Telemedicine and E–Health Services, Policies, and Applications: Advancements and Developments

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Chapter 17

Bridging the Abridged: The Diffusion of Telemedicine in Europe and China

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ABSTRACT

In this chapter, a comprehensive review of the development of telemedicine in China, with the focus on the establishment of PACS (Picture Archiving and Communications Systems) and image-guided tele-surgery, will be accounted for together with a comparative study in reference to the counterparts in Europe, leading to a framework of a sustainable, scalable, and flexible e-health infrastructure for the future global digital (paper-less) hospital. The study is drawn from the first-hand knowledge gained through the conduction of a 3-year networking project on Telemedicine: Tele-Imaging in Medicine (TIME, 2005-2007) funded by the European Commission under the Asia-link programme. It is the authors’ hope that this chapter resonates with the future prospect of telemedicine by providing the right contents, at the right time and to the right extent, especially when the implementations taking place are in countries with disparate economic development.

INTRODUCTION

Over the last twenty years, China has achieved unprecedented economic growth, with an accompanying growth of the wealthy and middle classes, which has led to the building of a well-off society in a comprehensive way. To this end, China is currently in the process of reforming its health care systems by equipping its hospitals with many modern medical systems, such as, medical imaging scanners, as well as building its own. Because of the size of its territory and
the number of its population coupled with the uneven development of the economy across the country, the distribution of the facility of modern medicine mainly resides in the major cities, such as Beijing and Shanghai. In order to reach to remote areas, China has begun the development telemedicine techniques in the late 1980s. In the first decade (~1990-2000), the main focus was on the implementation of communication networks with a faster and wider bandwidth, such as ISDN (Integrated Services Digital Network), in the hope to connect far and wide. Within this digital network service, tele-education, tele-conferencing, and tele-consultation have flourished. However, these activities mainly serve as demonstrations to showcase the feasibility of the communications networks and the advances of computer technology. With the advent of World Wide Web, many internet-based services are made available and more importantly free, such as Skype, making the services of tele-conferencing/tele-consultation not only affordable but also flexible and mobile, i.e., a network connection being able to set up in an operation room instead of in a conference room, bringing hopes of practical applications at the point of care, such as tele-surgery, a reality. The first case of tele-neurosurgery took place in 2005 between Beijing and Yan’an with a distance of 1300 kilometres.

By contrast, Europe is well advanced in many of these fields. Firstly, Europe originated imaging field when the first Nobel laureate, physicist Wilhelm Roentgen, discovered X-rays that led eventually to the birth of radiology, and thereafter the medical imaging industry. With the application of advanced computer techniques in the 1970s, Computerised Tomography (CT) and Magnetic Resonance Imaging (MRI) were invented, prompting another Nobel Prize award shared between the UK and the USA. With typically 80,000 2D images (e.g., in Geneva Hospital) generated per day, Picture Archiving and Communications Systems (PACS) have been developed to manage them. Up to 2005, most European countries have installed PACS in their hospitals with Norway topping the chart with 100% hospitals equipped with PACS. Elsewhere more than 70% hospitals in the countries of United Kingdom, Germany and Italy are implemented with PACS, whereas in China up to 2005, only 1% hospitals managed to install miniPACS, a stand-alone version of PACS.

On the other hand, PACS is not penicillin taking care of any type of images. In its current form, it can only archive radiologic images. Hence, a plethora of effort has been put into it to entail PACS with the ability of managing the other images. Unfortunately, it has been proven that the model of ‘one size fits all’ is not sustainable in the e-health domain.

This chapter will give a detailed account on the latest development of telemedicine and PACS systems with a focus on China. In comparison with their counterparts in Europe, the results are drawn from the completed TIME project funded by EU and the initial work conducted from the newly funded FP7 project WIDTH on Infrastructure for the Digital Hospital. The novelty of this chapter lies in the fact that it might be the first of the kind since most of existing literature reviews tend to be in comparison with the USA or Japan who has more presence in China than in Europe, aiming at exploring the breadth of innovations in the field of telemedicine and keeping abreast of the new developments, leading to a roadmap for the future global digital hospital.

It starts with a background study on the standards and terminologies that are currently adopted in telemedicine, including PACS, DICOM, HL7, RIS, HIS, and EU Asia ICT programme, in particular, the TIME project. This is then followed by the introduction of telemedicine activities that have been conducted or are on-going in Europe, specifically, in the United Kingdom, Switzerland, Italy, Norway and Poland. Although not comprehensive, it is representative of the range of recent advances. Preceding the Section on Lessons Learned, Telemedicine in China is detailed, spanning from Hospital Infrastructure, Tele-communications...
Infrastructure and Telemedicine Infrastructure to the Diffusion of PACS and Tele-surgery in China. Future trends are later discussed before the Conclusion is drawn. The chapter ends with the Acknowledgement and References.

BACKGROUND

Generally speaking, telemedicine refers to the use of communications and information technologies for the delivery of clinical care remotely. In reality, the means to be applied to access any type of medical care has to be physical, such as telephone, internet or any other communication network. Therefore the development of telemedicine, to a certain extent, follows the advances of Information Communications Technology (ICT). Telemedicine is therefore defined by the American Telemedicine Association (ATA, 2011) as the use of medical information exchanged from one site to another via electronic communications to improve patients' health status. Closely associated with telemedicine is the term Telehealth, which is often used to encompass a broader definition of remote healthcare that does not always involve clinical services (http://en.wikipedia.org/wiki/Talk%3ATelehealth). To this end, video-conferencing, transmission of still images, e-health including patient portals, remote monitoring of vital signs, continuing medical education and nursing call centres are all considered part of telemedicine and telehealth.

Starting out in the 1960s with demonstrations of hospitals that provided extended care to patients in the remote regions, the use of telemedicine has spread rapidly and is now becoming integrated into the ongoing operations of hospitals, specialty departments, home health agencies, private physician offices as well as consumers’ homes and workplaces. In its early days, telemedicine was employed as a communication channel between the user and the medical industry. For example, at the UK, a person can dial 999 for help in the event of a medical emergency and, at present can call NHS Direct for advice on any suspicious symptoms or simply asking for health recommendations. The specialities of telemedicine can cover nearly every medical domain, for example:

- Home Care
- Emergency Care
- Pre-hospital Care
- Out-patient Care
- Surgery
- Dermatology
- Psychiatry
- Oncology
- Pathology
- Ophthalmology
- Cardiology
- Radiology

PACS

One of the most important advances of computer technology brings to medical field for the last 30 years is the emerging array of medical imaging scanners, e.g., Computerised Tomography (CT), Magnetic Resonance (MR), Positron Emission Tomography (PET), or CT/PET and MR/PET, which have revolutionised the way we obtain detailed information from inside the human body. Since these medical images are acquired in digital forms as opposed to ‘films’, a systematic way has to be in place to store, manage, retrieval, or transmit them either locally or over a network. Picture Archiving and Communications Systems, more commonly known as PACS, has therefore emerged. It enables images, such as X-ray scans, to be stored electronically and viewed on video screens, so that doctors and other health professionals can access the information and compare it with previous images at the touch of a button. The arrival of PACS has since replaced large numbers of radiological films, the medium that had been around for over 100 years and had been almost the exclusive way for capturing, storing,
and displaying radiographic pictures. By then, film had been a relatively fixed medium with usually only one set of images available for each scan. By contrast, PACS technology permits a near filmless process, with all of the flexibility that a digital system can offer. PACS also removes all the costs associated with hard films and releases valuable space currently used for storage. Most importantly, PACS has the potential to transform patients’ experience of the care they receive across an array of networked hospitals, for example, NHS network in the UK. By this way, if a patient has relocated from one place to another, his/her medical records can be easily retrieved from the system as if from the same hospital.

The first generation of the software of PACS was developed in the mid-1980s in the USA and Europe (Huang & Taira, 1992) when modules of PACS were programmed and were implemented independently in the departments of different domains, e.g., paediatric, coronary, or neuro-radiology.

Because of its potential benefit of going ‘filmless,’ in 1982, a series of annual meetings, Euro-PACS (http://www.europacs.org/), was funded in Europe, to establish a scientific reference circle of reputable experts in the field of imaging informatics and PACS. Nearing its 30th anniversary, Euro-PACS had gained its credentials at the time when the deployment of PACS was still at its frontier with regard to technical innovations in medicine. Before this, there had not been any commercial system nor had vendor solution available, the annual meetings of EuroPACS provided a unique platform to interface the pioneers in the field with the technical innovations and developments, paving the way to its currently near-mature status. As of 2005, most European countries had installed PACS across many of their hospitals. Figure 1 illustrates such a development (Bergstrøm, 2006).

In terms of telemedicine, one particular technical issue of concern for PACS is the speed of data flow. Due to the fact that most of radiologic images are of higher resolutions and are going to higher dimensions (>2), in the late 1980s, a network with a typical capacity of 10 MByte per second such as IEEE 802.3 Ethernet was discov-

Figure 1. The implementation of PACS in a number of European countries (Bergstrøm, 2006)
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eread inadequate for PACS to transmit integrated data of audio, video, and text forms in one stream. A high-speed fibre optic network with rate up to 200 MByte/ps has since then been in place (Schmiedl, Rowberg, 1990) to replace the copper wire network, which slowly but surely pushed the further refinement of PACS in the 1990s.

**DICOM Images**

In principle, PACS can take an image of any format, such as TIFF (Tagged Image File Format), or lossy compression format JPEG, created by Joint Photographic Expert Group, as well as home grown formats built into an image scanner. In practice, in order to communicate images with each other to ensure an image acquired from one radiology department can be readable by the others, a standard format is required to prevent the repetitive work on converters translating formats from one to another. DICOM, also known as (aka) Digital Imaging and Communications in Medicine, was initiated in 1992 in the USA by ACR (the American College of Radiology) and NEMA (the National Electrical Manufacturers Association). Since then it has been developed in liaison with other Standardization Organizations in both Europe and Japan (NEMA, 2004), and currently has been widely utilised in medical imaging field, in an attempt to facilitate standard communications of medical images. ADICOM image contains multiple parts providing a means for expansion and updating. The advantages of using DICOM images include among many others that DICOM standard has been widely applied in the medical field, and that DICOM has a header file of fixed format and an image dataset, leading to a fixed size of vocabulary in terms of representation of pathology. For instance, a typical DICOM image comprises a textual header file containing around 700 lines detailing imaging time, modality, and manufacturer of the scanning, etc., together with an image data file. To most radiologists and clinicians, the context of around 100 lines can provide enough information for a patient. This standard has been continuously extended to meet the demands of practical applications. Recently in 2000, DICOM has been added Structure Reporting (SR) (Clunie, 2000) classes, Supplement 23 that is employed for transmission and storage of clinical documents. The SR classes fully support both conventional free-text reports and structured information, thus enhancing the precision, clarity, and value of clinical documentation. In addition, the SR standard provides the capability to link text and other data (e.g., blood test results) with a group of particular images or waveforms, arriving at storing the parameters of findings and bridging the traditional gap between imaging systems and information systems. In addition, SR also plays an essential role in Integrating the Healthcare Enterprise (IHE) by providing healthcare practitioners with an effective tool that encompasses a variety of clinical contexts.

