23 MULTIMEDIA FOR FUTURE HEALTH – SMART MEDICAL HOME

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CHAPTER 23 MULTIMEDIA FOR FUTURE HEALTH

23.1 INTRODUCTION

With recent advances in multimedia technology, its impact towards information technology in biomedicine is ever increasing [1-3]. Multimedia technologies are enabling more comprehensive and intuitive uptake of information in a wide range of fields that have a direct impact on our life, particularly in entertainment, education, work, and health. Systems and services have been developed to harness the advantages of multimedia technology which ranges from video-conferencing, online shopping in virtual environments, video-on-demand services and E-learning to remote healthcare [1, 4, 5]. The core components behind these multimedia technologies are human centered multimedia services, which combine many fields of information technology including computing, telecommunication, databases, mobile devices, sensors, and virtual/augmented reality systems. Human centered multimedia services are built upon three key research pillars as shown in Figure 1: (1) human-computer interaction (HCI); (2) multimedia delivery; and (3) multimedia data management. HCI (e.g. via the use of keyboard/mouse input devices) is the initial component of the multimedia information flow with the responsibility of generating outputs by interpreting inputs from the users. Multimedia delivery systems (e.g. the Internet) are responsible for transparent information delivery (e.g. streaming video) from sources to destinations. Finally, the multimedia data management components facilitate information access (e.g. browsing, retrieval, and indexing).
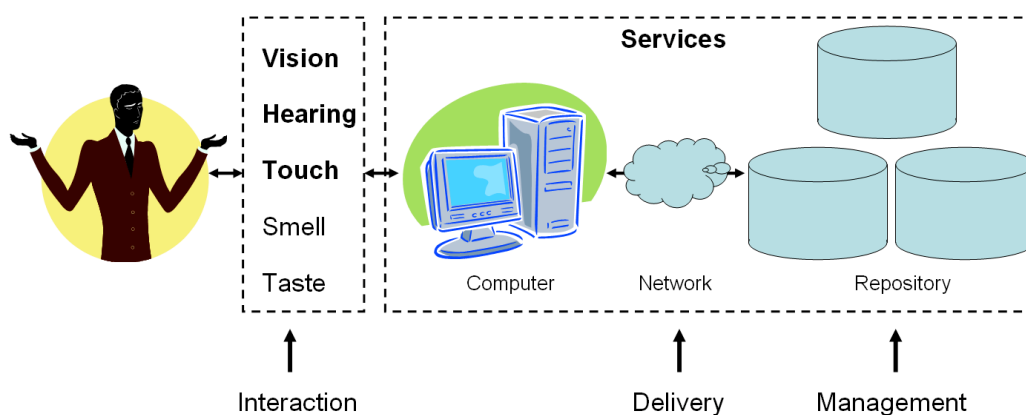
Figure 23.1. Illustration of the three pillars of human centered multimedia systems: (1) interaction; (2) delivery; and (3) management.

One area of biomedicine that has seen rapid transition and great benefit from state-of-the-art developments in multimedia technology is the *smart medical home*, known also as *smart houses* [3, 6-10] and is often considered to be the hub of future health care [11]. The smart medical home is a subcomponent of the concept of a *smart home* [3, 12, 13]. This notion of smart home was first introduced in the early 1980s, with the proposal to integrate

intelligent implementations of consumer electronic devices, electrical equipment, and security devices for the purpose of automation of domestic tasks, easy communication, and human-friendly control, as well as safety [3, 13]. Smart homes include devices that have automatic functions and systems that can be remotely controlled by the user with the primary objective of enhancing comfort, saving energy, and increasing security for the residents of the house. These developments have found applications in the field of enhancing the medical capabilities of homes for people with medical conditions and special needs.

The aim of smart medical home is analogous to that of smart homes, namely to create an integrated system of affordable, easy to use, intelligent health care tools for use by consumers in their home [6, 14]. The smart medical home has recently seen significant research and development [3, 9, 14-16]. This is attributed to the trend in the demands from consumers who are increasingly taking control of their healthcare. This trend is evident from the shift observable in medical treatment plans, which are increasingly moving from a hospital-based to a patient-centered system [17]. The same phenomenon is observable in the increased use of the Internet to search for health-related information, and in the billions of dollars being spent annually on alternative and non-traditional health products [9, 16, 18, 19]. More significantly, the health care system may not be able to cope with the impending influx of new patients as the population continues to age. It is expected that by the year 2020, the 65-year-and-older population in the United States (US) is expected to reach 53 million, an increase of 18 million from year 2000 [3]. Thus, the need for technologies that are able to complement the health care system, while enabling people to live healthier, longer lives in their own home is becoming critical. With the rapid expansion of networking and information technologies into our routine daily lives, through such technologies as the Internet, mobile phones, and interactive digital television (DTV), the acceptance level for potential smart medical home technologies is at an all-time high. The needs of our aging population will accelerate the movement and awareness of self-care and wellness, and will irreversibly alter traditional doctor-patient relationships [3, 7, 20].

This chapter presents latest research and development in multimedia technologies and the transition of these technologies into healthcare products for the smart medical home. It is subdivided into two parts: (1) Enabling multimedia technologies; and (2) Applications involving multimedia technologies in biomedicine. In the first part, a general introduction to multimedia technologies is presented, continuing into a discussion of the visual, audio, and other emerging media components for HCI in Section two. This is followed by multimedia content management in Section three, and the technologies for delivering this multimedia content are presented in Section four. The second part starts with a general description of biomedical technologies that either have already found or are finding their way into smart medical homes. Section five introduces and exemplifies developments in smart medical homes, with emphasizes on the enabling multimedia technologies. This is followed by Sections six to eight which present major fields of applications used in medical homes, respectively of telemedicine (monitoring, consultation, etc), sensors (wearable and stand-alone devices), and computer-assistance technologies (medication advisor, decision support, etc). Seamless integration of these different multimedia technologies is necessary for the medical devices used in a smart medical home. A more in-depth discussion of the biomedical information technology topics of telemedicine and

wearable medical devices in biomedicine can be found in Chapter 22. However, to fully appreciate the contents presented in this chapter, these topics will be briefly covered, with emphasis on their application to the smart medical home and their use of multimedia technologies. Section nine discusses potential applications of virtual/augmented reality, followed by the developments in patient awareness toward biomedical multimedia technologies in Section ten. Finally, a summary of the chapter is given in Section eleven.

