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A Framework of Emergency Clinical Decision Support System based on MDA and Resource Model

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***Abstract*—Emergency clinical decision making is a challenging issue in healthcare services, notably in the environment of complicated data processing. Effective and efficient clinical decision making highly depends on the sufficient information sharing of the involved working teams. However, emergency decision support systems are usually hard to be developed because that the problems of emergency decision are always unexpected and unstructured. This paper focuses on the developing of decision support system to coordinate actions carried out in emergency situations. A framework is proposed based on MDA (Model-Driven Architecture) approach and resource model to dynamically build decision support system when emergency events occur. The effectiveness of our method is discussed and verified in a case study of collaborative clinical decision making on traffic accident emergency rescuing. The result shows that the MDA approach combined with resource model has the potential to support information system evolution along with the emergency events.**

Keywords—Collaborative decision making; Emergency medical service; Model-driven architecture; Resource model; Clinical decision support system

I. INTRODUCTION

Emergency clinical decision making is challenging in healthcare servicing because that emergency events often involve more individuals and cause heavy damages. Emergency decision support systems are useful to improve the effectiveness of decision on emergency events handling. With emergency decision support systems, data of emergency events are shared among the decision-makers, and instructors responding to the emergency events handling are delivered from upper level decision-makers to lower level ones. With the thorough sharing of events and decision information, damages caused by emergency events may be reduced to the least [14][2] .

However, the development of emergency decision support systems is difficult. (1) The emergency decision problems are complex and hard to be solved. The process of emergency decision making needs to be studied to support the emergency events handling. (2) The emergency decision problems are unexpected and unstructured. The emergency decision support systems are hard to be constructed ahead of the occurring of the emergency events. More flexible architecture needs to be proposed for emergency decision support system development. (3) The coordination among decision makers is complex. In the era of big data, more sophisticated mechanism and platform of information sharing need to be designed for emergency decision support systems.

Efforts have been done in emergency clinical decision making, especially to coordinate the actions carried by different decision makers or medical teams[12][8].

Social network is considered useful in solving the problem of lacking coordination during emergency decision making[6]. Dynamic Data-Driven Application Systems are used to enable coordinated decision making in case of medical crisis [11]. W. Raghupathi and A. Umar explore the MDA in hospital information system development[15]. UML is used as the system modeling tool in the form of the class diagram. David Suarez et al. use decision matrix to support information obtaining for medium-sized urban emergencies [3]. A collaborative knowledge management architecture based on Linked Open Data was proposed to improve the availability of data accessing to better respond to emergency events [4]. Data standard and terminological systems are concluded to be success factor to facilitate the seamlessly information sharing of automatic advices provision when developing clinical DSS[5]. Medical services system incorporated with real-time traffic information databases are used in rural area emergency servicing[7].

More researches are still needed to explore the mechanism of information sharing and propose feasible method to support emergency decision making.

Our research aims to propose flexible, Model-Driven-Architecture and resource model based method to develop DSS dynamically to support emergency clinical decision making. When emergency events occur, resources assigned to resolve the emergency problems would be loaded dynamically into the DSS platform according to the decision process.

The paper is organized as follows. Emergency clinical decision-making process is discussed in Section2. Section 3 proposes a framework of dynamic emergency decision support system based-on MDA method. The detail of our framework of DSS is described in Section 4 using the case of emergency medical services in traffic accident rescuing. Conclusions are drawn in Section 5.

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II. Decision Making Process in Emergency Healthcare Servicing

Healthcare servicing activities could be divided into three phases including pre-treatment processing (patient transportation), in-treatment processing (diagnosis and laboratory testing), and post-treatment processing (payment and insurance documentation).Various professional staffs are involved in the whole healthcare serving process.

For emergency medical servicing, the pre-treatment and in-treatment phases are more critical. Most difficult emergency decision making problems also occur in these two phases. The main roles/entities involved in these two phases are composed of patients who need the emergency healthcare servicing, physicians who provide the healthcare servicing, ambulances which transport the patients to the hospitals, medical apparatus and medicine which are used in disease treatment. The relationship of the different roles is shown in Fig. 1.