**HL7**

Health Level Seven (HL7) is an all-volunteer, non-profit organization involved in the development of international healthcare standards (http://www.hl7.org/about/index.cfm), one of several ANSI-accredited (American National Standards Institute) Standards Developing Organizations (SDOs) (ANSI) operating in the healthcare arena. Most SDOs produce standards (aka specifications or protocols) for a particular healthcare domain such as pharmacy, medical devices, imaging or insurance (claims processing) transactions. ‘Level Seven’ refers to the seventh level of the International Organization for Standardization (ISO), i.e., the seven-layer communications model for Open Systems Interconnection (OSI). This application level (layer) that is independent of lower layers interfaces directly to and performs common application services for the application processes. Although other protocols have largely superseded it, the OSI model remains valuable as a starting point to begin the study of network architecture.
HL7’s domain is clinical and administrative data and is dedicated to offering a comprehensive framework and related standards for the exchange, integration, sharing, and retrieval of electronic health information that supports clinical practice and the management, as well as delivery and evaluation of health services. Specifically, it aims to create flexible, cost-effective approaches, standards, guidelines, methodologies, and related services for interoperability between healthcare information systems. At present, HL7 has more than 2,300 members, including approximately 500 corporate members, from 55 countries, who represent more than 90% of the information systems vendors serving healthcare.

One of the HL7 standards is Electronic Health Record / Personal Health Record (HER/PHR), within which the System Functional Model that provides a reference list of functions may be present in an EHR System (EHR-S). Described from a user perspective, the function list has the intention to enable consistent expression of system functionalities, allowing a set of standardized descriptions and common understanding of functions in a given setting, e.g., intensive care, cardiology, office practice in one country or primary care in another country, etc..

**HIS and RIS**

A Hospital Information System (HIS), aka Clinical Information System (CIS), is a comprehensive, integrated information system designed to manage the administrative, financial and clinical data of a hospital. This encloses both paper-based and machine-based information processing. CISs are sometimes separated from HISs in that the former concentrates on patient-related and clinical-state-related data (i.e., Electronic Patient Record [EPR]) whereas the latter keeps track of administrative issues. However, the distinction is not always clear and there is contradictory evidence against a consistent use of both terms.

The aim of an HIS is to achieve the best possible support for patient care and administration by the application of electronic data processing. Because of the variations in size and in specialty at each hospital, usually, each hospital has their own tailored in-house HIS. Specifically, it can be either composed of or independent of one or more software components with specialty-oriented extensions, such as a Laboratory Information System (LIS), or a Radiology Information System (RIS).

A RIS is a computerized database used by radiology departments to store, manipulate and distribute patient radiological data and imagery data (RIS, 2011). The system generally consists of capabilities of patient tracking, scheduling, result reporting and image tracking, and is critical to efficient workflow to radiology practices. Although RIS complements HIS, it can be substantially different in many ways from HIS, with many components being independent between the two. Furthermore, attention should be paid to the fact that the data structures in HIS and RIS are usually different. This is because that the retrieval system of HIS is centred around clinicians’ notes, whereas RIS is based on the ‘checklist’ of a scanning procedure. In order to interface them with each other, a converter, i.e., a look-up table, usually, should be in place.

Figure 2 illustrates a typical relationship between HIS, RIS, and PACS. On the one hand, HIS deals with patients’ check-in/check-out and scheduling for examinations. On the other, PACS manages patients’ image data. Whereas RIS interfaces the two systems with each other by connecting a patient’s personal records with his/her imagery data. Thus to ensure that HIS and RIS communicate with each other smoothly, five aspects should be taken into consideration (Guo, Huang, Gan, Yang, Jing, 2006):

a. **Patient information** – RIS must identify all the patients that are registered in HIS, i.e., to avoid repetitive entries or even
worse, wrong entries, RIS should be able to read all the information from HIS.

b. **Sharing the same clinical and management dictionary** – In order to process scheduling and billing information from HIS correctly, RIS should employ the same check list, materials and clinical management terms as in HIS. For the benefit of HIS, RIS should also adhere to the same information on facility and personnel that are allocated to the patent by HIS.

c. **Diagnostic information** – Usually, there are two ways to accept clinicians’ diagnostic reports. One is for out-patients and another is for the in-patients. For those out-patients, the notes written on papers are accepted that later can be input into the system. Whilst for the in-patients, HIS is employed for clinicians to input patients’ diagnostic/checking information, which can be obtained from RIS, including next checking time, follow-ups, reports, etc.

d. **Billing** – RIS needs to be able to give a price list, detailing the checklist for a patient who undergoes one or more scans. It should take into account of the categories that a patient belongs to, i.e., free, on-benefit, etc.

e. **Clinical report** – RIS should have the ability of checking a patient’s information, whereas radiologists can write reports based on the patient’s scanned images. Clinicians from different departments should be able to read them through HIS via a hospital network.
IHE

Integrating the Healthcare Enterprise (IHE, 2011) is a global initiative that creates the framework for passing vital health information seamlessly—from application to application, system to system, and setting to setting—across multiple healthcare enterprises. It might not create any new standard, but it is the nature of its proven process of collaboration, demonstration and real-world implementation of interoperable solutions that puts IHE in a unique position to significantly accelerate the process for defining, testing and implementing standards-based interoperability among digital health record systems by driving the adoption of standards to address specific clinical needs. For example, the IHE Technical Framework identifies functional components of a distributed healthcare environment solely from the point of view of their interactions in the healthcare enterprise. At its current level of development, it defines a coordinated set of transactions based on the HL7 and DICOM standards. IHE encourages implementers to ensure that any product that is implemented in accordance with the IHE Technical Framework also meet the full requirements of the standards underlying the IHE (Fu Fu, Jin, Dai, Chen, Wang, Li, Gao, 2003).

EuropeAid Programme: TIME Project

In the European Commission, EuropeAid (http://ec.europa.eu/) has been a major player on the external assistance scene and up to 2005 has committed €7 billion to more than 150 countries and territories in a bid to meet the daily challenge of improving lives worldwide and to build long-term partnerships.

Since the release of World Wide Web in 1990 by Tim Berners-Lee in Europe, the way people live has been changed forever by the emerging ICT (Information Communications Technology), in a good way. From then on, European Commission (EC) has initiated dialogues with Asia with the aim of helping the development of ICT in Asia and to strengthen the economic links between the two continents.

As a result, the first ASEM (Asia Europe Meeting) meeting took place in 1996 in Bangkok. Subsequently, second ASEM II was held in London in 1998 and the third ASEM III in Seoul in 2000. At the first meeting, it was stressed that intensified cross-flows between Asia and Europe in ICT were central to strengthening the economic links between the two continents. Moreover, an extensive survey in both Europe and Asia indicated that the potential and desire to co-operate existed on both sides. With this in mind, in 1999, EC launched Asia IT&C Programme Phase One, and thereafter, in 2004, Asia IT&C Programme Programme Phase Two.

The programme of EU-Asia IT&C had the aims of (http://cordis.europa.eu/fp7/home_en.html):

- Stimulating an open dialogue between governments, citizens and key players in the ICT sector, professional associations, chambers of commerce, NGOs (Non-Governmental Organisations), regulators, standardisation bodies, and the private sector of both regions;
- Improving co-operation in ICT between Europe and Asia (and within Asia), particularly in the least developed countries (LDC’s);
- The formation of long lasting ICT partnerships;
- Further integration of Asian countries into the Information Society;
- The strengthening of ICT mutual trade and investment flows between the regions; and
- Increasing the European ICT presence in Asia.

Five components of the EU-Asia IT&C programme were in place, including:

- Get-in-Touch & Keep-in-Touch Activities;
Short Courses (university or technical level);
- Liaison with European ICT Initiatives and Programmes;
- Understanding European and Asian Regulatory and Legislative Organisation Structures;
- Practical Demonstration Actions.

The project TIME (http://www.mitime.org/time/), acronym for Tele-Imaging in Medicine: A Cyber Bridge Interfaces China with Europe on Collaborative Health Care, received funding of €200,000 in January 2005 under the strand of Asia IT&C Phase II with the component of Get-in-Touch & Keep-in-Touch. It was coordinated by Gao, the first author of this Chapter, at Middlesex University, UK, with partners including University of Cambridge in the UK, Athens University of Economics and Business in Greece, Fuzhou University in China and Capital University of Medical Sciences in China. TIME strived to form a network for technology transfer from Europe to China; and to set up guidelines for the development of telemedicine systems (in particular for tele-imaging), in which it had succeeded, as will be described later. Figure 3 shows the TIME webpage.

The main motivation for running this project was that there was a mismatch of the levels of IT&C applications between developed and developing countries, and such a mismatch would affect global economic growth. For examples, in
Asia, mainly China, the first case of Severe Acute Respiratory Syndrome (SARS) appeared in 2003, whereas Avian influenza (bird flu) was discovered in both Asia and Europe. Due to their infectious nature, these diseases could affect global health if not being treated in a timely manner.

The methodology that the TIME project employed was to organise international conferences/workshops, opening up dialogues in a hope to form collaborative research between two continents. Figure 4 demonstrates the first conference MIT2005 (Medical Imaging and Telemedicine) organized in China in August 2005 with delegates coming from 9 countries. Taking into consideration the short space of 6 months spent from preparing to completion of the conference, the conference was a success. During the TIME project, Fuzhou partner, led by Prof. Qiang Lin, developed a LEJ-2 Omnidirectional M-mode echocardiography system (Figure 4, bottom-left) that was awarded the top price for technology innovation in China in 2007.

The second conference, on MIMI2007 (Medical Imaging and Informatics, http://www.mitime.org/time/mimi07.html) took place on August 14-16, 2007 in Beijing, as yet another element of the TIME activities. Delegates from 18 countries/regions (China, Japan, Korea, Pakistan, Singapore, Malaysia, Libya, Taiwan, Hong Kong, Macao, UK, Finland, Italy, Switzerland, Norway, Greece, USA, Canada) attended this event. Figure 5 illustrates two snapshots from the conference (top) and a visit to observe image-guided neurosurgery (bottom) during the conference. Significantly, these activities have borne fruit in a number of publications (Gao, et al., 2005; Gao, et al., 2008; Müller, et al., 2006; Müller, et al., 2008).

