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Treatment Protocol System for Telemedicine in a Wireless Communication Environment

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Abstract

We propose a treatment protocol delivery system for Emergency Medical Technicians and combat medics in situations when patients are unable to obtain medical care from physicians with sufficient facilities, such as casualties in a battlefield environment. In such situations, patients are often in emergency condition and time is a critical factor for them. Telemedicine with wireless communication support has an important role to play in alleviating this problem. By using advanced computer technology in both hardware and software, telemedicine can help medics provide better care for these patients.

Introduction

There are many situations in which patients require urgent treatment that cannot be provided locally from physicians, such as casualties in a battlefield environment. In such situations, patients are often in emergency condition and time is a critical factor for them. We propose a treatment protocol delivery system for telemedicine that can help solve such problems by providing medics or Emergency Medical Technicians (EMTs) with therapeutic plans for a patient along with remote c nsultation from specialized physicians at the base hospital. The Treatment Protocol System is designed to provide treatment pluns that can be tailored for specific patients when access is provided to the patient's medical record or to information from patient-monitoring equipment. With recent mobile telecommunication technology such information can be exchanged in real-time between the base site and the remote site (Pavlopoulos et al. 1998). The Treatment Protocol System is designed to work in both wireless and face-to-face environments. Our Treatment Protocol System is influenced by the treatment protocol system produced by Tsai (1990) for the MEDAS project (Trace et al. 1990).

Overview of the System

The Treatment Protocol System employs a rule-based approach to generate treatment protocols. The system knowledge base stores rules and facts that are extracted from various sources of medical information, such as clinical practice guidelines, medical texts and journals. The Treatment Protocol System consists of two main components as shown in Figure 1: a knowledge authoring module and a treatment protocol delivery module. The knowledge authoring module is used by medical experts, by doctors who create or update protocol knowledge for relevant clinical domains. The knowledge authoring module uses a conceptual model of the workflow (Grifoni et al. 1997) to visually construct the0skeleton of a treatment protocol. Using this model a treatment protocol can be defined by a domain expert in terms of the workflow of treatment activities. The system provides a visual tool that allows the expert to define treatment activities in a graphical representation associated with textual information as shown in Figure 2. The treatment protocol delivery module takes the skeletal treatment protocol from the knowledge base and combines it with clinical information about the patient from a patient clinical record or current observations and then generates a treatment protocol for that patient. The output treatment protocol is an executable protocol that is dynamically refined on the basis of events such as a significant change in the current patient's clinical state or the arrival of new clinical information. The method used in the treatment protocol delivery module is inspired by the Episodic Skeletal-Plan Refinement (ESPR) approach (Musen et al. 1996).

The main features of the treatment protocol system can be described as follows:

