Artigo de Revisão

The use of expert systems on the differential diagnosis of urinary incontinence

USO DE SISTEMAS ESPECIALISTAS PARA O DIAGNÓSTICO DIFERENCIAL DE INCONTINÊNCIA URINÁRIA

USO DE LOS SISTEMAS ESPECIALISTAS EN EL DIAGNÓSTICO DIFERENCIAL DE LA INCONTINENCIA URINARIA

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ABSTRACT
The differential diagnosis of urinary incontinence classes is sometimes difficult to establish. As a rule, only the results of urodynamic testing allow an accurate diagnosis. However, this exam is not always feasible, because it requires special equipment, and also trained personnel to lead and interpret the exam. Some expert systems have been developed to assist health professionals in this field. Therefore, the aims of this paper are to present the definition of Artificial Intelligence; to explain what Expert System and System for Decision Support are and its application in the field of health and to discuss some expert systems for differential diagnosis of urinary incontinence. It is concluded that expert systems may be useful not only for teaching purposes, but also as decision support in daily clinical practice. Despite this, for several reasons, health professionals usually hesitate to use the computer expert system to support their decision making process.

KEY WORDS
Urinary incontinence.
Women's health.
Expert systems.

RESUMO
O diagnóstico diferencial dos tipos de incontinência urinária é algumas vezes difícil de estabelecer. Via de regra, somente os resultados de exames urodinâmicos permitem um diagnóstico acurado. Entretanto, esse exame nem sempre é factível, porque requer equipamento especial e também pessoal treinado para realizar e interpretar o exame. Alguns sistemas especialistas têm sido desenvolvidos para assistir profissionais que atuam nessa área. Propõe-se aqui apresentar a definição de inteligência artificial; explicar o que são sistemas especialistas, sistemas de apoio à decisão e sua aplicação na área da saúde e, discutir alguns sistemas especialistas desenvolvidos para o diagnóstico diferencial da incontinência urinária. Conclui-se que esses sistemas podem ser úteis não somente para o ensino, mas também como apoio à decisão na prática clínica diária. A despeito disso, por várias razões, os profissionais de saúde usualmente hesitam em usar o sistema especialista computacional para dar suporte ao processo de decisão.

DESCRITORES
Incontinência urinária.
Saúde da mulher.
Sistemas especialistas.

RESUMEN
El diagnóstico diferencial de los tipos de incontinencia urinaria es algunas veces difícil. En general, solamente los resultados de exámenes urodinâmicos permiten uno diagnóstico preciso. Entretanto, no es siempre posible hacer ése examen porque requiere equipo especial y personal entrenado hacia realizar y interpretar lo examen. Sistemas especialistas tienen sido hechos hacia asistir los profesionales de salud en ese campo. Propone-se presentar aquí lo que es inteligencia artificial; explicar lo que son sistemas especialistas, sistemas hacia apoyo a la decisión y suya aplicación en el área de la salud y discutir sistemas especialistas hacia el diagnóstico diferencial de la incontinencia. Concluye-se que los sistemas especialistas puedan ser usados no solamente hacia la enseñanza, mas también como apoyo a la decisión en la práctica clínica. A pesar de eso, por varias razones, profesionales de salud usualmente resisten en emplear el sistema especialista computacional hacia dar soporte al proceso de decisión.

DESCRIPTORES
Incontinencia urinaria.
Salud de la mujer.
Sistemas especialistas.

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INTRODUCTION

The literature demonstrates the prevalence of urinary incontinence (UI) in 14% to 57% of women aged between 20 and 89 years, with complaint of episodes that range from sporadic to daily[1-4].

In Brazil, a study carried out with climacteric incontinent women aged between 35 and 81 years of age showed that stress urinary incontinence is the most frequent (30.7%), followed by urge urinary incontinence (14.2%) and mixed urinary incontinence (10%)[2].

The wide variation of the rate of prevalence can be explained by the use of different definitions and different methods for UI assessment, and by the characteristics of the population. In general, the number of individuals with UI is higher in the elderly population. However, many of the cases remain undiagnosed, due to the individuals do not seek treatment and yet the primary care professionals are not well trained to diagnose and to manage the situation.

As shown in the literature, UI causes a series of restrictions in the personal and professional lives of the affected individuals[5-6]. Therefore, adequate and careful guidance should be considered to manage UI cases, in addition to clinical or surgical management.