As part of the project, a framework of e-PACS, i.e., an online imaging system was developed to transfer and communicate medical images for research purpose, forming a collaborative platform as illustrated in Figure 6 (http://image.mdx.ac.uk). With server located at Middlesex University in the UK, the system at present accommodates over 100,000 2D and 3D images. Built on the open source GNU Image Finding Tool (GIFT) that was initially developed at the University of Geneva, the online database offers a facility of Content-Based Image Retrieval (CBIR). It is based on the Query-By-Example (QBE) paradigm whereby images from a collection that most closely resemble a query image in appearance (i.e., the content that an image is carrying) are retrieved from the server. The GIFT software is installed on the server side only.

On the client side, a web page based interface is given. The client-server communication is achieved using the XML-based Multimedia Retrieval Markup Language (MRML). All client-server communication, including queries from the client or results returned by the server, is realised using message passing. As a result, the client can be implemented in any programming language. The current TIME client is implemented using PHP (Personal Home Programming) language to generate dynamic web pages for the client web browser.

During the project, this system enabled the sharing of data among the project partners, with data including ultrasound images and digital human being transmitted from China, and ImageCLEF (ImageCLEF) data from Europe. Two main extensions to further enrich the system have since been conducted, one of a technical nature implemented during the TIME project and the other a pedagogical character that has been carried out after the completion of TIME.

The first extension involved contribution to the online interpretation of PET images. The brain PET collection contains images of a functional nature. As such they provide little structural information. A digit anatomic atlas is therefore provided by pressing the ‘Map’ button in Figure 6(b). This leads to a new window depicting slices of a standard template of the human brain with anatomic labels that can be displayed by clicking on the relevant locations of the slice. The second extension is concerned with teaching students undertaking a Biomedical Modelling and Informatics masters programme at Middlesex University using the da-
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Figure 4. The webpage of MIT2005 (top-left) and the delegates in the conference from 9 countries (top-right). Bottom-left: LEJ-2 Omni-directional M-mode echocardiography system developed during TIME project by Fuzhou partner team. Bottom-right: TIME team visited Fuzhou University where Prof. Lin (3rd from left) is from.

tabase, which is further funded by UK JISC (JISC) under Repository programme Phase 1 and Phase 2 respectively. The Phase 1 project MIRAGE (2009-2010) (aka Middlesex University Medical Image Repository with CBIR Archiving Environment) involved digesting more images into the server by including 3D images (Gao, et al., 2010; Qian, et al., 2011), especially in the brain domain, the data that are collected from the Chinese partner from Navy General Hospital. MIRAGE 2011 has just started and will be focusing on the development of an interface for visualization of 3D images and will be completed at the end of 2011.

TELEMEDICINE ACTIVITIES IN EUROPE

To a certain extent, it can be said that the advances in Information and Communication Technologies
(ICT) have brought forth telemedicine, the service that is able to provide health care, to perform clinical surgery and to present consultation to the patients remotely via ICT devices. Built on the advances of ICT emerged in the 1980s, especially in the hardware domain, many countries have initiated the application of ICT to health departments and formed telemedicine services.

Europe has led the way in many aspects in both medical imaging and ICT. As early as in 1895, the first Nobel laureate, physicist Wilhelm Roentgen, discovered X-rays that led eventually to the birth of a new medical speciality, radiology, and thereafter the medical imaging industry. Since the 1970s, advances in imaging techniques, and in particular the uses of the computer, have revolutionised the application of radiographic imaging techniques in medical diagnosis. In 1979, Professor Allan Cormack at Tufts University, USA, and Sir. Godfrey Hounsfield at EMI Limited, UK, shared the Nobel Prize in Physiology or Medicine for their work on Computerised Tomography.
Figure 6. TIME image retrieval database with CBIR facility. (a) (b) The interface and the login; (c) Select a group of images by clicking 'Random' button; (d) One or more images can be chosen as query (queries) by select ‘Rel’ (aka Relevant) of the pull-down menu under each image with the similar images returned when the button 'Query' being clicked; and (e) the template brain images for PET.
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In the same field, more recently, in 2003, Sir Peter Mansfield from Nottingham University, UK, together with Professor Paul Lauterbur from the USA, was jointly awarded the Nobel Prize for their discoveries in Magnetic Resonance Imaging (MRI). Figure 7 illustrates a set of 3D brain images for the same subject from each of the three imaging modalities of CT (left), MR (middle), and PET (right).

In addition, Europe has also been a major player in the field of IT&C. It was British physicist Tim Berners-Lee who invented the World Wide Web (WWW) while working at CERN in Switzerland in December 1990, allowing computers to talk to each other through a new language HTML (Hyper-Text Markup Language). Since he wrote the first browser, the WWW has changed the world, ushering in a new era that makes information more accessible than ever before.

Furthermore, in 2009, Charles Kao, aka the Godfather of Broadband, was awarded half of Nobel Prize in Physics (Nobel Foundation, 2009) for his groundbreaking achievements concerning the transmission of light in fibres for optical communication while working at Standard Telecommunication Laboratories, at the UK, revolutionised the telecommunications industry and paved the way to the advent of today’s information age by replacing the copper wire-based network that had been the main materials before the 1960s with optical fibres that can achieve a capacity of 2.56Terabit/second. As of 2010, submarine cables that are laid beneath the sea have linked all the world’s continents except Antarctica (Wiki, 2010), connecting the world into one.

In terms of the application of ICT to medicine, Europe has been very actively involved, which will be described in the following sections by listing a number of projects in telemedicine, the activities that the TIME project actively interacted with during 2005 to 2007. Although it is not intended to be a completed account nor a conclusive one, it is in the hope that the following description resonates with the latest diffusion of telemedicine in both Europe and Asia.

United Kingdom (NHS)

In United Kingdom (UK), the National Health Service (NHS) has established a unique national healthcare system providing free health for all since 1948 (Istepanian, 1999). However, at the advent of the new century, thanks to the accumulated funding constraints and the increased aging populations, the NHS faced fundamental changes in its operational structures and the quality of
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medical services it provided, reflected on long patient and operation waiting lists, shortages in hospital beds and community care, and inadequate medical facilities in intensive care and emergency units as well as nursing staff. One solution was to make healthcare more productive, technologically efficient by the application of the advances of ICT. Telemedicine therefore has gained a rapid growth since 1998 (TeleMed, 1997; TeleMed, 1998). Large number of research and application programs on telemedicine/telehealth flourished in different universities, hospitals, and health institutes, with a significant increase in funding from the national funding research councils including EPSRC (www.epsrc.ac.uk), ESRC (www.esrc.ac.uk), BBSRC (www.bbsrc.ac.uk), and MRC (www.mrc.ac.uk). At the mean time, the UK Telemedicine and E-Health Information Service (TEIS, http://www.teis.nhs.uk/about/TEIS.htm) was established in 1998 running by the University of Portsmouth and was formally launched in January 2004 with a goal to provide a background source of information to anyone researching the field or proposing a trial or planning a larger scale implementation of telemedicine. The service gives access to information about all aspects of telemedicine from telemedicine activities, contact information for the people or organisations involved, to publications and equipment that are currently available for telemedicine.

The UK’s largest e-health project is NHS Direct, which has been in operation since 2000. It is a 24-hour nurse led telephone help line supported by a website @ http://www.nhsdirect.nhs.uk, covering England and Wales. A separate service, NHS24 @ http://www.nhs24.com, covers Scotland. It aimed to ‘provide people at home with easier and faster advice and information about health, illness, and the NHS, so that they are better able to care for themselves and their families.’ Because of the huge impact it has made to society, NHS Direct has been acclaimed as the largest and most successful healthcare provider of its kind, anywhere in the world (Department of Health, 2011).

As a core service, a call to NHS Direct can often be the starting point of a patient’s treatment process. It currently handles more than half a million telephone calls per day with over 3 million web transactions each month. Users of the service, through whichever channel, are asked questions about their symptoms or problem. Common problems are often given simple self care advice, by which people can follow so as to avoid an expensive visit to a health care professional. More complex problems are assessed by a nurse and can then be given treatment advice or referred on to another service within the NHS. In addition, NHS Direct provides a number of commissioned services throughout the NHS, such as specialised support for patients with long term conditions, access to General Practitioner (GP) and dental healthcare out of hours, and a professional response system for times of public health anxiety.

In terms of collaboration with Asia on telemedicine, between 2005 and 2007, the TIME project was conducted between Europe and China as explained in the above Section. In 2011, a new FP7 project has been funded to continue the work of the TIME project, which will be coordinated by the author, Gao, in the UK. As a follow-up project, WIDTH (Warehousing images in the digital Hospital [WIDTH], interpretation, infrastructure, and integration) is under the FP7 People Marie Curie Programme with a total funding of €411,600. It comprises 6 European partners and 5 Chinese as listed at Table 1. It is expected that this three-year collaboration between Europe and China will not only promote the close tie that has been established between the two regions, but also contribute in a great deal to the global development of the digital hospital, while gaining perspective of future sustainable, flexible, and integrated health care systems in the digital hospital.

It is anticipated that the findings from the WIDTH project will be published in due course to inform researchers the lessons and experiences learned.
In 2001, the University Hospitals of Geneva in Switzerland and French-speaking countries in Africa initiated the RAFT project (Réseau en Afrique Fancophone pour la Télémédecine) by building a multinational telemedicine communication network in order to facilitate distance learning and tele-consultations through the internet-based platform (Bagayoko, et al., 2006). In 2001, the project started with the establishment of connections to Mali with four sites in Namako, including three regional hospitals and one rural hospital. Whilst in 2002, Mauritania was linked to the network with 7 sites in Nouakchott, together with 8 regional hospitals and 1 rural telecentre. Later between 2003 to 2004, Morocco was bridged when Burkina-Faso, Senegal, and Tunisia were connected. By 2005, the network grid had been extended to Cameroon, Ivory Coast, Madagascar, and Djibouti (RAFT). As a direct result, through utilizing the internet-based technologies, distance learning and teleconsultation were facilitated via various communication schemes. For example, there were programmes of North-South, South-South, and South-North distance learning and tele-consultation respectively as illustrated in Figure 8, where top-left showing the South-North distance learning and top-right the IT infrastructure implemented in Africa. Several other countries are currently in the process of joining this network. So far, this network has connected 18 Africain countries, extending its activities from French-speaking to English-speaking countries. Later in 2009, RAFT became a partner of the e-Diabetes programme (e-Diabetes Programme, 2009) developed by the World French-speaking Digital University (UNFM). The bottom row in Figure 8 illustrates the encounters between two RAFT team and the TIME team.
Italy

In 2004, Italy, Trieste University hosted an international conference on *EuroPACS-2004 in the Enlarged Europe*. During the conference, innovative and organizational solutions for the ICT-based integration of the health systems in the enlarged Europe were discussed and proposed by about 400 people from 47 Countries (Inchingolo, 2005). The key motifs of the conference focused on the ‘*Integrating the Healthcare Enterprise*’ (IHE) of world-wide projects and the integral solutions offered by Trieste. Figure 9 demonstrates the Trieste PACS system (left) and the virtual multi-regional Alpe-Adria PACS booth at the ‘*EuroPACS-MIR 2004 in the enlarged Europe*’.

