A WIRELESS HOME AUTOMATION SYSTEM FOR CHILDHOOD OBESITY PREVENTION

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PEOPLE ARE BECOMING MORE CONCERNED WITH THE PROBLEM OF CHILDHOOD OBESITY, WHEN EXCESS BODY FAT NEGATIVELY AFFECTS A CHILD'S HEALTH.

Childhood obesity is recognized as a serious public health concern due to the rising prevalence of obesity in children (Troiano 1995). In the United States, direct measurements of body mass and height obtained by the National Health and Nutrition Examination Survey indicate that about 15% of 6–19 year olds are classified as overweight (Ogden 2002). As the children spend a significant amount of their time at home, a sedentary lifestyle accounts for the leading cause of childhood obesity (Walker 1998). Many children fail to exercise because they spend time doing stationary activities such as playing video games or watching TV. Certain reports provide evidence that television viewing is a reason for increased body fatness and that reducing television viewing is a promising strategy for preventing childhood obesity (Andersen 1998, Robinson 1998).

On the other hand, exercise would help children control their weight. It also helps to reduce the risk of some illnesses such as high blood pressure, heart disease, sleep problems, and other similar disorders (Freedman 1993). Based on the mentioned facts, it is widely recommended that one should moderately exercise for at least 30 minutes five times a week (Sallis 1994, Pate 1998, Corbin 1994). Furthermore, it is reported that standards for recommended pedometer-determined steps per day for 6–12 year olds are 12,000 for girls and 15,000 for boys (Tudor-Locke 2004). This highlights the importance of physical activity for children. Accordingly, many control units have been implemented in games and appliances by parents in an effort to encourage children to perform physical exercise. Using these units, parents can limit the time that their children can spend playing computer or TV games by manually controlling the corresponding appliances using the GUI provided by these units (Thompson 2006, Coshott 2007). However, the units are not capable of preventing children from watching another channel or playing another game that is not equipped with the parental control option.

In this paper, the system proposed can mitigate the previously mentioned problems by controlling power outlets instead of controlling certain

TV channels or particular games. It has been several years since the introduction of smart homes. In such homes, RF (radio frequency) signals from special controllers are exploited to activate or deactivate power outlets. In some cases, the controller is able to regulate the intensity of room light as well. A number of research projects have been carried out based on these or similar controllers to build smart homes (Cook 2003, Jiang 2000, Cole 2002). Likewise, a certain type of RF power controller is used in this project in order to acquire complete control over the home's power outlets. In addition, a wireless sensor is utilized that can calculate the travelled distance and average pace for a walk (or a run) so as to monitor the daily activity level of children. The recorded data can later be uploaded to any computer via the USB interface. The goal of the proposed system is to make a virtual connection between power outlets and a wireless activity monitor sensor. This way, the children could be encouraged to do more exercise in exchange for more time of home entertainment (e.g., watching TV). The more exercise children perform, the more time they secure to do stationary activities. The proposed system, called *No Pain No Game*, is intended to prevent childhood obesity disease and thus improve childhood fitness levels.

The remainder of the paper is organized as follows. Section 2 provides a brief overview of related work in the context of home automation and childhood obesity prevention. Preliminary notions followed by the structure of the *No Pain No Game* system are covered in Section 3. The important features of the system are summarized in Section 4. Finally, Section 5 concludes this study and highlights future research directions.

RELATED WORK

There are several research projects based on home automation systems. As an example, MavHome smart home architecture developed at the University of Texas at Arlington allows a home to act as an intelligent agent (Cook 2003). In the MavHome system, a sensor network including light, humidity, temperature, smoke, gas, motion, infrared, and switches is developed to keep track of the home environment. Based on the data collected from the sensor network, a server makes a decision

THE PROPOSED SYSTEM CONTROLS POWER OUTLETS INSTEAD OF CONTROLLING CERTAIN TV CHANNELS OR PARTICULAR GAMES.

for resource management and executes the decision through the smart actuators (e.g., X10 ActiveHome Kit) with which the appliances in the home are equipped. Generally, the MavHome aims at maximizing the inhabitant's comfort and productivity and minimizing costs. For elderly and disabled people, the system can provide a fine health care and a higher level of security. As another example, to help people with disabilities, Jiang et al. has designed a voice-activated environmental control system which consists of a universal remote control with X10 home automation capability, a Motorola 6811 microprocessor, and an off-the-shelf voice recognition circuit (Jiang 2000).

