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Review Article

Contextual Decision Making for Cancer Diagnosis

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Abstract

Pathologist needs to routinely make management decisions about patients who are at risk for a disease such as cancer. The process of clinical decision-making is the essence of everyday clinical practice. Various factors influence their judgments and decisions since it context dependent. The term context contains a large number of elements that limits strongly any possibility to automatize this. The decision support system must benefit from its interaction with the expert to learn new practices by acquiring missing knowledge incrementally and learning new practices, it is called in deferent research human/doctor in the loop, which improves the health science sector by proposing the relevant decisions for patient.

Keywords: Medical Decision Making; Decision Support System; Cancer Diagnosis

Introduction

How doctors think, reason and make clinical decisions is arguably their most critical skill. Importantly, it underlies a major part of the process by which diagnoses are made. In all of the varied clinical domains where medicine is practiced, from the anatomic pathology laboratory to the intensive care unit, decision making is a critical activity. Medical diagnostic decision support systems have become an established component of medical technology. The main concept of the medical technology is an inductive engine that learns the characteristics of the diseases and can then be used to diagnose future patients with uncertain disease states. A cancer diagnosis is a human activity that is context-dependent. The context contains a large number of elements that limits strongly any possibility to automatize this. Recently, digitization of slides prompted pathologists to migrate from slide analysis under a microscope to slide image analysis on the screen. With the advancement in digital computing technology, many researchers have combined image processing and artificial intelligence to develop intelligent assistant systems to assist the pathologist in the diagnosis process. An Intelligent Assistant System (IAS) is an agent that is designed to assist an expert in his domain (in our case the expert is a pathologist). The goal of the intelligent assistant system is to help intelligently the expert in his decision-making process, not to provide an additional expertise in the domain. An IAS must be designed and developed in a formalism providing a uniform representation of knowledge, reasoning, and contextual elements.

The logic of the design and the realization of our system is built around three phases: (1) the capture of the information, (2) The structure of the information and (3) The content analysis,

1. **Phase of capture:** it is to capture and collect any information useful for the achievement of our process of modeling our consultant. There aredifferent types of information:
    a. **Medical Information:** This information concerns how the pathologists proceed in the diagnosis, it contains all the information of the expertise of the field.
    b. **Information for the support of reasoning:** it represents all types of media for which we take the decision: example a medical imaging, medical record.

2. **Phase of structure:** it is to structure and organize the information captured; this phase is important because of this last that derives the heart of our consultant.
3. **Analysis phase:** it must enable users to take the right decision in any context.

Model and Decision Analytic Model

A model represents a physical structure that have an actual entity or can be a series of mathematical equations that describe supply and demand.

A decision model often incorporates mathematical functions that represent what we know about the disease or the relationships between risk factors and disease, or disease and clinical outcomes. The impact of these assumptions can be evaluated in sensitivity analysis.

Different types of decision-analytic model structures are typically used in medical decision-making applications, but we propose to present briefly five models (decision tree, markov (cohort) model, microsimulation (individual) model, Dynamic model, discrete event simulation model).Finally, we provide a summary of the different of models in Table 1.

Model Type	General Description	Type of Decision Best Suited For
Decision tree	Diagrams the risk of events and states of nature over a fixed time horizon.	Interventions for which the relevant time horizon is short and fixed.
Markov (cohort) model	Simulates a hypothetical cohort of individuals through a set of health states over time.	Modeling interventions for diseases or conditions that involve risk over a long time horizon and/or recurrent events.
Micro simulation (individual) model	Simulates one individual at a time; tracks the past health states of individual and models risk of future events stochastically.	Modeling complex disease processes, when Markov models are too limiting.
Dynamic model	System of differential equations that simulates the interactions between individuals and the spread of disease.	Modeling interventions for communicable diseases, such as vaccinations.
Discrete event simulation model	Simulates one individual at time as well as interactions among individuals or within a health care system.	Evaluating alternative health care systems (e.g., workflow, staffing) though flexible enough to address questions in several different areas.

Table 1: Summary of types of decision model structures.

Cancer diagnosis and modeling cancer diagnosis

Cancer and cancer diagnosis

Cancer is a disease in which a group of cells exhibits irregular cell growth cycle. In a normal cell cycle, the cells undergo mitosis process to replicate itself and hence the cell grows [13] [14] The importance of making a timely and accurate diagnosis is fundamental for safe clinical practice and prevention error [6]. The task of making such a diagnosis involves doctors integrating key information from across all the stages of the clinical inquiry (including history taking, physical examination, and investigations).

