Managing Urinary Incontinence through Hand-held Real-time Decision Support Aid

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Abstract: In this paper, we present an intelligent system for the diagnosis and treatment of Urinary Incontinence (UI) for males as well as females, called e-URIN. e-URIN is an intelligent system for diagnosis and treatment of urinary incontinence according to symptoms that are realized in one patient and usually recorded through his clinical examination as well as specific test results. The user-friendly proposed intelligent system is accommodated on a hospital server supporting e-health tools, for use through pocket PCs under wireless connection as a decision support system for resident doctors, as well as an educational tool for medical students. It is based on expert system knowledge representation provided from urology experts in combination with rich bibliographic search and study ratified with statistical results from clinical practice. Preliminary experimental results on a real patient hospital database provide acceptable performance that can be improved using more than one computational intelligence approaches in the future.

Key-Words: - Incontinence, Decision Support, pocket PC, wireless

1. INTRODUCTION

Computerized decision support systems within health care have been considered since the mid-1950’s however, development in medical practice has been limited by a number of factors, such as the lack of models to capture medical decision making processes and non-integrated nor real-time patient care information systems [1]. In addition, the original expert systems were often seen as a challenge rather than a support to professional decision-making in healthcare. Urinary incontinence is involuntary loss of urine; some experts consider it present only when a patient thinks it a problem [2]. The disorder is greatly under recognized and underreported; the common estimate of 13 million people affected in the US is low. Incontinence can occur at any age but is more common among the elderly and among women, affecting about 30% of elderly women and 15% of elderly men [2], [3]. Incontinence greatly reduces quality of life by causing embarrassment, stigmatization, isolation, and depression. Many elderly patients are institutionalized because incontinence is a burden to caregivers. In bedbound patients, urine irritates and macerates skin, contributing to sacral pressure ulcer formation. Elderly people with urgency are at increased risk of falls and fractures [2].

A. TYPES OF INCONTINENCE

Incontinence may manifest as near-constant dribbling or as intermittent voiding with or without awareness of the need to void. Some patients have extreme urgency (irrepressible need to void) with little or no warning and may be unable to inhibit voiding until reaching a bathroom. Incontinence may occur or worsen with maneuvers that increase intra-abdominal pressure. Postvoid dribbling is extremely common and probably a normal variant in men. Identifying the clinical pattern is sometimes useful, but causes often overlap and much of treatment is the same [3]. a. Urge incontinence (UUI) is an urgent, irrepressible need to void that occurs just before uncontrolled urine leakage (of moderate to large volume); nocturia and nocturnal incontinence are common. Urge incontinence is the most common type of incontinence in the elderly but may affect younger people. It is often precipitated by use of a diuretic and is exacerbated by inability to quickly reach a bathroom. b. Stress incontinence (SUI) is urine leakage due to abrupt increases in intra-abdominal pressure (eg, with coughing, sneezing, laughing, bending, or lifting). Leakage volume is usually low to moderate. It is the 2nd most common type of incontinence in women, largely because of complications of childbirth and development of atrophic urethritis. Stress incontinence is typically more severe in obese people because of pressure from abdominal contents on the top of the bladder. c. Overflow incontinence (OUI) is dribbling of urine from an overly full bladder. Volume is usually small, but leaks may be constant, resulting in large total losses. Overflow incontinence is the 2nd most common type of incontinence in men. d. Functional incontinence (FUI) is urine loss due to cognitive or physical impairments (eg, due to dementia or stroke) or environmental barriers that interfere with control of voiding. Neural and urinary tract mechanisms that maintain continence may be normal. e. Mixed incontinence (MUI) is any combination of the above types. The most common combinations are urge with stress incontinence and urge or stress with functional incontinence. Finally, there is a variant of UUI, which mimics the symptoms of SUI and we decided to treat it as a separate case, since the therapy proposed is different from
SUI and UUI. Detrusor hyperactivity with impaired bladder contractility (DHC) is a condition characterized by involuntary detrusor contractions in which patients either are unable to empty their bladder completely or can empty their bladder completely only with straining due to poor contractility of the detrusor. It is defined as the presence of both detrusor overactivity during the storage phase, and underactive detrusor contraction during the evacuation phase [1].