23.2 MULTIMEDIA FOR HUMAN-COMPUTER INTERACTION

The aim of HCI is to mimic human-human interactions, though of course a complete picture of how human beings interact with the real world is not yet available to us, and remains one of the greatest scientific challenges. Interacting with computer is essentially the first step toward manipulating and utilizing digital information. Given the ever increasing role of computers in society, HCI has become increasingly important in our daily lives [21]. However, interaction between the human and computer via the use of traditional input devices that are often the combination of mouse, keyboard, joystick, or remote control, is far less flexible than spontaneous human-human interaction. The constraints derived from these devices have become even more restrictive with the emergence of techniques such as virtual/augmented reality [22, 23] and wearable computers [10, 15, 24].

In general, human-human interaction consists of all five basic senses of human cognition: vision, hearing, smell, taste, and touch [25]. The ultimate aim of HCI is to make use of all natural human actions, such as facial expressions, body movement, speech, eye gaze, and so on, in communicating with the computer, which interprets these and generates outputs that are understandable by the human operators. Vision and Speech are two of the most dominant senses, and hence they will be focused on in greater depth in the sections below, followed by a review of emerging technologies for other sensing modalities.

23.2.1 Visual Information Processing

Visual information refers to what a human perceives through their eyes or information captured by optical cameras. A key contributor in the field of visual information processing is face recognition technology [26], as used in such applications as security and surveillance systems [27], gesture recognition [28], lip reading for the deaf [29], and optical character recognition (OCR) [30]. One of the main limitations of current visual information processing systems is the need to apply constraints to the users, such as the need to wear gloves to ease hand tracking for gesture recognition systems, in order to provide enough information for the computation to make use of the data.

The other key research area in visual information processing is the way that computers *present* users with visual information. Computer graphics and visualization have greatly contributed to this issue providing approaches that include stereo or multiple-view image analysis, 3D reconstruction, view synthesis and rendering, 3D displays, graph drawing, etc. Computer graphics and visualization, as a field, aims to produce realistic representation

and visual information of data in 2D/3D, or in greater dimensions, through the use of mathematical models and algorithms [4, 31, 32] which include but are not limited to ray tracing, texture-based rendering, and illustrative rendering. Computer graphics and visualization techniques have already been widely applied to a large variety of domains including public transport, biology, social science, archaeology, and so on. These research areas focus on facilitating information comprehension for the users by the utilization of virtual environments, generally in order to permit users to capture computational information through their visual senses. In general, visual information processing requires intensive computation and therefore continuous research on how to achieve efficient computation is of great importance. Chapter 9 covers the applications of visual information processing for digital medical images.

23.2.2 Speech Processing

Apart from visual information, another dominant modality in human communication is sound, with speech in particular. The two main areas for speech processing in HCI are speech recognition and speech synthesis. The concept of speech recognition is for a computer program to acquire analog signal (speech) from a microphone, convert it to a digital waveform and process it to search for a matching wave (recognition) [33, 34]. The conversion requires sophisticated algorithms that compare the input with a database of known words. Once the words are recognized, these words are often represented in digital text format. Automatic Speech Recognition (ASR) has been a research topic towards this aim for decades [34] and has advanced tremendously. Many prototypes (e.g. Sphinx project II [35]) and commercial systems (e.g. IBM ViaVoice [36]) are now readily available. Most speech recognition systems are based on statistical models of the acoustic features of spoken words and of natural language. Therefore, it is error-prone due to: (1) the diversity of different speakers; (2) physical or emotional change of a speaker; and (3) different physical environment (e.g. noise). This issue has been partially addressed by the introduction of *training* and *adaptive tuning* algorithms, which require an initial training session but allow continuous updates to the software's model of the user's speech through user conducted error checking and corrections. Most current ASR systems constrain users to special training, a special speaking style (e.g. prepared vs. spontaneous and discrete vs. continuous) and known physical environments.

Speech synthesis is a process of converting unrestricted text into speech and communicating information to users. As reviewed in [37], speech synthesis systems in general operate via the following steps. First, the text is converted into a symbolic linguistic/ phonological description. Second, the phonological component converts the set of orthographic symbols into a set of distinctive features or sounds (i.e. phonemes) depending on phonological model. The phoneme is the most popular form of phonological representation and the set of phonemes of a language can be understood as the smallest segments of sounds that can be distinguished by their contrast within words. Finally, this abstract symbolic description is transformed into an acoustic signal. The success of speech synthesis has been beneficial to many applications such as automatic telephone banking and taxi booking. A trend in speech synthesis is to reinforce the message with

paralinguistic cues so that communication moods and other content beyond the text itself can be delivered. Research in such area is called expressive text-to-speech synthesis with interest in non-emotional expressive speaking styles growing in recent years. It has been recognized that depending on the domain and the target group of speech applications, different expressive styles are required. For example, expressing suspense and global storytelling style is essential to storytelling applications. Theune et al. [38] proposed to generate expressive speech for storytelling applications through a set of prosodic rules extracted from human storytellers' speech. Recently, IBM [33] introduced an expressive text-to-speech engine which can be directed, via text markup, to use a variety of expressive styles including questioning, contrastive emphasis, and conveying good and bad news for American English.

23.2.3 Emerging Sensing Modalities

Motivated by the tremendous need to explore better HCI paradigms, there has been a growing interest in developing innovative sensing modalities [39-43]. Besides the vision and speech senses for HCI, computers can also simulate tactile sensing which enables the feeling of *realism* through the use of haptic devices, for example, in virtual reality [41]. Haptic interfaces allow users to input commands into the computer by means of hand movements and provide users with tactile and force feedback that are consistent with what the user is viewing, thus providing users with senses to manipulate 3D virtual objects with respect to features such as shape, weight, surface texture, and temperature [42]. Haptic interfaces provide the opportunity for complex yet potentially more intuitive means of interacting with a computer, and this ability has been widely explored in medical applications [42, 43] as discussed in the following sections.