Many of the cases remain undiagnosed, due to the individuals do not seek treatment and yet the primary care professionals are not well trained to diagnose and to manage the situation.

It is not so difficult to determine the presence of urinary incontinence because it can be determinate when there is any complain of involuntary loss of urine[7], and only few times urinary leakage may need to be distinguished from sweating or vaginal discharge[8]. On the other hand, the differential diagnosis of incontinence classes (stress urinary incontinence, mixed urinary incontinence, urge urinary incontinence and others) could be difficult to be established in some cases. It involves the assessment of health history, clinical examination and urodynamic testing. Based on a bibliographic review it is concluded that patient history alone is not an accurate tool in the diagnosis of stress urinary incontinence or detrusor overactivity, and should not be the sole determinant of diagnosis or treatment[9]. As a rule, only the results of urodynamic testing allow a sufficiently accurate diagnosis[10].

However, in daily practice this exam is not always feasible, nor can it be immediately performed because it requires not only special equipment, but also trained personnel to lead and interpret the exam. While the definitive diagnosis is not available, some interventions are necessary to minimize symptoms and improve quality of life for the incontinent person.

Artificial Intelligence is the ability of a machine to perform functions that would be considered intelligent, if performed by a human being, for example, to make a decision[11]. One possible application of this concept are expert systems, specialized computer programs designed for a specific area of knowledge, that uses artificial intelligence.

Expert systems have been implemented to support decision making in several areas of medicine, but few works has been done in the field of female urinary incontinence diagnosis[10]. Some expert systems have been developed to assist not only specialists, but also general practitioners[12]. In nursing, the circumstances are not very different. Moreover, Brazil has few nurses who are specialists in this area, and an expert system could be very useful in clinical practice or teaching. In addition, according to some authors[13], expert systems could be particularly well suited for use in urodynamic investigations.

There are few articles that discuss the application of expert systems on the differential diagnosis of urinary incontinence. So the aims of this paper are, based on literature, to present the definition of Artificial Intelligence; to explain what Expert System and System for Decision Support are and its application in the field of health and to discuss some expert systems for differential diagnosis of urinary incontinence.

METHOD

It was made a literature review about expert systems for differential diagnosis of urinary incontinence on the data bases LILACS, PubMed/MEDLINE and using the key-words: expert AND system AND incontinence; expert AND system AND urinary AND incontinence, since 1966 until 2007. It was identified 14 articles, from them 10 were available and nine presented expert systems built to make the differential diagnosis of urinary incontinence, which are discussed here.

ARTIFICIAL INTELLIGENCE

The term Artificial Intelligence was introduced by Dr. John McCarthy in 1956, at the Massachusetts Institute of Technology, during a conference on the possibilities of providing intelligence to machines. According to McCarthy, Artificial Intelligence is the ability of a machine to perform functions that would be considered intelligent, if performed by a human being. Some examples of these functions are: reasoning, speech, learning, natural language, decision making and others. The concept is defined taking into account the principle of similarity, that is, using its set of programs and architecture, the machine performs the same function that man does using his mind and body. Based on this, it is proposed that the computer, through its own means, could perform man's intelligent functions[11].

One of the areas of study of artificial intelligence is Knowledge Processing, that is, the storage and manipulation of knowledge by the machine so that it can be used to solve problems, as is done by expert systems[11,].

EXPERT SYSTEMS

Expert systems are specialized computer programs, designed for a specific area of knowledge, which make it easier to implement and to codify a more restricted knowledge base. It is possible to clearly define the knowledge representation, the decision rules and the data that support the decision by an expert system. Besides that, such systems can produce more useful results by solving difficult diagnostic problems[14-15].

These systems, therefore, decipher problems that are normally solved only by specialists, that is, professionals that accumulate knowledge and expertise, which enable them to solve the more difficult problems[16].

The following characteristics are present in expert systems[11]:

- They simulate the manner in which one or more human specialists solve a problem;

- They use the knowledge of one or more people (not taken from the scientific literature or other non-human sources of knowledge) explicitly represented in the program. This knowledge is acquired through particular techniques from Knowledge Engineering;

- The preferential tasks for this kind of system are fundamentally those of a symbolic nature, which involve complexities and uncertainties usually only solvable with *good sense* rules and implementation of reasoning similar to human thinking;

- The capability of using knowledge in problem solving permits that the search for solutions of complex problems be conducted in a guided manner, in opposition to the search for exhaustion of conventional computerized systems. The system, when *informed* of the characteristics of the problem, decides during processing which is the more probable path to contain the solution. In conventional computing, all the solution pathways are blindly explored, which demands computer resources that are often not available. By using Artificial Intelligence techniques, the search is guided during the process, shortening the solution pathway of the problem.

