Context-Aware Emergency Remedy System Based On Pervasive Computing

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Abstract. This study proposed a Context-Aware emergeNcy rEmedy system (CANE), based on the operations of a real hospital, to provide complete and convenient functions for emergency processes and medical consultants using mobile communication networks. The CANE system combines emergency medical services with GIS/GPS technology, mobile multimedia communications and context-aware controls. The CANE system largely focuses on allowing the EMT personnel to arrive at the accident location in the shortest possible time and give first aid the proposed dispatching procedure and the GPS/GIS location-aware service. When an ambulance is on the way to the specified hospital, the EMT can deliver the patient's symptoms, including the data of the medical equipment and the audios/videos of the patient, to the hospital doctor via the personal communication network, e.g., GPRS. Based on real-time multimedia information, a physician can recommend to EMT the most suitable treatment for the patient on the way to the hospital.

1 Introduction

With the wide deployment of wireless/mobile communications and the increase in the number of wireless/mobile users, mobile information services, such as the telemedicine application system over mobile medical network [1], [2], [3], [4], [5], [6], have become popular. For mobile telemedicine services [7], [8], [9], users can apply handheld devices, e.g., Smart Phone, PDA, or Tablet PC, to connect with the medical network and to access medical information via the on-line hospital. These pervasive healthcare and pervasive telemedicine services can improve communications among patients, physicians and other healthcare workers, and enable accurate medical information to be delivered anytime and anywhere, thereby reducing errors and improving access [10], [11], [12].

As human society progresses, levels of natural and man-made calamities/accidents increase significantly [13]. In a natural or man-made accident, the arrival of the Emergency Medical Technician (EMT) arrives at the accident location quickly to treats the patient is the most important for saving a patient's life. However, some situations are unpredictable and uncontrolled [14], [15], [16]. For example, the ambulance driver might not know the correct accident location very well, or the

emergency center might dispatch several ambulances for the same emergency [17], [18]. Such uncontrollable situations prevent saving the patient in time and waste the social and medical resources [12], [19]. In contrast to a conventional emergency rescue where the EMT person lacks expertise and is unfamiliar with the patient's health history, the EMT person can call doctors at the hospital to obtain treatment suggestions [20]. However, the information from the distance ambulance is insufficient to help doctors make an accurate diagnosis and recommend the appropriate treatment. This uncertainty and lack of instant diagnosis can seriously jeopardize the patient's life [3], [21], [22]

This study proposes a "Context-Aware emergeNcy rEmedy system (CANE)" to achieve efficient ambulance dispatching and real-time multimedia symptom delivery for emergency rescues. CANE is also a mobile telemedicine system supplying a platform by which the hospital physicians can communicate with the EMT person on the ambulance and give appropriate treatment suggestions to save the patient on the way to the hospital. CANE uses GIS/GPS technologies to achieve the location-base services, which could help the rescue center to dispatch ambulances appropriately for all emergencies [23].

The rest of this study is structured as follows. Section 2 describes the infrastructure and system components of the proposed CANE system. Section 3 describes implementation and the usage of the CANE system. Conclusions are finally drawn in Section 4.

2 System architecture design

This section describes the system architecture and components of the CANE system, and the procedure of dispatching ambulances among the patients, the hospital and the rescue center.

2.1 CANE system architecture

CANE is a three-tier architecture composed of (i) the Front Emergency Point (FEP), (ii) the Emergency Control Center (ECC) and (iii) the Emergency Medical Service Hospital (EMSH). Figure 1 depicts the proposed system architecture. Each subsystem in CANE is described as follows.