Another sensing modality that has seen an exponential increase in research interest is the monitoring of brain electrical activity (via EEG). The brain activity can be monitored non-invasively from the surface of the scalp and has harnessed to directly control a computer [40]. The "hands-free" nature of such HCI is potentially useful in situations where hands are needed for other tasks, such as in aircraft piloting. Such sensing modality is also of paramount importance for physically disabled patients, as it allows them to interact with the latest information technologies.

23.2.4 Virtual/Augmented Reality

Virtual reality (VR), formerly known as a *visually coupled system*, is a concept which aims to integrates all the sensing technologies seamlessly and allow users to gain more realistic experience in a physically and perceptually appropriate manner [22]. This approach is generally believed to be the next generation of HCI [44], as it leverages the multi-modal nature of human-human interaction to facilitate multimedia computing without the need for specialized training. One of the first multi-modal HCI systems can be credited to Bolt [45]. His *Put-That-There* system fused spoken input and magnetically tracked 3D hand gestures using a frame-based integration architecture. The system was

used for the simple management of a limited set of virtual objects such as the selection of objects, modification of object properties, and object relocation. Even though the natural feel of the interaction was hindered by the limitations of the technology at the time, *Put-That-There* has remained the inspiration of all modern multimodal interfaces. A comprehensive review of multi-modal HCI can be found in [21, 46].

More advanced VR systems demand support from advanced multimedia technologies that include computer graphics, visualization, speech recognition, and haptic interaction. This demand is clearly illustrated by Schreer et al [4], where the state of 3D multimedia technologies including 3D video reconstruction and rendering, and 3D audio processing, have been reviewed for their applications to VR as well as tele-presence. Recent trends in VR systems have resulted in less dependence on special wearable HCI devices (i.e., head mounted displays (HMDs) and sensory gloves) and a move towards larger scale 3D displays and systems that minimize HCI requirements [4]. This has further facilitated the development of more immersive VR systems, leading to the development of augmented reality (AR) systems, which differ in that the visualized information and real-world visual objects co-exist in the same user interaction space [23].

23.3 MULTIMEDIA CONTENT MANAGEMENT

Creating and publishing digital multimedia content today is easier than ever before, at both individual and organizational levels. Every individual in the world is a potential content producer who is capable of creating digital content that can be easily distributed and published. The ease of content production is accelerating its growth, and thus leading to problems in content management and content identification. Health care is a domain which stands to significantly benefit from enhancements in content management [47]. In a typical health care system, patient records consisting of multimedia content (images, audio, etc) are stored electronically, and this content needs to be searchable by physicians. Thus, with the growth in the patient records, the ability to manage these contents, such that searching may be performed efficiently, is becoming increasingly important. In order to efficiently utilize the advantages of multimedia data, it is essential to develop intelligent approaches to processing and managing these data, and indexing their content.

23.3.1 Multimedia Content Analysis

Multimedia data is typically annotated manually with textual descriptions and then stored in a database management systems (DBMS) which controls access to these data [48-50]. However, such a solution was found to possess serious constraints when applied to multimedia content management [51]. The problems associated with manual annotation are the fact that this approach is labor intensive and subjective to the operators, and the limited capabilities of traditional textual annotation in contextualizing multimedia contents. For instance, it is not feasible to contextualize the *texture* visual feature of each image by keywords. Therefore, in the early 1990s, content-based retrieval was proposed to resolve these issues and allow users to access multimedia data based on their perceptual content.

As multimedia data have different formats and characteristics (e.g. image, video, and audio), different approaches are utilized to contextualize their contents. The ever improved field of computer vision and image processing as described in Chapter 7 has greatly contributed to the growth of visual feature extraction. Visual features such as color, shape, and texture are extracted to characterize image and video content [52]. For example, the color histogram is utilized to represent the color distribution of a given image, shape for object contours, and texture for visual patterns (e.g. stripes) [53-55]. Additionally, motion information can be exploited to contextualize the movements of objects and cameras in the categorization of videos [56].

In medical domain, visual features such as shape and texture have been utilized for medical image retrieval [47]. Due to the advances in image processing and possible inclusion of prior knowledge, CBIR has a great potential in medical image database applications. Current developments of content-based image retrieval of medical images can be found in Chapter 4.

Much as with visual features, audio feature extraction has benefited significantly from advances in audio processing that are enabling the use, for example, of loudness and harmonicity as features to characterize audio content [57], with a good example being the automated classification of music genres [58].

23.3.2 Multimedia Content Description Interface

The great potential of multimedia retrieval has attracted much interest from a large number of researchers to conduct research in this area. Therefore, many feature extraction approaches have been proposed to characterize both the perceptual and conceptual contents of multimedia data. Meanwhile, it lacks a systematic way to exchange the features and to model multimedia content through these features, which may result in proprietary solutions in multimedia content access. Motivated by such a demand, the motion picture experts group (MPEG) in 1996 initiated MPEG-7 to look into the issues of providing interoperable descriptions to bridge multimedia content and its consumption and facilitate multimedia content access [59]. Unlike previous MPEG standards which target the compression and reproduction of the data itself, MPEG-7 is geared towards enhancing that data which describes the context and contents of the multimedia data, the so called *metadata*.

MPEG-7 descriptions are intended to provide extensible metadata solutions for a wide range of applications, where content description can be at different levels of abstraction, from the low-level (automatic and statistical features) to the representation of high-level features that convey semantic meaning. In addition, highly structured MPEG-7 descriptions support the combination of low-level and high-level features in a single description. Examples of content-based access with MPEG-7 include finding information using spoken queries, hand-drawn images and query by humming [59], as well as the personalized service of TV news [60, 61]. MPEG-7 has also been adopted to facilitate the management, delivery, and access of medical data as demonstrated by Rege et al [62] in whose study human brain images were annotated and used to capture the semantic information such that both the retrieval tasks and answering – domain specific complex

queries can be supported for image-guided neurosurgery. Similarly, EEG images were organized efficiently by combining textual information and low-level image information with MPEG-7 [63]. In a recent study, Cuggia et al [64] introduced an integration of MPEG-7 with existing medical standards to manage digital audiovisual medical resources.