In order to make a decision about a given subject, the human expert, starting with the facts found and hypotheses formulated, searches in his memory for previous knowledge that has been stored for a long time, in his formative years and in the course of his professional life, about such facts and hypotheses. Then, in accordance with his experience and his accumulated knowledge on the subject he makes his decision. During the reasoning process, he verifies the importance of the facts found and goes on formulating new hypotheses and verifying new facts; and these new facts will influence the reasoning process. This process is always based on previously accumulated knowledge. A specialist may not arrive sat a decision with this reasoning process if the facts on hand to apply his previous knowledge are not sufficient. He may, for this reason, arrive at a wrong conclusion; but this mistake is justified in function of the facts found and his previously accumulated knowledge.

An Expert System should, besides inferring conclusions, have the capability of learning new knowledge and, in this manner, improve its reasoning performance and the quality of its decisions. Since the Expert System is not influenced by external elements, as occurs with the human specialist, it should offer the same set of decisions for the same conditions[16].

Therefore, the expert systems may be used in two different ways[17]:

1. Decision support: the program helps the professional to remember topics or options, which it is believed he knows, but may have forgotten or ignored. This is the most common use in medicine.

2. Decision making: it makes the decision for someone, as it would imply something beyond his training and experience level. This is the most common use in many industrial and financial systems, but it is already being used in medicine also.

The structure of an expert system is composed of four essential components[16]:

1. Knowledge Base: an information base containing all the relevant knowledge about a problem in an organized form[11] - the place where the facts (data) and the rules are stored. The content of the knowledge base is of two main types: **factual knowledge**, in the form of proven information and accepted by the scientific community, is knowledge contained in scientific literature; and **heuristic knowledge**, in the form of *common sense* rules obtained through the experience of experts. These rules result from the intuition of specialists that usually cannot prove them scientifically and from them is derived the strength of the expert systems[11];

2. Acquisition Interface: used to modify and add new knowledge to the base by the experts;

3. Inference Mechanism: a set of intelligent methods of knowledge manipulation[11]. Part of the program that will interact with the user in the search mode and access the knowledge base to make inferences about the case proposed by the user; and

4. User Interface: it is activated each time the user requests an explanation about a particular decision made by the system, or about any fact or knowledge stored in the base.

The independence between the form of specialized knowledge storage and the form of utilization of this knowledge allows the updating of knowledge stored in the system without implying in modifications of the program code and this allows for the conclusion proposed to be based on updated knowledge about a given knowledge domain[11].

SYSTEMS FOR DECISION SUPPORT

The decision-making process occurs at several points of activity of the health professional. Some of them are quite elementary, as in the case of interpretation of a laboratory result. However, there are three important and strongly interrelated aspects where the computer may assist in the decision-making process. They are: the diagnosis; the prognosis and the therapeutic planning[16].

The systems for decision support may be classified as systems with limited or no capacity for making their own decision (recovery of data, computer-assisted mathematical calculations, primary data analysis and interpretation) and automated reasoning/inference systems (disease classification systems, expert systems based on consultations and expert systems based on criticism)[18].

The systems for health decision support are specialized consultation systems designed to supply information to professionals, assisting in consultation, in image recognition and interpretation, in therapeutic criticism and planning, in diagnostic support and also information storage, recovery and generation of warnings and reminders. The following are examples of supporting systems: QMR and Iliad; electronic books (as AT or DEF); systems for reference consultation (MEDLINE); Dombal (abdominal pain program); Mycin (antibiotic therapy) and others[19].

Study[20] defines a clinical decision-support system as *any computer program designed to help health professionals make clinical decisions*. Therefore, these systems may or may not be expert systems that require artificial intelligence resources.

EXPERT SYSTEMS IN THE HEALTH AREA

The first expert system in medicine was developed in the beginning of the 1970s by Dr. Edward Shortliffe, from Stanford University, EUA. The program, called MYCIN, recommends the selection of antibiotics in cases of bacteremia or meningitis, based on characteristics of the infectious agent and on the clinical data of the patient, such as the infection site, signs, symptoms and other associated medical conditions. Although it was not the first program for decision support, it was the first to use symbolic knowledge in a format based on rules[17].

