An ontology-based consultation system to support medical care on board seagoing vessels

Gabriele Carletti¹, Paolo Giuliodori², Vincenzo Di Pietri³, Alessandro Peretti¹, Francesco Amenta¹, ³

¹Telemedicine and Telepharmacy Centre, University of Camerino, Camerino, Italy
²School of Science and Technology, Computer Science Division, University of Camerino, Camerino, Italy
³Research Department, International Radiomedical Centre (CIRM), Rome, Italy

ABSTRACT

Background: A realistic possibility to obtain medical care for patients located in remote sites such as seagoing vessels, in which health professionals are not available, is to contact a doctor via telecommunication systems. In general, the medical knowledge of who on board ships is in charge of medical care is quite limited and therefore, in a first level telemedical consultation, the flow of information should be correct and its efficiency should be maximised. This paper describes an application conceived to improve requests of medical assistance from sailing ships. The ultimate objective of this system is a) to standardise as much as possible the requests of medical advice at a distance, b) to overcome language barriers and jammed-related troubles that could make difficult or not understandable a telephone conversation.

Materials and methods: The application is based on a software engine extracting data from an ontological knowledgebase built ad hoc using Protégé.

Results: Compared to the conventional consultation systems based on telephone and e-mail, the proposed device is more accurate and complete in terms of information contained in the request of assistance. Moreover, data received by the medical centre can be more easily managed, as they can be standardised.

Conclusions: The system described here allows people responsible of medical care on board ships to forward detailed requests of assistance containing symptom-guided information on patient clinical conditions. This may represent an innovative tool for medical consultations at distance allowing the remote centre to provide more precise and quicker medical advice.

Key words: teleconsultation, remote medical advice, ontology, Protégé, medical assistance on board ships

INTRODUCTION

Telemedicine, consisting in the application of information and communication technology (ICT) to the solution of medical problems and in the exchange of medical information, is changing our approach in the delivery of several health services. Telemedicine includes a growing variety of applications and services the use of which will increase in the near future.

Teleconsultation (e.g. the medical visit made via ICT) can be divided into different levels based on the players involved and the complexity of the information exchanged. A basic (first level) teleconsultation is the electronic/telephonic communication between a client (patient) and a physician. A second level teleconsultation involves a physician or another health professional and a specialist delivering health care services and information over small and large distances. In the second level teleconsultation, data, information, images and/or voice are exchanged. A higher level of teleconsultation (third level) involves a medical team of a hospital addressing specific questions to the team of...
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Java methods and classes can easily be called in a JSP page. A software application was then built as the engine to interact with the “.owl” generated Protégé file.

Basic software technology and JSP

The system is based on a web service implemented in JSP. JSP seemed to be the most suitable solution, providing a Java library capable of interacting with the OWL standard. Java methods and classes can easily be called in a JSP page. The following are the main JSP pages (Fig. 3).
The system allows for saving data in an XML database:

- main.jsp, main page that allows the user to select the principal sign and answer the detailed information and the additional signs; it contains all the JavaScript functions related to the web service, such as the “Yes/No” functionality (Fig. 4);
- save.jsp, process page that saves the information inserted by the user in the XML database;
- menu.jsp, a navigation page;
- style.css, defines the CSS style of the elements.

The system even allows the doctors of the medical centre to answer the requests inserting a diagnosis and the admin to edit saved data. These are the relevant JSP pages:

- save_diagnosis.jsp, process page that saves the diagnosis inserted by the doctors in the XML database;
- view_data.jsp, allows doctors and admin to see and edit all the records. Admin could then, for instance, decide to delete one or more users’ records and doctors to add or modify a diagnosis;
- delete_users.jsp, process page that permits to delete users’ records from the XML file.

The two principal pages concerning the final user (patient, doctor or admin) are “main.jsp” and “view_data.jsp”, the first to insert, the second to view data. The other pages, excluding “menu.jsp”, are processing pages and have the task to interact with the XML database and to modify it.