In the context of activity monitoring, in a number of projects X10 components are integrated into a toolkit which is intended to monitor the daily activity of an individual (Cole 2002). In addition to the home automation systems, certain appliances are developed to encourage children to exercise. For example, an interrupter system can be added to an existing connection between a game console and its controller (Coshott, 2007). The interrupter sys-

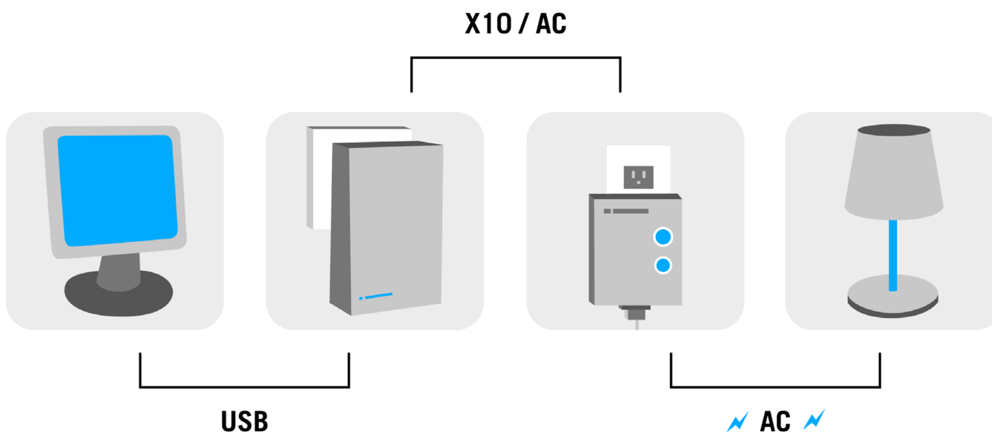

FIGURE 1
A TYPICAL CONFIGURATION FOR X10 CONTROLLED APPLIANCES.

tem is used selectively to enable and interrupt the modified connection between the game controller and the game console, dependent on the detected operation of the exercise machine. Accordingly, the parents can arrange it in such a way to block normal playing on the game console unless the child performs an adequate amount of exercise on the exercise machine.

In (Annavaram 2008), a wireless body area network is developed for wearable monitoring applications, and the intended use of the system is to avoid pediatric obesity. The network is composed of heterogeneous sensors (e.g., heart-rate sensor and accelerometer sensor), and the goal is to recognize, predict, and reason automatically about human physical activity and behavior states by the evaluation of multimodal sensing and interpretation.

THE PROPOSED SYSTEM

No Pain No Game is a home automation system that encourages children's daily exercise by rewarding them with more home entertainment time. In other words, the time children spend doing stationary activities should be proportional to the time they spend doing physical exercise. Aside from the interface software, the system is composed of three parts: a sport kit that monitors the exercise records, a controller that commands the power outlets, and a database that stores the health statistics and exercise records of children. The current version of the system exploits Nike + iPod Sport Kit as a means to monitor the physical exercise. It also uses X10-based devices in the shape of controllable power outlet modules in order to acquire full control over different entertainment appliances. Microsoft Access databases are utilized to store the relevant exercise data. The software that connects these three parts is written in Visual Basic and C Sharp and runs on a Windows platform.

X10 Standards

X10 is an international and open industry standard for communication among electronic devices used for home automation. It primarily uses power line wiring for signaling and control, where the signals involve brief radio frequency bursts representing digital information. A wireless radio protocol is also defined, where the data packets are very similar to those used for power line wires. The operating frequency of the wireless protocol is 433 MHz and 310 MHz in the European systems and U.S. systems, respectively. It should be noted that the wireless protocol allows the operation of keypad remote controllers on top of the underlying wired X10 modules.

X10 is popular in the home environment, with millions of units in use worldwide and new components inexpensively available. Figure 1 illustrates a typical configuration for an X10 network.

By using The ActiveHome Pro Scripting Interface provided by X10, one can create software,

THE SENSOR FITS INSIDE SPECIAL NIKE SHOES AND A WIRELESS RECEIVER IS CONNECTED TO AN IPOD.

web pages, and other tools that use the USB Interface to control and interact with X10 modules, sensors, and remote controls (The ActiveHome Pro SDK from X10). The address of each module is set by the dials located on it. Accordingly, one can command the interface to turn on the intended module by providing a valid address corresponding to the module. Upon receiving a command (e.g., from a remote control), the interface reports the action of receiving the command which enables the user to benefit from certain options. For the sake of more reliability, each packet is sequentially sent twice to make sure the receivers understand it even in the presence of power line noise.