At first, most of the research systems were developed to assist in the diagnostic process. After the initial enthusiasm, there was growing disillusionment with such systems. Most of them did not leave the research laboratories, partly because they did not earn sufficient support from clinicians to be introduced in daily tasks. Many others became educational expert systems[17].

EXPERT SYSTEMS FOR DIAGNOSIS OF URINARY INCONTINENCE

Systems with rule-based logic

The rule-based logic was invented in the 1970s decade and was able to eliminate some difficulties of algorithms. They are sentences, usually conditioned phrases, of the type *IF something occurs THEN other thing occurs, OTHERWISE another thing is expected*, stored in a file containing the knowledge base. Example[17]:

IF the patient has headaches **AND** the pain is very strong **AND** the pain is constant **AND** the pain increases with noise **AND** the pain increases with light **THEN** the diagnosis is Migraine.

A simple rule-based logic system was developed for preoperative assessment of women complaining of involuntary loss of urine and scheduled to undergo surgery for incontinence[13-14]. The aim of the system, according to the authors, was to use the parameters obtained at urodynamic investigations to arrive at the correct diagnosis. The expert system shell[a] EXSYS, a rule-based system with the possibility of assigning probabilities to the different solutions, was used. Tree diagrams were created for each diagnosis and the corresponding predictive values (statistical approach) were calculated; then rules based on the authors' experience (heuristic approach) were added. The results of testing the expert system prospectively on 100 patients showed that the system had a good performance for stress incontinence, but not for mixed incontinence (misclassification rate of 3% and 80%, respectively)[13]. In another article, the authors presented the results of a testing on 54 patients. The systems had high specificity for all diagnoses (91.7% to 100.0%), but low sensitivity for urge and mixed incontinence (50.0%)[14]. The authors concluded that the expert system had been found reliable in a clinical setting and was useful for teaching purposes[13-14], but the results for urge and mixed incontinence are not so satisfactory.

In nursing it was developed two expert systems based in rules: the ALTURIN.EXP[21], that used a shell program named EXPERTMD (version 2.07) and the ALTURIN.SDD[22], built with a program named System for Diagnoses Determination (SDD, version 1.0). Both used the terminology of the North American Nursing Diagnosis Association (NANDA) and had a good performance (both sensibility and specificity upper to 98%), but need more tests before to be used in clinical sets.

System based on genetic algorithms

Algorithm is a step-by-step procedure, a sequence of actions to solve a problem or reach an objective. In computing, programming consists in representing/describing

[a] Shell is a system that may be used to prepare new expert systems by means of addition of new knowledge, corresponding to the new problem domain[25].

an algorithm in a programming language. Algorithms are ancient processes; Euclid's Algorithm dates from 400 to 300 BC and calculates the greatest common divisor (GCD) of two positive integers[23].

Algorithms are characterized for implementing decisions in the form of conditional commands built into a program. Currently algorithms are used in programs of small size and low complexity that give support to medical decisions. They have some restrictions related to the difficulty in finding and correcting errors and due to the fact that their knowledge base is not independent from the program[24].

Genetic Algorithms (GAs) could be understood as global optimization algorithms that use a random parallel and structured search strategy, oriented to the search for *high aptitude* points, that is, points where the function to be minimized (or maximized) has relatively low (or high) values. The GAs explore historical information to find new search points where better performance is expected. This is accomplished through iterative processes, where each iteration is called **generation**[26].

The starting point for utilization of GAs as a tool for problem solution is the representation of these problems in such a way that the GAs may adequately work over them. Traditionally, individuals are genotypically represented by binary vectors where each element of a vector denotes the presence (1) or absence (0) of a given characteristic: the **genotype**. The elements may be combined forming the actual characteristics of the individual, or his **phenotype**[26].

A machine learning system named Galactica has been developed which uses a genetic algorithm to discover the rules for an expert system from databases.

The basic operational principle of GAs is that a **selection criterion** will result, after several generations, in more apt individuals generated through manipulations applied over the initial group of individuals[26].

A set of operations is necessary so that, from a given population, successive populations are generated that (it is expected) will improve their aptitude with time. These operations are basically: **crossover** and **mutation**. They are used to ensure that the new generation will be completely new, while having somehow characteristics of its parents. In order to prevent the best individuals from disappearing from the population by manipulation of genetic operations, they may be automatically placed in the next generation, through elitist reproduction. This cycle is repeated a certain number of times[26]. If the GAs were developed correctly, the population (set of possible answers) will converge to an excellent solution, but not ensured the best one, for the proposed problem[27].