The Java classes

The Java classes work as interface between the application, the ontology and the XML database (Fig. 3). The main Java classes used were:

- OWLAPI, it acquires all the information contained in the ontology. For instance, when the page “main.jsp” is loaded, this Java class gets all the principal signs or when a user selects a principal sign, a method of the OWLAPI acquires
from the ontology all the related detailed information and additional signs. This class takes advantage of the Protégé Java Library that permits to interact with an RDF/XML model that in fact is the structure of the ontology;

— **Email**, the task of this class is to send email to the medical centre with the list of information inserted by the user and to the user if a doctor has inserted or modified a diagnosis;

— **XmlReader**, this class is called when the page “view_data.jsp” is loaded. It takes all the records contained in the XML database;

— **XmlWriter**, as XmlReader it interacts with the XML database and inserts users’ records and doctors’ diagnosis.

**THE PATIENT’S USER INTERFACE**

**Detailed info navigation and answering**

The hierarchical organisation of concepts and the superclasses make easier and less time-consuming for the user to navigate the information. Selecting the main sign, the system asks to consider a series of additional signs and detailed infor-
These are organised in big groups (superclasses). If the patient doesn’t manifest the sign to which the group is referring or doesn’t want to consider that superclass, he can simply answer “No” (or don’t click) to the relevant superclass (Fig. 4).

By clicking on a superclass, the series of detailed info about that clinical status appears. They can be answered in the following three main ways (Fig. 5):

— boolean selection (Yes/No);
— multiple selection;
— typing (generally a string or a number).

Other information

Patient’s general info. Some basic details on the patient needing medical assistance and simple information on his personal history should be provided:

— age;
— name;
— birthdate;
— sex;
— nationality;
— rank.

Patient’s clinical history and drugs administered. Basic medical history and drug history of the patient should be included in the following order:

— previous most significant diseases;
— chronically administered drugs;
— drugs administered for the actual condition.

Submission of data

Once answered all the detailed information referring to all the superclasses as described above, the user can submit them, sending the data package to the maritime telemedical centre (TMAS) (Fig. 5).

The system has been adapted in particular for naval communication. Then, a series of information about the ship is required to be inserted, such as:

— ship name;
— ship type;
— ship owner;
— call sign;
— master;
— ship nationality;
— port of departure;
— port of arrival;
— speed;
— position;
— telephone/fax/e-mail.

SYSTEM TESTING

Tests of the system are ongoing in collaboration with Centro Internazionale Radio Medico (CIRM), the Italian TMAS [9] using seagoing vessels as a prototype of isolated places. CIRM medical assistance is given to ships of any nationality sailing worldwide. The service is provided 24 h a day and 365/366 days per year by doctors on duty. The centre receives the request of assistance and gives instructions for the case. For assessing the quality of the system, 150 teleconsultations between seagoing participating voluntarily to the experiments (users) and CIRM medical team (experts), were evaluated. Evaluation of the system involved both the user’s and the expert’s side and both user’s satisfaction and technical aspects. The parameters listed below were considered compared to standard communication systems:

— accuracy of the request (number of non-ambiguous signs communicated per request);
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Table 1. Evaluation of the system effectiveness using 150 teleconsultations from seagoing vessels (user) and Centro Internazionale Radio Medico (CIRM) headquarters in Rome (expert)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tester</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy of the request</td>
<td>Expert</td>
<td>High</td>
</tr>
<tr>
<td>Accuracy of the possible diagnosis</td>
<td>Expert</td>
<td>High</td>
</tr>
<tr>
<td>Speed — overall</td>
<td>User-Expert</td>
<td>Medium</td>
</tr>
<tr>
<td>Speed — diagnosis</td>
<td>Expert</td>
<td>High</td>
</tr>
<tr>
<td>Usability</td>
<td>User</td>
<td>High</td>
</tr>
<tr>
<td>Williness to use</td>
<td>User</td>
<td>Medium</td>
</tr>
<tr>
<td>Completeness of the info</td>
<td>User-Expert</td>
<td>High</td>
</tr>
<tr>
<td>Easiness of data managing</td>
<td>Expert</td>
<td>High</td>
</tr>
<tr>
<td>Reliability of the system</td>
<td>Expert</td>
<td>High</td>
</tr>
</tbody>
</table>