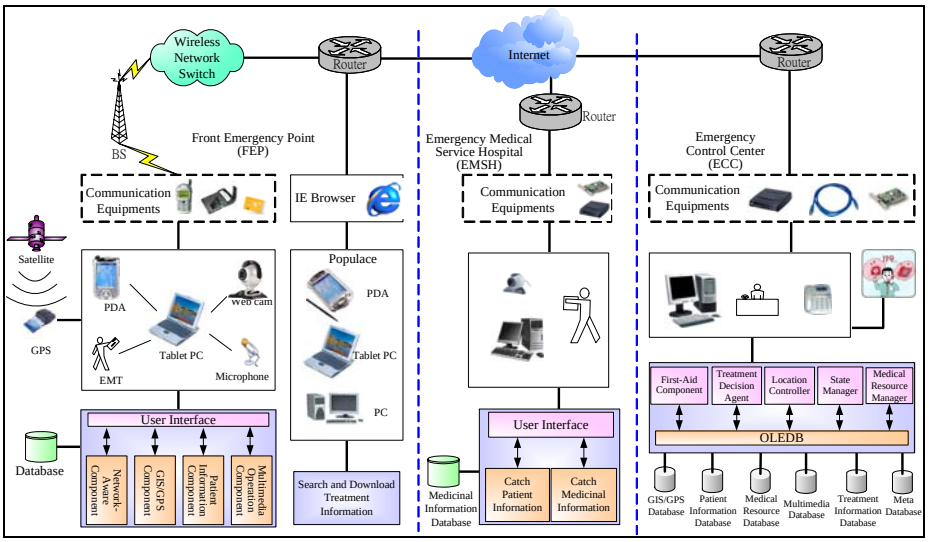

Fig. 1. The CANE system architecture.

1. Front Emergency Point (FEP) subsystem: The FEP subsystem in each ambulance helps the EMT staff to complete emergency operations. The GIS/GPS function of the FEP subsystem helps the ambulance driver find the exact location of the patient and hospital in time. Based on the FEP subsystem, the EMT can send the real-time data about the symptoms, pictures and videos and audios of the patient to the hospital. The doctor at the hospital diagnoses the patient from a distance and gives appropriate treatment suggestions to the EMT staff. To promote the mobility capability of the ambulance and emergency person, Tablet PC and PDA combining mobile communication network, e.g., GPRS, are applied in the FEP subsystem. Because the GPRS bandwidth is limited and critical, the related GIS information is built into the FEP database to reduce the bandwidth consumed.
2. Emergency Control Center (ECC) subsystem: The ECC subsystem coordinates the communications between the FEP and EMSH subsystems. The ECC subsystem constantly collects the information of hospitals' medical resources and ambulances' locations. The context-aware capability of the ECC subsystem can efficiently dispatch ambulances to victims and then to the appropriate hospital, which provides sufficient medical resources and spaces. Based on the proposed dispatching procedure, the ECC subsystem filters the calls for the same incident to prevent multiple ambulances from being dispatched to the same emergency.
3. Emergency Medical Service Hospital (EMSH) subsystem: The EMSH subsystem established in each hospital constantly receives the information of patients' conditions and ambulances' locations. The distance information gives the hospital a head start in assessing the patient and preparing appropriate treatment to ensure successful emergency rescue.

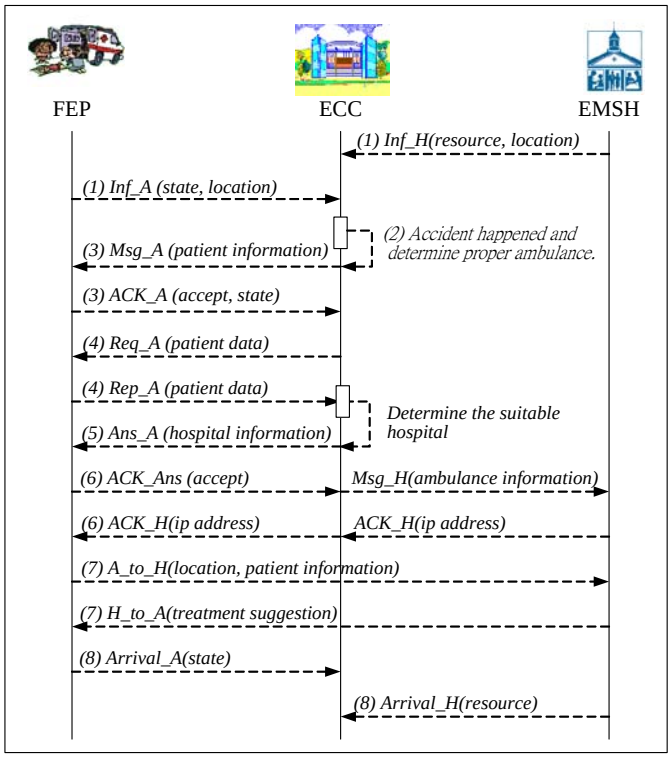

Fig. 2. CANE dispatching process.

