

# Simplifying Home Health Monitoring By Incorporating a Cell Phone in a Weight Scale

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## ABSTRACT

The overweight under-exercised aging baby-boom generation is creating an epidemic of chronic diseases that is placing a tremendous burden on the health care system. Frequent monitoring and contact between a patient and health care professional can help the patient control their diet, get more exercise and increase medication compliance. These factors produce dramatic improvements in patient health and well being. We present a home health system to manage heart disease that monitors patient weight and symptoms and support verbal communication between patient and health care professionals. The system embeds a cell phone, electronics and a large battery inside a weight scale to simplify installation and use, leverage cell phone cost-performance and speed up prototype development.

## Categories and Subject Descriptors

J.3 [LIFE AND MEDICAL SCIENCES]

## General Terms

Measurement, Design, Human Factors

## Keywords

Home health monitoring, cell phone, wireless, embedded system, chronic disease management

## 1. INTRODUCTION

Aging baby-boomers are placing a considerable burden on the health care industry. Chronic diseases such as diabetes, heart disease, and hypertension represent a significant proportion of health care costs due to their long term needs and debilitating complications. Clinics and hospitals are expensive places to deliver health care for chronic conditions. The inconvenience to patients and limited availability of health care professionals makes frequent visits to clinics for health monitoring impractical. Research shows that patients are more successful at controlling diabetes and losing weight when there is frequent and personal contact between the patient and health care professional [3].

Home monitoring transforms the roles and relationship of patient and physician; monitoring shifts from physician to patient and communication shifts from face-to-face to asynchronous messaging [2]. By actively participating in monitoring, the patient learns how their behavior affects their health.

The home is an ideal location to monitor patient vitals and symptoms. Blood sugar, blood pressure and weight are vitals that can be measured by a patient at home with modestly priced devices. However the data collected is of little use without interpretation and response. The goal of our research is to create a home monitoring system that is cost effective and improves the patient's quality of life. The system must be easy to install and use, provide accurate and useful data accessible to health care professionals, and foster communication between patient and health care professionals.

## 2. PRIOR WORK

Glucose meters, blood pressure cuffs and weight scales are available for less than US\$100. To be useful, vital measurements need to be incorporated into the patient's electronic medical record. Symptoms such as dry mouth, dizziness and swelling must also be captured and entered into the medical record. Any data entered into the electronic medical record must be accurate and authentic, i.e. the patient's identity must be verified when the vitals are measured.

The simplest home monitoring device displays a vital reading, leaving it up to the patient to record the data. Clearly this is not practical for long term monitoring. Some devices store and upload measurements to a personal computer. However the inconvenience of uploading and providing access to health care professional makes this approach impractical. A more sophisticated and home monitoring system sends collected data to a remote server over a phone line, requiring the device to be located near a phone jack.

Incorporating a Bluetooth radio in the medical sensor provides freedom of placement in the home, but the process of pairing (associating) the wireless medical sensor with a hub adds a level of installation complexity. To be accepted by the patient, monitoring technology must be easy to install, use and comprehend [1]. The technology must integrate into the social setting of the home, rather than transform the home into a clinic.

We report on the design and construction of a prototype home monitoring system that a patient can use to manage their chronic condition and improve their health. The patient stands on the

scale, states their name and reports their symptoms by answers a few yes/no questions. Data and voice communication is provided by an inexpensive cell phone embedded in the scale, creating a compact, portable, easy to use system.

### 3. HEALTH MONITORING SYSTEM

Our project focuses on patients with cardiac disease, requiring daily monitoring of patient weight and symptoms. The system consists of three components: a patient scale, a remote server and a health care terminal. The scale collects patient weight and self-reported symptoms. The information is sent as voice and text messages to the server over a commercial wireless carrier. The server identifies the patient, populates the patient’s electronic medical record and hosts a web-based patient monitoring program. A health care professional uses the patient monitoring program to view patient weight and symptoms, download new symptom questions to the patient’s scale, and conduct asynchronous (voice mail) and synchronous (phone call) communication with the patient.

A block diagram of the functional components of the patient scale and server are shown in Figures 1 and 2, respectively. The details of the system components and how we implement them are described below.

#### 3.1 Patient Scale

A conventional bathroom scale (HoMedics SC-202 LED Digital Bathroom Scale) provides a familiar experience for the patient with ample space inside for all system components, shown in Figure 3, creating a compact easy-to-use system. A scale with an LED display is selected to simplify data capture. An inexpensive microprocessor (Zilog Z8F6402) reads the control lines of the scale’s LED display to capture the weight. The microprocessor composes an SMS text containing the weight and sends it to an email account.