23.4 MULTIMEDIA DELIVERY

Multimedia data places considerable demand on computing resources and subsequently presents formidable technical difficulties for storage, networking, and computing infrastructures. Compression techniques are critical to deliver multimedia content to a wide range of communities. Telecommunication technologies offer valuable opportunities for distributing multimedia data. Undoubtedly, the Internet is one of the most popular manners, though it is not initially designed for multimedia services. Wireless sensor networks have also recently enabled a paradigm shift in the science of monitoring applications, such as weather and soil moisture [65]. In this section, we will introduce a new potentially useful delivery system, the digital TV, which enables the distribution of multimedia content as well as interactive data. It is expected that almost every nation is in the process of transforming analogue TV to digital TV [66]. We will also introduce the MPEG technology, which is the most routinely utilized multimedia delivery standard.

23.4.1 Digital Television

The TV has long been an integral part of our life, whether as an entertainment appliance or as a window to the world. Its legacy role of high penetration media-delivery in households will be further emphasized in the digital TV (DTV) era, since DTV via satellite, cable, and terrestrial broadcasting provides much better picture and sound quality as well as more opportunities for applications such as interactive services and data-casting. A TV that receives its signal digitally is no longer just a passive box that displays pictures and sound. A DTV that is properly equipped can be a powerful and interactive computer with similarities to networked desktop PCs. Access to such TV has even been extended to handheld devices such as mobile phones and personal digital assistants (PDAs). These advantages will significantly enrich the viewing experiences and take it beyond its current dimensions, in addition to fostering a number of novel applications (such as the ability to access health information and medical consultation) in the field of home health care and M-Health [67]. Cable TV networks have also been demonstrated to transmit alarms, emergency calls and biomedical data and provide home telecare interactively [68].

Traditionally, users follow TV program schedules in order to watch their favorites. This situation has changed since video cassette recorder (VCR) was introduced, thereby allowing the users to record programs and watch them in their convenience. Increases in modern computing and storage capacity are bringing users with more improved services such as video-on-demand and digital recording.

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23.4.2 Multimedia Compression

Today, we can enjoy digital music almost anywhere with music players becoming smaller and being able to store increasing numbers of songs. In addition, digital video can be watched through the Internet, DTV, and even hand-held devices. Behind all these successful multimedia products are standards that provide interoperability, and thus generate a marketplace in which consumer equipment manufacturers can produce competitive yet conformant products.

In terms of static images, the JPEG standard has achieved enormous success [69], as is evident from the use of JPEG in all digital camera to store pictures. In order to accommodate advances in multimedia technology, JPEG has evolved into JPEG2000, using wavelet compression as the core technique [70] to develop a new image coding standard for different types of images (e.g. bi-level, gray-level, and color), with different characteristics (e.g. natural, scientific, medical, and text), and thus allowing different imaging models (e.g. real-time transmission and image library archival) preferably within a unified and integrated system. The advantages of JPEG2000 have spurred its application in biomedicine. For instance, Khademi and Krishman [71] successfully used JPEG 2000 for robust and real-time digital mammograms compression with efficient database access and remote access to digital libraries that was shown to reduce the time required during diagnosis.

Different standards of MPEG which include MPEG-1, MPEG-2, and MPEG-4, have been proposed for different applications, a decision which forms a large part of the MPEG format's popularity. MPEG-1 (issued in 1991), entitled *coding of moving pictures and associated audio at up to about 1.5Mbps* is the first standard by the MPEG and is intended for medium-quality (e.g. VHS quality) and medium bit-rate video and audio compression. MPEG-1 organizes audio coding schemes in three layers, simply called Layer-1, Layer-2, and Layer-3. Encoder complexity and performance (sound quality per bit rate) progressively increase from Layer-1 to Layer-3. Each audio layer extends the features of the layer with the lower number. The popular MP3 file format is an abbreviation for MPEG-1 Layer-3, which set the stage for the ongoing revolution in distributing digital music.

MPEG-2 (issued in 1994) [72], entitled *generic coding of moving pictures and associated audio* was designed to support more coding schemes, wider range of bitrates, and more choice in video resolution (e.g. HDTV). Although MPEG-2 systems have video and audio specifications that are largely based on the MPEG-1 specifications, it provides higher-picture quality by using higher data rates. As to audio encoding, Advanced Audio Coding (AAC) is added to provide a significant performance increase over the backward compatible audio. MPEG-2 tries to be a generic coding standard for a wide range of applications by comprising a large set of tools to meet the requirements of various applications. The tool sets are characterized in terms of *profiles* and *levels* that are defined to provide coding solutions with appropriate complexity as well as to limit the memory and computational requirements for various applications. For example, set-top boxes (STBs) of standard definition TV (STDV) and high definition (HDTV) correspond to the implementation of different profiles/levels of MPEG-2 standard.

MPEG-4 (issued in 1999), entitled *Coding of Audio-Visual Objects* is the latest video coding standard and is designed to move from the pixel-based to an object-based approach [56]. This is achieved by embodying a significant conceptual jump in audio-visual content representation, and object-based modeling, and thus enabling an audio-visual scene to be built as a composition of independent objects with their own coding, features, and behaviors. Temporal and spatial dependencies between objects can also be described with a binary format for scene (BIFS) description. In summary, the object-based coding approach in MPEG-4 allows for hybrid natural and synthetic coding, content-based interaction and reuse, content-based coding (e.g. text coding tools for text objects and 3D model coding for 3D objects), and universal access, which has the potential to revolutionize the way users create, reuse, access, and consume multimedia content. The power and advantages of the object-based representation also make MPEG-4 a standard that can be applied to applications ranging from low bit-rate personal mobile communications to high-quality studio production.

