Describing and Forecasting the Medical Resources assignments for Disaster Medical relief Forces Using an Injury-Driven Ontology Model

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ABSTRACT

Available medical resources are the basis of efficient disaster medical relief. The medical resources assignment for disaster medical relief forces is usually fixed. However, the injury condition distribution changes in different disaster and so does the demand for the medical resources. So the assignment of medical relief forces should be more flexible and based on the injury. We analyzed the component parts and rules of disaster medical relief, defining the related concepts and rules. Then, we constructed the describing rules of injury-treatment-medical-technique-resource-assignment process. Based on these, we established the ontology of disaster medical relief system and the injury-driven medical resources assignment ontology model (MRAOM). We used the model to describe the medical relief situation after earthquake to demonstrate the model could describe complicated situations. We also used the model to describe and forecast the medical resource assignment of treating batch wounded to demonstrate the model's validity.

Keywords

Medical Resources Assignment, Disaster Medical Relief, Injury-Driven Ontology Model.

INTRODUCTION

Sudden-onset disasters could cause mass casualty incidents in short time, creating a surge in demand for emergent medical service (Reinhardt et al., 2011). Studies have shown that approximately 90% of the injuries are reported and rose in the first 7-14 days after disaster, so the disaster medical relief in the first 3 weeks are

crucial.(Zhang et al.,2012; Zhang et al.,2011; Akbari et al.,2004)

Generally, the disaster medical relief system is divided into 3 levels.(Miao and Nie,2004; Lu,2008) 1st level provides first aid which uses rapid effective methods to save life on the spot, such as basic life saving, hemostasis and wounds binding techniques. 2nd level provides advanced life saving methods which include lifesaving surgeries, severe shock correcting and other techniques aiming to decrease mortality and disability. 3rd level provides all kinds of medical services which are necessary to cure injuries and patients. 1st level is consisted of all kinds of medical rescue teams that could get to the spot as soon as possible. 2nd level is consisted of normal-function municipal hospitals nearby. 3rd level includes comprehensive healthcare organizations most of which are facilities of Department of Health Care. Studies have shown that the mortality of injuries within 1st level is the highest, while the 2nd level takes the second place. (Jiang et al.,2012) A large percentage of injury deaths occur on the field before evacuation to 2nd level medical facilities. (Cranmer,2005) This indicates that great emphasis should be placed on the 1st and 2nd level during a disaster medical relief.

Most medical institutions in the disaster area could be damaged, so the 1st level and part of 2nd level medical institutions are consisted of strengthen medical forces from the non-disaster areas, inside or outside the country, civilian or military. (Auerbach et al.,2010) Strengthen medical forces should meet the medical demand in the disaster area. The efficiency of first aid is crucial, and the basis of the efficiency is the availability of the right medical resources. Most strengthen medical forces' resources assignment is fixed. But the real needs of the resources could change according to the different injury condition distribution in the different disaster scene. So sometimes the availability of some medical resources would be low and affect the medical rescue efficiency.

This research aims to describe and forecast the medical resources assignments based on different medical relief forces and different injury condition distributions. However, emergency medical rescue is complicated, and the composition of medical forces are diversified. We choose ontology method to construct the injury-driven model to express the complicated medical rescue knowledge and help multiple-source strengthen medical forces to understand the model. Thus, organizers of disaster medical relief could have an increased awareness of the overall disaster medical rescue environment, allowing them to make better decisions more rapidly.

This article divided the process of medical resources assignment modeling into four parts: 1.The description and definition of component parts of the medical relief; 2. The definition of rule of disaster medical relief and injury medical treatment; 3. The description and definition of injury treatment profiles and medical resource assignment rules; 4. Constructing ontology model of medical relief entities and domain rules. Finally, we gave two examples to demonstrate the usage of the model.

ANALYSIS OF THE MEDICAL RESOURCES ASSIGNMENTS FOR DISASTER RELIEF

Generally, medical resources assignment is part of emergent readiness plan. The description of the emergent readiness plan needs to choose and reconstruct emergent domain knowledge. (Mendonca and Wallace,2007) As for the description of medical resources assignment, both medical and emergent domain knowledge should be chosen and reconstructed. Emergent readiness plan knowledge modeling is a interdisciplinary project and tremendous progress has been made about this modeling. Some researches proposed to construct the relationships between mission and executive condition based on an incident-mission framework. (Mors et al.,2005) Some described the structure and dynamics of the emergent organizations based on the extended sequence locus language. (Hoogendoorn et al.,2005) But most methods of illustrating the emergent readiness plan could not solve the problem of knowledge sharing.

Ontology is a knowledge description method that is easy to conceptualizing, sharing and illustrating.(Grigoris and Frank,2008) This method could clearly and accurately describe the domain concepts and their relationships. It could also describe the complex domain knowledge and its feature. So ontology could be an effective method to construct the medical resources assignment modeling.

The basic idea of describing and forecasting the medical resources assignment using an ontology model is as follow: 1. Different level of care has different treatment goals and contain different medical facilities with different medical treatment units. 2. When different injuries got to different medical facilities and went through different medical treatment units, they would accept different medical techniques to improve their condition. 3. The basis of different medical techniques is different medical resources. So the determination of medical resources assignment is based on both injury conditions and the function of medical facility.

The Component parts of the Disaster Medical Relief

Generally, most of the medical institutions in the badly damaged areas within the disaster zone are damaged. However, most injuries would occur in these areas and need medical treatments urgently. Most strengthen

medical relief force would arrive in these areas and strengthen the local medical facilities. These strengthen forces belong to 1st level or 2nd level medical care aiming to lifesaving and reducing disability. The forms of these forces are rescue teams with highly mobility or field hospitals with the placement of resuscitative surgery units as close to the first responder as possible.