From 1991 to 1995, Trieste University led a project on Open-PACS, with the aim to distribute PACS services and to pioneer a surgical PACS by releasing the AT&T Commview PACS that had been installed in 1988 in Trieste (Inchingolo, 2005). Subsequently, in 1995, Trieste started project DPACS (aka data PACS) in an attempt to initiate an open, scalable, cheap and universal system.
with accompanying tools to store, exchange and retrieve all health information (Fioravanti, et al., 1997). It was anticipated to offer an integrated virtual health card to the European Citizen, prompting the latest development of PACS that can be traced in a number of projects funded by the European Union’s 7th Framework Programme (EU FP7) (http://cordis.europa.eu/fp7/home_en.html).

The other development in Italy comes from the University of Pisa, Division of Diagnostic and Interventional Radiology (www.rad.unipi.it). Since 1994, the division has been actively involved in the field of IT applications to Radiology, with EU funded projects including among many others:

- PARCS – The project carried out design and implementation of a PACS based on a parallel architecture;
- HIM (High-performance information Infrastructure in Medicine) – the project included experimental use of ATM (Asynchronous Transfer Mode) networks for the transmission of radiological images;
- Tip-TV (LIVE, Lifetime Investment in Vocational Education) – the project prepared training courses for radiology technicians in the field of CT post-processing; and
- Europe-MMM – to prepare a multimedia course accessible from the internet or a CD-ROM for radiology students.

In particular, the project E-learning @ University of Pisa has developed a niche interactive system for uploading and consulting teaching materials that can be applied to performing self-evaluation tests and exams, targeting at medical students. Further more, they have co-funded ENDOCAS (Centre for Computer Assisted Surgery) as shown in Figure 10 (ENDOCAS, 2011), with a goal of implementing an Imaging Assisted Surgery (IAS) systems to provide information help, action help, and training help, which can be achieved by offering assistance on planning surgical intervention, integrating mechanic components of the robots, and simulating complex environment for surgical training respectively. At the European Conferences of Radiology 2007 and 2008, Professor Caramella from Pisa and
Professor Pokieser from Vienna delivered ePACS courses on Cardio CT and Breast Imaging. The concept of ePACS offers a new way of learning that is built on a modified web-based PACS system and the basis of original radiological reports. Students can either learn by themselves or be guided to train in a simulated radiological working environment as demonstrates in Figure 10, where top-left shows a webpage of ENDOCAS and top-right the IAS. At bottom-left, Prof. Caramella gave an introduction to the TIME team and the TIME team was practicing IAS robotic system at bottom-right.

Norway

Although the hospitals in Norway are state owned, they work as private health enterprises. Distributed in regions with separate boards, each region is managed by a dedicated director and is connected to the other regions using intra-regional broadband communications.

Norway has a long history of the development of telemedicine thanks to the nature of national geography with an elongated shape, forming one of the longest and most rugged coastlines in the world. Within this geography, there are around
50,000 islands off the much indented coastline, home to one of the most sparsely populated countries in Europe with a population of only 4.9 million. With this in mind, telemedicine provides a niche solution and has been eagerly promoted in Norway. As early as in the 1990s, Norway pioneered projects with Teleradiology-services, which had been in great demand when it comes to consultation in the situations of emergencies, seeking for second opinion and information retrieval between hospitals and the primary health care units. Within which, Teleradiology-services are carried out in 2 ways. One is to perform communications from RIS/PACS to RIS/PACS, and the other is to interface Teleradiology-services with the use of IHE and the new services with XDS-profiles (extended data services). By the end of 2005 nearly all the hospitals in Norway had digital x-ray scanners with RIS and PACS installed. Moreover, all the Regional Health Network could communicate with the National Health Network (Bergstrøm, 2005).

In 2006, Norway, Trondheim organised the 24th EuroPACS conference. The TIME project team jointed in and delivered a China-EU-workshop, which was a great success with around 100 delegates attended. Figure 11 illustrates the Call for Papers.

During the conference, two live operations were demonstrated as displayed in Figure 12 (top-row) taking place at Oslo University, and visit to St. Lovas Hospital by the TIME team (bottom-left). The bottom right reflects the meeting with Norwegian team during the conference.

During the meeting, the TIME and Norwegian teams had an inspiring discussion on the future opportunities to collaborate in the field of telemedicine, which has attributed to the success of the forthcoming FP7 project WIDTH to start in 2011.

**Poland**

Despite the fast development of telemedicine as a scientific and practical discipline it was still considered a novelty in a global scale. That is because telemedicine in nature is a strictly interdisciplinary field, combining together medicine, computer science, telecommunications, multimedia technology, biomedical engineering, psychology, electronics as well as certain branches of physics (e.g. acoustics and optics).

*Figure 11. The 24th EuroPACS webpage with TIME workshop (in red box)*
Bridging the Abridged

Figure 12. Live operations (top row) shown at EuroPACS 2006 via video conferencing links. Bottom left, visit to St. Lovas Hospital by the TIME team, whereas on the bottom-right meeting between the two teams of the TIME and Norwegian.

and mathematics (data analysis techniques) (Telemedicine, 2005). To this end, in 2005, the Third International Conference on Telemedicine and Multimedia Communications was held in the modern health care centre in Kajetany, near Warsaw in Poland. The conference was held jointly with counterparts in both USA and Germany via their video-consultation rooms, in an effort to showcase the advantages and the huge benefit of tele-communications, such as reducing the cost and time of travelling as demonstrated in Figure 13. On the left, a tele-conferencing session was in place whilst on the right, the delegates who attended the conference.

With focuses on Tele-medicine, PACS and multimedia, the conference gave an opportunity for the TIME project to stay abreast of the current developments in the field. In particular, the project on Tele-Pathology in the Developing Countries in South East Asia brought more attention and similarity to the TIME team, the work that was carried out between Germany, Switzerland, and Southeast Asia including Thailand, Vietnam and Cambodia (Stauch, et al., 2005). In Asia, there has been very limited number of experienced doctors and fewer experts. For example, in Cambodia, up to 2000 there were only 6 qualified pathologists who were running a morphological service by providing
As a result, there was a huge backlog of microscopic samples waiting to be analysed. With the advent of telemedicine, not only distance diagnosis can be achieved but also distance learning and training can be offered to local trainees. Subsequently, the project was initiated in 1996 between Thai and Germany. By 2000, it had established a central service system, DIAGAID and iPath (http://telepath.patho.unibas.ch/ipath/) as an internet-based platform for communication of specimen samples and experts’ diagnosis, served by the University of Basel at Switzerland. It was expected that by training local participants, the numbers of specimen sending to the central service, i.e., the server, could be reduced from 100% to 60% for pathological diagnosis. From 2002 to 2003, there were still 100% cases sending to the server located at the University of Basel, whereas 80%, 60% and 50% cases were recorded in the years of 2004, 2005, and 2007, respectively (Chhut, 2008), suggesting the tele-training programmes to the local doctors had made significant impact.

More activities in many other European countries are being carried out. For example, the project, Regional Telemedicine Forum (http://regional-telemedicine.eu/project), started in late 2010. between countries of Denmark, Estonia, France, Italy, Norway, Poland, Spain, Sweden, and United Kingdom is working on exploring alternative models of telemedicine related policies and in addition, from practical implementation of telemedicine services already provided by other European regions. Another Telemedicine Forum is conducted between Norway and Portugal (http://www.innovasjonnorge.no/portugal) to address the status and opportunities of Telemedicine and Health ICT in both Portugal and Norway, and beyond.

TELEMEDICINE IN CHINA

With its huge population and vast territory China presents a great challenge in supplying modern advanced health care services to all parts of the country. On the other hand, continuing IT&C advances in the delivery of healthcare via telemedicine can help in providing healthcare to remote and under-served populations. In this Section, the development of telemedicine in China is addressed with emphasis on the infrastructures in hospitals, tele-communications, and telemedicine.

Hospital Infrastructure

In many ways, the situation in China is quite different from the other countries. Being the most populated country in the world, China also enjoys...
having the 3rd largest area. Table 2 lists a number of key demographic data in both China and the UK for the purpose of comparison, whereas the classification of hospitals in China is given in Table 3.

By accommodating more than 1.33 billion people, China represents 20% of the world population. In comparison with the UK, the population density in China is only half that of the UK with a ratio of 0.55 between the two countries. However, in terms of bed numbers in hospitals, China has only half as many beds as in the UK with 1.4 doctors per 1000 people, whilst the UK has 2.3 per 1000 people. With only 6.1% hospitals (Grade 3) in China that have been equipped with PACS in comparison with 70% in the UK, China is far behind when it comes to the implementation of modern advanced medical equipment with a ratio of 0.087 between the two countries.

Hospitals in China are categorized into three grades with four levels of each grade consented by the Chinese Ministry of Health who conducted the classification according to the facility, equipment, and staffing that each hospital can offer. The grades as shown in Table 3 include Grades 1, 2, and 3 with the highest grade being 3A+, standing at an international leading position with only two hospitals (i.e., Beijing Union and PLA 301 General Hospital), whereas Grade 3A is expected to be the leaders nationally. In total, as of 2008, there are 19,246 classified hospitals (including both in-patient and no-bed hospitals) and 2 millions doctors in service in China (Fu, et al., 2006; Grade, 2011). Within these hospitals, there are 2.2 million beds with 149 (1%) hospitals having beds over 800 (Grade 3A/3A+), whilst 1930 hospitals (12%) offer beds between 300- to 800 (Grade 2A/3B).

Within Grade 3 hospitals, radiology departments are in place to be responsible for acquiring medical images from modern medical image scanners, including CT, MR, and/or PET as well as from film digitisers to digitise X-ray films and many other forms of pictures/images.

