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Tele-triage of Child with Abdominal Pain Using the Internet-based Decision Support System

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Abstract

The paper describes an Internet-based decision support system that will help emergency room (ER) medical personnel in triage of children with an abdominal pain. The system will be suited for admission management procedures typical for Canadian and Polish pediatric hospitals. At present a child complaining of an abdominal pain is initially triaged in ER as: appendicitis (requiring surgical consult), other (not yet determined pathological problem), and resolution (harmless pain caused by non-pathological problems). This triage indicates how to take care of a patient. Children classified as 'appendicitis' are immediately referred to surgeon, those with 'other' triage stay in the emergency room or in a hospital and undergo further consultations, and the others, diagnosed as 'resolution', are released home. Main objectives of developing and introducing the system are: support of triage accuracy by the emergency room staff, and reducing management costs. The computer system will be built using client-server architecture. Server, accessible over the Internet, will be responsible for storing records of diagnosed patients in the database, analyzing stored data with the use of AI and machine learning techniques, and for supporting triage of new patients. Client, running in web browser, will be used for entering data and presenting suggested triage. Apart of the Internet-based system, a mobile version, running on the PDA devices will be also developed.

1 Triage of child with abdominal pain

1.1 Introduction

Abdominal pain is a common clinical emergency. The challenge at the triage of such patients is to differentiate those who may safely be discharged home from those that require urgent medical or surgical attention. Notwithstanding the technological advances in diagnosis, the management of a patient with abdominal pain is to a large extent reliant on the clinical expertise of the caregiver. The process of reaching the final diagnosis may necessitate in-hospital observation. As abdominal pain is especially dominant as an emergency in childhood, delay in diagnosis may result in anxiety to the child, the family and the medical staff.

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The more experienced the clinician in the assessment of children with abdominal pain the more rapid and the more reliable the management.

Evidence from both clinical and psychological studies points to an obvious advantage to the rapid triage (initial assessment) of patients with abdominal pain. The central difficulty of such triage is the choice of clinical symptoms and signs (attributes) that in combination contribute the most to the diagnosis and management. A relevantly reduced set of attributes should assist the triage nurse and help the ER physician.

1.2 Tele-triage

Fig. 1 presents the typical way in which children complaining of abdominal pain are managed in the ER. It also establishes a framework for use of the decision support system in tele-triage of the patients.

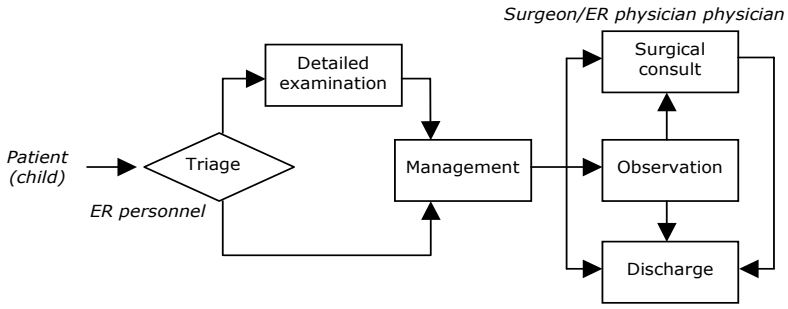

Figure 1. ER management of child with an abdominal pain

At present, a child is examined (this includes the necessary tests) by the ER personnel (i.e. triage nurse and ER physician) to determine his/her the triage. The possible outcomes are: 'resolution', 'surgical consult', and 'other'. 'Resolution' means that the abdominal pain was caused by non-pathological problems, and the patient can be discharged. 'Surgical consult denotes that acute appendicitis is suspected. In such case the patient is referred to a surgeon, who continues the management. 'Other' triage also indicates possible pathological problems and the patients are normally kept for in-hospital observation.

As mentioned above, triage is a first stage in a patient management process. The final (actual) diagnosis is known when the patient is discharged, and in case of being triaged as 'surgical consult', after the surgery from a pathology report.