23.4.3 Multimedia Framework

As mentioned in the sections above, MPEG has played a key role in developing the standards for multimedia-enabled products and applications. However, in general, each multimedia entity needs to communicate with its environment, clients, and applications. A solution is required to offer users transparent and interpretative consumption and delivery of rich multimedia content, so that the coding and metadata standards can be linked with access technologies, rights and protection mechanisms, adoption technology, and a standardized event reporting mechanism under the umbrella of a complete *multimedia framework*. Furthermore, the need for a solution also stems from the fact that the universal availability of digital networks, particularly the Internet, is changing traditional business models, adding the new possibility of the electronic trade of digital content in addition to the trade of physical goods. The aim of the framework is to fill the gaps in the multimedia delivery chain and to create seamless and universal delivery of multimedia. As such, MPEG-21 (issued in 2000) was introduced to provide a complete framework for delivering and managing multimedia content throughout the chain encompassing content creation, production, delivery, personalization, consumption, presentation, and trade, to meet its vision "to enable transparent and augmented use of multimedia resources across a wide range of networks and services" [73].

MPEG-21 proposed a new distribution entity termed the digital item (DI) for use in interaction with all users in a distributed multimedia system, where a user is any entity that interacts with the MPEG-21 environment or that makes use of a DI. Such users include individuals, consumers, communities, organizations, corporations, consortia, governments, and other standards bodies and initiatives around the world, and their roles are identified specifically to their relationship to another user for a certain interaction. In particular, content management, intellectual property management, and content adaptation shall be regulated to handle different service classes. MPEG-21 is thus a major step forward in multimedia standards. It collects together the technologies to create an interoperable infrastructure for transparent and protected digital media consumption and delivery. Many

application domains have benefited from adopting MPEG-21. MPEG-21 has been utilized to establish personalized video systems [61] and in backpack journalism scenarios [74]. Together with MPEG-7, MPEG-21 can also be leveraged to create distributed multimedia databases [75]. Successful applications of MPEG-21 have also been reported in the medical and health care domains. The intellectual property management and protection (IPMP) function of MPEG-21 was employed to provide accurate audit trails to authenticate appropriate access to medical information (e.g. patient records) which are shared nationally in England [76]. It has been shown that MPEG-21 can be utilized to implement information architecture for electronic health records (EHR) and the features of MPEG-7, such as universal accessibility and interoperability will make the architecture highly interoperable in both existing health care systems and different multimedia systems [77].

23.5 SMART MEDICAL HOME

The primary aim of medical homes is to develop an integrated health system that is personalized to individual person's home. This technology will allow consumers, in the privacy and comfort of their own homes, to maintain health, detect the onset of disease, and manage its symptoms. The data collected *24/7* inside the home will augment the data collected by physicians and hospitals. The data collection modules in the home start with the measurement of traditional vital signs (blood pressure, pulse, respiration) and work to include measurement of *new vital signs*, such as gait, behavior patterns, sleep patterns, general exercise and rehabilitation exercises [3, 7]. The smart medical home has the potential to delay, or partially remove the dependence on retirement nursing homes, and thereby extend the person's quality of life. Incorporating smart medical devices into homes can potentially make a strong and positive impact on the lives of persons with physical disabilities and those with chronic diseases [7, 78, 79]. Clinical studies have demonstrated that the use of medical devices in the patient's home has the ability for early identification of adverse trends in clinical signs which can be used to reduce the time spent in hospital [79]. This is enabled by the combination of multimedia technologies such as networked care systems (telemedicine) with integrated sensors that monitor clinical signs, medication reminders, health education, and daily logs. Figure 23.2 illustrates an example of the multimedia-enabled components that make up a smart medical home.
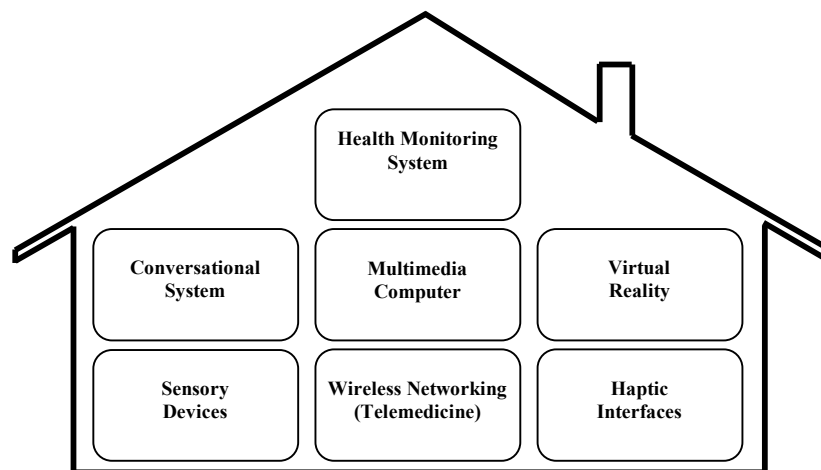
Figure 23.2 – Primary components for the smart medical home using multimedia technologies. These components all share the purpose of improving health care and quality of life of the consumers. In a typical scenario, the health information collected from the sensors and conversational system in the medical home is transmitted (wireless networking) to doctors in the hospital. The received information is then augmented with already existing patient information and can be used by the doctor for diagnosis and consultation with the patient via tele-consultation (telemedicine) using a multimedia-enabled computer with haptic controls. Treatment prescribed for the patient maybe the use of virtual reality system that is designed for surgical rehabilitation.

23.5.1 Recent Projects in the Smart Medical Home

Numerous medical devices and systems have been designed and developed for home environment with the purpose of providing health benefits to the residents. There are many large projects in the field of smart medical home which brings together knowledge and expertise from many different disciplines of engineering and biomedicine. Table 23.1 presents selected projects involved with smart medical home that have made significant research contribution and continue to expand in its aim of establishing a smart medical home.

The AgeLab in MIT [e1] of Table 23.1 aims at filling the demands that are arising from aging population, with the opportunity to invent the future of healthy and active living. *Smart medical advisor* is a wireless system that is able to use the consumer's health information to help the consumer make food purchasing decisions. Another project titled *adaptive devices for independent living* is an assistive device to deliver personal information, basic health care, support and critical assistance for older adults and people living with a degenerative condition. Employing a combination of state-of-the-art technologies, these devices are being designed to be user-friendly, so even those with limited amounts of technology skills can benefit from their design in their own home.