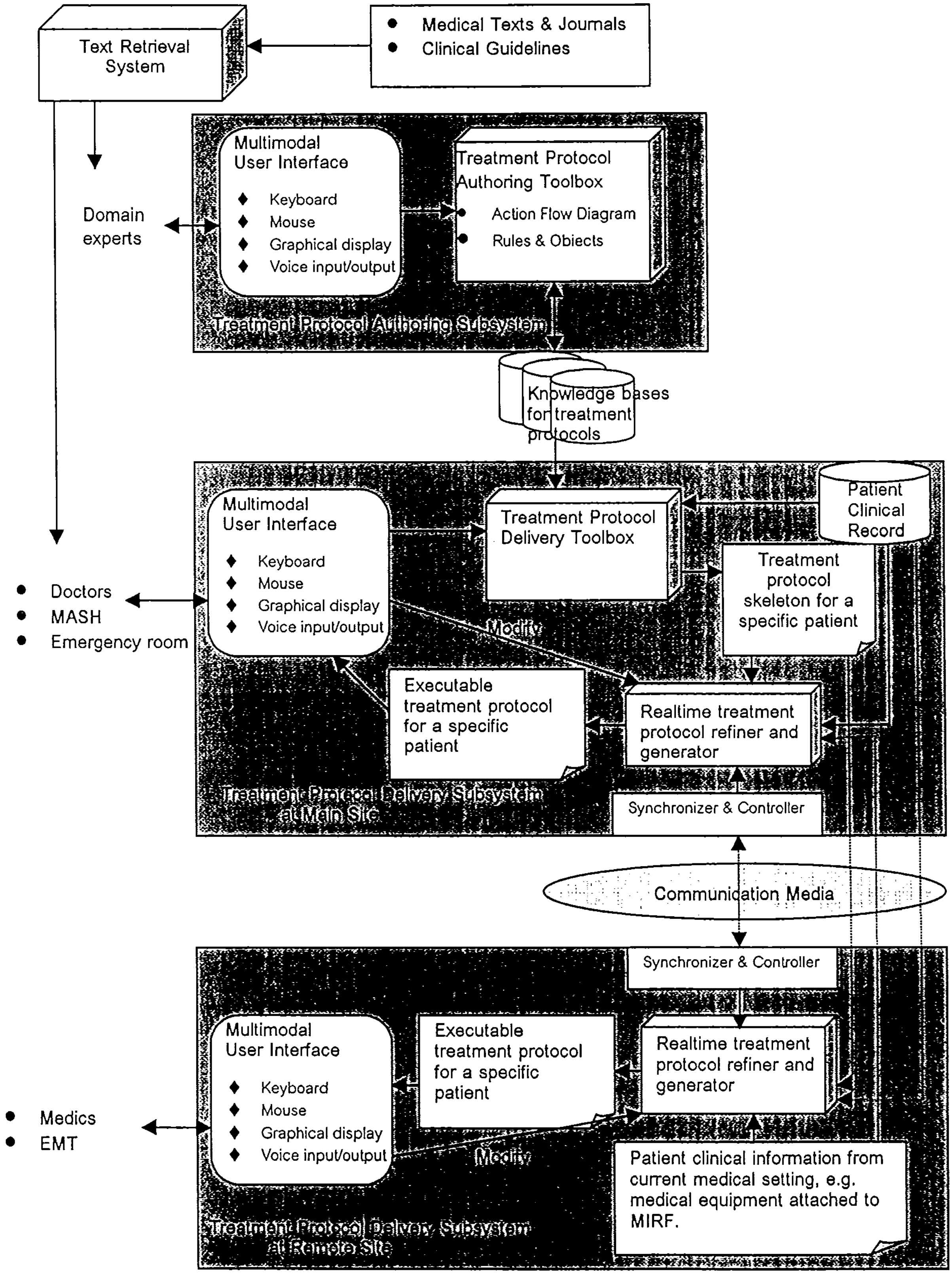

Figure 1. The Treatment Protocol System Architecture.