A machine learning system named Galactica has been developed which uses a genetic algorithm to discover the rules for an expert system from databases. Galactica devised accurate diagnostic rules for female urinary incontinence from difficult heterogeneous data. The percentages of correctly classified stress, mixed and urge urinary incontinence testing cases were 89, 86 and 87%, respectively. However, these rules were rather general, consisting of 4-6 out of 13 conditions available in the data. Diagnostic rules for stress and mixed incontinence extracted from straightforward homogeneous data were highly accurate, classifying 100% of testing cases correctly as well as being specific, having from 10 to 11 conditions. More specific, but less accurate, rules were found from heterogeneous data with a biased fitness function. All of the rules were correct, i.e. every condition in the rules had the expected value specified by the expert. Although Galactica achieved a slightly better classification than the discriminant analysis, it is argued that the genetic approach is better than the statistical one, due to symbolic rules being comprehensible, whereas understanding a complex mathematical model requires statistical expertise[28].

Although this expert system presented good performance, there are no recent publications of the authors showing that the system has been used in clinical sets.

Fuzzy Logic

Expert systems in the health care area must consider the uncertainty of the diagnostic process. The fuzzy logic was developed based on the concept of partially true values, varying from *completely true* to *completely false*, and has become a powerful instrument to manage imprecision and uncertainty. It is used in diagnostic systems, image analysis and, more recently, in epidemiology and public health[29-30].

Lotfi A. Zadeh introduced the theory of fuzzy sets in the 1960s as a way to model the uncertainty within natural language (e.g. *ever*, *frequently*, *sometimes*, *rarely*, *never*)[31]. The theory of fuzzy sets considers that a set could have members that belong to it only in part. Such fuzzy sets have imprecise boundaries and, therefore, a gradual transition from membership to non-membership of an element in its fuzzy set is observed. A fuzzy relation could express a partial or imprecise relationship between elements of some sets, as opposed to a precise one in the case of a crisp relation in which any elements can either be related or not. In the fuzzy relation, there are gradual relationships that vary from *1* for being fully in relation to *0* for not being in relation at all, through all intermediate values[31].

Using the software shell EXSYS, it was has designed an expert system to aid the gynecologist in the management of stress urinary incontinence. This allows greater sophistication over the traditional algorithmic flow chart, as it avoids the non relevant data and facilitates a treatment plan specific to the requirements of a particular practitioner. Input variables like the skill level of the operator and the availability of urodynamic investigations guide the user to approaches that are most suitable for her or his practice. Using fuzzy logic to cater for uncertainty in decision making, the program is more realistic than classical algorithms[32]. Unfortunately, the article that presents this system was written as letter to Editor and do not demonstrated the results of its use in practice. So it is not possible to appreciate its performance.

A model based on fuzzy logic was recently elaborated for making differential diagnosis of alterations in urinary elimination, considering the nursing diagnosis approved by the NANDA and the maximum-minimum composition of fuzzy relations. It was tested with 195 cases and the model was able to determine the diagnosis in total accordance with a panel of three experts for 79.5% of the cases. The model diagnosed 19% of the cases with partial concordance with the panel of experts. Only for three cases (1.5%) the model showed a different diagnosis. Therefore, despite its simplicity, this model presented a good performance[33].

The model performance was evaluated with 195 cases from the database of a previous study, resulting in about 79% of total concordance, when compared with the panel of experts. Total discordance was observed in 3 cases only (1.5%).

CONCLUSIONS

In spite of the good performance of the expert systems to differential diagnosis of urinary incontinence presented here, there are problems associated with using systems based in artificial intelligence to decision support on this field, which also happen in other medical expert systems.

Firstly, health professionals frequently hesitate to use the computer system to support their decision making process. There are a lot of reasons for this to happen, from ignorance about of these computer systems to insecurity about of the paper that they can carry out.

Second, there are important ethical aspects that should be considered and that are commonly misunderstood. One of them referred to the difficulties in determining correctly the responsibility if the *opinion* of the expert system are incorrect. On the other hand, with an ever increasing medicolegal environment, the surgeon may be found to be negligent if the expert system had not been preoperatively consulted[32].

However, the development of expert systems may be useful not only for teaching purposes but also as decision support in daily clinical practice, making expert knowledge accessible to less experienced professionals and helping health professionals to manage with a lot of information that are important for an adequate diagnostic process and patient treatment.

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