Figure 14 illustrates the official statistical data on the number of hospital beds and doctors distributed in both urban and rural regions from 1952 to 2000 in China (China Statistical Yearbook, 2003).

It can be seen from Figure 14 that there is a big gap between rural (green patterns) and urban

<table>
<thead>
<tr>
<th>Table 2. Infrastructure data in China as of 2008 in comparison with their counterparts in the UK (Wiki-2, 2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population (million)</strong></td>
</tr>
<tr>
<td>China</td>
</tr>
<tr>
<td>UK</td>
</tr>
<tr>
<td>ratio</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3. The number of in-patient hospitals in China classified by the ministry of health (Grade, 2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Number of hospitals</td>
</tr>
</tbody>
</table>
Bridging the Abridged

In terms of the number of beds, the numbers in the rural areas, in particular from the 1980s, have decreased, whereas in the cities, the number has doubled since the 1980s. On the other hand, the gap between the numbers of doctors are increasing with more and more doctors are in place at city hospitals. At the mean time, the number of medical doctors and physicians in the counties stagnated or even declined since 1988.

The Diffusion of PACS in China

When the EuroPACS conference series started in 1984, China had just begun its initial stage of economy reform. In 2006, two decades later, the first Symposium of China-PACS-RIS was held in Beijing, reflecting the latest development of PACS in China. Although a number of advanced imaging scanners are brought in after the economic reform in several high grade hospitals (3A+/3A), such as CT, MR and PET, the majority of hospitals mainly house the following scanners due to their lower cost:

- X-ray
- US – ultrasonic scanner
- DR – document scanner
- DSA – Digital Subtraction Angiography
- DF– digital Film scanner
- CR – Computer Radiography scanner
Technically, two types of PACS are in service, named whole hospital PACS (usually called PACS) and miniPACS respectively. While whole hospital PACS provides a system of image management over one or multiple networks, miniPACS offers an off-line archiving service with a facility of external online archiving on-demand. In this way, miniPACS is available at limited cost in comparison with whole-PACS. As a result, In China, the implementation of PACS started with miniPACS. In 1994, the first system of miniPACS was installed at Beijing Union Medical College Hospital (Fu, et al., 1995) based on a UNIX platform. The features included an image reviewing workstation, an image archiving server and a soft reporting workstation, whereas a long-term archiving device in the module file format (MOD) was developed in-house. In 1996 (Fu, et al., 2006), the first DICOM 3.0 compatible miniPACS was purchased from Siemens at Sichuan Province. At the same year, research projects on the topic started to take interests within China with the establishment of many domestic companies. However, in the two years that followed, i.e., from 1997 to 1998, the development on PACS went less progressive. The main barrier at the time was that PACS could only function well on UNIX systems that were then considerably expensive in China, due to the face that only UNIX systems could deliver high enough processing speed at the time to display images smoothly, whereas the then PCs with Win95/Intel Pentium architecture could only compete with lower specifications. On the other hand, at the time DICOM was only available for UNIX and offered fewer image modalities. To further exacerbate the situation, Asia was mired in a financial crisis during that time, triggering less spending. Most importantly, China was lagging behind at the development of technologies. The complete concept of digital imaging, storage and communicate had just started to be appreciated within hospital sectors. In the following two years, i.e., from 1999 to 2001, miniPACS took China by storm with many hospitals directly ordering the systems from abroad, giving rising to the second tide of implementation of miniPACS in China. Table 4 gives a list of majority hospitals that implemented the solutions of miniPACS in China from 1999-2001 together with a few between 2003 and 2005.

A typical miniPACS offers the services of **Soft Reporting**, **Image Reviewing**, **Image Archiving**, and **Jukebox/Tape Library** (Based on CD-R, DVD-ROM, MOD, or DLT), the four features however that somehow appeared not functioning completely. This is due to the following factors:

- Lack of local research and development team to maintain the system in relation to localization, integration, and service to ensure that miniPACS can be properly configured.
- Differences in the workflow and management between the radiology department in China and overseas, and also differences among the hospitals in China resulting in the less efficient use of PACS, i.e., a PACS that works perfectly in one hospital may not work well in another.
- High performance coming from high cost. Because of the relatively low cost of miniPACS in comparison with whole PACS, limited performance should be expected.
- Scarce experiences in using UNIX platform applications in hospitals, arriving at a less performed PACS with little communications with the other parts of hospital systems (such as HIS, RIS) since most people were accustomed to Personal Computers (PCs) running Windows systems.

After three years’ effort, the miniPACS supplied by ROGAN could be run successfully on the
platform Intel/Windows at Shanghai First People’s Hospital (Tao, Miao, 2002), while integrating with the Chinese RIS, showcasing the performance and impact of the whole hospital PACS. Although a miniPACS starts with a relatively lower price, more components have to be purchased when it comes to integration with the other systems in the hospital, such as RIS or HIS. In many cases, a brand new whole hospital PACS had to be brought in order to fill the gap of missing components from a particular vendor. As a direct result, starting from 2001, many hospitals in China tended to invest in whole hospital PACS solutions and sometimes together with RIS, which can be seen from the list in Table 5.

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Year of Installation</th>
<th>Beds</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing Tumour Hospital, Beijing</td>
<td>February 1999</td>
<td>300</td>
<td>SIEMENS</td>
</tr>
<tr>
<td>The first Affiliated Hospital of Medical College of Zhejiang University</td>
<td>March 1999</td>
<td>1100</td>
<td>AGFA</td>
</tr>
<tr>
<td>Zhejiang Province</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beijing Red Cross Chaoyang Affiliated Hospital of Capital University of</td>
<td>March 1999</td>
<td>900</td>
<td>GE Hangwei Medical System</td>
</tr>
<tr>
<td>Medical Sciences, Beijing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shanghai First People’s Hospital, Shanghai</td>
<td>October 1999</td>
<td>1000</td>
<td>ROGAN</td>
</tr>
<tr>
<td>Beijing Xuanwu Hospital Capital University of Medical Sciences, Beijing</td>
<td>August 2000</td>
<td>900</td>
<td>SIEMENS</td>
</tr>
<tr>
<td>Beijing General Navy Hospital Beijing</td>
<td>October 2000</td>
<td>800</td>
<td>SMIT</td>
</tr>
<tr>
<td>Zhejiang Taizhou Central Hospital Zhejiang Province</td>
<td>October 2000</td>
<td>400</td>
<td>SIEMENS</td>
</tr>
<tr>
<td>Zhejiang Province</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yunnan Provincial Hospital, Yunnan Province</td>
<td>December 2000</td>
<td>1000</td>
<td>SIEMENS</td>
</tr>
<tr>
<td>Shanghai Ruijin Hospital, Shanghai</td>
<td>June 2001</td>
<td>1500</td>
<td>EBM</td>
</tr>
<tr>
<td>Yunnan Province</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Affiliated Hospital of Guiyang Medical College Guizhou Province</td>
<td>October 2001</td>
<td>800</td>
<td>GE</td>
</tr>
<tr>
<td>The first affiliated hospital, Kunming Medical University, Yunnan Province</td>
<td>2003</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td>Wuhan Asia Heart Hospital, Hunan Province</td>
<td>2005</td>
<td>500</td>
<td>KONICA</td>
</tr>
</tbody>
</table>

In each hospital at China, HIS was established first before RIS. So when PACS was installed, the issue of compatibility between the three systems becomes dominant as it sometimes does not go down well with the other two. To ensure that they interface with each other, hospitals have to make choices as to which product from which provider should be purchased. Different companies have different views on the relationship between PACS and RIS. Some think they are independent, whereas the others consider them as one, depending on the functionalities each system can offer. For a PACS, it mainly manages image data flow, scanner connections, image storage, compression, retrieval, querying, all boiling down to the point of
images and focusing on techniques with emphasis on security and sustainability. As for RIS, it takes care of work flow or clinical flow and centres at patients, i.e., RIS is for communication and compromising, reflecting on flexibility and agility. In a way, it can be said that RIS is part of HIS. So it is very reasonable to consider that PACS and RIS are separate, giving rise to the importance of which brand of systems should be employed.

On the other hand, in term of communications, PACS and RIS share one local network, residing in the radiology departments and being separated from HIS that utilises a global network, in a bid to ensure that the data flow goes smoothly. The interface between the local and global networks can be bridged using the internet service i.e., the Internet Explorer (IE). In this way, the huge flow of image volumes within radiology departments will not affect the whole hospital data flow running using HIS with reasonably wide bandwidth. Thus, the e-patient record can be formed through IE by obtaining both an image-based report and a textual report.

Table 5. List of hospitals with full PACS solution in China from 2001 to 2005

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Year of Installation</th>
<th>Systems Installed</th>
<th>Beds</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing Tiantan Hospital</td>
<td>2001</td>
<td>PACS</td>
<td>960</td>
<td>NEUSOFT</td>
</tr>
<tr>
<td>Beijing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shanghai Ruijin Hospital</td>
<td>2001</td>
<td>PACS</td>
<td>1500</td>
<td>EBM</td>
</tr>
<tr>
<td>Shanghai</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuzhou Dongfang Hospital (Fujian Province)</td>
<td>2001</td>
<td>PACS</td>
<td>1200</td>
<td>TIANJIAN</td>
</tr>
<tr>
<td>The Affiliated Hospital of Qingdao Medical College</td>
<td>2002</td>
<td>PACS</td>
<td>900</td>
<td>GE</td>
</tr>
<tr>
<td>(Shandong Province)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beijing Xuan Wu Hospital Capital University of Medical Sciences</td>
<td>2002</td>
<td>PACS</td>
<td>900</td>
<td>GE</td>
</tr>
<tr>
<td>Beijing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beijing Tumour Hospital</td>
<td>2002</td>
<td>PACS</td>
<td>300</td>
<td>HUAHAI</td>
</tr>
<tr>
<td>Beijing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chong Qing South-west Hospital, Sichuan Province</td>
<td>2002</td>
<td>PACS</td>
<td>1000</td>
<td>TIANJIAN</td>
</tr>
<tr>
<td>Taiwan New Building Hospital, Taiwan</td>
<td>2002</td>
<td>PACS/HIS</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>Cancer Institute and Hospital, Chinese Academy of Sciences</td>
<td>2005</td>
<td>PACS/RIS</td>
<td>1198</td>
<td></td>
</tr>
<tr>
<td>Beijing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nanjing Medical University, First Affiliated Hospital Jiangsu</td>
<td>2005</td>
<td>PACS/RIS</td>
<td>2200</td>
<td>SONY</td>
</tr>
<tr>
<td>Province</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beijing General Army Hospital, Beijing</td>
<td>2002-2005</td>
<td>PACS/RIS/HIS</td>
<td>4000</td>
<td>GE</td>
</tr>
<tr>
<td>The first Affiliated Hospital of China Medicine University,</td>
<td>2005</td>
<td>PACS</td>
<td>1300</td>
<td>IBM</td>
</tr>
<tr>
<td>Liaoning Province</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The third affiliated hospital, Zhongshan University, Guangdong</td>
<td>2003</td>
<td>PACS/RIS</td>
<td>1000</td>
<td>GE</td>
</tr>
<tr>
<td>Province</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zhunyi Medical College, Guizhou Province</td>
<td>2003</td>
<td>PACS/RIS</td>
<td>1500</td>
<td>SIEMENS</td>
</tr>
</tbody>
</table>
The Infrastructure of Tele-Communication in China

Telemedicine stems from technologies of communications and computer information, within which the clinical care is delivered via a line-telephone, wireless mobile phone, video-conferencing equipment, or internet between medical specialists (and patients) in two or more different locations (e.g., countries) for the purpose of conducting consulting, remote medical procedures or examinations. Hence to provide any kind of tele-service, a tele-communication facility has to be in place first.