CANE system combines the wire and mobile communication networks to let emergency staff and doctors communicate with each other and help treat the patient. Figure 2 shows the CANE system dispatching process. The operation steps are described as follows.

1. Step 1: ECC subsystem constantly collects the resources of hospitals and the locations/states of ambulances using the messages Inf_A(state, location) and Inf_H(resource).
2. Step 2: When ECC subsystem receives an emergency call and the patient needs an ambulance to carry him to a hospital, the ECC subsystem determines an appropriate ambulance and tells the ambulance to go to the patient's location.
3. Step3: When the EMT staff member in the ambulance receives the message Msg_A(patient information) from the FEP subsystem, he responds by accepting or rejecting the rescue mission to the ECC subsystem via the message ACK_A(accept, state).
4. Step 4: The ECC subsystem asks the FEP subsystem to transmit the information of the patient. Therefore, when the ambulance arrives at the accident location, the EMT person transmits the symptoms, including the patient's pictures/videos, from the web cam on a handheld device, to the ECC subsystem.

5. Step 5: The ECC subsystem determines the appropriate hospital according to information received from the FEP subsystem, and directs the ambulance driver.
6. Step 6: When ambulance drivers request to go to the emergency hospital, the ECC subsystem informs the selected hospital and gives the doctors information of the patient. Then, the ECC subsystem establishes a communication channel between the FEP subsystem and the EMSH subsystem, and the EMT staff and doctors can then talk with each other.
7. Step 7: When the communication channel is established between the FEP subsystem and EMSH subsystem, an EMT staff member transmits the patient's symptoms, including pictures, videos and EKG, to doctors at the hospital. Physicians can then immediately diagnose and give appropriate treatment suggestions. Thus, the hospital staff can assess the patient and prepare treatment before the patient arrives.
8. Step 8: When the ambulance arrives at the selected hospital (EMSH subsystem), the FEP subsystem transmits the message Arrival_A(state) to announce that the first-aid mission is accomplished. The ambulance is thus available to provide assistance on another emergency. The EMSH subsystem also transmits the message Arrival_H(resource) to update the medical resource database in the ECC subsystem. After the appropriate calculation and update, the ECC subsystem can determine an appropriate EMSH subsystem for the next emergency rescue.

2.2 Functionality of CANE system

This sub-section describes the designed functions of the CANE system in detail.

1. Front Emergency Point (FEP) subsystem: FEP provides four main functions, (i) location-aware operations for ambulances, (ii) patient information delivery, (iii) multimedia symptom capability and (iv) network-aware operations. The corresponding system components achieving the four functions are described as follows.
   - The GIS/GPS component provides the location-aware operations for ambulances. This GIS/GPS component obtains the location information from the embedded GPS device. The real-time location information helps the ambulance driver to find the right route quickly.
   - The Patients Information component records the patient information. When the ambulance is on its way to the emergency hospital, the EMT person records the patient information, e.g., personnel information, EKG and blood pressure, and then transmits the collected information to physicians via the mobile network. The information enables hospital staff to start assessing the patient and preparing treatment.
   - The Multimedia Operation component enables symptoms to be depicted using multimedia. The text/voice-based information is usually insufficient to help doctors to perform correct diagnosis and treatment suggestions from a distance. Multimedia symptom information, including pictures and videos of the patient's symptoms, provides doctors with comprehensive information, allowing them to make correct and quick diagnosis and treatment suggestions for the EMT person,

and the more preparing time for the doctors themselves, and may make the difference between life and death.
- The Network-Aware component detects the network connection status. This component ensures stable communication, especially given the large volume requirement of multimedia information and the limited mobile network bandwidth.