B. CLINICAL DECISION MAKING INTELLIGENT SYSTEMS

Clinical decision-making is a complex task requiring a knowledgeable practitioner, and reliable informational inputs involving the identification and management of patients’ health needs. Most research in health-care decision-making is grounded in either decision analytic theory or information processing models. Analytic models stress achieving optimal decisions systematically and rationally by pre-specification of decision alternatives, determining the probability of the alternative occurring, and the utility of the alternatives to the decider [1]. Traditionally, an intelligent system that helps clinicians to diagnose and treat diseases is used to identify a patient-specific clinical situation on the basis of key elements of clinical and laboratory examinations and consequently usually refine a theoretical treatment strategy, a priori established in the guideline for the corresponding clinical situation, by the specific therapeutic history of the patient [2]. Depending on the patient’s data, it models patient scenarios which drive decision making and are used to synchronize the management of a patient with guideline recommendations. The so-called guideline-based treatment choice can be considered under the main difference between management of acute and chronic disease that is the time. Guideline dependence introduces a computer-assisted intelligent Decision Support Systems (DSSs), based on technologies that provide to the patient “most likely” treatment scenario [4]. So, the creation of an expert system to assist non-expert doctors in making an initial diagnosis would is very desirable [5], [6].

In this paper, we present an intelligent system for the diagnosis and treatment of UI for males as well as females, called e-URIN. e-URIN primarily aims to help in the diagnosis and treatment of UI diseases effectively under the consideration of clinical and special test findings. Also, it can be used by medical students for training purposes on UI management and introduce a computer-assisted environment for pocket pc that is able to synthesize patient specific information with treatment guidelines, perform complex evaluations, and present the results to health professionals quickly.

II. MEDICAL KNOWLEDGE MODELING

Appropriate diagnosis of UI requires urology doctors with long experience in UI management. One of the problems is that there is no a widely accepted approach yet [1], [7], [8]. Therefore, except from the fact that we had a number of interviews with an expert in the field, we also used patient records and bibliographical sources. Our approach to knowledge modeling included three steps. First, we constructed a model of the basic diagnosis and treatment process. We relied on the expert and the literature at this step (Fig. 1). Then, we specified the parameters that played a role in each entity of the process model. At this step, we relied on the expert and the patient records. Finally, we determined the fuzzy models for the values of the resulted linguistic variables. We had, however, to iterate a number of times on this last step to improve the model (Fig. 2).

A. INPUT-OUTPUT VARIABLES

Based on our expert, we specified a set of parameters that play a role for each of the entities in the process model that represent patient data (Fig. 1). Finally, we resulted in the following parameters for each entity in the process model.

According to the model, we distinguish between input, intermediate and final parameters at each sub process.

Input parameters:
1. Medical History: (a) Alzheimer, (b) Multiple Sclerosis, (c) Myelomeningocele, (d) Epispadias, (e) Oblitaration, (f) Bladder trabeculation, (g) Diabetic neuropathy,
2. Incontinence Description: (a) Loss during coughing, (b) sneezing, (c) laughing or physical activity (d) Involuntary loss and strong desire, (e) Frequent or constant dribbling, (f) Frequency and (g) urgency.
3. Previous Incidents: (a) Stroke, (b) Incontinence surgeries, (c) Sacral cord lesion, (d) Low or supra sacral cord lesion,
4. Other Medication: (a) (anti)cholinergic, (b) opioids, (c) radiation therapy,

Intermediate input parameters/Special tests: (a) Cystometry: >300 ml causes urgency/contractions, (b) Instantaneous leakage at cough test, (c) Delayed or persisted leakage at cough test, (d) PVR>100, (e) Elevated postvoid PVR, (eg>50). And exclusionary questions for (f) age (g) Chronic impairment of physical or (i) cognitive function.