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The smart medical home project in the Rochester University's center for future health [e2] of Table 23.1, is a controlled environment in which to do research, pre-concept testing, concept testing, pilots, and prototype testing. The center's overall goal is to develop and integrate *personal health system for home*, such that all technologies work seamlessly and allow consumers, in the privacy of their own homes, to maintain health, detect the onset of disease, and manage disease. Selected projects for smart medical home include *smart bandage* – wearable medical devices, *motion understanding* – investigating the ability to learn human motion for medical diagnosis, *conversational medical advisor* – system that has conversational interface for consumer use, i.e., medication management, and other medical home components such as networking and decision-support.

Medical automation research center at the University of Virginia [e3] of Table 23.1 has a research and development project working on smart house technologies. These are passive and unobtrusive technologies for monitoring elders' activities, designed with privacy and security in mind. Some of the monitoring technologies developed are *sleep monitoring system* – using non-invasive sensors to gather sleep and physiological signals, and *smart in-home monitoring system* – which is composed of a suite of low-cost, non-invasive sensors (strictly no cameras or microphones), and a data logging and communications module, in addition to an integrated data management system, linked to the Internet for the purpose of lessening the burdens on the caregivers and to increase quality of life for the elders.

These projects, as well as others [e4] of Table 23.1, varied in technical aspects, audience, management aspects such as from single institutional research to international collaboration, and hence provide broad overview and insights into the requirements and prospects to be involved in the smart medical home.

Table 23.1
Selected Homepages of Projects Involved with the Smart Medical Home

Project Name	Institution	Features	Homepage
[e1] AgeLab	Massachusetts Institute of Technology	Developing systems for aging populations, such as Medical advisors and Adaptive devices for independent living.	http://web.mit.edu/agelab
[e2] Smart Medical Home	Center for Future Health, University of Rochester	Integration of health technologies for home, with projects based on motion understanding, a conversational medical advisor, smart bandages, and others.	http://www.futurehealth.rochester.edu/smart_home
[e3] SmartHouse Technologies	Medical Automation Research Center, Virginia University	Health technology for elders, with emphasizes on health monitoring which includes smart in-home monitoring and sleep monitoring.	https://smarthouse.med.virginia.edu
[e4] Personal Ambulatory Monitoring	E-Health Research Center, CSIRO	Investigating chronic disease management solutions from home by monitoring patient's vital signs.	http://www.e-hrc.net

23.6 TELEMEDICINE IN THE SMART MEDICAL HOME

Telemedicine refers to the utilization of multimedia technologies that consist of audio, visual, and network, for use in medical diagnosis, treatment and patient care. This is made possible through the exchange of health information, which allows the provision of health care services across geographical, time, social, and cultural barriers between patients and physicians [80-83]. There has been significant growth in the field of clinical applications for telemedicine: this includes, for example, the domains of tele-consultation [84, 85], tele-radiology [86, 87], and remote patient monitoring [88].

Tele-consultation and remote patient monitoring are fundamental technologies for a successful smart medical home. As an example, for patients under-going chronic disease management, it is necessary to consult physicians on a regular basis [78]. Health monitoring technologies has the potential to reduce the need for the patient to physically meet the physician: rather, the practitioner could perform tele-consultation via video conferencing, with the necessary medical information shared through remote monitoring systems [88]. Another technology that is often found together with telemedicine for use in the smart medical home are the special sensory devices that are used to aid in communications, such as gesture recognition [89] and speech recognition [6]. Greater details regarding sensory devices and health monitoring systems are discussed in the following section.

23.7 SENSORY DEVICES AND HEALTH MONITORING

Due to a continuous decline in size, costs, and power consumption of sensory devices, it is now common to find sensors embedded in different places and objects, such as at home appliances/furniture [7, 9], to wearable items like wristbands [81], jewelry [89], and clothing [24, 90, 91]. This section will discuss sensor technology and its application to the smart medical home.

23.7.1 Wearable Devices in Healthcare

Wearable devices can be broadly defined as mobile electronic devices that can be unobtrusively embedded in the user's outfit as part of clothing or as an accessory [91, 92]. These devices are made up of three main components: (1) Sensors which measure vital health signs; (2) Computing hardware that processes, displays and transmits information from the sensors; and (3) Clothing which acts as the supporting element and cosmetic exterior of the device [91]. These mobile devices are fundamentally designed to be operated and accessed without interfering with the user's daily living activities [91, 93]. There has been much literature that discusses the development of wearable devices for medical applications, for example, sensors to measure vital signs of dementia patients [93], evaluation of response to stressful training situations [94], and the rehabilitation of stroke

and cardiac patients [95]. These studies and others have demonstrated that wearable devices have the potential to become integral components of a modern healthcare system, as they can provide alternative options and solutions to numerous medical and social requirements [10, 15, 96]. These devices not only improve the provision of health care to enhance the quality of life of the chronically ill and the disabled, but have also been proven to be financially rewarding by saving the health service money via hospitalization reductions, either through prevention or by helping provide appropriate means for independent living.

Instead of measuring health signs, a study by Starner et al [89] introduced a wearable device for use in measuring the tremor of the patients hand as the user makes a gesture. A pendant that consists of a small camera was designed to be worn by a patient, such that the pendant records and interprets hand gestures that are performed by the wearer. The measurement of tremors, particularly in older populations, was shown to be beneficial in detecting the signs of various medical conditions.

23.7.2 Health Monitoring Systems

There is a clear need for health monitoring systems to form a part of the smart medical home, thereby providing both the monitoring of the occupant's vital health signs and the ability to react to changing health signs [7, 9, 80, 81, 94, 96-99]. These systems are necessary, for example, a monitoring system that automatically alerts the hospital staff when patient's vital conditions are abnormal, and a patient tracking system that is used to track patients that may need unexpectedly require immediate assistance. In a typical health monitoring setup, sensors are used to measure patient's vitals that feed information to the monitoring system (see Section 23.7.1).