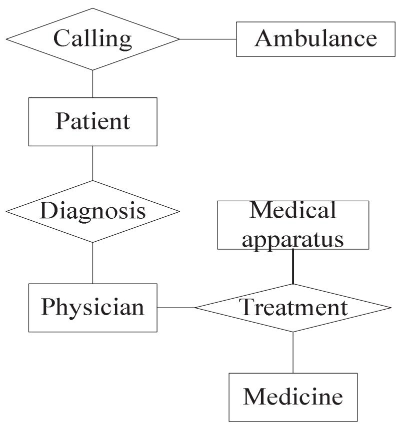

Fig. 1. E-R diagram of emergency medical servicing roles

In Fig. 1, resources of physicians, ambulances and medical appliances cooperate to make decisions and take actions to deal with patients in emergency situations. Thus, emergency medical servicing is a group decision making process. The group members of decision making include ambulance drivers, doctors and nurses.

Usually group decision making is an iterative process trying to find the best or satisfactory solution from multi alternatives to satisfy multi utility criteria, which is described as follows [10].

$$\max f(x1,x2,\ldots xn)=\{f1,f2,\ldots fn\}$$
$$\text{s.t. } g(x1,x2,\ldots xn)<0 \quad (1)$$

In (1),*f1, f2* and *fn* are the utility criteria which are restricted by *g(x1,x2,… xn)*.

Alternatives are defined as follows, in (2).

$$\cup A_i \quad (2)$$

Each alternative A_i has its utility value under each evaluation criterion *j* as in (3).

$$\cup f_{ij} \quad (3)$$

The final alternative to the group decision making problem is often chosen after several rounds of feedbacks or voting [9].

However, for emergency clinical decision-making problems, to take actions as quickly as possible, to adjust the actions with the evolution of the events, are more critical than to choose alternatives. In our research, we define a decision process focusing on the coordination of task groups and the dynamical adjustment of decision alternatives, shown in Fig. 2.

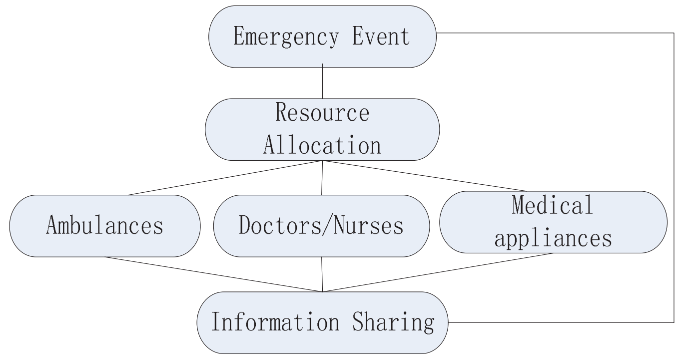

Fig. 2. Emergency clinical decision making process

In Fig. 2, the process of emergency clinical decision making iterates the following two steps:

- Resource allocation. After the severity of the emergency event is evaluated, resources are collected to carry corresponding actions.
- Information sharing. During taking actions, information should be shared among resources. With the evolution of the emergency event, not using resources are released out or new resources are applied in.

With iteration of these two steps, emergency clinical decision making is an interactive process of resource possessing and releasing. In order to support this iterative process, a more flexible software platform is needed to facilitate resource assigning and coordinating.

III. A Framework of Dynamic Emergency Decision Support System

A. *Model Driven Architecture Approach*

Model Driven Architecture (MDA), proposed by Object Management Group (OMG), is often used in large scale application development aiming at systems integration and interoperation[1]. As shown in Fig. 3, it includes three phases of Platform Independent Model (PIM), Platform Specific Model (PSM) and running system. In MDA method, Platform Independent Model (PIM), which is developed by domain experts, is used to specify functional demands of the systems. Then PIM models are transferred to Platform Specific Model (PSM) and checked by software engineers. The PSM models are oriented to the development platform of the goal system, and could be easily turned into systems running code.