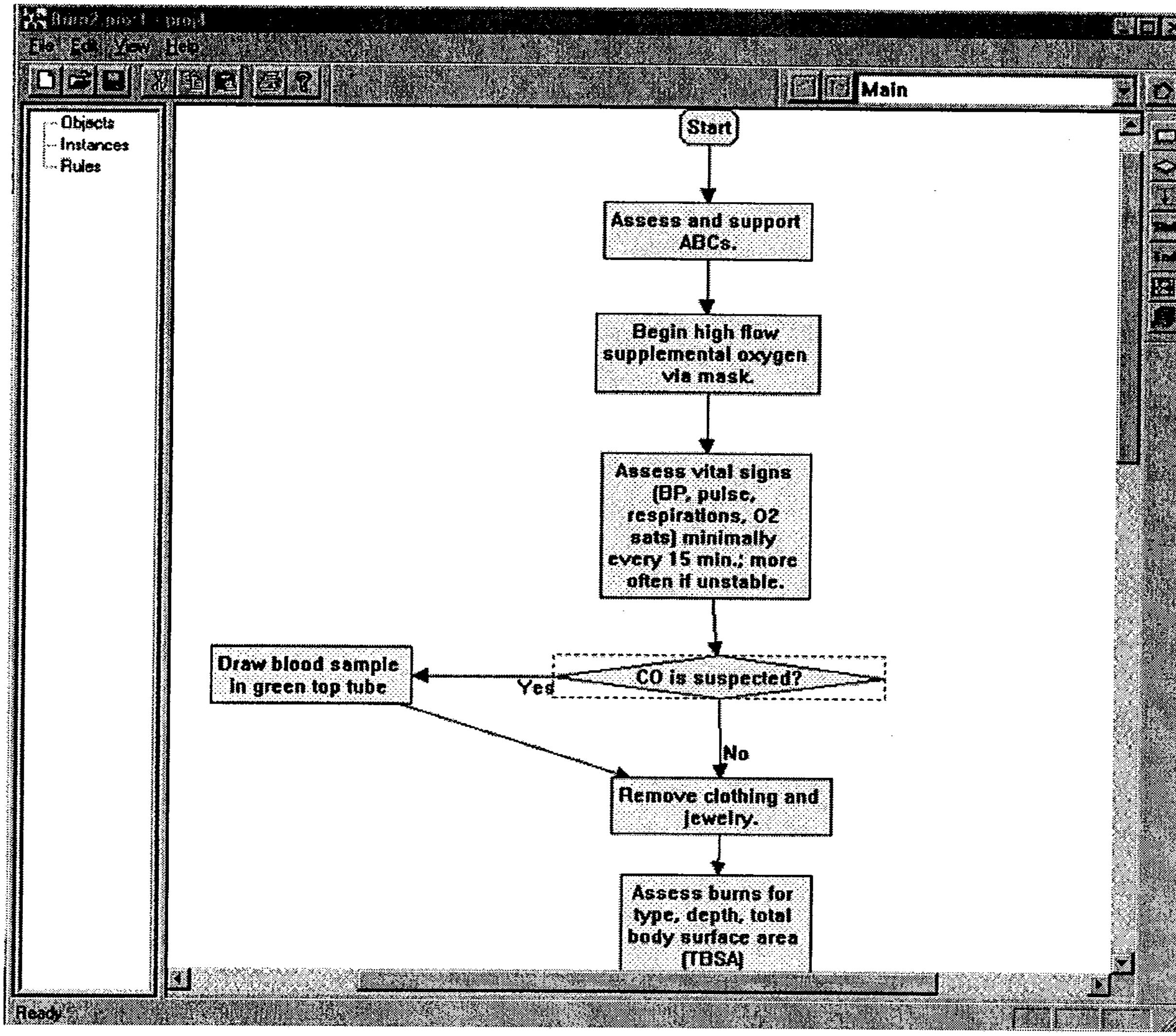

Figure 2. The Example of a Flow Diagram of Treatments for Burns (Source: Region Hospital Emergency Medical Services, Available at URL http://www.regionsems.net).

1. The system provides a treatment protocol in the form of a sequence of medical actions that EMT's or medics can easily follow. The system will track the user actions so the users will always know what has been done anþ what to do next.

2. The system utilizes clinical practice guidelines as the main source of the system knowledge. The treatment protocol authoring tool described earlier captures the guideline content and logic in a form understandable to the system and uses it to generate treatment protocols.

3. The system interacts with the Medical Record System directly. Clinical data can be acquired from and submitted to the Medical Record System. The Treatment Protocol System will be able to display the medical records with analyzed clinical data in the form used by the front end of the Medical Record System. The integration of medical record information into telemedicine also brings up important considerations of confidentiality and privacy issues if the information is transmitted over a public network (Richardson et al. 1996).

4. The system uses a controlled medical vocabulary that is widely accepted by many other institutions. This will allow the system to exchange comprehensible knowledge with other medical systems remotely.

5. The system provides multimodal user interfaces as the front-end component to interact directly with the user. In addition to ordinary I/O systems (e.g., mouse, keyboard, display monitor and printer) a speech recognition system is also provided to allow voice data entry and voice output for the system. The voice interface capability will be useful for most health care providers who are rarely accustomed to using a keyboard or mouse and who usually need their hands to do other more important tasks in emergency situations.

6. The system provides a visual environment that can display a graphical representation of system knowledge to users. Some of knowledge elements may have associated graphical representations (e.g., treatment protocol objects can be shown as a flow diagram, and an object hierarchy can be shown as a tree structure.) However, the text representation can be shown alongside its associated graphical representation. Each graphical representation is displayed in its own window and has its own interface to users.

7. The system is multimedia-capable. Therefore images, sound, animation, and video are supported in the system. This feature is necessary because much medical information is in multimedia form beginning with radiographic images. Since most multimedia file formats are space consuming, which can strongly affect performance when files are transferred between sites, we rely heavily on advanced transmission techniques.

8. The system has internet/web connectivity wkth access to medical information provided by many worldwide web sites. The system may also use the internet/web as a communication medium for connecting with some of our remote sites.

