Wireless health as a novel paradigm in healthcare

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Wireless health aims at drastically reducing healthcare costs and loads by combining innovations in wireless sensing, embedded information-technology infrastructures, and medical fundamentals.

In response to the nation’s healthcare crisis and equipped with the necessary technological maturity, the new area of wireless health (WH) is developing rapidly. With a fundamental aim to revolutionize and restructure the healthcare system, its practical goal is to develop novel wireless systems, sensors, and architectures poised to prevent diseases, diagnose medical conditions, and rehabilitate users whenever possible or necessary. In addition, WH data streams will become a valuable resource for populating electronic medical records with pertinent information from patients located outside the hospital.

Researchers at the Wireless Health Institute (WHI) of the University of California Los Angeles have developed concepts for generic WH architectures and data-processing systems, as well as a number of practical applications. One example is a personal-activity monitoring (PAM) system, a low-cost solution to capture human-motion profiles and for automated identification of activity types and behavioral structures. Many clinical studies suggest the importance of activity in disease prevention, mediation, and recovery/rehabilitation. At the same time, a conventional approach to ‘prescribing’ activity or using qualitative or quantitative activity measures to aid in improving outcomes does not exist. Motion sensing based on WH principles has the potential to meet these requirements.

The architecture in Figure 1 shows an example of information flow within the system from various wireless sensors, located at a user’s home or at a clinic, to medical enterprises (e.g., hospital, individual physicians, nurses, or care givers) and third-party organizations (e.g., call centers or insurance companies). Within the WH concept, sensors, instruments, and devices have wireless interfaces (e.g., Wi-Fi or Bluetooth) or other means of transmitting information to the network (e.g., a USB connection to an Internet-enabled computer). This layer is termed ‘body area and local-area wireless.’ Once the information has been collected, it is securely transmitted via intermediary devices (e.g., wireless routers or Internet-enabled computers). Subsequently, the information is securely routed via the Internet to organizations with authorized data access, such as medical enterprises or third-party providers. Once the data reaches its endpoint, it is typically archived, processed, and made available to qualified personnel (physicians, nurses, etc.) for interpretation and analysis.

Figure 1. Example of wireless health (WH) system architecture. WAN: Wide-area network.

Figure 2. Integral components of a WH system.

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Figure 3. Examples of motion-data capture and analysis. The top two plots show raw data (g force, equivalent to acceleration) and classified output for a sensor attached to a patient’s ankle, and the bottom two plots show the same for one attached to a patient’s wrist.

The WH architecture also provides opportunities for information-flow or decision-making optimization. Figure 2 shows some of the integral components of the WH system. It may not always be necessary to transmit all sensor data to a medical enterprise. Instead, local processing can be done on intermediary mobile platforms such as a cell phone or the wireless sensor itself. For example, a heart-rate sensor detects various components of the waveform produced by the subject’s heart, usually each second. However, the heart rate is determined as an average of peaks in the heart-waveform signal per minute. Therefore, by performing local processing on the sensor or an intermediary device, we can reduce the demands on network transmission by 100-fold.

In addition, WH researchers have developed various algorithms that are capable of reaching diagnostic decisions based on the collected data.1,2 In such cases, the medical enterprise and individual user can be notified of a problem immediately. Although automated diagnosis is an application of the future— pending sufficient validation trials and government approval— examples of this technology are available today and will become a reality. This will offload hospitals, drastically reduce healthcare costs, and extend health services to underprivileged sections of society and to those living in remote areas.

One of the current WHI projects focuses on collecting motion data from users and interpreting it for activity classification and characterization. The applications of this technology are vast. A few examples include ensuring patient health and wellness by monitoring the amount and intensity of daily activities, providing feedback on proper exercise amounts and techniques, and remote monitoring of neurological-rehabilitation users to determine if they comply with the prescribed exercise regime, whether they are adequately active, and if recovery/rehabilitation progresses.

These applications are accomplished using miniature, low-cost PAMs that contain motion sensors, such as accelerometers (which measure acceleration) and gyroscopes (for measuring turning rates), and intelligent processing algorithms. The latter extract unique features from the motion data and perform classification. Their final output is a list of activities that was performed by the user at different times. The algorithms can also provide detailed activity analysis. For example, for walking activities, they can determine the speed, cadence (number of steps per minute), and symmetry (ratio of swings between left/right legs). WHI research has produced classification algorithms that can successfully identify a patient’s state with more than 95% accuracy.

The top and third panels in Figure 3 show examples of raw data captured from a miniature motion sensor attached to an ankle and a wrist, respectively. Figure 3 also shows classification output from the WHI intelligent-processing algorithm (second and bottom panels). The classification system accurately captures the subject’s motions. The green line on the classification plots shows rare misidentifications of the states caused by transitions between activities.

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References


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