Making an appropriate clinical diagnosis remains fundamentally important for the patient for the outcome initiates a cascade of subsequent actions, such as prescribing a drug or performing an operation, with real-world consequences. Pathologists are problem-solvers, fascinated by the process of disease and eager to unlock medical mysteries, such as cancer, using the sophisticated tools and methods of modern laboratory science.

Histopathology is a branch of pathology that deals with the examination of tis- sue sections under a microscope in order to study the manifestation of diseases. The tissues are processed, sectioned, placed onto glass slides and are stained. The stained slides are examined under the microscope by a pathologist.

An important tool for the detection and management of cancer is an analysis of tissue samples under the microscope by a pathologist. Looking at the cancer cells under the microscope, the pathologist looks for certain features that can help predict how likely the cancer is to grow and spread. These features include the spatial arrangement of the cells, morphological characteristics of the nuclei, whether they form tubules, and how many of the cancer cells are in the process of dividing (mitotic count). These features have taken together, determine the extent or spread of cancer at the time of diagnosis.

Modeling cancer diagnosis

Cancer has been characterized as a heterogeneous disease consisting of many different subtypes. [12] the early diagnosis and prognosis of a cancer type have become a necessity in cancer research, as it can facilitate the subsequent clinical management of patients.

Machine learning is a branch of artificial intelligence that employs a variety of statistical, probabilistic and optimization techniques that allows computers to ”learn” from past examples and to detect hard-to-discern patterns from large, noisy or complex data sets. This capability is particularly well-suited to medical applications, especially those that depend on complex proteomic and genomic measurements. As a result, machine learning is frequently used in cancer diagnosis and detection. [12]: a variety of techniques in Machine learning have been used as an aim to model the progression and treatment of cancerous conditions and is not new to cancer research, including Artificial Neural Networks (ANNs), Bayesian Networks (BNs), Support Vector Machines (SVMs) and Decision Trees (DTs) have been widely applied in cancer research for the development of predictive models, resulting in effective and accurate decision making. According to the latest PubMed statistics, more than 1500 papers have been published on the subject of machine learning and cancer. However, the vast majority of these papers are concerned with using machine learning methods to identify, classify, detect, or distinguish tumors and other malignancies.

The complexity of cancer development manifests itself on at least three scales that can be distinguished and described using mathematical models, namely, microscopic, mesoscopic and macroscopic scales. [11] proposes a neural-fuzzy approach for modeling breast cancer diagnosis. The neural-fuzzy approach models the diagnosis system as a three-layered neural network. The first layer represents input variables with various patient features, the hidden layer represents the fuzzy rules for diagnostic decision based on the input variables; and the third layer represents the output diagnostic recommendations. [20] describes the de- lays that occur in the detection, diagnosis, and treatment of cancers, including those of the head and neck. This model comprises four-time intervals that together make up the total time between the appearance of signs or symptoms of cancer and the commencement of treatment. These intervals are: appraisal, help seeking, diagnostic and pre-treatment.

The technical aspects of some of the ontology-based medical systems for cancer diseases is discusses in [1]. They proposed ontology based diagnostic methodology for cancer diseases. This methodology can be applied to help patients, students, and physicians to decide what cancer type the patient has, what is the stage of cancer and how it can be treated. The proposed methodology contains three basic modules namely, the diagnostic module, the staging module, and the treatment recommendation module. Each module (diagnostic, staging or treatment recommendation) can be applied as a stand-alone application according to the user requirements. For example, if the user knows the cancer type and wants to determine the cancer stage it can use the staging module by providing the cancer type and signs and symptoms and the module will determine the current stage and so on.

Computer aided/assisted diagnosis (CAD)

Researchers in medical informatics are interested in using computers to assist physicians and other health care personnel in difficult medical decision- making tasks such as diagnosis, therapy selection, and therapy evaluation. Clinical decision-support systems are computer programs designed to help health care personnel in making clinical decisions Shortlifie., *et al*. (1990) Since one of the first reported systems in 1964, the field has matured considerably and has produced systems for various medical domains. Notable among these are MYCIN for the selection of antibiotic therapy, INTERNIST-1 for diagnosis in general internal medicine, and ONCOCIN for the management of cancer patients.

Various signal processing and machine learning techniques have been introduced to perform computer-aided detection and diagnosis. Early works have focused on image processing and classification techniques to extract features of the image and predict the outcome (i.e., whether benign or malignant) in the image [8] and [19]. A neural network-based algorithm [2] and the use of an ensemble of SVMs aiming to transform the feature vector to a new representation vector [18] are proposed to solve the diagnosis problem.