*“High”, “Medium” and “Low” indicate respectively for better, same as, and worse compared to standard (telephone or e-mail) previous communication systems.*

— accuracy of the diagnosis made by the centre (number of correct verified diagnosis/total cases);
— speed of a complete round: time to make the request/time to provide the answer;
— speed of the diagnosis;
— usability (easiness of use, even by an inexpert user);
— williness to use;
— completeness of the information;
— overall reliability of the system.

A score from “High” to “Medium” to “Low” was assigned by the testers (users and experts) for each of the above parameters.

RESULTS

The system described here has shown the capability to forward accurate remote requests of assistance with no technical problems in terms of software functionality and integrity of data transmission.

Differently to other tools that are diagnosis-oriented [10], the proposed system does not provide diagnostic solutions, but results efficient in guiding the user towards the collection of appropriate signs, already codified according to the guidelines provided by the maritime telemedical centre, with no possibility for self-ambiguity and ensuring the information transmitted to be as complete as required.

Table 1 summarises the results reporting the prevalent mark on the total number of evaluations provided by the testers. The system has shown, in respect to the existing consultation tools, a higher completeness and accuracy of the request of assistance in terms of information transmitted, a quicker and more accurate diagnostic possibility and an overall high usability and reliability.

DISCUSSION AND CONCLUSIONS

The system allows the user to prepare telemedical requests of advice with precise and circumstantial information. A substantial advantage derived from adopting the application for telemedical consultation consists in the fact that a great number of specific information about the patient (automatically suggested starting from the main symptom) could be transmitted to the physicians in charge of medical assistance, increasing the chance to get a correct and faster advice. Moreover, data transmitted are encoded using a standard vocabulary and a standard formulation. The information transmitted is therefore more easily managed by the centre. The system will also contribute to constitute a patient’s historical data repository as a support for further teleconsultations.

Thanks to the ontologies, an easy to obtain multi-language selection is available. This option could reduce communication barriers caused by language troubles, misunderstandings and verbal hesitations mostly due to the unavoidable use of technical clinical terms. Problems of jammed telephonic communication are also eliminated through the direct transmission of data.

As a result, the user is able to get a faster and more accurate answer of assistance from the maritime telemedical centre. Referring to the maritime assistance, a correct and quick diagnosis could avoid unnecessary transfers of the patients, limiting costs for changes of course/evacuations and discomforts for the crew.

In 2013, CIRM reported several problems in providing correct diagnosis due to imprecise information from the ship side. The test of the support communication system described here, showed an improved definition of the medical problems to be treated. The potential advantages of the system appear therefore promising.

FUTURE IMPLEMENTATIONS

As a possible future enhancement of the system, we are considering the possibility of crowdsourcing the requests, through a server, from the mobile terminal of the patient
Figure 6. General architecture showing the flow of the information for a future possible distribution system. The users’ request dispatched to the server would be redistributed to a set of experts and the answers would be both returned to the user and stored into a knowledgebase creating the basis for automatic diagnosis (a mobile version should be first developed) to a pool of clinicians. Once the clinicians will answer the requests, these data will be returned back to the patients and stored into a knowledgebase (as actually for the XML database), creating the fundamentals for further automatic processing of medical information (Fig. 6).

This will allow the development of a medically-validated, punctiform, status-diagnosis association. In the second automated phase, the clinicians’ work will be significantly reduced, but reliable medical answers could be still obtained since they will be inferred from researches and learning processes on the knowledgebase.

Considering the application, it would be interesting to investigate the possibility to perform automatic reasoning on the main ontology in order to infer new knowledge and to rearrange the existing data structure such as the subclasses hierarchy and the positioning of the instances.

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REFERENCES