All phone functions are controlled by the microprocessor through electronic switches (CD4066 quad CMOS switch) connected directly to the printed circuit keypads of a simple cell phone (Nokia 2115i “Shorty”, US\$40). The microprocessor electronically closes keypad contacts, electrically simulating a human pushing phone keys. This hardware hack of wiring directly to the keypad switches enables us to use any cell phone without requiring a software development kit or APIs.

The cell phone microphone and speaker are wired to an audio recording and play integrated circuit (Winbond ISD5008), enabling the patient’s voice and incoming voice calls to be locally stored. This allows cell phone voice calls to be placed at schedules times, to load balance the server and cell phone carrier resources. Touch tones are used on the voice channel as control signals. Outgoing touch tones are stored in the audio integrated circuit’s memory. Incoming touch tones are decoded locally (California Micro Devices CM8870 DTMF decoder).

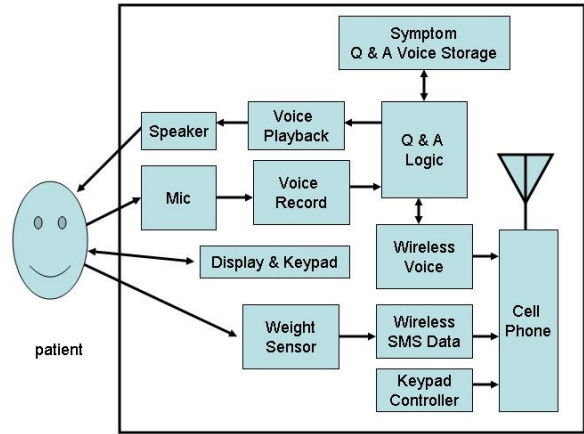


Figure 1. Patient Scale block diagram.

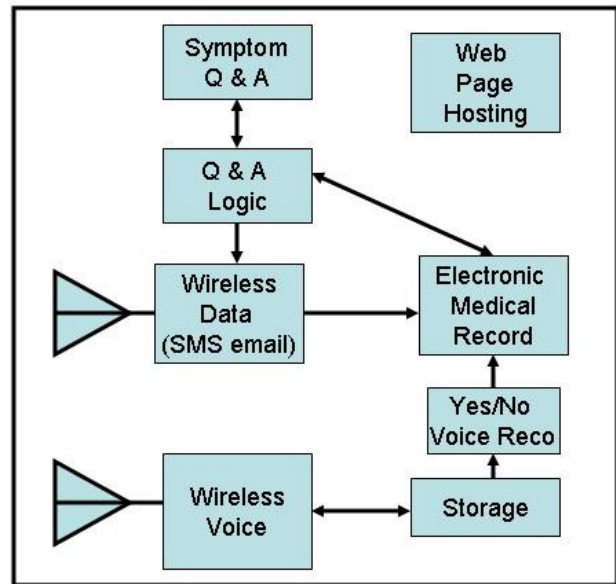


Figure 2. Remote Server block diagram. In our prototype the Yes/No Voice Reco function is replaced with a keypad.

A keypad and display are provided as another channel for symptom status questions and answers, and was used in lieu of yes/no voice recognition, which was not available at the time of prototype construction. Figure 4 shows the patient scale prototype, including a pole to support a keypad and LCD display. The development electronics are external to the scale for easy access during prototype development, and will be installed inside the scale in final form.

The cell phone is only turned on during communication (about 1 minute a day) which combined with a large battery provides months of operation between charging. Configuration information (e.g. scale PIN and audio memory pointers) is stored in non-volatile memory (Microchip EPROM 24AA16).

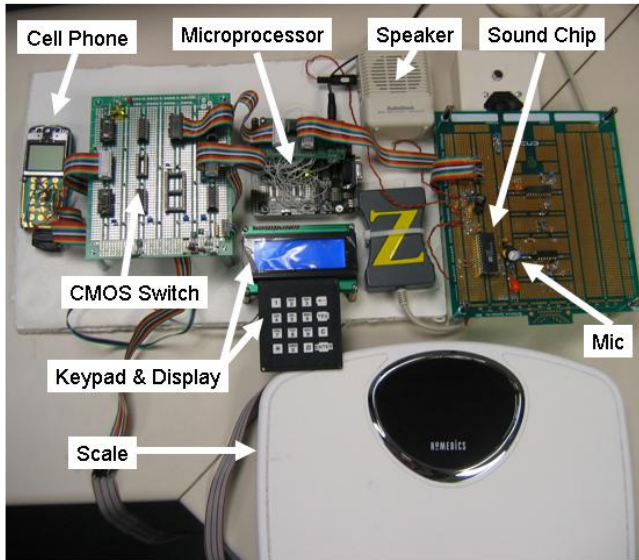


Figure 3. Patient Scale prototype development hardware.