Initially, it had been employed for radiology images [7], but over the last decade, it has also found its application with histopathology images. The area of Computer Aided Diagnosis combines methods or algorithms from Digital Image Processing and Pattern Recognition. It has been shown in a study that CAD has relieved the pathologist from the routine monotonous work of scanning slides [9].

Context and the role of context in medical decision making

Context

The role of context can greatly influence how knowledge is organized and utilized in a knowledge-based system. Brezillon defines context from an engineer's position as "the collection of relevant conditions and surrounding influences that make a situation unique and comprehensible" [3]. This definition illustrates the potential value of the context for the purpose of providing focus on a system. The context allows groupings of knowledge for specific situations, thus the sys- tem can avoid superfluous questions unrelated to the current context.

At least, there is now a consensus around the following definition context is what constrains reasoning without intervening in it explicitly [3].

Modeling context for medical decision making

In order to integrate context in the process of diagnosis, [17] proposed a novel design framework for a computer-aided in breast cancer diagnosis system. The system incorporates contextual information and makes diagnostic recommendations to physicians, aiming to minimize the false positive rate of diagnosis, given a predefined false negative rate.

They considered the contextual information of the patient (also known as situational information) that affects diagnostic errors for breast cancer. The contextual information is captured as the current state of a patient, including demo- graphics (age, disease history, etc.), the breast density, the assessment history, whether the opposite breast has been diagnosed with a mass, and the imaging modality that was used to provide the imaging data. The proposed algorithm is an on-line algorithm that allows the system to update the diagnostic strategy over time. They proposed a diagnostic recommendation algorithm that is formulated to make diagnostic recommendations over time. The algorithm exploits the dynamic nature of patient data to learn from and minimize the false positive rate of diagnosis given a false negative rate.

In [15], their goal is to achieve a semantic platform which is open and generic for digitized histology integrating a cognitive dimension. The system offers automatic semantic annotations to reach for supporting a diagnosis, taking into account the explicit and implicit medical knowledge field, reflections of the pathologist and contextual information of breast cancer gradation.

And this as part of a project "Mico": Cognitive microscope (Mico) that aims for a change in medical practices by providing an environment new medical imaging Anatomy and Cytology Pathological, enabling reliable decision making in histopathology.

[5], Author focuses on the formalization of medical practices in chronic inflammatory bowel disease diagnosis as a contextual graph to identify a consensus methodology. They have identified a ”Glocal” search in the decision-making process with a global exploration for detecting zones of interest, and a zoom inside the zones of interest.

The term «Glocal" is proposed as an association of global and local. It associates a phase of superficial exploration for finding a zone of interest and a phase of fine-grained analysis of a zone of interest. This search concerns contextual elements at different levels of granularity as identified from the analysis of digital slides and they discussed the role of the local approach in other domains like Control and Command rooms for the army and subway-line monitoring.

For a continuing of the project ”MICO" and in order to support the evolution towards digital pathology, the key concept of [16] approach is the role of the semantics as driver of the whole slide image analysis protocol. All the decisions being taken into a semantic and formal world.

As part of modeling decision making using contextual graphs, [4] present an example of a workflow manager that is developed in a large project in breast cancer diagnosis. The workflow manager is a real-time decision-making process in which the result of an action may change the context of the decision-making process. Their goal was developing a decision support system for users who have a high level of expertise in a domain not well known or too complex. Their expertise is composed of chunks of contextual knowledge built mainly by experience under a compiled expression. The decision-making process uses this expertise to propose critical and definitive decisions. In the MICO project, the expert is an anatomo-cyto-pathologist who analyzes digital slides (coming from biopsies) to diagnose if a patient in a surgery has or does not have breast cancer.

Critical discussion and our approach

Discussion

The importance of making a timely and accurate diagnosis is fundamental for safe clinical practice and preventing error and the developers of new technologies conduct much research to develop a Decision Support System that is able of helping pathologist in making contextual decisions for cancer diagnosis. [17] dis- cusses the performance of context for minimizing diagnostic errors by identifying what knowledge or information is most influential in determining the correct di- agnostic action in order to minimize the false positive rate of the diagnosis is given a false negative rate, but they do not offer for pathologists actions in order to do to reach a correct diagnosis.

The role of context can greatly influence how knowledge is organized and utilized in a knowledge-based system that is proved in the majority of papers. Many technical were introduced to build Decision Support System for Cancer diagnosis, which integrates a numeric slide and others integrate clustering technique. But the problem that we do not find a search that integrates both the both technical. Another important point is that the majority of the proposed work treating breast cancer, but not rigorously examines other cancers.