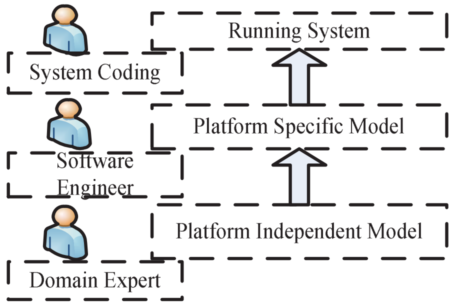

Fig. 3. Model driven architecture apporach of software development

Base on the method of MDA shown in Fig. 3, software development would be more flexible. Business model would be composed by the domain expert in advance, not considering how and where to build and deploy the running system. The business models could be transferred to various running systems on different platforms. Thus, application systems to solve same kinds of problems could be composed flexibly to adapt to diverse environment.

The difficulty in MDA is the automatic transforming of different models, for instance transforming PIM to PSM, and transforming PSM to running system. That needs the models are built in formal methods. In our method, we focus on the formal definition of resources used in the process of emergency medical servicing. We define these resources, such as doctors, nurses, ambulances and medical appliances using resource model in PIM. These resources are described in XML and loaded in running systems conveniently.

B. Resource Model

Resource model has URI to identify the database location where it is stored. The data resource could be accessed through Web using its URI. The data resource model is shown in Fig. 4.

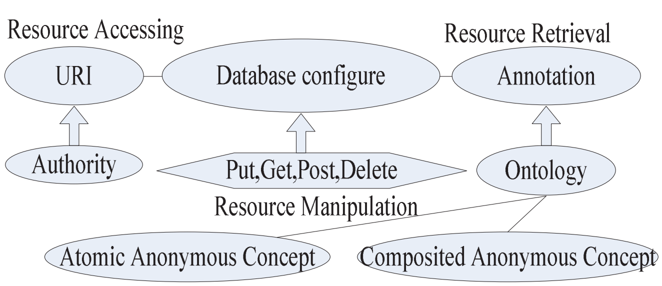

Fig. 4. Resource model

Using the resource model of Fig. 4, two types of data resources could be defined.

(1) Basic resource is composed directly from databases.

Definition 1: Basic resource *BR:= <DBconfig, Property set>,Property set={C1,C2,…Cn}.*

(2) Composite resource is composed of other basic resources or of composite resources.

Definition 2: *CRcomposite:=<DBconfig,Sub-Resources >*

Sub-Resource:=<DBconfig, ResourceRelation>

In resource model, four kinds of standard operations are provided to execute corresponding resource management functions, which are *Put*,*Get*,*Post* and *Delete*, during the whole resource life cycle time. For instance, we use "*Put*" to register a resource in PIM, use "*Get*" to load a resource into running system, use "*Post*" to communicate with other resources and use "*Delete*" to release a resource from the running system.

C. A Framework of Dynamic Emergency DSS based on MDA and Resource Model

Based on the approach of MDA and resource model, we design a framework of emergency DSS, shown in Fig. 5, emphasizing information sharing and resources allocation during emergency events handling.

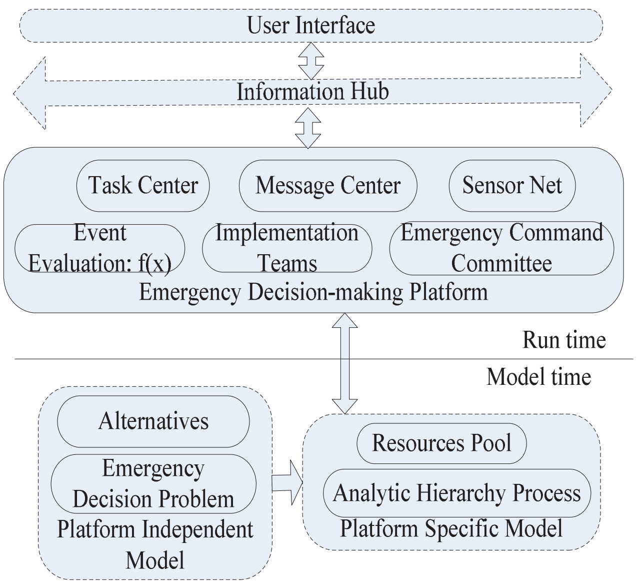

Fig. 5. Framework of dynamic emergency decision support system

In Fig. 5, we divided the DSS developing into two phases, including system modeling and system configuring.