2. Emergency Control Center (ECC) subsystem: The ECC subsystem is composed of (i) the First-Aid Information Component, (ii) the Treatment Decision Agent, (iii) the Location Controller, (iv) the Medical Resource Manager and (v) the State Manager.
   - First-Aid Information Component: If the FEP person requires the first-aid information, the FEP person transmits the patient's symptoms to the ECC subsystem. The First-Aid Information Component responds with the first-aid operations to the EMT person. The multimedia database supplies the multimedia first-aid information. The FEP person can easily understand the operation first-aid steps from the Virtual Reality (VR) demonstrations or pictures.
   - Treatment Decision Agent: Treatment Decision Agent provides the EMT people and doctors with the required treatment information. The EMT person and doctor can quickly obtain the patient's anamnesis from the Treatment Decision Agent, which uses the patient information database to record the patients' health histories, e.g., name, sex and allergies. Treatment Decision Agent also provides physicians with appropriate treatment suggestions, including the appropriate emergency hospital (EMSH subsystem), based on the treatment information and medical resource databases.
   - Location Controller: The ECC staff dispatch ambulances by monitoring the ambulances' locations and the corresponding emergency states. The Location Controller determines the closest ambulance for an accident, and provides the ambulance driver with appropriate routes to the dedicated hospital based on GIS/GPS database. The GIS/GPS database records the GIS map and the paths of the hospitals locations to accomplish a quick rescue.
   - Medical Resource Manager: The Medical Resource Manager collects the medical resources of EMSHs, e.g., the number of available sickbeds, the medical specialty and the hospital location based on the medical resource database records.
   - State Manager: State Manager processes the states of an emergency mission, which include the processing authority of the FEP system between the ECC subsystem and the EMSH subsystem. The related state information is recorded in the meta-database.
3. Emergency Medical Service Hospital (EMSH) subsystem: The EMSH subsystem established in each hospital constantly receives information about patients' conditions and ambulances' locations. The EMSH subsystem receives the pictures and real-time A/V streams about the patient from the ambulance. Then, the EMSH specialists can diagnose and give treatment suggestions to improve the patient's chance of survival. The EMSH subsystem estimates the arrival time of the ambulance, allowing the hospital staff could prepare treatment in advance for the patient. The EMSH subsystem also automatically transmits the hospital's medical resource status to the ECC subsystem for medical resource management.

3 The CANE system implementation and usage

The feasibility and practicality of the CANE system was considered by discussing its design and development with the staff of a teaching hospital. CANE system is based on the operations of a real hospital, providing complete and convenient functions for emergency processes and medical consultants via mobile communication networks. The CANE software and hardware configuration is described as follows.

1. System software: CANE was developed using Visual C++, Visual studio .NET 2003, eMbedded Visual Basic, ArcGIS 8.0 and MS SQL 2002.
2. System hardware: The equipment applied included Tablet PC, PDA, Web Cam for CF/USB, wireless microphone/earphones, and GPRS module.

Figures 3, 4 and 5 depict the CANE system usage. Figure 3 depicts the ambulance EMT using a PDA to record the patient's personal information, such as sex, age and symptoms. The EMT immediately transmits the patient's medical records to the hospital to maximize the preparation time available to treat the patient. Furthermore, if the provision of medical records is insufficient to help hospital physicians diagnose the patient, then the CANE system provides the picture and whiteboard functions for the EMT personnel to show the patient and describe the patient's photograph using the whiteboard. According to Fig. 4, a physician can easily understand and observe that the patient's left hand was fractured and, then, give the appropriate treatment suggestions to the EMT personnel.

Figure 5 depicts the GIS/GPS location-aware service for the ambulance driver. Using the location-aware service, the ambulance driver knows the exact locations of the accident and hospitals, driving direction, expected arrival time, driving speed, signal strength of satellites and the longitude and latitude of current location. When an accident occurs, the staff of the ambulance dispatch center can determine the appropriate ambulance to go to the accident using the functions depicted in Fig. 6. From the functions, the people can understand where the ambulances are and whether they have emergency tasks.