The proposed decision support system (DSS) is designed for use by the ER medical personnel to support the triage. There is no apparent need to support surgeons, because they are usually able to diagnose appendicitis with very high accuracy. However, their availability in the ER is limited and they cannot examine every patient. Current practice shows that the triage accuracy achieved by the ER triage nurse is approximately 50-60%. Thus, the proposed system will be aimed at increasing this accuracy and, what is even more important, at helping to reduce a number of incorrectly triaged patients.

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1.3 Collected data

Clinical attributes considered by ER personnel and used by the DSS are given in Table 1. It should be noticed that not every member of ER personnel is able to conduct all examinations necessary to obtain values of the attributes. ER triage nurse is trained to acquire values for some of the attributes (for example temperature), while ER physician is able to carry out all the tests.

Most of the attributes are nominal (e.g. gender or type of pain), however there are also numerical ones (e.g. temperature or WBC), and some that indicate a location of a condition on patient's abdomen (e.g. location of pain or site tenderness). Values of these latter attributes are collected with a help of special abdomen pictograms, on which attending ER caregiver marks proper location.

Attribute	Description
Age	Patient's age
Sex	Gender
AbdPainDur	Duration of pain
AbdPainSite	Location of pain
AbdPainType	Type of pain
Vomiting	Number of times vomiting occurred
PrevVis	Previous visit to ER in last 48 hours
Temp	Temperature
AbdTend	Site tenderness
AbdGuard	Localized abdominal muscle guarding
LocAbdRebTend	Localized abdominal rebound tenderness
AbdPainShift	Shifting of pain
WBC	White blood cell count

Table 1. Patient's clinical attributes used by the system

Values of numerical attributes and those describing location of a condition are internally processed by the system. Numerical values are discretized according to medical practice, and "location" attributes have values converted into nominal ones using an algorithm developed by surgeons and ER physicians for that specific purpose.

2 Internet-based DSS architecture

The Internet-based DSS will be implemented using client-server architecture. Its detailed scheme is presented in Fig. 2.

2.1 Server

The server of the system will be implemented as a set of CGI scripts that will be invoked by a web server when requested. The server will be responsible for the following tasks:

- managing patients' databases,
- analyzing records stored in databases,
- deriving at the triage, i.e. classifying patients.

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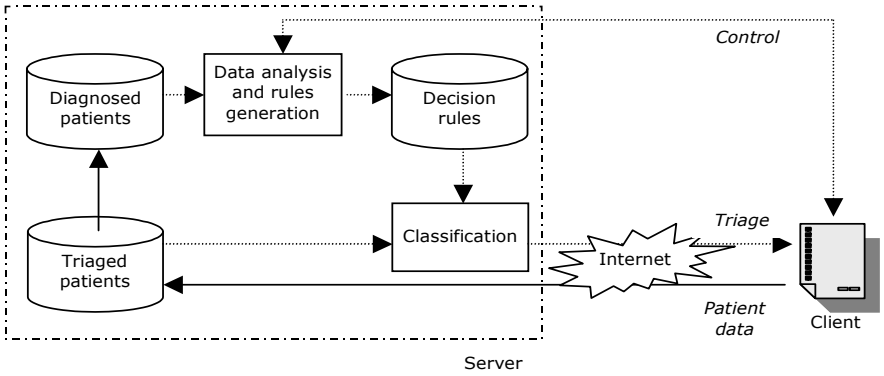

Figure 2. Architecture of the Internet-based DSS

The server will be responsible for management of two databases containing triage information and records of the diagnosed patients. The triage database will contain information about patients being examined in ER or staying in hospital for observation, for whom final diagnosis is not known. The diagnosed patients database will store records of patients for whom final diagnosis is available. The triage database will be fully accessible from the client side, while the diagnosis database will be locked for the modifications. Patients' records will be automatically moved from triage to diagnosis database, as soon as the final diagnosis is obtained. Once a record is moved, there will be no possibility of modifying it.