In system modeling, decision problems are firstly defined, and alternatives are pre-designed independently to the specific resources used in the emergency events handling. Resources, including team members and command committee members, need to be defined and maintained before emergency happening. These key resources are related to the location where the emergency events occur. Thus, the modeling for these rescuing resource should be specified to the implementing platform of the emergency clinical DSS.

When emergency events happened, resources, such as command committee members are loaded into emergency decision-making platform according to the location where the emergency events happened and the severity level of the emergency events. Meantime, emergency plan is also loaded into the task center for the members of command committee to refer to.

In emergency DSSs, on-line information collecting and sharing is important to reduce information uncertainty during decision-making. Thus, information hub is a key component for emergency DSSs.

Because user interface would give a unified view of the evolution of the emergency events to help commanders to make correct decision, and team members to choose correct actions, the function of the component of user interface should be extended. User interface should emphasize displaying multi-dimensional information of the emergency events with multi media.

For emergency medical services, platform independent model of DSS includes the followings.

Emergency Event of EMS= (*Time*, *Location*, *Type*, *Wounded Number*)

Platform specific model of DSS includes the followings.

Resource1=*Ambulance* (*Vehicle*, *Driver*, *Ambulance Men*); Resource2=*Hospital* (*Operating Room*, *Surgery Doctor, Nurse*}

Resources are described in XML. A data resource instance is shown in Fig. 6.

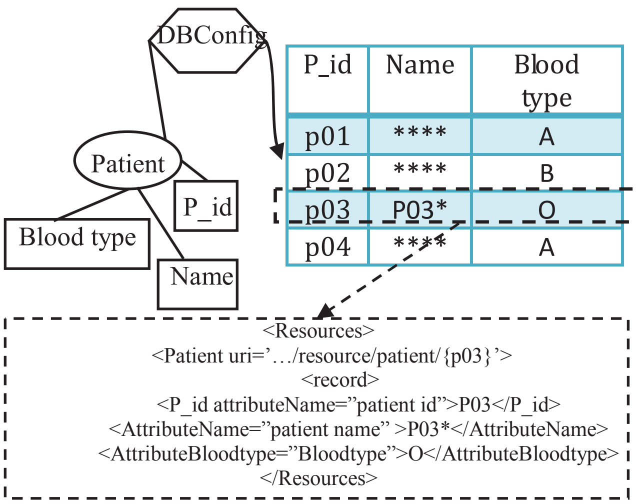

Fig. 6. A basic resource described in XML

In Fig. 6, the data resource of "*patient*" has three properties: *P-id*, *name* and *blood type*. These properties are the attributes in databases which could be accessed according to *DBConfig* in resource definition.

A composite resource is given in XML in Fig. 7.