Nike + iPod Sport Kit

The Nike + iPod Sport Kit (Figure 2) consists of a wireless sensor and a small wireless receiver that plugs into an iPod. The sensor is a piezoelectric accelerometer pedometer that fits inside special Nike shoes and a wireless receiver that is connected to an iPod. Each sensor has its unique serial number that is used as an identification number for each child in the proposed system. The personal training application on the iPod can provide information on distance and speed while a user is listening to music. By considering the number of steps taken and the elapsed time, users (children) can schedule their desired workout in the form a specified distance or a certain time period that can fit a plan based on their goals and their previous performance. The exercise records are stored in files with XML format. The proposed system will upload those files to the server and extract the useful data from the files. Therefore, the data can be analyzed to decide how much entertainment time the child has earned.

The Proposed No Pain No Game System

In the proposed system, a server is maintained by parents while children will use remote controls sending matching signals to trigger the appliances. A child must register his or her sports

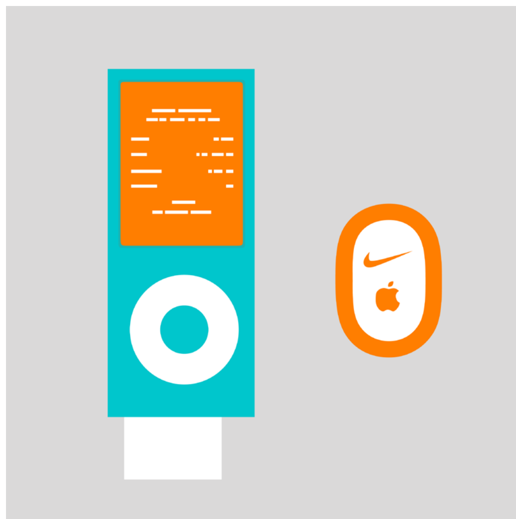

FIGURE 2
APPLE NIKE + IPOD SPORT KIT.

kit on the server, given that every sensor has a particular identification number. The proposed system simultaneously analyzes the current exercise records when children update the database with new exercise records merely by plugging their iPod into the client computer. This means that the server automatically calculates the total time budget that a child is allowed to use his/her intended appliances (e.g., TV). A formula is applied to derive the time budget based on the calories burned by the child:

$$Calories = \frac{METs \times 3.5 \times w}{200} \times T \quad (1)$$

where *MET* (Metabolic Equivalent of Task) is a physiological concept that shows how intense the exercise is (Dr Gily's Health Portal), *w* is the child's

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weight in kilograms, and *T* represents the total duration of exercise (e.g., running or walking) in minutes.

MET expresses the energy cost of physical activities as multiples of the Resting Metabolic Rate (RMR) and is defined as the ratio of metabolic rate (and therefore, the rate of energy consumption) during a certain physical activity to one's metabolic rate at rest (quiet sitting), set by convention to 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ or equivalently 1 kcal $\cdot$ $kg^{-1} \cdot hr^{-1}$. By convention 1 MET is considered the resting metabolic rate obtained during quiet sitting. MET values of physical activities range from 0.9 (sleeping) to 18 (running at 17.5 km/h). It should be noted that the MET value for watching television is 1 and for walking at a speed of 3.2 km/h is about 2 (Metabolic Equivalent 2009).

After the burned calories are derived, a basic requirement for this value is enforced. If the amount of burned calories is less than a certain quantity (called the basic requirement), no time budget will be granted. However, if it exceeds the basic requirement, the basic amount of time will be given, plus extra time depending on the bonus rate and the overhead. The required amount of calories, the amounts of the basic time budget and extra time can all be adjusted by the Account Management Interface.

The total time budget for each child is stored in a database by Microsoft Access. The time budget gets verified and consumed every time a child tries to activate an appliance. Moreover, after the time budget is depleted, the server will automatically power off the related appliance (e.g., TV). A child has to perform more exercise and then plug in his/her iPod into the client computer in order to increase the time budget again. Figure 3 illustrates the structure of the *No Pain No Game* system.

The implementation of the system is constructed with two ends, the client and the server (Figure 3). On one end, the program on client computers will parse iPod exercise records by creating XML readers supported by the .NET Framework. After validation, the files will be sent to the server unless they are expired. On the other end, the server will increase the corresponding time budget by an appropriate formula based on children's BMI and exercise records. The server also verifies whether the sensor identification number of the record is valid, and it makes sure that the record is not outdated. Meanwhile, if one wants to register more children (through Account Management) or verify the status of all children, the server can update or retrieve the data as required (see system block diagram illustrated in Figure 4).