The server will process information stored in the diagnosis database to find the most discriminatory and information-rich clinical attributes and to generate decision rules for classifying triaged patients. The most valuable attributes (with regard to information content) will be selected using an approach based on rough sets theory [4] and fuzzy measures [1]. As patients' data contains large number of missing values, an extended version of rough sets approach – suited for dealing directly with missing values [2] – will be applied. After selecting relevant attributes, an algorithm called Explore [5, 7] will be used to induce decision rules. The Explore algorithm is aimed at finding decision rules that meet requirements as specified by a user. One of these requirements concerns rule strength, i.e. rule generality (strong decision rules can be seen as capturing general patterns). Unlike in other rule induction algorithms that work in a completely automatic way, here the user is able to specify strength of the rules to be generated. This feature of the Explore algorithm is especially useful, due to the fact that strength of decision rules is often dependent on the class for which they are induced. Thus in our case, it was possible to find very strong and general rules for patients belonging to 'resolution' and 'surgical consult' classes, while the 'other' class seems to contain unique and specific examples that are almost impossible to generalize. Usefulness of the methodological approach described above was proved in a pilot study involving a sample patients' data. [6]. Decision rules were generated from the database collected in 1997 at the Children's Hospital of eastern Ontario in Ottawa, Canada and then translated into a clinical algorithm (a system of conditional statements accepted by the medical profession). The clinical algorithm was used to suggest triage of patients' records collected in 2000. Comparing to triage accuracy of the ER triage nurse, accuracy of the clinical algorithm was

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better at the 70% level. Moreover mis-classifications of the algorithm were clinically acceptable with 18% of healthy patients being classified as 'appendicitis', but none of those with appendicitis was misclassified as resolution.

Data analysis in the DSS will be fully controlled from the client side. Firstly, it will be possible to check and modify the list of selected attributes (albeit it will be possible to eliminate from the list those clinical attributes that can not be collected by a triage nurse). Secondly, a user will be able to set all the parameters of the Explore algorithm. Finally, it will be possible to modify the set of generated rules, for example by fine-tuning or removing rules conflicting with medical practice.

Decision rules generated during data analysis stage will be used for classifying patients' records stored in the triage database. This classification will be invoked by the client, and the suggested triage, will be presented on the client side.

2.2 Client

The client, implemented as a set of web pages, web forms and Java applets, will be run in a web browser. It will offer two work modes: *basic* – triage support mode, and *advanced* – data analysis mode. *Basic* mode is intended for common use in ER. Client working in this mode will enable ER medical personnel to:

- enter and modify patients' data,
- invoke classification of patients records stored in the triage database (classification will be performed on server side),
- present suggested triage.

The client operating in a *basic* mode will also allow to complement patient's record with final diagnoses. These patient records, for which final diagnosis is entered, will be moved to the diagnosis database and locked.

Advanced mode will be occasionally used (when the diagnosis database is extended with many new records) to invoke and control process of data analysis and rule generation. When working in this mode, users will be able to check and modify the list of selected clinical attributes, set parameters for the rules generation algorithm, and finally verify and modify the set of generated decision rules.

A working mode of a client will be established after user's login procedure. Most of the users will have accounts with basic privileges (i.e. enabling them to work in *basic* mode), while several users (e.g. surgeons and ER physicians, nurse administrator) will have accounts with advanced privileges, allowing to invoke a client in the *advanced* mode.

3 Mobile DSS architecture

The Internet-based DSS will be supplemented by its mobile version that will work on PDA handheld devices (specifically it will be developed for palmtop computers running PalmOS operating system). Scheme of the mobile system is presented in Fig. 3.

The mobile component will extend the functionality of the DSS with the following features:

- data will be collected and stored just at the patient's bed,
- data can "follow" a patient management by being transmitted from one PDA to another using an infra red wireless interface (IrDA).