System Components

The system consists of two parts: one is resident at the main computer at a base hospital or other central site and the other is resident at a remote site on a battlefield or in a helicopter or an ambulance. At the main site the system is connected to the central databases directly and is able to access remote databases in other institutions by existing media, e.g., over telephone lines or the internet. The system at the main site provides the patient's history information. At the remote site, the system is connected to medical equipment that provides current information about patient's condition. The systems at both sites will exchange information about the patient.

The program instance at the remote site is used by the medic who provides treatment to the patient. In the meantime a physician or nurse using the instance at the central site can observe the procedures at the remote site, can send messages, and can override the treatment protocol suggested by the system or bring up another one on the remote screen. Although the remote site instance can operate independently if communication is lost, the system is much more effective when synchronization is maintained between the two sites.

Knowledge Engineering

Because of the complexity of the available practice parameters and the multiple sources of knowledge in our medical domain, the process of building or updating a treatment protocol for a specific domain is divided into two main steps. In the first step the Text Retrieval System (see Figure 1) helps the domain expert to identify all relevant information in the source text (which may be an AMA practice guideline, a medical textbook or a journal article). The second step contains tèe actual construction of the protocol (or modification of the existing protocol) with support from the system.

In the first step, the Text Retrieval System generates an index of medical terms from the medical sources chosen; they may be online or locally available. The system then provides the domain expert with a search engine that can retrieve related information about one or several given terms. By the time this phase is over, the domain expert has identified and collected together the pieces of text containing the information that s/he wants to use in constructing the protocol.

In the second step, with the information found using the Text Retrieval System as a guide, the domain expert actually builds the treatment protocol for a specific domain (or modifies an existing protocol). To support the expert in this phase we provide the Treatment Protocol Authoring System.

The Treatment Protocol Authoring System employs an object-oriented approach to model real world facts. Facts and rules in the rule-based model are represented as several classes of objects, e.g. rule objects and protocol objects. Some necessary classes of objects are predefined by the system and are ready to be used by users. The domain expert may have to know a little more about the object-oriented approach if they want to define a new class or extend the existing class. To make the task of knowledge construction more comfortable for the expert the Treatment Protocol Authoring System provides a tool to represent some object classes in their associated graphic representation. After the domain expert finishes creating the treatment protocol, the protocol knowledge is then stored in the knowledge base and is later used by the Treatment Protocol Delivery System.

We are just starting to build this part of the system and there are significant knowledge engineering problems still to be solved.

Knowledge Representation

Rule-based and object-based models are used to represent our system knowledge. Since the rule-based approach is employed in our system as the main problem solving method, production rules are necessary as the key knowledge elements for the inference engine. However, production rules alone do not have adequately expressive power to represent complex domain knowledge such as the knowledge in a clinical context. The object-based model has an advantage in structural and organizational behavior over the rule-based model. So we will use the object concept to abstract domain knowledge into hierarchical objects, whereas the rule-based model is used to add the operational knowledge that controls the state and behavior of the objects.

Each object in the clinical context (e.g., patient, disease, symptom, and treatment) can be defined in an object class that contains attributes and operations. Objects may have relations to each other. All necessary objects in clinical context will be predefined in the system. However, the expert can define new objects by establishing subclasses of predefined classes.

The treatment protocol system is a rule-based expert system. The system knowledge consists of rules that are extracted from clinical practice guidelines, medical texts or journals. In our system, rule premises and actions can be defined as the expression of object attributes from defined classes. The domain expert can also define rules as preconditions of a class operation. By using rules and facts (e.g., patient clinical information) the inference engine can modify the treatment protocol for a particular situation or a particular patient. Figure 3 shows the diagram of some objects in clinical context. The circular blocks denote classes and the rectangular block denote their attributes.

A major focus of our work is how to display rules and supporting diagrams or pictures on the screen in a form that is easy to use in stressful situations. Figure 4 shows some sample rules extracted from practice guidelines for burns and some respiratory signs and symptoms. Which rule for burns is displayed will depend on what the system knows about the patient's injury or drug allergies. The object-oriented representation of rules can be represented as shown in Figure 5.

The medic can click on an unfamiliar name or abbreviation to get an explanation, but we plan to use the standard vocabulary for emergency medicine developed at Medical College of Wisconsin so that we expect that this will happen rarely. The user can indicate with a single click whether s/he has decided to perform a suggested action or not.