According to systematical point of view, we could consider the whole level of care or one medical facility as one system. Then we could divide the system into small medical treatment units according to the medical function. Every medical function units are related to different medical techniques. Different rescue team or field hospitals could choose the placement of different medical function units with diversified medical techniques based on the goal of mission as well as the possible injury condition distribution. Carrying out different medical techniques would need different medical resources. So in different mission scenes, the same rescue team or field hospitals could have different multiple medical function units with different medical resources assignment.

Definition 1 Define the whole set of medical function units as: $B=\{b_1,b_2,\ldots,b_n\}$.

Definition 2 Define certain rescue team's or field hospital's set of medical function units as: $B_i=\{\quad\}$.

The medical function unit b_i could not be divided or it couldn't execute any medical treatment. For example, Pre-operation unit could not be divided or it couldn't finish the works before an operation.

Meanwhile, B_i is the subset of B which means $B_1,B_2,\ldots,B_n$ should satisfy the condition： B=B

Particularly, every B_i is not definitely mutual independent, which means there could be intersections between B_is. That means B1,B2,…,Bn don't have to satisfy the condition $B_i \cap_{i\neq j} B_j = \emptyset$.

Definition 3 Define the whole coverage of the medical function of the units as:

Then the coverage of the medical function of the international medical relief force, including rescue team or field hospital, is: π'

The brief structure of the international medical relief force is showed in figure 1.

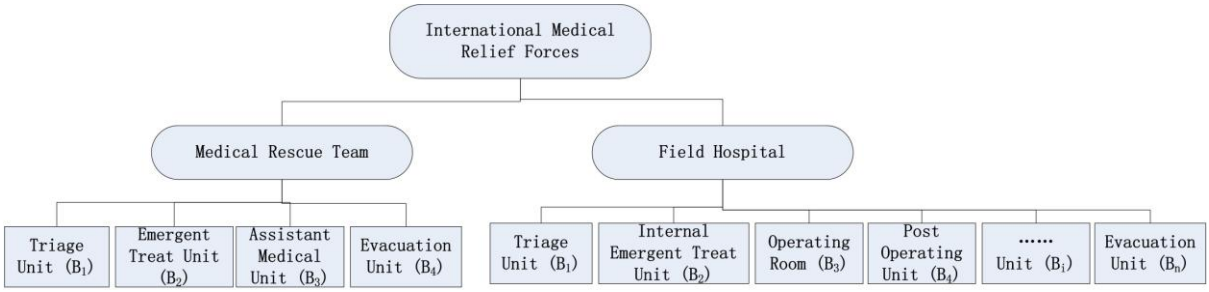

Figure 1. Brief Structure of the International Disaster Medical Relief Forces

Different function medical unit could carry out different medical techniques. Part of the relationship of function unit, medical techniques and medical resources types are showed in table 1. The medical resources which are used for the same medical techniques are combined together and signed with a specific number.

Table 1. Part of the relationship of function unit, medical techniques and medical resources types

Function Unit	Medical Technique Description	Medical Resources	Resource No.
Triage	Measure Vital Signs	Sphygmomanometer; Stethoscope	1
	Assessment &Evaluation of Patient Status	Otoscope & Opthalmaloscope	2
	Bowel Sounds Assessment	Stethoscope	3
	Circulation Check	Stethoscope	3
	Blood Gas Estimate	Analyzer Clinical Chemistry	4
	Determine Electrolyte Levels	Analyzer Clinical Chemistry	4
	.....	.....	...

Emergent Treat	Emergency Control of Hemorrhage	Bandage (Elastic or Gauze); Dressing First Aid Water-Gel; Sponge Surgical Guaze; Tape Adhesice Surgical Woven	11
	Establish Adequate Airway	Airway Nasopharyngeal / Pharyngeal	12
	Start Intravenous Infusion Site	Catheter & Needle Unit; Infusor Pressure Blood Intravenous; Intravenous inj Set; Alcohol Impregnated Cotton	13
	Insert Oro/Naso Gastric Tube	Lubricant Surgical Tube; lidocaine Hydrochloride Jelly Tube; Tube Stomach Surgical Plastic Lumen	14
	Cardiac Resuscitation	Defibrillator Monitor-Recorder; Heparin Sodium injection; Injector Tube plas Medication Needle Cart; Defibrillator Auto External	15
	Catheterization-Suprapubic	Catheterization Kit Urethral Bot-outlet Drain Bag; Lidocaine Hydrochloride Jelly Tube; Lubricant Surgical Tube	16
	.....	.....	...
Op-Room	Operation Preparation	Bag Sterilization Biohazard Disp; Detergent Enzymatic Cleaner Instrument Surgical Tube; Disinfectant Surgical Instrument Cidex	31
	Patient Preparation	Razor Surgical Preparation Disposable Plastic; Skin Preparation Kit Pre-Operative Sterile	32
	Induce/Maintain General Anesthesia	General Anesthesia Equipment Set	33
	Emergent Surgeries (hemostasis surgery, skull drilling drainage, gastric excision repair anastomosis, resection of spleen or kidney, ...)	Clamp Artery; Forceps Hemostatic; Forceps Intestinal; Forceps Tissue; Handle Surg Knife; Holder Suture Needle; Knife Sternum; Bone Surgery Corrosion Resisting; Retractor Abdominal; Retractor General Operating; Retractor Rib; Retractor Vein; Scissors General Operating Surgical; Cannula Brain Frazier	34-40
	Clean & Prepare Surgical Instrument Sets	Wash Basin; Cleaner & Lubricant Surgical Instrument Can; Detergent Enzymatic Cleaner Tube; Disinfectant Surgical Instrument Cidex; Surgical Towel Pack	41
	Assess Electrolyte Levels	Analyzer Clinical Chemistry	4
.....	.....	.....	.....