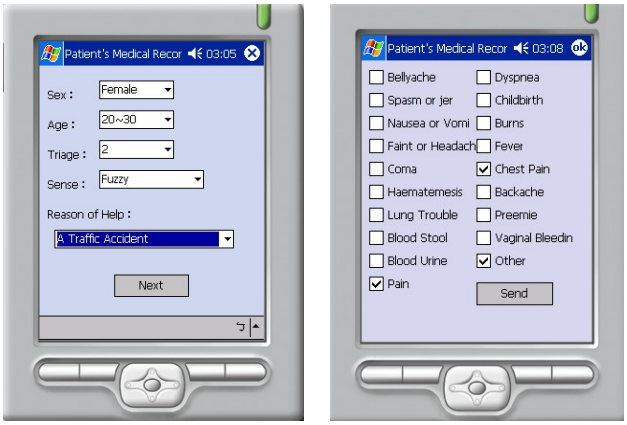

Fig. 3. A patient's medical records illustrated in a PDA.

Fig. 4. The picture/whiteboard functions.

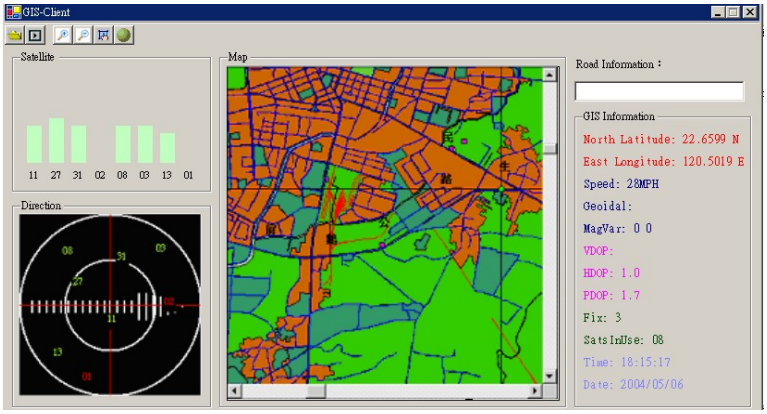

Fig. 5. The GIS on the ambulance.

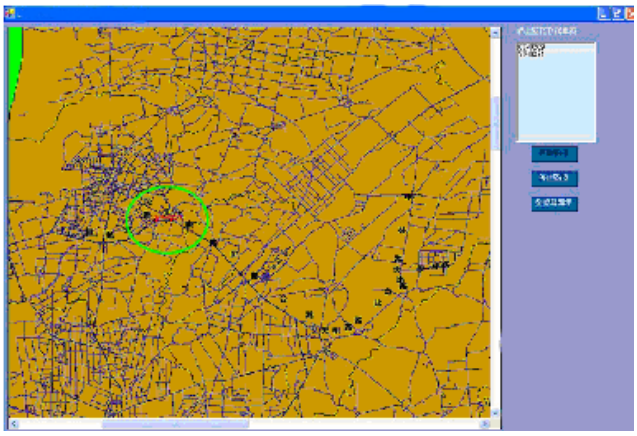

Fig. 6. The ambulance's locations at the Emergency Control Center.

4 Conclusions

The rapidly increasing application of handheld devices and the deployment of mobile communication environment are accelerating the development of pervasive telemedicine services. The proposed CANE system tries to compensate the limitations of conventional emergency medical services, by which the EMT personnel merely inform doctors about patient's symptoms by telephone. CANE improves the efficiency of the emergency remedy using advanced pervasive multimedia techniques. Physicians can make accurate diagnoses and recommend appropriate treatment suggestion to the EMT staff based on the context-aware information, including the real-time multimedia data about the patient's symptoms. The context-aware information helps physicians to diagnose illnesses and gives the hospital staff a head start in assessing the patient and preparing suitable treatment. Real-time pervasive access to the patient is one of the improvement factors in extending lives and lengthening the rescue time. To achieve practical usage in the near future, the researchers are cooperating with a local teaching hospital to refine and verify the effectiveness and value of the CANE system.

Many counties make much of emergency and use a diverse array of information technologies to assist emergency person to complete emergency tasks. However, many emergency staffs think that this approach increases their loads by adding extra equipment in emergency. Moreover, emergency care combining the state-of-art Information technology is required immediately before telemedicine becomes legal in Taiwan.

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