The integration of the knowledge of a domain expert may sometimes greatly enhance the knowledge discovery process pipeline. The combination of both hu- man intelligence and machine intelligence, by putting a ”humanin- the-loop” would enable what neither a human nor a computer could do on their own. This human-in-the-loop can be beneficial in solving computationally hard problems, where human expertise can help to reduce an exponential search space through heuristic selection of samples, and what would otherwise be an NP-hard problem, reduces greatly in complexity through the input and the assistance of a medical doctor into the analytics process [10] and [21].

Our contribution

A cancer diagnosis is a human activity and context-dependent. The term con- text contains a large number of elements that limits strongly any possibility to automatize and it’s due that the medicine is an art, not an exact science and rational because:

1. It uses the biological knowledge to try to explain and understand the ”etiology” of disorders observed in a person.
2. There are too many parameters to be considered and it’s impossible to establish parameters of recognition because of the independence between parameters.
3. This discipline is also called the art of diagnosis. The known diseases diagnostics will eventually understand the etiology of a disease. Epidemiological data, statistics, and specific to the patient guide the therapeutic choice.
4. It has the role of ensuring the health of society. She must know cure, but also heal. It has a role in solving social problems and exclusion in the relief of pain problems and support people in later life. It must also have a preventive and educational role for the population.
5. The role of context can greatly influence how knowledge is organized and used in a knowledge-based system.

Our goal is to develop a decision support system to the pathologist that has a high level of expertise in their domain that analyses digital slides (coming from biopsies) to diagnose if a patient in a surgery has or not cancer.

The decision support system must:

1. behave as an intelligent assistant, following what the expert is doing, how he is doing it, anticipating potential needs.
2. work from the practices developed by the experts with all the contextual elements used by the expert during practice development.

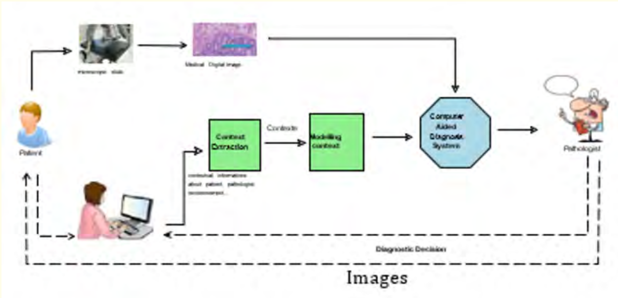

Figure 1: Context information's.

Figure 2 shows our approach how it is based on the context and we are going to explain the choice of different contexts which may exist. We will explain each contextual element by taking an example. In a service Anapath the analysis of a blade can be done in different ways: systematic (from left to right and from top to bottom: thus the direction of viewing) or well to do a search on areas of interest specific well or do a zoom in the first area encountered it is a way of research without any reflection, etc.

Other contextual elements may be taken into account example:

- The person who makes the analysis (doctor or technician), the conditions of work (at the beginning of the day or at the end of the day),
- The temperature may also have an influence on the decision-making example. In Anapath service, the levy is going to have a displacement of a lab to the other,
- A question must be asked "if the technician who place the levy decided to take a break or have a cigarette outside the service, is this the time spent and the climate change may not affect the temperature and the quality of sampling and by the suite on its viewing and interpretation by the doctors?

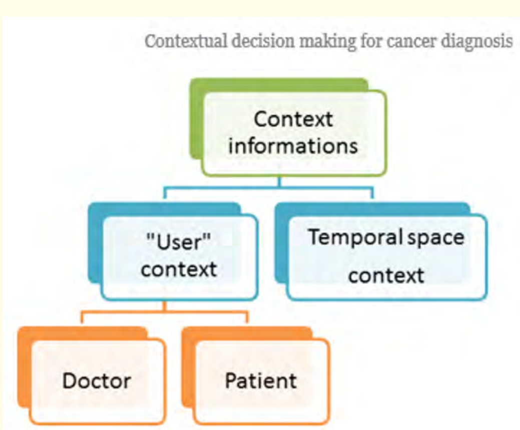

Figure 2: Cancer diagnosis process overview.

We distinguish also many other sources of contextual elements according to the doctor himself:

- Its preferences, point of view, etc.
- Also on the task to achieve (patient already come 3 times).
- On the situation where the task is performed (period of work overload, patient "recommended" by the boss, etc.)
- The local environment (the equipment just to have a fault).

We can conclude that all these contextual elements can have an influence on the quality of the diagnosis and also on the decision-making.

Conclusion

The diagnosis of cancer [13] is a human activity that depends on the context in which it is made. Scanning slides prompted pathologists to pass from analyzing glass slide to the screen. This migration offer the possibility of procedural on at least part of their analytical methods, also integrating other types of reasoning support offer a large flexibility and expand the reasoning field with the aim of improving the quality of service.

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