Definition 4 Define all the medical techniques as: $T=\{t_1,t_2,\ldots,t_n\}$. Then the medical techniques within a certain medical function in a certain medical facility of a certain level of care is: $Ti=\{L,F,U\backslash t_1,t_2,\ldots,t_k,\ t_k \in T\}$. L represent level of care, F represent medical facility, U represent medical function unit.

Medical resources are the basis of carrying out the medical techniques.

Definition 5 Define all the medical resources as: $R=\{r_1,r_2,\ldots,r_n\}$. Then a certain medical technique ti related medical resources are: $Ri=\{r'_1,r'_2,\ldots r'_n\}$ and $Ri \subset R$

Medical resources are mainly the equipments, instruments, medicine and medical staff. According whether to the resource could be reused or not, medical resources could divided into consumable resources and non-consumable resources.

Rules of Disaster Medical Relief

From the analysis of the component parts of the medical relief, the relationship of medical resources and medical demands are reflected by the treatment of the injuries going through the medical facilities in the different level of care. So the rules of disaster medical relief is the main ground of the medical resource

assignment. When every different injury goes through the medical facility, the injury condition gets better and certain medical resources are consumed. So generally, the rules of disaster medical relief are established in the form of "if…then". This means the injury treatment profiles are based on the injury condition. Its formalized definition is as follow：

Rule 1 Injury Treatment MITDomainRules=（InjuryCondition, TreatmentGoal）

This represent that when the injury satisfies the logical condition expression InjuryCondition, the TreatmentGoal should be achieved.

This rule expresses the relationship between injury condition and the treatment goal that the medical facility should achieve. TreatmentGoal is the most urgent medical treatment goal the medical facility should achieve based on the injury condition. It includes the chosen of care level, medical facility and medical function units in order to achieve the treatment goal. For example, for a batch of burned injuries, the treatment goal is to relieve or control the injury hazards and sustain life. Then we should choose the nearest rescue team belonging to the 1st level of care and carry out basic and advanced life supporting medical techniques.

Injury Treatment Profiles And Medical-Technique-Resource Relation Rule

The core rule of medical resources assignment is how the medical technique in the medical function units related to medical resource based on the injury condition. This part of rules include injury treatment profiles and medical-technique-resource-assignment relationship rules.

Injury Treatment Profiles

Injury treatment profile is a treatment process describing series of medical treatments which are accepted by certain injuries when they go through certain medical facility. According to different injury conditions, the profile set is consisted by different treatment process subsets. Its formalized definition is as follow.

Rule 2 Injury treatment profiles within the medical facility UstandardProfile=（goal, {treatmentProcess$_1$,…, treatmentProcess$_n$}）

Goal stands for the treatment goal which this medical facility should complete to relieve the injury hazards or improve certain physiological function. TreatmentProcess$_i$(1 n) stands for the treatment process that the medical facility should take to complete the treatment goal.

Treatment goal is a status that the injury should get after going through the medical facility. It is the basic line of injury medical treatment and its formalized definition is as follow.

Rule 3 goal=(name, params, input, output, interval)

Name stands for the medical facility's name. Params stands for the parameter description of the treatment goal. Input and output stand for the injury condition before and after going through the medical facility. Interval=[startTime, endTime] stands for the time interval that the injury goes through the medical facility which is also the interval time between the start and end point of injury treatment.

Treatment process describes a certain treatment pathway within the medical facility when the injury condition satisfy certain condition. It is constituted by a series of medical techniques with complex time relationship. Its formalized definition is as follow.

Rule 4 TreatmentProcess$_i$=(precondition$_i$, medicaltechniqueflow$_i$, timeConstraints$_i$, anotation$_i$)

Precondition$_i$ stands for the precondition of injury when accepting the treatment process. Medicaltechniqueflow$_i$ indicates series of medical techniques which are used in the treatment process. TimeConstraints$_i$ presents the time constraint set of using the medical techniques and the key point of the treatment process. Anotation$_i$ stands for other information we should take notice when using the treatment process.

The logical relationship of treatment process and its time constraint：

1. Logical relationship of treatment process.

We use flow model based on PetriNet to describe the medical techniques and the precondition of carrying them out. The process is constituted by series of medical technique and the routing structure between them. Medical technique is the basic element of the treatment process. The routing structure between them could be described

by 4 logical relationships, including sequent, parallel, choose and circulate control. This routing structure could describe the logical relationship and executing order of the medical techniques. Any treatment process could be described through reasonable organizing of the medical techniques and the four basic routing structure.

Taking the treatment process of the injury whose spine might be hurt as an example to show the modeling of treatment process. As figure 2 shows, the treatment goal is to evacuate the injury without hurting his/her spine's function. So the medical facility should determine whether or not use spinal arthodesis before evacuation. If the injury type is penetrating trauma, locating in head & neck or limbs (pre 1), then we should check the injury's neurologic function. If neurological disorder exists, which is pre1-1(t3), then we should use spinal arthodesis before evacuation (t7). If neurological disorder doesn't exist (pre1-2(t4)), then the injury could be evacuated immediately. If the injury type is blunt trauma (pre2), then we should check and evacuate the injury's consciousness. If the consciousness change get GCS<15 (pre2-1(t5)), then we should use spinal arthodesis before evacuation (t8). If the injury consciousness change get GCS≥15 (pre2-2(t6)), then we should check and evacuate whether or not the spine exists pain or softness, the neurological function has obstacles and the anatomical structure of the spine changes. If any of this three conditions exists (pre2-2-1(t9)), then we should use spinal arthodesis before evacuation (t11). If none of these conditions exists (pre2-2-2(t10)), then we should consider whether or not there exists the injury mechanism of the spine. If the injury mechanism doesn't possibly exist (pre2-2-2-1(t12)), then we could evacuate the injury without spinal arthodesis. If the injury mechanism possibly exists (pre2-2-2-2(t13)), then we should determine following conditions exist or not: 1) evidence shows that the injury take alcohol or drug; 2) other traumas; 3) couldn't normally exchange. If none of these conditions exists (pre2-2-2-2-1(t14)), then we could evacuate the injury without spinal arthodesis. If any of these conditions exists (pre2-2-2-2-2(t15)), then we should use spinal arthodesis before evacuation.