Lined Network

The people in China live geographically in 22 provinces, five autonomous regions and four metropolitan municipalities. Such a vast population and territory sets a correspondingly vast challenge to keep people in touch with each other. Starting from the late 1990s, China has established more than 2 million kilometres (Wiki-3, 2011) nationwide optical cable network, built on Asynchronous Transfer Mode (ATM), in which data are encoded into small, fixed-sized cells, Synchronous Digital Hierarchy (SDH) and Dense Wavelength Division Multiplexing (DWDM) technologies, laying a lasting foundation for tele-communications through lined telephones. In addition, several submarine cables (i.e., the cables that are laid beneath the sea), have been installed. As of 2008, there are around 362 million land-line users (of both private and business) in China, equivalent to 81% households/business suites on the assumption that an average household accommodating 3 people.

In terms of networks that are employed for the purpose of telemedicine, three major routes (Wang, Gu, 2009) have been connected, including the Golden Health Network (GHN), the International MedioNet of China (IMNC) network, and the Peoples’ Liberation Army (PLA) telemedicine network. Since the implementation in 1997, IMNC has been widely applied to telecommunications between medical specialists within around 300 hospitals (1.5% of all hospitals) that have registered on this line cross China. As the network is primarily a telephone line employing a low bandwidth, the major activities between these hospitals have been limited to communications with textual data, being analogous to an internal telephone line.

On the other hand, merely providing cables is not sufficient. With the advent of internet service, large numbers of video image data are called for in addition to audio signals. Faster transmission is therefore in demand, not only for just viewing still pictures but also for visualising moving videos together with accompanying sound simultaneously. Technically, this requirement has led to the establishment of a set of communications standards, i.e., Integrated Services Digital Network (ISDN) (Wiki-4, 2011) in 1988. The key feature of ISDN is that it integrates speech and data on the same lines, adding features that were not available in the classic telephone system. ISDN is a circuit-switched telephone network system and can typically provide up to 128 kbit/s. In the event of transmission speed, when the same telephone line is converted to a non-loaded twisted-pair wire (i.e., without filtering out any bandwidth by increasing the inductance by the inserting of a loading coil), it becomes hundreds of kilohertz wide (i.e., broadband) and can carry several megabits per second, coined the name broadband since 1996.

Teleconferencing Systems

In order to make the presence of telemedicine felt, many hospitals in China, such as Peking Union Medical College Hospital, have acquired video-based teleconferencing systems in an attempt to deliver telemedical services. Because of the high cost of proprietary video conferencing systems, the hospitals that can afford to install them in China are more likely to be the last ones that are in need of advice due to their own rich supply of
expertise and resources. Furthermore, although China has a small number of telemedicine systems in many of these leading hospitals, they hardly communicate with each other because of different standards of hardware and software that are employed in China, yielding these systems are essentially stand-alone.

To access rural and regional medical centres, connections have to draw from the existing resources that are in considerably less quantity for many hospitals in the rural regions.

**Wireless Network**

Because of the wealth that China has grown since the 1980s, China has tapped into a fashion-conscious market, with specially interest in those high-tech gadgets. As a result, mobile phones are a must-have accessory among young generations. Unprecedentedly, China has around 833 million (62%) mobile phone users (Wiki-3, 2011), thanks to the satellite network systems. The primary service of a mobile phone at present is to transfer voice data although other services have been deployed gradually, including email reading, web accessing, and messaging, admittedly at a higher cost since internet surfing involves downloading a number of pictures, taking longer to complete, in comparison with landline services. However, with such large army of mobile users, personal health system can be exploited in the future, offering services based on the wireless network.

**Internet Network**

By 2010, China has 420 million internet users (31.6% of its population) (China Daily, 2010) with 277 million accessing web pages via cell phones. Since broadband is the most popular way to access the internet with a wired connection, with 98.1% of wired Internet users choosing broadband, a total of 364 million people are now online in China, leading China being the second largest market of internet users after USA (Zhu, Wang, 2005) with major activities covering online chat, gaming, and internet surfing. Because of the very low cost of internet via land lines, web-based practices of telemedicine is much feasible in China, especially when many online meeting applications, such as Skype, are at the moment free available. In comparison, Europe has 475 million internet users, amounting to 58.4% of its population.

**Telemedicine Infrastructure**

To a certain extent, the first generation of telemedicine in China (Zhao, et al., 1998; Chen, Xia, 2009) started from a famous event. In 1995, a case of text-based consultation via emails had been reported, when the email was sent from Beijing to the U.S. and later the whole world, concerning a patient with heavy metal poisoning, by which a prescription of medicine was recommended and obtained that eventually cured the patient. Considering the high cost to setup a teleconferencing suite, internet based applications flourished in China in the late 1990s. It took off in 1998 when a much publicised activity of tele-consultation based on Internet took place (http://michaelfuchs.org/china/, http://telemed.stanford.edu/), whereby doctors from both China at Xi’an Medical University Hospital and the USA, Stanford University Health Care, conducted a conferring and reviewing session discussing the cases of two critically ill children, by the application of audio, video, and whiteboard, the emerging facilities at the time. Although feasible, much of the event was to prove the viability of webcast architecture, leading to a number of subsequent applications all with the same intention of showcasing. The similar view is shared by Hsieh et al (Hsieh, et al., 2001). In addition, much of the effort still focused on tele-consultation and tele-education as detailed in (Zhao, et al., 2010; Wang, Gu, 2009).

The real turning point of telemedicine came in 2005 when a series of operations via tele-manipulation/tele-neurosurgery were concerted to removal brain tumours using image-guided
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key-hole surgery technique (Tian, et al., 2008). The operation distance is 1300 kilometres away in Yan’an, a mountainous region, whereas the tele-manipulation was conducted from Beijing, with a home-made frameless stereotactic surgical robotic system CAS-BH5. The transmission of neuro-navigation data, planning, monitoring and manipulating was carried out through a digital network with a speed of 2 MByte/s on the platform of Internet. In total, 10 patients were operated on that year with 90% of patients improved neurologically with no complications, the conclusions being drawing from a 12-month post-operation check. When compared with local operations where a 93.3% improvement is achieved (Tian, et al., 2008a) based on the results of over 1000 cases, the accuracy of tele-surgery is very much similar to the conventional operation although not conclusive. The details of this activity will be addressed in the Section of Tele-neurosurgery in China given below.

**TELE-NEUROSURGERY IN CHINA**

With the advances of information and imaging technology, application of robotic systems to the health sector is a burgeoning field in assisting surgeons manipulating, monitoring, and/or guiding operations, with the advantages of being higher precision of targeting, persistence of longer duration, and having the ability of pre-operation planning drawing from patients’ images. As of 2001, there are around 270,000 cases of image-guided robotic operations conducted every year worldwide (MedMarket Diligence, 2002).

Unlike keyhole approaches applied on many other organs (e.g. in the abdomen as shown in Figure 12 [top-left]), where a micro-camera can be inserted inside to provide an augmented view, for a brain that is a compact organ and extremely of high value, there is simply no ‘room’ to accommodate any extra instruments as every tissue in a brain plays an important role to ascertain a person’s normal life. Minimal invasion and sacrifice of healthy tissues are hence the prerequisite for a brain intervention. Therefore, only recently, the first case of robotic image-guided neuro-surgery took place in the USA in 1985 (Kwoh, et al., 1988) for the procedure of biopsy using robotic stereotactic technique, i.e., to probe the tumour with a tip through a small burr hole (~3 mm) drilled on the skull. In order to ‘see’ inside a brain while performing keyhole surgery, surgeons relied on a CT scanner that performs scanning in real time while the robotic system was mounted on the gantry of the CT. Although this system was applied only for biopsy at the time, it implied potentials of applications to the other procedures. Also, because it is a robotic system, i.e., controlled by a computer, it is well suitable for being operated ‘remotely,’ leading to a tele-robotic system when coupled with the advances of computer communications techniques.

**Frame and Frameless Stereotactic**

Before modern imaging tomographiers were invented, many approaches had been developed in order to locate the exact position inside a brain. Among them, stereotaxis was the most popular one and was conceived by Horsley and Clark (Horsley, Clarke, 1908). The method employs an external three-dimensional frame as a reference to locate a position in the brain and was applied to animals as early as in the 20th century (Kandel, 1972). The frame is a mechanical apparatus attached to an animal’s head and incorporates a Cartesian coordinate system. In this way, the movement of a probe to be inserted into the brain can be monitored.

Wearing a frame is cumbersome in both a scanning suite for acquiring images and in an operation room during surgery, hence frameless stereotaxis has gradually replaced the frames. By which, landmarks, i.e., fiducial marks, on a skull have to be defined in advance to assist geometric registrations. Significantly, with the
benefit of advances of computer hardware and software, frameless stereotactic can achieve the same precision as that with a frame. China began this kind of procedure in the late 1990s. Figure 15 illustrates the approach using both frame (left) and frameless (right) stereotactic neurosurgery. In total, between 1998 and 2005, about 4,000 operations with frame and 1,500 with frameless stereotactic have been performed at the Navy General Hospital (NGH) (Yu, et al., 2000; Gao, et al., 2009) at Beijing China, led by Professor Zengmin Tian, vice president of NGH.

Due to its high success rate of near 100%, Prof Tian’s work on frameless stereotactic operation has elicited considerable interest in China in the non-medical press. The television programme Approaches to Science explained the procedure as illustrated in Figure 16. In the figure, it shows (a) the logo of the TV programme; (b) a team led by Prof. Tian (second from right) studying the MR images from a patient; (c) the planned route to target the tumour; and (d) computer graphics illustrating the registration between images and the patient’s brain.