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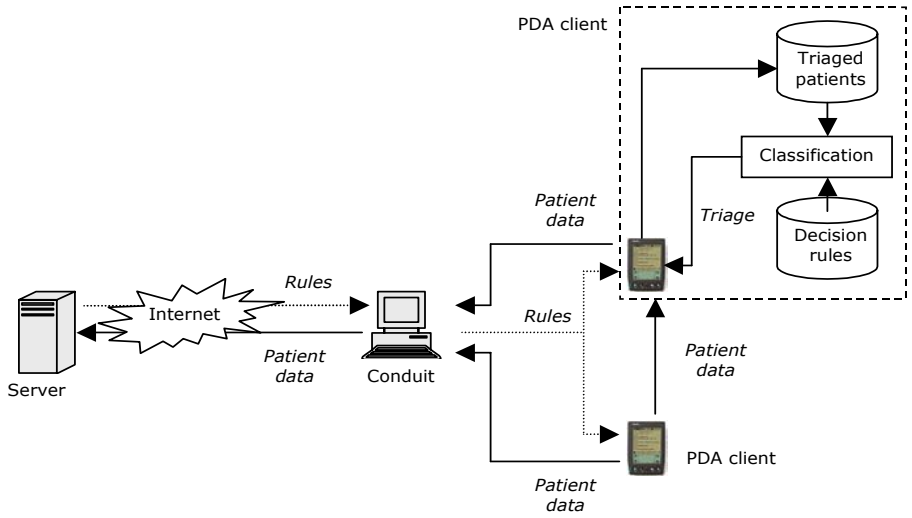

Figure 3. Architecture of a mobile DSS

Such setup will eliminate need for writing down the test and examination results and entering them manually into a web-client running on a computer located in the ER room. Moreover, a nurse will be able to transfer all patient's data gathered so far to another attending health care professional (other nurse, ER physician or surgeon), who might carry out additional tests and collect more information. It will be possible to classify the patient and to obtain suggested triage at every stage of the data collection process, however, more available information should lead to more accurate and reliable triage decision.

The mobile system will consist of two main components:

- a PDA client running on palmtop computers,
- a conduit application running on a desktop computer.

The PDA client, implemented as PalmOS application, will be responsible for managing local triage database, containing data of triaged patients, and classifying patients using information from the local database with the rules obtained from the server. The client will also be used to enter and modify patients' records and to present triage.

The conduit, developed as Windows application, will exchange data between PDA clients and server. It will retrieve patients' data from local databases of PDA clients and send them to the server. In the opposite direction, the conduit will download most recent decision rules from the server and synchronize them with rules stored in PDA clients, thus ensuring that the up-to-date set of rules is used to determine triage. Communication between conduit and server will be conducted over the Internet, and on the PDA side, data will be transferred using wireless interface or cradle device.

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4 Summary

The paper describes DSS for triage of children with an abdominal pain. The system will be built using client-server architecture with server accessible over the Internet. Such solution will facilitate use of the system by many remote hospitals, and will allow them to share the data and knowledge (expressed in form of the decision rules). In this way, the ER triage will be streamlined and less dependent on a medical culture of the particular hospital. Moreover, it will be possible to base triage on the knowledge and information coming from several hospitals, including teaching and community ones.

The Internet-based system will not require additional investment, or dedicated hardware or software (to the only requirement is an ability to access the system via the Internet). It will be possible to extend the system with a portable component, running on PDA computers. The portable component will require additional hardware (palmtop computers), but will offer extended functionality and usability. It is worth observing, that the portable component was initially proposed by the medical staff participating in the research.

Methodology that will be used on the server side to analyze patients' data and to generate decision rules has been already tested. The results show that it is possible to improve triage accuracy in comparison with the typical accuracy of the ER triage nurse. Such improvement means that:

- treatment costs might be decreased, as it will be possible to minimize a number of expensive procedures (such as USG),
- patient's management process should be streamlined and shortened by arriving at accurate triage in a shorter time with a smaller number of tests and specific examinations.

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