A monitoring system that measures patient's blood pressure and records in electrocardiogram was presented by Hung et al [80]. Here, the novelty was the use of a mobile phone as the monitoring interface using the wireless application protocol (WAP), such that web-enabled mobile phones could be used as a health monitoring device. In another study, Anliker et al [81] presented an advanced care and alert portable tele-medical monitor (AMON), which is a wearable medical monitoring and alerting system designed for cardiac/repository patients. This system combines the measurement of multiple vital signs, online analysis, and cellular communication to a telemedicine center, in a wearable wrist device that is unobtrusive for everyday use. In another paper, Korhenen et al [9] reported a wireless wellness project (WWM) which aims to develop a prototype system for homes supporting ubiquitous computing applications for wellness management and home automation. The WWM focused on building a home network where multiple simple household and health monitoring devices were connected. An Internet-based information and support system for patient home recovery after coronary artery bypass graft (CABG) surgery was presented in the work by Brennan et al [99]. This system was designed to extend the scope of nursing services to patients from hospital through home, in addition to providing information and support that are tailored to individual patients' needs during recovery in a timely manner.

23.8 SPEECH RECOGNITION AND CONVERSATIONAL SYSTEMS

Speech and language processing systems, that enable users to communicate with computers using conversational speech, are expected to greatly improve our healthcare system through the development of easier and more efficient manner to communicate and interact with computers [6, 100-102].

23.8.1 Speech Recognition in Medical Applications

Speech recognition systems provide computers with the ability to identify spoken words and phrases, and thereby allow their use as an interface to command and control computer program [100], as well as to provide a means of control for physically impaired people [103]. Recent studies have shown that the quality of speech recognition and its usability are continuously being improved, with increases in speech recognition systems being adopted in medical applications [100, 101, 104]. In the medical field, these innovations have primarily been incorporated into dictation systems for the development of reporting systems [104]. For example, speech recognition systems are steadily replacing conventional transcription services in hospitals, primarily driven by potential increase in operational productivity (shorter time for examination) and to reduce the time required to index the reports into the hospital's information system [100]. The ability for the user to create his/her own vocabulary dictionary in speech recognition systems has increased its usability and acceptance in the medical field, which enables the addition of medical vocabulary and technical medical terms. A key factor in the rapid growth of speech recognition systems has been the introduction of picture archiving and communication systems (PACS) [105]. PACS enables immediate availability of medical images, which has greatly increased the time between the availability of these images and their corresponding reports [100].

23.8.2 Conversational Human-Computer Interface (HCI) Systems

Conversational systems differ from speech recognition in that these systems not only recognize the words inputted by the user, but also attempt to interpret the meaning of these words, i.e., understanding the spoken dialogue of the user. Dialogue systems have found various applications, for example, intelligent dialogue systems [106], problem solving assistant and speech translational systems [107], which demonstrated the use of a mobile device which recognizes the user input in Japanese and outputs an English translation of the input. In another study, Polifroni et al [108] reported the use of dialogue input to allow users to search information from the web, such that the interaction with the computer was natural and flexible.

The adaptation of speech recognition and conversational HCI systems in the smart medical home domain has created several novel applications. In particular, the medication advisor project proposed by Ferguson et al [6] is an intelligent assistant that interacts with

its users via conversational natural language, with the purpose of providing the users with information and advice regarding their prescription medication. This study has shown that the dialogue system between human and computer has the potential to aid people in managing their medication, and that such systems can find many other smart medical home applications that can improve and enhance the lives of people.

23.9 MULTIMEDIA TECHNOLOGIES FOR PATIENT EDUCATION AND CARE

Informing patients with regards to diagnosis, surgery and treatment is necessary and often has a significant impact on patient awareness of medical procedures [16, 99, 109-113]. The use of multimedia to facilitate patient awareness is becoming widespread, with the advent of visual, audio, interactive, and Internet content which compliments traditional paper-based information brochures. The acceptance of multimedia usage and the relay of information from these media are an important aspect of patient awareness. Two topics are discussed in this section: (1) utilization of multimedia content for patient education and awareness; and (2) multimedia technologies for reducing patient anxiety inter- and intra-operations.

23.9.1 Multimedia for Patient Education and Awareness

The use of multimedia has been an inseparable tool in education as it enables the presentation of visual, audio and interactive information. The use of multimedia computer for patient education is becoming widespread in healthcare industry from the increase in use and acceptance of computers by patients, as well as the improvements in technology modules that have eased comfort and usage of these educational systems [109, 114, 115]. This is becoming ever-important with patients requiring increased access to medical information to help facilitate decisions about their healthcare. Krishna et al [116] discussed a trial on the affect of Internet-enabled interactive multimedia asthma education program, with presented results indicating significant increase in asthma knowledge to both patients and caregivers. Furthermore, this study also found that this knowledge has also resulted in reduction of symptom days and emergency department visits. Fagerlin et al [117] developed and evaluated a multimedia education program for prostate cancer patients. The program was operated on a stand-alone PC and participations used a selection of on-screen buttons that controlled interaction and navigation, with an assistant providing instructions and support. The study reported that the majority of the information needs were fulfilled, however, like many other studies, the information provided was not completely satisfactory [115].

Another area that is benefited from the use of multimedia is in the delivery of information to patients and their families in the hospital waiting rooms. These waiting rooms typically have large amount of information in print media forms (pamphlets and posters) in regards to the preoperative procedures. Often there is also a nurse, social worker, physician, or volunteers present to assist patients and families of these information as well as progress of the patients through talking in person or over the telephone. Such

practice of information delivery is *low-tech*, and can potentially benefit from the use of multimedia technologies [118]. Wheeler et al [111] presented the use of videotapes containing information regarding the use of antibiotics which was shown to improve patient awareness of the drug and understanding. It went on further to state that the conventional paper media (pamphlets) were not read by the patients, reinforcing the advantages of using multimedia contents. In another study, Oermann et al [119] demonstrated the advantage from the use of multimedia content in informing patients. Here, educational videotape was also used to show instructions in clinical waiting area, and concludes that such video instructions can be an effective and efficient teaching intervention for health information.