Final output parameters:
1. Diagnosis (a) UI mechanism (b) SUI (c) UI diagnosis.
2. Treatment: Final treatment according to current UI and other preexisted diseases (a) pelvic floor training (b) biofeedback, (c) electric stimulation, (d) medication and (e) surgery

B. UI DIAGNOSIS AND TREATMENT

The knowledge base of the expert system includes production rules, which are symbolic (if-then) rules with Boolean or crisp variables. The variables of the conditions (or antecedents) of a rule are inputs and the variable of its conclusion (or consequent) an output of the system. To represent the process model, we organized production rules
in three groups: UI classification rules, UI diagnostic rules and treatment rules inspired from model presented in Fig. 1. The current patient data are stored in the Patient Database, as facts. Each time that the reasoning process requires a parameter value, it gets it from the database or the user. In a pure interactive mode, it could be given only by the user.

For each patient dataset that is stored in the Patient Database, UI diagnosis Rules decide to ask for the parameter special test values in order to give to the user the final diagnosis. Fig. 3 presents how the rule groups and the facts or user are used or participate during the reasoning process to simulate the diagnosis process.

<table>
<thead>
<tr>
<th>Symptom/Diagnosis</th>
<th>UII</th>
<th>SUI</th>
<th>MUI</th>
<th>OUI</th>
<th>DHIC</th>
<th>FUI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alzheimer</td>
<td>+</td>
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<tr>
<td>Sclerosis</td>
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<tr>
<td>Myelomeningocele</td>
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<tr>
<td>Epispadias</td>
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<tr>
<td>Oblitration</td>
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<tr>
<td>Bladder trabeculation</td>
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<tr>
<td>Diabetic neuropathy</td>
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<tr>
<td>Loss during coughing, sneezing, laughing or physical activity</td>
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<tr>
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<td>Frequent or constant dribbling</td>
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<tr>
<td>Chronic impairment of physical or cognitive function</td>
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</tbody>
</table>

Each time that the reasoning process requires a value, it gets it from the patient database or from user interaction. A sample of UI diagnostic rules can be seen in Table 1. Finally there are a small number of Treatment rules, which according to the resulted disease provide the appropriate treatment strategy.

### III. e-URIN ARCHITECTURE

The developed intelligent system has the structure of Fig. 2, which is similar to the typical structure of such systems [7], [8]. The knowledge base of the expert system includes rules, which are symbolic (if-then) rules. The variables of the conditions (or antecedents) of a rule are inputs and the variable of its conclusion (or consequent) an output of the system as the result of the internal inference engine of the system (Fig 3). The user uses URIN through a handheld device with wireless
connection. Thus authorized users in the Urology clinic have access to the web-based intelligent platform.

IV. IMPLEMENTATION ISSUES

The user interface has been developed with Macromedia Flash 8.0, and the intelligent system has been developed in CLIPS 6.1b Expert System Shell. Patient data in the Database are organized by using CLIPS templates. The total number of rules is 21. All of them have salience 0, except for 2, which have 30. The first rules refer to the questions and the next one to diagnosis and treatment. There are 5 input rules which read the user’s answers. The answers are yes or no, except for 1 rule where the possible answers are 0, 1 or 2, as the possible cases are 3. Each of the 5 input rules refers to a set of questions relative to a subject. Consequently, we have:

- rule for incontinence description with 3 questions
- rule for other diseases with 6 questions
- rule for previous incidents with 3 questions
- rule for other medicine or treatment with 2 questions
- rule for medical tests with 3 questions

Fig. 2. The general structure of wireless intelligent decision support system e-URIN
Besides, there are more input rules which are fired only if some variables are “yes”. So, there are 4 more questions asked only in some cases, formed in 2 rules. The first is fired if the patient has PVR>100 and the question is about her age. The second is fired if the patient has stress or urgent incontinence, and its questions have to do with some more symptoms that may lead to detrusor hyperactivity with impaired bladder contractility, which is a type of urgent incontinence but mimic stress incontinence. As a result the questions asked vary form 17 to 21, except for 2 cases, where functional incontinence is diagnosed. In this case the system is halted as this diagnosis is exclusionary.

As for the conflict strategy, the one which fires the last rule added in the agenda (depth) is used.