Robots

With the help of a frame or frameless stereotactic system, minimally invasive techniques can be performed on tumour removal or biopsy from a brain by locating a precise position on a skull (and thence the target in the brain). The procedure normally involves the drill of a burr hole (1-10 mm), which usually is done manually. During an operation, surgical dexterity can be limited to a certain extent by surgeons’ physiological tremor. Therefore, robotic hands or robots have been introduced into operation theatres in the late 1980s (Kwoh, et al., 1988; Kelly, 2000), which could replace stereotactic frame and accomplish precise position location, and precision bone drilling.

In China, the building of robotic system for neuro-surgery began a decade later and mainly confined to tumour resection in order to achieve minimally invasive operations. Thanks to the expensive cost of buying a commercial Robot, such as RoboDoc, China began building its own. From 1997 to 2007, in collaborating with Beijing University of Aeronautics and Astronautics, Navy General Hospital developed their own robotic systems from CAS-R-1 (Computer Assistant Surgery-Robot, Type 1), and CAS-R-2 to CAS-BH5 as depicted in Figure 17. The robotic system employs a six-jointed server-controlled (or called a Programmable Logic Controller [PLC]) and motorised robotic arm (Figure 17[a]) and a software system responsible for location calcula-
In operation, the system allows for identification of the intended target defined by CT or MR images, delineating boundaries, planning optimized route, opening burr holes, and incising tumours.

The first operation took place in 1997 (Tian, et al., 1998) by CAS-R-2 for assisting tumour removal. In the following 10 years of its service, over 2000 cases of operations have been carried out with total effect rate of 93.3% (Tian, et al., 2008a). Formal consents were complied prior to any operation in those cases.

Tele-Neurosurgery

In general, the advent of robotics in an operation room provides the ability to position the probe-directing system rapidly, to compute the necessary trajectory and target coordinates in an error-free manner, and to remove tumour more completely. On top of these benefits, it also offers the possibility of being controlled remotely, i.e., to conduct tele-neurosurgery.

Subsequently, in 2005, the CAS-R-2 robotic system was modified into CAS-R-BH5 (Figure 17[b]) that was employed in performing the first series of tele-neurosurgery in China, exclusively.
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Figure 17. The development of a home-made robotic system for neurosurgery in China (a) CAS-R-2 for local operation and (b) CAS-BH5 for tele-surgery; (c) drilling the hole by the robotic arm supervised by Prof. Tian; and (d) probe introduction using robotic hand. © Courtesy of Prof. Tian.

for removal of tumours and taking place between Beijing and Yan’an as shown on the map in Figure 18. The distance is 1300 km between Beijing where Navy General Hospital resides and Yan’an, a mountainous city.

CAS-R-BH5 has five degrees of freedom (i.e., 6 joints) and weighs about 40kg with dimensions of $280 \times 800 \times 1100 \text{ mm}^3$. The system runs three modules that are responsible for conducting surgical planning, target directing and tele-manipulation operations. The system of surgical planning (Module 1) provides surgeons with expedient tools to store, retrieve and analyse relevant data, to study collectively the case history, to visualise reconstructed 3D images in order to define the boundary of a target for more complete removal, and to locate centrally the brain tumours by the safest and least invasive route possible. The module for target directing (Module 2) is concerned with the robotic arm in arriving at the precise position of the skull in order to perform the opening and in pointing to the direction of the route defined by module 1. Via a rapid and accurate measurement and calculation, the length of the probe (or catheter) is determined in order to minimise the trauma to normal tissues. The
module 3 focuses on telemanimulation systems, which spans from network communication, video transmission, graphics simulation, to human-machine interaction, providing technical supports for surgeons who are performing the tele-operation procedures. The system comprises two terminals, one being the master to conduct the remote controlling locating at Beijing and another, the operation terminal, i.e., the slave one, residing at the same room as the patient, to be employed to carry out the resection of physical tumour. Figure 19 schematically illustrates the relationship between the two (Tian, et al., 2008).

The platform of telecommunication is the Internet with the speed of transmission being 2 Mbytes/s. Although it is lower than the current standard of broadband with a typical speed of 20 Mbyte/s, the transmission was good enough to allow real-time online visualization and communications. The following procedures are then required to complete a tele-surgery successfully.

- Slave to master – Firstly the patient’s data (e.g., MR/CT scan, history record and the live view of patient in the operation room) from slave computer were transmitted to the master computer;
- Master to slave – The experts sent back the surgical plan and confirmations of surgical procedures, including the precise movement the robot arm should comply in order to arrive at the exact location pre-defined from Module 1 on the skull of the patient.
- Slave to master – the registration data between robotic arm and the fiducial markers on the patient’s skull to ensure the error was below the pre-defined threshold. Otherwise, the following step repeated.

Figure 18. The map showing the distance (arrow) between Beijing (⁎), the control centre guiding the operation, and Yan’an (the red box) where the operation took place. © Courtsey of Prof. Tian.
Master to slave – A series commands that the arm should following in the light of six joints instructed from master to slave then to the robot, e.g., forward/backward, left/right, up/down, side tilting, anterior/posterior tilting of the supporting device itself, and forward/backward of the probe (Tian, et al., 2008).

The speed of the movement of robotic arm was at 8 mm/s. Figure 20 demonstrates the whole process of the tele-operation, where (a) shows the master computer where surgical planning is drawn on; (b) the computer screen showing the activities in the remote operation room; (c) tele-mentoring and tele-manipulation; and (d) activities in the operation room.

The clinical outcome is then graded based on the Glasgow Outcome Scale (GOS, http://www.nervous-system-diseases.com/glasgow-outcome-scale.html), the measurement of a 5-point score given to victims of traumatic brain injury at some point in their recovery as shown in Table 6.

GOS is a very general assessment of the general functioning of a person who has suffered a head injury. Based on the data of 10 patients who were operated on using tele-neurosurgery procedure in 2005, four patients recovered nearly completely with 5 points on the GOS scale, whereas three with 4 GOS scores. Two patients are with GOS score of 3 and one with 2. These results are obtained from the follow-ups for each patient that took place between 3 to 14 months after surgery, with the average of 12 months.

Between 2005 and 2006, thirty-two patients underwent surgery of tumour removal at Yan’an with the technique of tele-surgery and were all successfully recovered without any complication with the average GOS point of 4. The mean accuracy of remote fiducial registration is within the range of 1.50 mm, whilst the standard deviation is 0.32 mm between the planned and actual target (Tian, et al., 2008a).

LESSONS LEARNED

China is still in the developing stage and in the process of reform of its health care systems. Due
Figure 20. Remote control of operations. (a) The master computer where surgical planning takes place; (b) The computer screen showing the activities in the remote operation room; (c) tele-mentoring and tele-manipulation; and (d) activities in the operation room. © Courtsey of Prof. Tian.

Table 6. GOS scale of 5 points

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<tr>
<th>GOS point</th>
<th>Description</th>
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<tr>
<td>1</td>
<td>Dead</td>
</tr>
<tr>
<td>2</td>
<td>Vegetative State (meaning the patient is unresponsive, but alive; a “vegetable” in lay language)</td>
</tr>
<tr>
<td>3</td>
<td>Severely Disabled (conscious but the patient requires others for daily support due to disability)</td>
</tr>
<tr>
<td>4</td>
<td>Moderately Disabled (the patient is independent but disabled)</td>
</tr>
<tr>
<td>5</td>
<td>Good Recovery (the patient has resumed most normal activities but may have minor residual problems)</td>
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to its unique situation, i.e., large populations distributed in a vast area, China should opt for the solutions that fit her best. During the analysis of recent studies, the following recommendations should be considered in the future.

In light of the installation of PACS in China, the following suggestions are made:

a. **Strategic plan with incremental realisation**: The assurance for PACS to live up to its full potentials is to update PACS incrementally when needed. For example, if a hospital only has CT scanners at the time, PACS should mainly work for CT and can be updated when the other imaging modalities arrive, e.g., MR, or PET, leading to a lower cost, lower maintenance, and less training time. Many hospitals in China install a miniPACS in the first instance, and later find out that the existing PACS is lacking in capability of expansion when they need to grow. Consequently, they face a dilemma as to whether to re-purchase a whole PACS at an expensive cost that they might not be able to afford or to buy another mini-PACS at a lower cost as a temporary solution that however might not be compatible with the existing one, causing information separation.

b. **Subsustainable software providers are the key to success of implementation of PACS**: Because of the modular structure of PACS, system suppliers should be able to provide updated modules when they are available as well as sustainable maintainence, especially when the circumstances of a hospital change, i.e., extension or updating computer operation systems. Therefore, frequent communication between the technical support team from the software provider and the hospital is important.

c. **Good management of PACS**: Since a PACS as well as RIS stores valuable medical images, carrying key information related to both patients and hospitals. Its safety is paramount.

On the other hand, the seamlessly clinical flow together with PACS information flow can improve a patient’s clinical outcome significantly. Therefore, a team of technical personnel should be in place to make sure PACS is functioning effectively and efficiently.

d. **Connections**: Some PACS systems have interfaces with DICOM and some not, especially when a specific scanner has its own image format. Another connection issue should be considered is the link with RIS, to which a number of miniPACS systems have encountered difficulties.

e. **Integration**: Integration is still behind the high-end requirements. Although there are several applications that have been extended to the clinical department, from a strict definition point of view, the whole hospital integration of PACS has not been in place in China yet per se. In terms of techniques, the necessary hardware components and the technology for system integration with a successful PACS installation are now readily available in China. However, in the event of integration, software development in order to interface with each other is still far behind the requirements of hospital customers. For example, it is not sufficient for PACS software to act alone to store, communicate, and display images, acting like a warehouse. A PACS should work together with RIS/HIS by offering efficient support to radiologists and physicians in many aspects, including routine conferencing, consultation, interpreting, communication of image findings through hospital information networks and doctors’ workstations, workflow management, integration with RIS/HIS, and computer-assisted diagnosis. The advantages of digitalization and integration of PACS, HIS and RIS will be, apart from reduction of film cost and space, the optimised workflow with the access to digital images from everywhere.
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at any time seamlessly for the benefit of patients.