23.9.2 Multimedia for Reducing Patient Anxiety

Multimedia technologies have been used as a tool for reducing patient's anxiety [112, 120-122]. The use of multimedia has the potential to reduce the need for sedatives to help patients relax during inter- and intra-operations [123] and thereby benefiting the wellbeing of the patients. Different methods have been used to alleviate anxiety and fear during the operative periods, ranging from friendly hospitals, multimedia embedded operating theatre environment, and the availability of relevant information and explanation. It is common to find music being played in the operating theatre during surgery [120, 121]. Music was shown to reduce patient anxiety by lessening the unfamiliar noise and auditory stimuli that occur during surgery, as well as for therapy to reduce anxiety before surgery. Even though the use of multimedia has advantages to the patients, there have been many reported studies that suggest these aids to patients can cause distraction to the physicians and nurses during operation, primarily in hearing of vital signs and potential conflict in communications to staffs when music is used in the operating room. Therefore, it is important to take the above issues into consideration when the multimedia systems are designed.

Apart from music, Man et al [112] presented the effect of intra-operative video on patient anxiety with results indicating ease in patients anxiety during operation and in overall, improving comfort and satisfaction. In this study, the patients undergoing surgery was equipped with specialized designed glasses that includes liquid crystal display (LCD) screens and audio, used to playback video.

23.10 MULTIMEDIA OPERATING THEATER AND VIRTUAL REALITY (VR)

Computer-driven simulations of operating theater in VR are articulating huge interests from both education and clinical environments [124-127]. The ability to utilize multimedia components to create real-time simulation of the surgery procedures in a controlled and realistic setting, i.e., a virtual theatre, provides the operating surgeon with the ability to perform pre-operative planning and practice, surgical education, and training. Such systems have demonstrated usefulness where the outcomes of surgical operation are often

determined by the technical skills of the operating surgeon. In particular, the use of virtual/augmented reality for surgical planning and education has great potential to be evolved for medical home uses, i.e., virtual simulations that are targeted to increase emotional comfort of older and disabled patients at home [3, 128, 129].

23.10.1 Multimedia Operating Theatre

The utilization of computers in surgical procedures is often referred to as computer assisted/aided surgery (CAS) and/or computer-integrated surgery (CIS) [130]. Recent studies have shown that the use of CIS has the potential to contribute in the general cost cutting trend in health care by making it possible to have fewer staff perform the same surgery in less time than with traditional methods [131]. Refer to Chapter 18 for further details in regards to CIS, and other related topics.

Multimedia technologies play an essential role in the development of CIS systems. In a typical CIS, these systems consist of image viewing (2D/3D) software, telecommunication system with video/audio conferencing, and interactive user interface that utilize input devices which provide haptic feedback, such as a *joystick* device [132, 133]. Other multimedia devices have also be utilized, such as the use of remote visualization in the operating theatre [126], where a projection of the images is displayed and controlled by the surgeon using a joystick. Gering et al [134] reported a camera and position sensory device which was embedded into a surgical cutting knife, where the captured video was used to navigate through a volume rendering of the patient's data in relation to the knife. There has also been introduction of robotic that is controlled using computers for use in surgery [135].

23.10.2 Virtual Reality (VR) for Medical Teaching and Training

Recent studies in biomedical information technologies demonstrated the capability of using VR in surgical procedures as a tool for simulation and training [124, 136-139]. As described in section 23.2.4, VR can be used to enable users into an immersive environment that is made up of multimedia contents to simulate realistic conditions of surgery [125]. One of the key potential of this multimedia technology is its application to aid in education by allowing interactive training of surgical procedures [139, 140]. VR can compliment traditional approaches to teaching of surgical skills which usually involves *see and do* approach [141], and has been demonstrated on a number of applications, such as for simulating a vascular reconstruction in a virtual operating theatre in [125], as well as to use it for neurosurgery planning in virtual workbench [138]. Alternative use of VR in medical education is described by Johnsen et al [142]. Here, the experience in interaction between patients and medical doctors were simulated through the use of virtual characters. These life-size characters were projected to screens and were used to interact with using gestures and speech.

VR in biomedicine is not only restricted to teaching and training, but also for numerous healthcare applications. Flynn et al [115] reported a virtual reality system that has been utilized to enhance recovery of skilled arm and hand movements after stroke. Particularly with redundant input, VR system enables physically or cognitively handicapped people to the access of computers.

23.11 SUMMARY

This chapter has discussed the advances in multimedia technologies and their applications to the smart medical home (and hospitals). The core technologies covered include human-computer interaction, multimedia content management, and multimedia delivery, followed by their impact on the development of medical applications for smart medical home (and hospitals), including telemedicine, sensory devices, speech and conversational systems, patient education and care, operating theaters and virtual reality. This chapter has also discussed some new technologies that may have potential future applications, which facilitate "the future hospital is not just in the hospital". There is no doubt that multimedia information technology is becoming increasingly important in healthcare delivery and in improving the quality of people's life.

Acknowledgement

23.12 EXERCISES

1. Analyze the influence of MPEG standards in health care systems for medical homes.
2. State and discuss the most significant differences between MPEG-4 and MPEG-1/2.
3. Describe a multimedia-enabled health care system or product and identify what enabling multimedia technologies have been adopted.
4. Telemedicine is a term used to describe the telecommunications technology for medical diagnosis and patient care when the provider and client are separated by distance. List three or more telemedicine applications, with their similarities and differences.
5. What are the advantages and disadvantages of a virtual operating theatre in the training of physicians?
6. Multimedia is often utilized to reduce patient anxiety in both the waiting room and operating theatre. What other benefits does multimedia have in these environments for the patients?
7. Wearable devices are different to other medical devices in that it they must not only be designed to aid in the user's health, but also to be comfortable and unobtrusive. What are the guidelines to follow in the design of wearable medical devices?

CHAPTER 23 MULTIMEDIA FOR FUTURE HEALTH

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