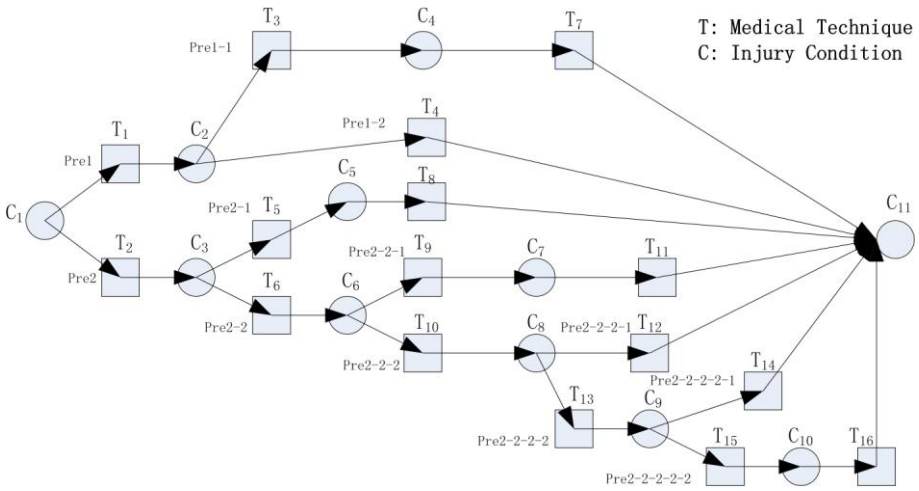

Figure 2. Brief Treatment Process Logical Relationship of The Injury With Possible Spine Wounds

2. Time Constraint

The timeliness of disaster medical relief is crucial. Injuries especially critical injuries should be treated within limited time. So there is a complex time synchronization relationship between using the medical techniques.

The time constraint include two types, one is qualitative constraint and the other is quantitative constraint. Because of the complexity of injury condition and medical treatment, even carrying out the same medical technique could hardly determine the definite time information. So we could use the qualitative constraint to describe the abstract time condition of using some medical techniques. Generally, we could describe the qualitative constraint of completing certain medical technique using "equal, before, meet, overlap, start, during, after and finish by".

Other medical techniques with definite operating time, we could use quantitative constraint to describe the start and finish time of the techniques. The formalized definition of quantitative constraint could be described as follow:

Rule 5 timeConstraint = (a≤preTimepoint-postTimepoint ≤b)

PreTimepoint and postTimepoint indicate the start time, finish time and injury treatment process reference time point.

Thus the treatment process time constraint could refer to the constraint of medical techniques.

Medical-Technique-Resource Relation Rule

When describing the rule of medical-technique-resource relationship, two points should be strengthened. One is that using a specific medical technique should be based on the medical resources within the medical facility. The other is that the use of a specific medical technique is trigged by the injury condition and should satisfy the time constraint.

We use the PDDL2.1 language based on the artificial intelligence planning to give the formalized definition of the rule as follows.

Rule 6 (Medical Technique) MTechnique= (name, params, precondition, resources, agent, effects , interval, place)

Name stands for the name of medical technique. Params represent the parameters of description. Precondition indicate the specific injury condition. Resources stands for the medical resources which are needed in carrying out the medical techniques. Agent represent the medical relief facility that implement the medical techniques. Effects indicate the treatment effects after using the medical techniques. Interval stands for the time interval that needed for medical technique implementing. Place represent the location.

Rule 7 (Medical Resources)Resources=consumResources ∪nonexpendResources

ConsumResources={cr } represent the set of consumable medical resources. nonexpendResources={nr } represent the set of nonexpendable medical resources. If and only if the medical facility has adequate medical resources, medical techniques could be carried out and could do the deed. Effects={me } stands for the medical effects.

Rule 8 (Consumable medical resources) cr=(logicalExpression, t, n)

This represent the consumable medical resources should satisfy the logical Expression after the medical technique has started t time and the amount should be n.

Rule 9 (Nonexpendable medical resources) nr=(logicalExpression, interval, n)

This represent the nonexpendable medical should satisfy the logical Expression. And during the interval time (interval=(minTime, maxTime)) of medical technique usage, the number of occupied nonexpendable medical resources is n.

Rule 10 (Treatment Effect) tre=<logicalAtom, flag, time>.

This indicate the improvement of the injury condition after t time since the applying of the medical technique. If the improvement is clear, then the sign of treatment effect is flag=true and the logical Atom is added to the injury condition. If not, the logical atom is deleted from the injury condition.

MODELLING OF THE INJURY-DRIVEN ONTOLOGY MODEL

Based on the systematic analysis, we established the medical resource assignment ontology model (MRAOM) by reusing and expanding ABC、OWL-S、SWRL ontology vocabulary & expression. The modeling include knowledge modeling of disaster medical relief system, medical relief domain rules, injury treatment profiles and medical resources assignment rules. The brief structure of MRAOM concepts and relationships is showed in figure 3. The block indicates class, the solid arrow indicates property and the dotted arrow indicates subclass.