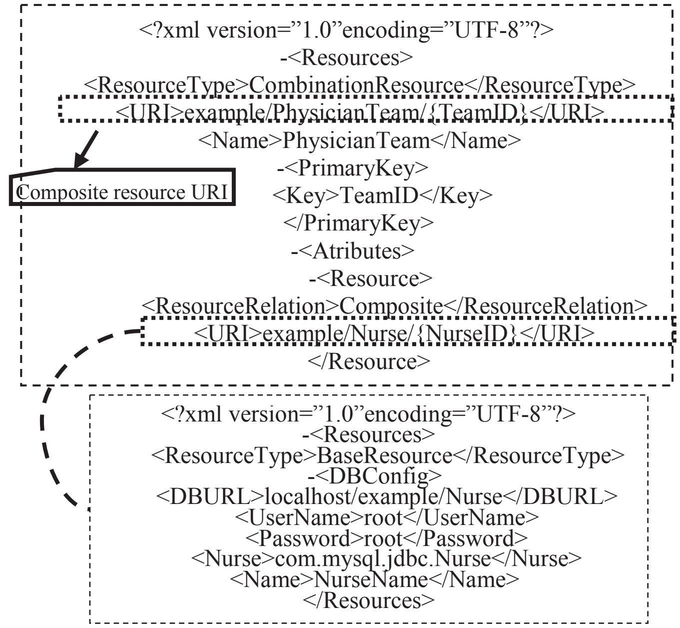

Fig. 7. A composite data resource described in XML

In Fig. 7, the composite resource "*PhysicianTeam*" composes of basic resource "*Nurse*".

IV. CASE STUDY AND DISCUSSION

A. *Case study*

We use a traffic rescuing medical servicing case study to demonstrate how to rapidly deploy an emergency DSS system using our developing method. Because that the process of emergency rescuing is a complicated process of clinic decision making, it needs close cooperation of doctors from various departments and hospitals to take efficient and effective activities. During the treatment, clinic data sharing of medical knowledge and organizational coordination is critical and challenging nowadays because that the mobile embedded real-time instruction greatly increases the amount of clinic data. The data environment is becoming more and more changeable and divergent. Patient data are collected and distributed dynamically on the Internet to form a complicated data environment.

Decision alternatives are modeled using resource model, as shown in Fig. 8.

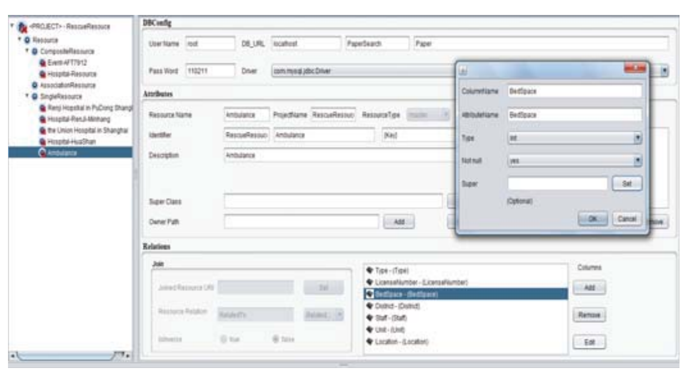

Fig. 8. Interface for system modeling

In Fig. 8, each rescuing alternative is described as combined resources which could be interpreted by the platform of emergency DSS.

In our method, emergency DSS system is generated dynamically when emergency events occur. The resources for rescuing are assigned dynamically with the evolution of the emergency events, which is shown in Fig. 9.

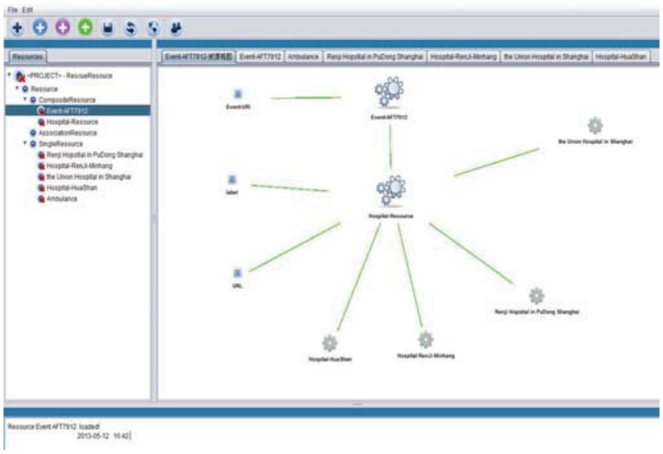

Fig. 9. A program interface of assigning rescuing resources

In Figure 9, the left column is the alternative chosen in decision making. When the alternative is interpreted into the emergency DSS for EMS, the rescuing resources will be selected, which is shown in the right column. In our method, the rescuing resources are of hierarchy structure, corresponding to the AHP method used in emergency decision making.