Conclusions

The treatment protocol system described here is an ongoing project. We are attempting to build a medical system that takes advantage of the current advanced technologies in telecommunication, multimedia, and modern user interfaces. While the main task of the system is to provide treatment protocols to medical personnel who take responsibility for patients in emergency situations, we have also focussed on improving the human-computer interface of the system. We have many plans for future improvements. Since the system is usually used in stre{ ful envmronments where manual procedures, such as data entry, are likely to be error-prone (Petroni et al. 1991), advanced usgr interfaces like voice input or better screen design can increase the accuracy of human tasks. Our system will have the ability to accept human-voice commands and to generate spoken output. This will free the user to use his hands in other important tasks.`&It will also be useful in the dark. We hope to test the system at Cook County Hospital. We need to observe real users in the field in order to evaluate the system.

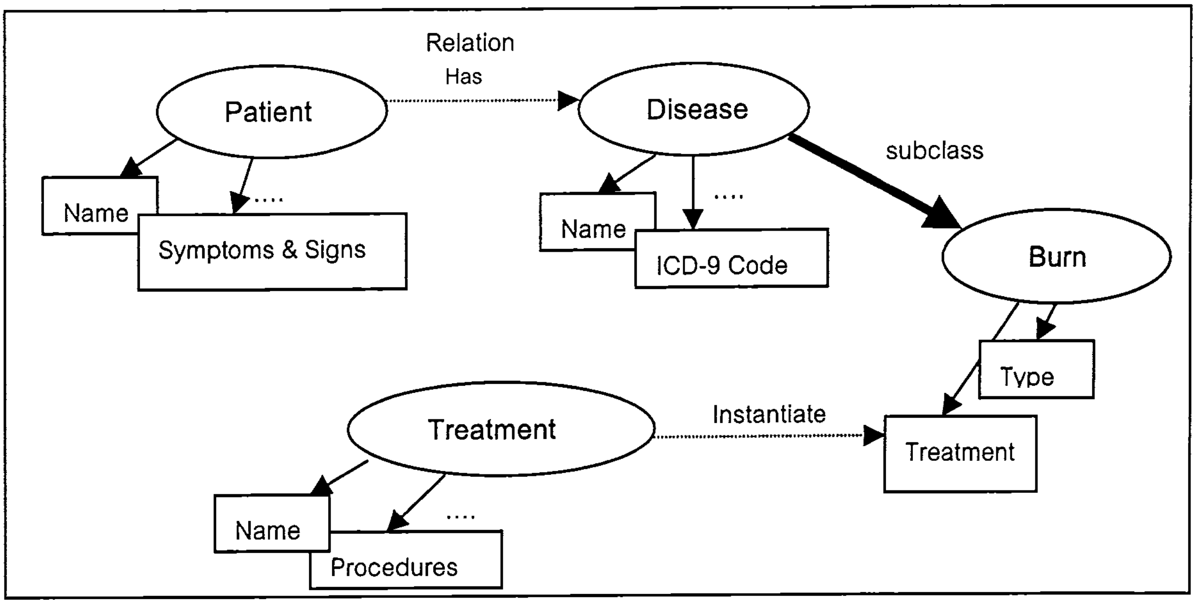

Figure 3. A Diagram of Some Objects in a Clinical Context.

RULE-1
IF 1) Patient has burns, and
2) Burn type is Chemical burns,
THEN 1) Perform BLS, and
2) Wash burn area with copious amounts of water or NS for 20 minutes.
RULE-2
IF 1) Patient has burns, and
2) Burn type is Chemical burns, and
3) Burn area is eyes,
THEN 1) Perform BLS, and
2) Irrigate burn area with copious amounts of NS until the patient reaches the hospital.
RULE-3
IF 1) Patient has burns, and
2) Burn type is Inhalation burns,
THEN 1) Perform BLS, and
2) Reassess frequently and consider the need for early intubation, and
3) Perform BLS with variance or ALS and consider albuterol neb for bronchospasm.

Figure 4. Sample Rules for Burns Expressed in English.

Defrule (Patient.HasDisease.Name("burns") and Patient.HasDisease.Type("Chemical burns")
=> Perform(Burns.Treatment.Context("BLS"));
Perform(Burns.Treatment.Action("WASH_1")))

Note: WAHS_1 is a new defined action for washing burn area with copious amounts of water or NS for 20 minutes.

Figure 5. The Representation of Rule-1 in Object-Oriented Form.

Acknowledgments

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