f. **Updating with the newly evolving technologies**: In principle, a PACS can be updated whenever it is necessary thanks to its modular nature. In practice however, it is far from ideal. In China, a PACS has been constrained in unpredictable ways by contingencies that arise in the field, e.g., a new arrival of an emerging technology. For instance, the current installed systems have difficulties to cope with large amount of slices produced by modern Multi-Detector-CT and 3.0T MR studies. Multi-slice CT and 3.0T MRI scanners generate large quantities of image data flow with a typical dataset up to thousands of 2D slices, far beyond the capacity of the system that a PACS is installed can offer. The alternative would be to print them all on films with more than 10 sheets (even 50 sheets) per dataset in order to analyse/visualise. In addition, a dedicated image processing system is also in demand that can not only store these up to thousands of images for per dataset, but also can manipulate and deliver them to multiple remote clients, without putting too much strain on the host processor of server itself. Therefore a server with a powerful processing speed for images of 2D/3D/4D should be in place on which to install PACS, with the hope that it will be able to face the challenges coming from the evolving new technology.

g. **Standard architecture**: The most important issue for the Chinese Ministry of Health is to establish the State Drug and Device Admittance System (SDA approval) (Fu, et al., 2006). Two types of certification systems can be adapted for independent modality and integrated system respectively, i.e., modality licence (Type 1) and system licence (Type 2). Furthermore, adoption to the current international standards should take place as soon as possible, especially in the field of information system standard (DICOM, HL7, HIPAA, IHE, etc.) for the sake of application, certification, security, management, and integration, as well as in the area of standard for the State Medical Insurance Information Exchange.

h. **Quality control/assurance**: In China, the procedure of routinely quality control and assurance is very relaxed as a PACS does not provide a check to the quality of a monitor for image viewer. As a result, the verification of acquired images is normally neglected. On the other hand, because of the high cost of a high-resolution monitor for viewing medical images, the soft reporting of CR/DR images is conducted on the normal colour monitor. Although this is strongly discouraged in hospitals, it is the reality in China since there is not any coherent rule for digital diagnosis, partly due to the newness of the emerging imaging scanners in China.

i. **Conformation with HL7 and IHE**: Conformation with HL7 and IHE is another issue on the agenda towards the establishment of the future digital hospital. Although it has a long way to go, especially in the case of China, it should be taken into consideration as early as possible not only to avoid huge capital investment in the future but also to be able to contribute to the process of clinical decision making.

j. **Showcases in need**: In China, as of 2002, only two hospitals have implemented whole-scale PACS while the others are still in the process of deploying miniPACS. Within these two hospitals, i.e., Shanghai Ruijin Hospital and Beijing Tiantan Hospital, those large-scale PACS systems have been slowly defused and integrated. It is therefore essential that more model hospitals should be established to showcase the deployment of PACS, pointing to a cost-effective solution to be exploited in the other hospitals in the future.
During the Execution of the TIME Project, Attention was drawn to the Problem of Language Barrier

a. Increasing specialisation within disciplines is one of the difficulties when interfacing with other fields, especially when it comes to the translation between two languages. This was exactly what happened in some sessions at the MIT2005 conference. Some Chinese speakers could not explain their work in details in English to the audience (e.g. in the area of insulin), whereas the people who knew both English and Chinese well did not have sufficient medical background to translate this information precisely. With this in mind, in the 2nd conference organised by the TIME project, MIMI2007, simultaneous translation was in place to overcome this barrier. Although this simultaneous-translation only facilitated key-note speakers in the preliminary session, precaution was taken to select chair persons in each Session to ensure that every session was equipped with the necessary expertise in both English and Chinese, leading to the success of the MIMI2007 conference.

b. The language barrier has always been an issue in any collaborative work involving Chinese (or any Asian country) and Europeans. Although many leading Chinese scientists have been studying/visiting in an English-speaking country for a certain period, there still exist a number of communication problems.

c. The TIME project was aimed at ordinary Chinese people, reflecting at the selection of the first conference of MIT2005 being held in a remote area in China. Every delegate enjoyed the conference and its beautiful scenery. However, some facilities were not up to the standard in those remote areas in China. For example, although the conference venue was located at a 4* hotel, the hotel neither accepted credit cards nor other means of payment apart from cash. Surprisingly, there was not a single person in the hotel who could speak English.

China Telemedicine

a. Due to the disparity of economic development in both Europe and China, China has to develop telemedicine systems that fit its purpose instead of simply copying the systems that work well in the other countries. For instance, at the UK, the success of NHS Direct owes much to the fact that everyone in the UK (and many other developed countries) is connected with 100% of households having land line telephones and 122% people have mobiles (many users have more than one handset), which proffers advices to anyone who has any doubt on their health. Whereas in China, because of the huge number of the population, large number of knowledgeable nurses has to be required to provide the service, which is highly unlikely. In addition, many peasants who live remotely do not have any means of communications (more than 30% households without land lined phones) nor electricity. Centralised local or regional medical centres are therefore a way forward and can facilitate telemedicine services.

b. In the light of digital divide between rural areas and big cities, it is very unlikely in the short period for China to go to paper-less (digital) hospital. Region-based medical centres or hospitals are still in demand to provide basic health care and advice to the local people.

c. The nature of relatively independence of hospitals in China has made hospitals as competitors as well as collaborators, hampering the development of telemedicine. This because each hospital is relatively finance independent. A typical example appears to be
in the purchase of PACS. On the one hand, the main purpose of PACS is to allow communications between each other. Whereas on the other, some hospitals install PACS with the intention to prevent the data flow going to the other sites, albeit for the benefit of security. Therefore a centralised management system with top-down architecture should be promoted to share and communicate.

d. Since over 60% population own a mobile phone, wireless applications could be considered in providing a reliable, day-to-day modern medical service to any location and in any environment. This approach should be treated as a strategic means of meeting the priority of providing medical care to everyone. Further more, any new gadget can appeal to huge number of followers in China, the trend could be exploited towards the application of telemedicine.

e. Similar to the other developing countries (Androuchko, 2010), Chinese Government is promoting eHealth vigorously, which can be evidenced by the way of implementation of communications networks. However, due to each medical staff’s busy schedule, extra training of ICT and eHealth is not on the agenda yet, leaving telemedicine is practiced mainly on individual basis.

f. On the other hand, since most of medical insurance only covers 80% of medical cost, even for many medical staff, each individual has to cover the remaining cost, which results in a degree of competition between hospitals and in a way might hamper the development of eHealth systems. Top-down policy is in need to ensure the collaboration and co-existing, especially between urban and rural hospitals.

**FUTURE TRENDS**

In the developing countries it is certain that telemedicine is a way forward to allow health care services being accessed evenly by the people. To this end, collaboration with the developed countries is one of the future trends to acquire expertise, knowledge, and experience with less cost and in a short time period.

IHE is a useful system framework that has the capability to solve the interactive problem in the integration of healthcare systems. The sophisticated HIS/PACS/RIS/LIS workflow and environment supported by various vendors employ different interfaces that should interact. For instance, HL7 would be the choice to provide a common framework for interfacing and exchanging data (not only for DICOM images, but also for transaction of information) between disparate vendors. Significantly the lack of process conformity within healthcare delivery environments that experience continuously changing and transforming healthcare requirements demands continuous ‘negotiation’ between users and vendors. In this case, IHE would be the answer to integrate disparate HIS/PACS/RIS/LIS systems together as an integrated, scalable ‘plug-in’ Healthcare Solution. The ultimate aim of integrated Healthcare solutions is to implement not only the operational management control systems, but also the systems for strategic decision support.

Medical images are highly heterogeneous with a variety of domains (brain, abdominal, cardiac, etc.), modalities (MR, CT, X-ray, microscopy, photography, ultrasound), formats (DICOM, TIFF, JPEG), and dimensions (2D [retinal], 3D [brain], 4D [e.g., a 3D heart over a period of time], and even 5D [e.g., a functional 4D at a specific anatomic location]). Thus it is impractical to standardise these data into a ‘one size for all’ model. To exploit such data or other demographic data effectively requires a novel architecture to ensure accessing not only from data sources of distributed collections, but also without prior standardisation of the original data, entailing each database with scope, scale, and the necessary flexibility. Therefore, incremental approach is appealing.
With over 800 million mobile users in China, it certainly has got momentum. Telemedicine services, in particular the services that focus on well-being and health care, should aim at mobile phone applications.

The advances of technology should make greater impacts to the poorer people who are still in poverty in the underdeveloped countries in helping them weather the storm. From personal point of view, this helping hand should be ushered by a number of developed countries, like the project RAFT. In this way, benefits can be felt not only in a short period, but also with less cost. Likewise, to reinforce the effort, a top-down policy should be opted for with a certain degree of governmental involvement. On the other hand, with the implementation of telemedicine, those people can profit not only in relation to health issues, but also in terms of education by bringing up their literacy rate, for underdeveloped countries have lower literacy rate, e.g., Ethiopia has 35.9% of Literacy rate whereas 99% occurs in most of the developed countries (http://en.wikipedia.org/wiki/List_of_countries_by_literacy_rate), and are in need of means for accessing and learning.

CONCLUSION

Although the techniques of telemedicine/telesurgery are available, the calls for employing them vary from country to country. In the UK, medical resources are evenly distributed across the whole country and are provided by the National Health Service (NHS), coupled with adequate emergency systems that are equipped with fast means of transportations. In this way, a patient can be located to an intended hospital within required time. In contrast, China has a very different geographic pattern. Many places, e.g., mountainous regions, are difficult to locate even with several means of transportations. Significantly, China is still in the developing stage and has a long and bumpy way to go in order to allow everyone access their much needed health care, especially for those 70% peasants who live in the remote areas, far afield from those big cities where modern medical equipment are concentrated. In this case, China should be in favour of the services allowing telemedicine/teleservices to be provided over the Internet. By this way, it can save time, personnel and money substantially without compromising patients’ safety. Considering over 300 million people are with land telephone line and over 800 million are with mobile phones, tele-services in medicine have huge potentials in China. One of the promising areas is tele-surgery like the one pioneered by the Navy General Hospital in Beijing. The strength of the approach lies in the knowledge transfer. Due to the limited number of experts in the field, performing remote surgery retains its positive features. In particular, it has the ability that one expert team can supervise several tele-surgeries that are operated at different locations at the same time, reducing patients’ waiting list, prolonged suffering, and the cost of experts’ time.

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KEY TERMS AND DEFINITIONS

**Digital hospital**: paper-less hospital

**e-Health**: healthcare services provided via electric systems or devices.

**HIS**: Hopstial Information Systems

**IHE**: Integrated Healthcare Enterprise

**PACS**: Picture Archiving and Communications Systems

**RIS**: Radiology Information System

**Telemedicine**: Practicing medicine remotely via tele-communication systems, e.g., telephone, internet, etc.

**TIME Project**: Telemedicine in Medicine: a cyber bridge interfaces China with Europe on collaborative health care.