Disaster medical relief system ontology modeling

The aim of the modeling is to describe the entity of disaster medical relief system and their relationship, as well as the characteristics of the dynamic changes of the entity during the medical relief process. We promote concepts and relationships of medical relief mission, environment elements, medical demands (injury condition distribution), entity structure, and medical resource based on the ABC ontology model.

Ontology of medical relief mission and medical demand

1. Ontology of medical relief mission

The classification of the mission ontology is according to the different types of the disaster. Different disaster correspond to different medical relief mission ontology. MRAOM uses methods to establish mission ontology as follows.

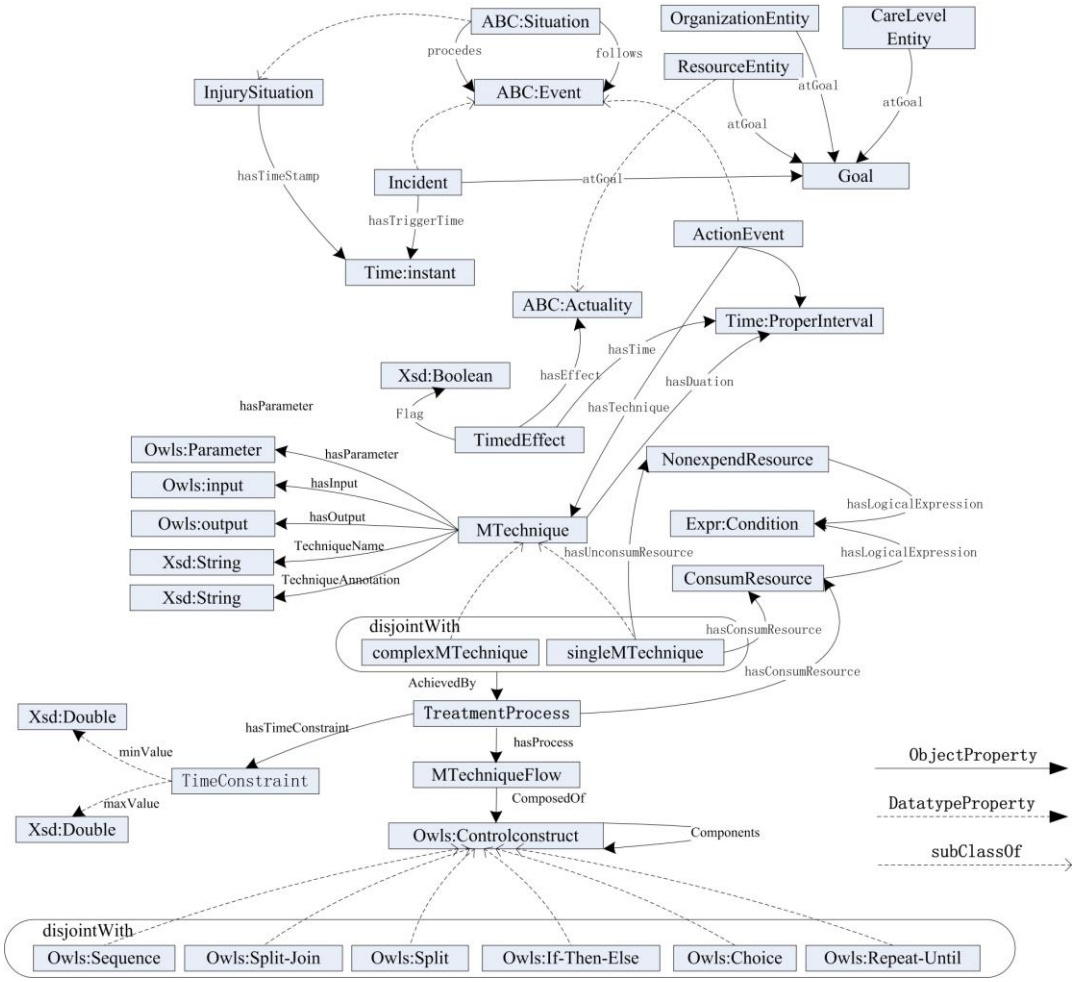

Figure 3. Brief Structure of MRAOM Concepts and Relationships

a) Establish **incident** as subclass of **ABC: event** describe the disaster. Establish properties **asTriggerTime** and **hasLocation,** with range **time: instant** and **location,** indicating the time location of the mission. Establish data attribute **type,** representing the type of disaster, such as earthquake, tsunami and soon.

b) Establish **actionevent** as subclass of **ABC: event.** Establish properties as **hasTask** and **hasInterval** with range **task** and time: properInterval, indicating the type of task and the interval time of executing the mission.

2. Ontology of medical demand

Disaster medical relief demand generally indicates the amount of injuries and the distribution of injury condition at the point of time. So it belongs to situation modeling. Establish **injurySituation** as the subclass of **ABC: situation** indicating the relief demand situation. Establish properties **hasTimeStamp** with range **time:instant.** Establish data attribute **number** and **type** to indicate the amount and condition type of the injuries.

Based on these ontology models, disaster medical relief could be modeled as a discrete event system and describe the relief process as incident series of relief mission and demands. The model could describe the dynamic action based on the changing demands.

Ontology of Medical Relief Entity

Medical relief entities include 3 classes of entity, which are care level entity, medical relief organization entity and medical resource entity. We establish the entity ontology as follows.

1. Establish **treatmentlevelEntity** as the subclass of **ABC: actuality**, indicating the level of care. It include data attribute **name** with range of **string,** indicating the name of care level. Add property **atGoal** with range **Goal**, indicating the treatment goal of the care level.