Next rule asks the user to input parameters about specific medical tests:

```
defrule cough_test "ask questions"
  (initial-fact) =>
  (printout t "QUESTIONS ABOUT MEDICAL TESTS" t)
  (bind ?leakage (ask-question "If she has instantaneous leakage during cough test insert 1. If she has persisted or delayed leakage insert 2. Otherwise insert 0. " 1 2 0))
  (if (eq ?leakage 1)
    then (assert(instant_leakage yes))
    else (if (eq ?leakage 2)
      then (assert(persisted_leakage yes))
      )
  )
  (bind ?cystometry (ask-question "Cystometry: with fluid >300 ml does she have urgency or contractions(yes/no)? " yes no)
  (assert (cystometry ?cystometry))
  (bind ?pvr (ask-question "Does she have PVR>100(yes/no)?") yes no)
  (assert (pvr ?pvr))
  (if (eq ?pvr no)
    then (assert (end yes))
  )
```
Next rule inserts as final diagnosis Detrusor Underactivity,

Rule 16: If patient cholinergic opioids is yes and spinal cord injury is yes then disease is detrusor underactivity.

has been implemented in CLIPS as follows:

(deftemplate DURIN
  (defrule DETRUSOR_UNDERACTIVITY
    (or (cholinergic opioids yes)
        (spinal_cord_injury yes)
        (diabetic_neuropathy yes))
    =>
    (assert (detrusor_underactivity yes)))

To implement reasoning flow, different priorities have been used for different rule groups (named salience(?)).

The final response of the system on pocket PC screen is like Fig 4.

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**V. PRELIMINARY EVALUATION RESULTS**

We used e-URIN for a number of 95 patient records from the Hospital Database with different types of prostate diseases. The corresponding treatment results were compared to the results of our expert doctor. To evaluate e-URIN, we used three metrics, commonly used for this purpose: accuracy, sensitivity and specificity (abbreviated as Acc, Sen and Spec respectively), defined as follows:

\[
\begin{align*}
\text{Acc} &= \frac{(a + d)}{(a + b + c + d)}, \\
\text{Sen} &= \frac{a}{(a + b)}, \\
\text{Spec} &= \frac{d}{(c + d)}
\end{align*}
\]

where, \(a\) is the number of positive cases correctly classified, \(b\) is the number of positive cases that are misclassified, \(d\) is the number of negative cases correctly classified and \(c\) is the number of negative cases that are misclassified. By ‘positive’ we mean that a case belongs to the group of the corresponding initial diagnosis and by negative that it doesn’t.

The evaluation results are presented in Table 3 compared with the mean results of a team of four non-expert doctors and show an acceptable performance using as a “gold standard” for a system like this 90%.

**Table 3. Evaluation results for initial diagnosis of UI disease patients according to the expert doctor**

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Non EXPERT doctors</th>
<th>URIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCURACY</td>
<td>0.75</td>
<td>0.91</td>
</tr>
<tr>
<td>SENSITIVITY</td>
<td>0.78</td>
<td>0.95</td>
</tr>
<tr>
<td>SPECIFICITY</td>
<td>0.79</td>
<td>0.93</td>
</tr>
</tbody>
</table>

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**VI. CONCLUSIONS AND RELATED WORK**

In this paper, we present the design, implementation and evaluation of e-URIN, a intelligent system that deals with diagnosis and treatment of Urinary Incontinence diseases that is used through pocket PC from the web server of the Urology Clinic of our University Hospital improving the usability of most similar approaches in the same medical field [5], [6], [7], [8], [9], [10], [11], [12], [13]. All of them are PC based, Most of them [5], [6], [7], [8], [9] and [10] deal only with women UI, even after their improvement and some others only with the nursing management of UI [11], [12], [13], [14]. None of them is web-based for remote access or designed or modified for pocket PC use. The diagnosis process was modeled based on expert’s knowledge and existing literature. Input variables were specified based again on expert’s knowledge and the statistical analysis of the records of 95 patients from a hospital database. Input-output values were determined by the help of expert, the statistical analysis and bibliographical sources. Experimental results showed that e-URIN did quite better than non-expert urologists, but worse than the expert. A possible reason for that may be the determination of the values of the variables. A fuzzy approach of the same system may give better results [15]. One the other hand, use of alternative or more advanced representation methods, like hybrid ones [16], [17] may improve the systems’ accuracy and provide adaptability to new knowledge.
REFERENCES


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