During the decision making, information is displayed collectively, as shown in Fig. 10.

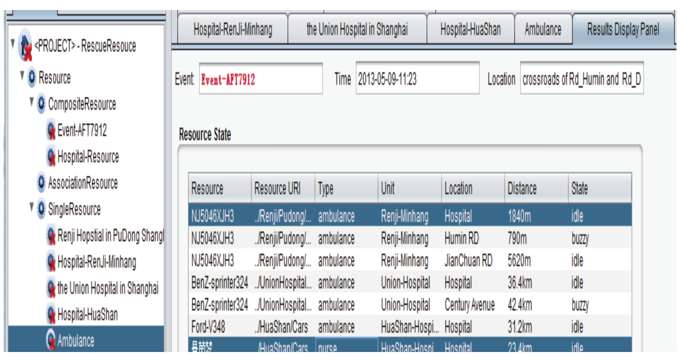

Fig. 10. A program interface of DSS information displaying

In Fig. 10, various kinds of information could be displayed in uniform resource description, so that decision makers could get an all-round view of emergency event evolution and make relatively suitable decision with the help of the DSS platform.

B. Discussion

P. D. Haghighi et al. use semantic method to improve emergency medical decision making [13]. The details of comparison are shown in Table I.

TABLE I. COMPARISON WITH SIMILAR SYSTEM

Key Indicator	Our approach	P. D. Haghighi [13] Ontology approach
Supporting dynamical emergency task assignment	√	×
Supporting inconsistent data resource accessing across multiple platform	√	√
Ability of integrated decision support information displaying	√	√
Ability of system re-configuration in running time	√	×
Flexibility of DSS alternative modeling	√	×
Version control	×	×
Intelligent decision making supporting through providing knowledge based reasoning function	×	√
Extensible knowledge management ability	×	√

Comparing features from system development flexibility, rapidity, and changeability, our approach based on MAD and resource model has three features as follows.

- DSSs developed based on MDA method are more flexible for emergency medical servicing. The emergency decision making is an iterative and evolution process. Emergency decision support system based on MDA approach could deploy the system according to the business model dynamically. For different phases of emergency events handling, decision makers could design different alternatives, so that the DSS systems could evolve with the decision maker choosing different alternatives in different emergency event handling phrases.

- The running system of emergency clinical DSSs developed using our method would be deployed more rapidly than traditional system development method. Because the emergency events are unexpected and urgent to be reacted as quickly as possible, alternatives should always be prepared before the events occur. In traditional DSS development method, these alternatives usually be defined in documents and difficult to be interpreted in running DSS. In our method, these alternatives are defined as business process and described using business process execute language, such as BPEL, so that the alternative could be deployed to the DSS platform and executed more easily.

- In our method, resources used in emergency events handling could be managed more dynamically on the DSS platform with the evolution of the emergency decision. Emergency events handling would involves kinds of resources. The coordination of large scale of resources is complex. In our method, we design resource pools in DSS architecture to manage multi types of resources. We also use technology of resource model to display heterogeneous information resources during decision making.

V. Conclusions and Future Research

In order to improve the decision quality of emergency events, in this paper, the process of emergency decision making is investigated. An iterative clinical decision making process is proposed and designed to handle emergency medical servicing events. Furthermore, based on MDA method and resource model, a dynamic emergency DSS architecture is proposed to implement the iterative process of emergency decision making. Emergency handling alternatives are modeled using platform independent model. Resources used to manage emergency events are modeled using platform specific model. The running DSS systems are generated, loading and running decision alternatives designed in advance using business process execute language, when emergency events occur. The case study of EMS in this paper shows that our method is feasible and effective.

From this research, we conclude that information sharing is the key task in emergency clinical decision making. In order to deal with the challenge of big data, further research work will focus on the cloud computing platform application in clinical data accessing of real-time clinical DSSs development to support more effective emergency event handling.

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