2. Establish **organizationEntity** as the subclass of **ABC：agent**, indicating the medical facility. It include data

attribute **name** with range of **string**, indicating the name of the medical facility.

3）Establish **resourceEntity** as the subclass of **ABC：actuality**, indicating the medical resources in need.

These ontology are all general concepts in the medical relief domain. In order to describe the entities more specific, we should establish particular entity concept models based on these general models.

Ontology Model of Medical Relief Domain

MRAOM use **Swrl：atom** to indicate fact. As for the problem of using SWRL ontology expressing logical atom conjunction, we use **Expr：condition** to model precondition. Thus, we could realize the ontology modeling of complex logical condition.

Establish class **domainRule** to indicate the rule of medical relief domain. It includes properties of **hasHead** and **hasCondition**, with ranges of **Swrl：atom** and **Expr：condition**, indicating the fact and precondition of the medical relief domain rule.

Ontology Model of Injury-Driven Medical Resource assignment

Medical Technique Flow modeling

Based on the ontology model Owls：process, MRAOM establishes class MTechflow, indicating the medical technique flow which is used in the injury treatment. Add data attribute TechflowName and TechflowAnnotation with range of string, indicating the name and information of the flow. Establish properties hasParameter, hasInput, hasOutput and hasResource. The first three property ranges are Owls：parameter and the 4th is properType&Number, indicating the describing parameter, input injury condition, output parameter and the medical resources that are needed to carry out the medical technique.

When establishing instance of medical technique flow, we should also establish the instance of techflowResource of resource: properType&Number as well as the instance resourceType and resourceNumber of resource: instant, indicating the type and amount of medical resources used in the flow.

The medical technique could be divided into single technique and complex technique. Single medical technique could be done by single medical function unit while complex medical technique should be completed by multiple medical function units.

1. Modeling of single medical technique

Establish class **singleTechnique** as subclass of **Technique**, indicating single medical technique. Establish properties **hasconsumResources**, **has unconsumResources**, **hasTimedEffect**, **atGoal** and **excutedBy**, with ranges of **consumResources**, **nonexpendResources**, **timedEffect**, **goal** and **organizationEntity**, indicating the consumable and non-expendable medical resources, applying effect, goal of applying and executing entity of the medical technique.

Define technique applying effect as **te=<logicalAtom, flag, time>**. MRAOM model the logical atom as **logicalAtom** based on the instant **effectLogicalAtom** of class **ABC：actuality**. In order to stamp time, we establish instant **effectTimeStamp** of **time: interval**, with properties **hasBeginning** and **hasDurationDescription.**

Establish class **TimedEffect** indicating the effect of applying the medical technique after a period of time. Add data attribute **flag**, with range of **boolean**, indicating the sign of applying effect. Add properties **hasEffect** and **hasTime**, with ranges of **ABC：actuality** and **time: interval**, indicating the applying effect logical atom and the time point of generating the applying effetct.

2. Modeling of complex medical technique

MRAOM establishes complexMTechnique as subclass of MTechnique, indicating complex medical technique which should be completed by multiple medical function unit during the injury treating. Add property achievedBy with standardized injury treatment profile. One complex medical technique model could have one or more property achievedBy, indicating multiple pathway that could complete the technique.

Medical Resource modeling

1. Consumable medical resource modeling

(Consumable medical resource) cr=(logical expression, n)

MRAOM establishes class **consumResources**, indicating consumable medical resource, including properties **haslogicalExpression** and **hasConsumStamp**. The ranges of the properties are **Expr: resources** and **number：interval**, indicating the logical expression and the number tag of the consumable medical resource, valuing **instantLogicalExpression** and **consumNumberStampInterval.**

2. Non-expendable medical resource modeling

(Non-expendable medical resource) nr=(logicalExpression, interval, n)

MRAOM uses class **Expr: Resource** to model logical expression **logicalExpression**. Establish instant **intervalLogicalExpression** of **Expr：resource**. In order to indicate the time (interval=(minValue, maxValue)) during which the medical technique occupied, establish the instant minTime of time: interval. The properties **hasBeginning** and **hasDurationDescription** are valued as **techniqueStartTimePoint** and **minValue**. Meanwhile, establish instant **maxTime** of **time: interval** with properties **hasBeginning** and **hasDurationDescription**, valuing **techniqueStartTimePoint** and **maxValue**.

Injury Treatment Profile Modeling

Injury treatment profile could connect the injury condition, medical techniques, medical resource and treatment time together. So the modeling of it is very important.

Establish class **treatmentProcess**, with properties **hasCondition**, **hasProcess** and **hasTimeConstraint**, ranging **instantCondition**, **MTechflow** and **timeConstraint**, indicating the injury condition, medical technique flow and time constraint of the injury profile. Establish data attribute **hasAnnotation**, with range of **string**, indicating the information of the profile.

The modeling of injury treatment process and time constraint are as follows.

1. Modeling of injury treatment process. According to Rule 4, injury tretment process could be described by work flow. Based on the OWL-S modeling idea, MRAOM uses the subclass of **Owls：controlConstruct**, such as Sequence、choice、split+join、iterate、condition、if-then-else、any-order、repeat-while and repeat-until, to realize the modeling of the sequent structure, chose structure, parallel structure and circulate structure of injury treatment process.

In order to describe the treatment steps of injury treatment, MRAOM establishes class **treatmentStep** as the subclass of **Owls：controlConstruct**, indicating a certain step of the injury treatment process. It includes property of **technique** with range of **MTechnique**, indicating the medical techniques used in this treatment step.

