an opioid analgesic, as opposed to possessing the quality to actually cure the disease. Inputs from the crowd will be used to establish the 'single' most effective solution to be recommended to the individual seeking medical advice.

5.4. Step four: Analyzing the solution

The final step in designing crowdsourcing systems for medical diagnosis involves testing the efficacy of the solution obtained in step three. This additional step is to add a more robust solution seeking mechanism where, in conjunction with the solution, we are adding a condition that the solution proposed by the panel of medical experts and the crowd is actually effective.

To implement this step or phase, one needs to ensure that the patient (individual seeking medical recommendations) remains in contact. One must recognize that the crowd does not play a role, nor are the medical experts involved – verifiability of the solution is the main purpose and can be conducted via standard laboratory tests or known medical examination procedures and inputs from the patient. Further, when scrutinizing the solution offered by the medical crowdsourcing system, it would be pragmatic to evaluate its effectiveness in a continuum of failure and success, rather than simply labelling the solution as either a success or failure.

As to where the solution will fall in the continuum should be based on results provided by scientific evidence and the reaction (or response) from the patient herself. For example, when a proposed solution is offered to a patient, it will be deemed a complete failure if it does not relieve the patient of the medical problem as well as medical (or laboratory) tests also suggest failure. Another situation may be that the patient suggests that the medical issue is mitigated due to the treatment offered, but the medical tests conducted on her reveal otherwise. In this case, the solution offered can be regarded a partial success. Also, further investigation should proceed to see if the medical solution offered to the patient had a compelling semblance to some form of palliative cure.

A third scenario could be that the patient is unhappy with the cure provided. However, medical or scientific tests show that the patient was indeed provided the right treatment that cured her of the medical condition. In this situation too, the solution provided may be considered a limited success. Additional evaluation of the patient should be conducted to verify if she has high health anxiety or is a hypochondriac. The fourth situation could be that both the patient as well as scientific laboratory tests suggest that the medical solution selected by the crowdsourcing system has cured the patient. This entails that the solution offered was a complete success.

6. Technology 'means' of the crowdsourcing system

In order to successfully manage the crowdsourcing system, the supporting technology plays a vital role [18]. In this section, we discuss technology features that must be incorporated in crowdsourcing systems for medical diagnosis.

Basic elements of technology-enabled crowdsourcing system must include a supporting platform that facilitates the integration (and distribution) of crowdsourced data [4]. Crowdsourcing systems should embrace tools that provide filtering mechanisms to identify high quality inputs from the crowd, aggregate them for evaluation, and 'purge' erroneous contributions. Furthermore, algorithms should be designed to serve a complementary or synergistic role with the crowd [7]. Algorithms should be based on heuristics so that they continue to evolve with time and exposure to information and inputs from the crowd and experts. Technology should allow integration of the incoming crowd-derived contributions and capture the 'depth' and 'breadth' of knowledge from the crowd. It should also facilitate a dialog between experts from different medical backgrounds, ultimately leading to better understanding of medical grammar prevalent in different traditions.

Homogeneous contributions are those that fulfill some defined specifications. A crowdsourcing system that seeks homogeneous contributions values all valid contributions equally [20]. In comparison, a crowdsourcing system that requests heterogeneous contributions values every contribution differently, based on the unique attributes associated with each individual contribution. When designing medical crowdsourcing systems, due to the diverse nature of knowledge associated with medical domain, it may be good practice to develop technology features in the system that can derive value from both homogenous and heterogeneous contributions from the crowd.

Further, at the input phase, or when individuals (seeking cure for their health condition) are entering information (medical history, specifics of the symptoms, etc.) about their individual medical cases to obtain suggestions from the crowd, crowdsourcing systems interfaces should be designed to allow 'virtual' interaction of these individuals with the crowd. This implies that agents seeking solutions to their medical problems should not be limited to sharing just their medical information, images, and videos with potential solvers. Crowdsourcing systems should include interactive features by using ideas from current virtual reality systems that allows users to experience real-world settings in highly interactive simulated environments.

7. Concluding remarks

Medical crowdsourcing systems must include procedures and methods so that ideas from all levels of knowledge expertise (from the layperson to the medical expert) are considered in the 'pool' of alternatives or potential 'candidates'. Creating layers of filter in the process of narrowing crowd ideas should be an integral aspect of the structure of the crowdsourcing system. Heuristic-based algorithms that represent learning systems, or systems that learn continuously from diverse medical inputs and take advantage of the constant changes in medicine and technology, must be engaged so that they are robust enough to complement expert opinion and inputs from the crowd in the selection and filtering process.

This paper draws on ideas from the crowdsourcing classification outlined by [16] to propose a step approach to design crowdsourcing systems to increase the likelihood of offering the appropriate medical solution or treatment to an individual with a health condition for which cure is unknown. In our step approach, we argue that crowd cannot be the only entity to solve the problem. Because of the nature and complexity of the problem that is being undertaken, we recommend that an eclectic group of medical experts should be included. The knowledge base of the solutions proposed by them must be derived from a breadth of medical knowledge inputs and a depth of medical know-how.

Solutions to medical problems that are rare could reside in selected pockets of the global medical community that might not be considered conventional and may not have been granted the legitimacy of the typical approach to solving medical problems. There are some publicized success stories of the application of unconventional medical solutions to treat or cure medical problems. One such example is that of Gordie Howe, the legendary professional Hockey player who became paralyzed after suffering a life-threatening stroke. He was injected with needle into his spinal canal to inject stem cells in the hope that they would migrate to his brain heal his body. Although the company that came up with the idea was located in the United States, the treatment was conducted in Mexico since the practice of injecting stem cells into human beings was not an acceptable medical practice in the United States. The treatment was successful and Gordie Howe was back to leading a normal life.

There are several other examples of medical solutions emanating from unexpected sources. The pancreas sits deep inside the human body which makes it difficult to scan using normal x-ray procedures. In addition, there is no 'trademark' symptom to alert an individual. A high school student from Houston, Texas claims to have come up with a robust tool to detect pancreatic cancer (Safer 2013). Though his method is yet to be completely tested, however well-known scientists have agreed that it holds promise. This is an example of how the advancement of medical knowledge can come from unknown sources, and not necessarily from prestigious research institutions or groups of scientist. Notwithstanding its humble antecedents, these solutions can pave the way for enhancement of medical knowledge.

The above examples emphasize the promise of the application of crowdsourcing to health care where diverse ideas from a variety of sources help solve medical problems. The attempt is to bring ideas from disparate sources, and not restricting to traditional way of thinking or generally established norms of practice followed by one particular medical tradition or philosophy.

While the stringent scientific standards traditionally followed by modern Western medicine should continue to be the norm, the advent of an effective crowdsourcing service not only offers alternative remedies, but in some cases might actually open the eyes of followers of Western medicine to other non-traditional paths which not only have the evidence of the belief of ancient cultures behind them, but also prove themselves in modern laboratory settings. Thus, crowdsourcing has the potential of expanding the knowledge base of the dominant suppliers of most medical solutions which are typically rooted in modern Western medicine. The anchoring of the crowdsourcing service to stringent scientific standards will also alleviate the potential risk from lawsuits emanating from the claims that the appropriate medical practices were not followed.

In sum, an efficient crowdsourcing service not only has the potential of providing the most effective medical solution to individual patients, but also expand the medical knowledge of the suppliers of traditional Western medicine.

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