Figure 4. Assembled Patient Scale development system with pole mounted patient interface. Insert shows detail of patient interface unit.

### 3.2 Remove Server

The remote server receives SMS text messages from the scale as email. The text message contains patient weight and keystroke

answers to symptom questions. The server uses a Gmail RSS feed service (<https://gmail.google.com/gmail/feed/atom>). An RSS reader, written in Java, indicates when a new message is received in the Gmail account. HttpRequest and HttpResponse protocol are used to get data from the RSS feed, which is in XML format. The XML is parsed to extract the title, content and timestamp of each SMS message.

Voice communication is handled by a commercial phone server (TellMe studio <https://studio.tellme.com/>) that runs a rule-based script written in VoiceXML. After each weigh-in session the scale calls the phone server, identifies the patient by a unique scale PIN and uploads verbal answers to symptom questions and any messages the patient has left for health care professionals.

The phone server downloads any new symptom questions and messages created by a health professional to the scale. Communication flow control between the scale and phone server (e.g. marking the beginning and ending of symptom questions and answers) is conducted on the voice channel using touch tones.

The server hosts a web page running Flash to provide health care professionals means to upload new patient status questions to the scale and view patient weight history.

### 3.3 Health Care Terminal

The health care professional uses a browser to view patient weight and listen to verbal answers to symptom questions and patient comments. In order to make the home monitoring system economical, a health professional needs to monitor hundreds of patients. To effectively manage such a large group, some form of automatic rating of patient status must be performed. Further work is required to create a health assessment tool that identifies the patients that require attention. Typically a template of nominal weight and symptom values are established for each patient and those patients that exceed the norm are flagged as needing attention.

### 4. Discussion

The home monitoring prototype demonstrates how the integration of a cell phone into a conventional scale can create a stand-alone, easy to install medical monitoring and communication system. Text messaging provides a simple and effective means to transmit medical data across a commercial mobile phone network. The small data packets can easily be encrypted if necessary. The availability of asynchronous (voice mail) and synchronous (phone call) voice messages provides a variety of communication options to the patient and health care professional.

The use of voice for capturing symptoms raises important user interface questions. How will patients feel talking to a scale? Is it better to use a computer-synthesized voice or the voice of the patient's personal physician? Is voice recognition reliable enough for processing yes/no responses in a variety of acoustic environments and speakers? Will voice recognition work when

the microphone is mounted in the scale (about 2 meters from the speaker)? Is speaker verification by template matching reliable enough?

In our prototype a keypad is used to capture patient responses to symptom questions. This could be as simple as two buttons to capture yes and no responses. The pole does require some basic assembly but has the following advantages; places the microphone and speaker closer to the patient for better acoustic fidelity, gives the patient an object to talk to, provides visual feedback indicating scale operation. Voice recognition was not available during prototype development and was not tested. We later discovered a microcontroller capable of performing speaker independent recognition of up to 10 words with no user training (Sensory RSC-464 Speech Recognition Microcontroller). Performing voice recognition of symptom responses in the scale electronics would allow interactive questions trees (e.g. if patient answer 'yes' to question A, system then asks question B, else system asks question C). Voice recognition would eliminate the need for the keypad and support pole, simplifying installation and increasing placement options and aesthetics (e.g. the scale could slide under a bed).

Our system monitors patient weight. A similar system can be built to monitor blood pressure or glucose. If a patient needs to monitor more than one vital sign, several sensors may be incorporated into one device (e.g. weight scale and blood pressure cuff). Or each device could have its own embedded cell phone. We believe the experiences of Ballegaard [1] justify the cost of placing a cell phone in each device, to avoid the complexity of local networking.

## 5. Conclusions

The combination of aging baby-boomers with poor diet and exercise habits is creating a health care crisis. Management of chronic disease is placing a growing drain on health care resources. Home monitoring can ease this burden by shifting health care delivery from the clinic to the home, from the physician to the patient. Involving the patient in daily health monitoring teaches the patient the impact of personal behavior on their health status. Active coaching and attention by health care

professionals and their proxies (e.g. a server that automatically monitors vitals and symptoms and provide feedback) reinforces compliance and health improvements.

To be successful a home monitoring system must be easy to deploy, use and comprehend. The system must blend into the home and not appear as something that belongs in a clinical. A weight scale is a common item in a bathroom. By embedding a cell phone into the scale, we enable weight and symptom monitoring, and communication with a health professional, without sacrificing the simplicity of use and appearance of the scale.

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