As the same as modeling complex process using OWL-S ontology model, the modeling of injury treatment process has tree structure. The root of tree is the instance of class **treatmentStep** and the root node is the instance of subclass **Owls：controlConstruct**.

2. Modeling time constraint

Use the property of **time：properInterval** to express the qualitative time constraint of applying medical techniques. As for quantitative time constraint, MRAOM establishes class **timeConstraint** according to Rule 5. Add properties **hasPreTimePoint** and **hasPostTimePoint** with range of **time：instant**. The value of it indicat the start and end time of the injury treatment. Add data attribute **minValue** and **maxValue**, indicating the minimum and maximum of the quantitative time.

Establish instance **deadlinTimeConstraint** of **timeConstraint**, indicating the time constraint of the medical technique. Its properties are **hasPreTimePoint** and **hasPostTimePoint**, valuing **time:instant** or **referenceTimePoint**, indicating the start and end point of the technique.

RESULTS & DISCUSSION

MRAOM is the model describing the knowledge system structure of international disaster medical relief

resource assignment. It could describe the major elements and rules of disaster medical relief resource assignment and realize the management and modeling of the domain knowledge. In order to display the utility and effectiveness of the model, we take earthquake medical relief as an example to show the usage of the model. The modeling tool is Protégé V4.3. Part of the model usage is as follows.

Model Usage of Describing Medical Relief Situation

The description of medical relief situation include the situation of injuries and the entities of medical relief system. The situation of injuries is described by the amount of injuries, the types of injuries and the severity degrees of injuries. The types of injuries include fracture, burn injury, crush injury, combined injury, etc. The severity degrees of injuries include minor, moderate, severe and critical. Suppose an earthquake had taken place at 7:59 on April 14th, 2010. 120 injuries were found by search team on that very day. The medical staffs at the front reported the types of injuries as fracture, crush injury and combined injury. The medical evacuating units reported that 40% of injuries were severely injured and 20% of the injuries were critical injuries. The medical relief system included two levels of care. The first level included medical rescue teams from local medical facilities and international medical team. The second level included field hospitals composed by medical forces at home and abroad. The model is used to describe the medical relief situation as showed in Figure 4.

I0 indicates the earthquake disaster. The time stamp is "2010/4/1407:59" and the location is L0. This disaster triggered medical relief situation RS0. RS0 described the medical relief situation of "2010/4/14", including the injury situation and medical relief system situation. The RS0 triggered medical relief action RA0 which indicates more emergent medical response actions to save more injuries. As showed in Figure 4, MRAOM describe the disaster medical relief system and its relief process as a discrete event system. The model could also describe the system's dynamic changes and the treatment process sequent changes.

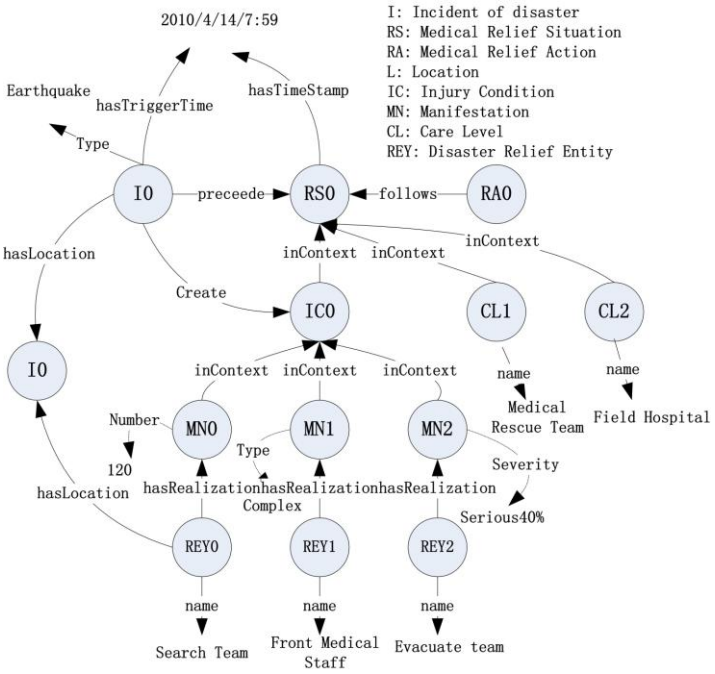

Figure 4. Brief Description of Medical Relief Situation After the Earthquake

Model Usage of Describing and Forecasting the Injury-Driven Medical Resource Assignment Process

The medical resource assignment of international disaster medical relief varies according to different injury condition, different medical relief facility and different type of disaster. Given the limited space available, only the treatment and resource assignment process of batch wounded with possible spine injury treated within the medical rescue team before evacuation was described in figure 5. The basic treatment process was described in figure 2. As showed in figure 5, the resource assignment process based on the injury treatment ontology model is tree structured. The non-root nodes are the subclass incident of class **Owls:construct** describing the structure of injury treatment process. The root nodes are incident of class medicalTreatmentStep, describing the steps of the injury medical treatment process. The combination of Medical Resource No.4, 5, 6, 8, 9, 10 is the possible

medical resource assignment of medical rescue team for treating batch wounded with possible spine injury before evacuation.

CONCLUSION

Medical resources assignment is the basis of international medical relief. This article promote an injury-driven ontology model to describe the process of injury treatment and forecast the resource assignments for different medical relief facility, different injury condition and different disaster type. This ontology model could help medical staffs with different background knowledge from different area or country have common understanding of the complex knowledge in the disaster medical relief domain. The features of this MRAOM describing and forecasting the medical resource assignments are: 1. Based on the systematic point of view, the model abstracts the entities of the medical relief into medical relief system so as to describe the complex features and dynamic activities during the injury treatment process; 2. The model could construct the complex structure and describe time-limited characteristic of the medical resources assignment.

This model describes the features of injury treatment process and medical resources assignment. However, the model is not perfect for lacking enough theoretical validation. The next step of our research would do further theoretical validation and validate the model with real cases. We would also describe the relationship between the medical relief entities and the relationship between different types of the medical resources. Based on these, we would develop a support decision-making system to help the decision makers make resources assignment for specific mission.

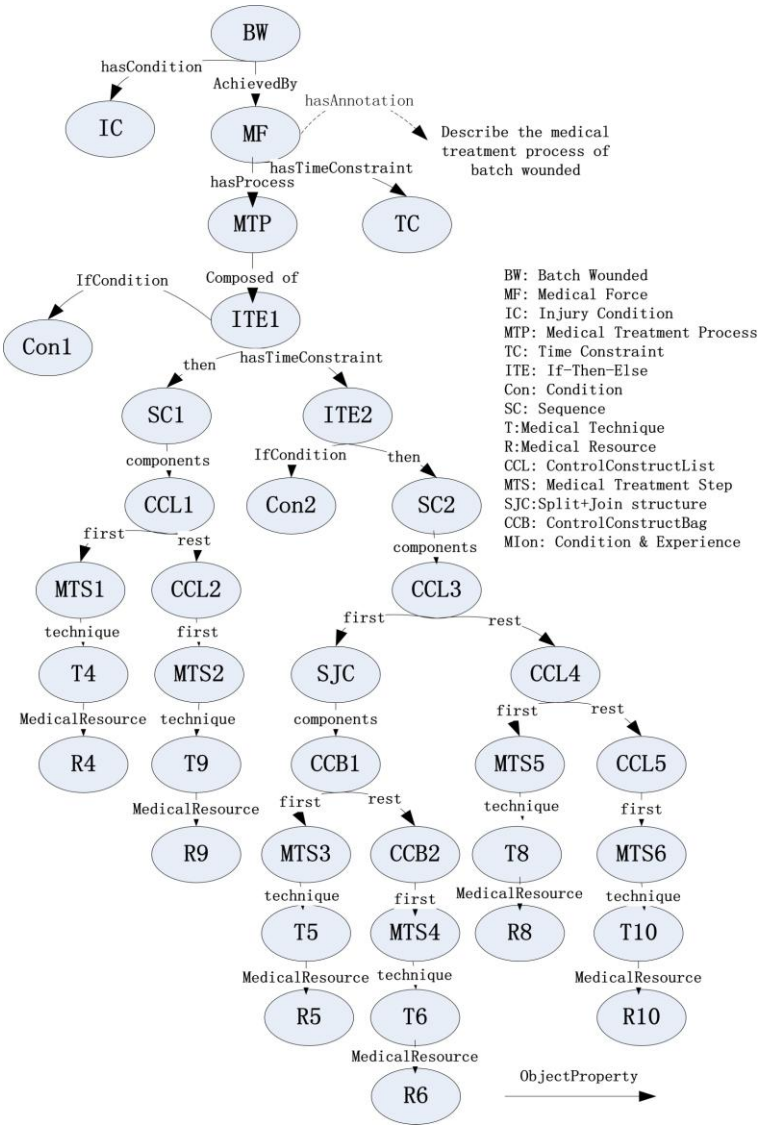

Figure 5. Part of Medical Resources Assignment Process of Batch Wounded Treatment

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REFERENCES

Akbari, ME., Farshad, AA., and Asadi-Lari, M. (2004) - The devastation of Bam: an overview of health issues 1 month after the earthquake, *Public Health*, 118, 403-408.

Auerbach, PS., Norris, RL., Menon, AS., et al. (2010) Civil-military collaboration in the initial medical response to the earthquake in Haiti, *N Engl J Med*, 362, e32.

Cranmer, HH. (2005) Hurricane Katrina. Volunteer work-logistics first, *N Engl J Med*, 353, 1541-1544.

Grigoris, A., Paul, G., Frank, VH., et al. (2012) A semantic web primer. PHI press, India.

Hoogendoorn, M., Catholijn, M., Popova, V., et al. (2005) Formal modeling and comparing of disaster plans, *Proceedings of the 2nd International ISCRAM Conference*, Brussels, Belgium.

Jiang, J., Li, YP., Huang, XL., et al. (2012) Lessons learnt from Wenchuan earthquake: Performance evaluation for treatment of critical injuries in extremely-hit areas After great earthquake, *Chin J Evid-based Med*, 5, 12, 504-511. (in Chinese)

Lu SB. (2008) Importance of classified treatment of the wounded in Wenchuan earthquake. *Med J Chin Peoples Liberation Army*, 33: 919. (in Chinese)

Mendonca, DJ., and Wallace, WA. (2007) A cognitive model of improvisation in emergency management, *IEEE Trans on Systems, Man, and Cybernetics-Part A (Systems & Humans)*, 4,37, 547-561.

Miao, CG., and Nie, GZ.(2004) Exploration on mode of earthquake emergency command, *J Nat Disasters*, 13:48-54.

Mors, A., Valk, J., and Witteveen, C. (2005) An event-based task framework for disaster planning and decision support, *Proceedings of the 2nd International ISCRAM Conference*, Brussels, Belgium.

Zhang, LL., Liu Y., Liu X., Zhang Y. (2012) Rescue efforts management and characteristics of casualties of the Wenchuan earthquake in China. *Emerg Med J*, 28:618-622.

Zhang, LL., Liu X., Li YP., et al. (2011) Emergency medical rescue efforts after a major earthquake: lessons from the 2008 Wenchuan earthquake. *The Lancet*, 3,379:853-861.