Moreover, the server handles the events when the Power Control Module (ActiveHome Automation System interface) receives signals from remote controls. Each received signal will be mapped to a particular child and the module he/she has requested. Therefore, the server can retrieve the corresponding data and determine if it should send a command (*sendrf* in this case) to the automation system in order to trigger the requested module. In addition, for each appliance, there is a timer in the server to update and monitor the available time budget and, correspondingly, to turn off the appliance when the time budget has exhausted. A detailed block diagram of the server is depicted in Figure 5.

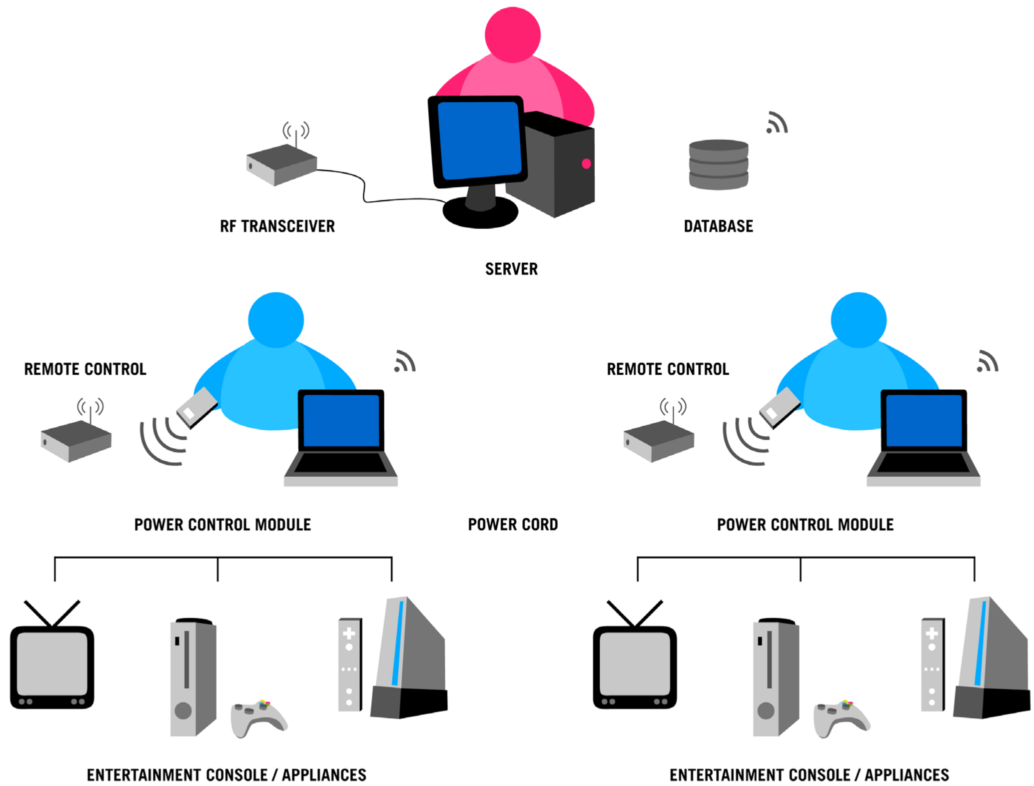


FIGURE 3
STRUCTURE AND APPLICATIONS OF *NO PAIN NO GAME*.

SYSTEM FEATURES

Since each child has his/her own iPod + Nike Sport Kit, the system can distinguish between different children by evaluating their identification numbers. Furthermore, the system takes into account the date of exercise records to avoid copies of previous exercise records from being taken into consideration. This validation process prevents children from cheating to some extent. For example, a child will not gain any extra time budget by plugging in the iPod twice with the same exercise record.

As can be seen in Figure 6, a user-friendly GUI on client computers is provided for children to use so that they can easily learn how to update the exercise records without any difficulty. Furthermore, the system allows children to watch TV or use other entertainment appliances only if they have performed an adequate amount of exercise throughout the day. This gives the children a sense of achievement while the parents need not worry about their kids being too inactive. Additionally, parents can record the time and let the system monitor the activity level of their children and the status of the entertainment appliances. They can view earlier data (e.g., how many calories have been burned) and observe the progress of their child's fitness level. Figure 7 shows an example table containing a child's recent exercise data. This exercise table is accessible from the server.

DISCUSSIONS AND FUTURE WORK

In the proposed system's current form, after performing exercise, a child connects the iPod to the client computer. This will update a database on the server, and eventually a new schedule for the related appliances will be sent from the server to the ActiveHome Automation System. However, it is more desirable to operate the system in real time, where the updating process is done automatically and wirelessly. This can be done by using a Bluetooth adapter connected to the iPod. This way, there is no need for the child to connect the iPod to the computer in order to extend his/her time budget.

Apart from Nike + iPod Sport Kit, other types of sport kits can be added to the system in future to

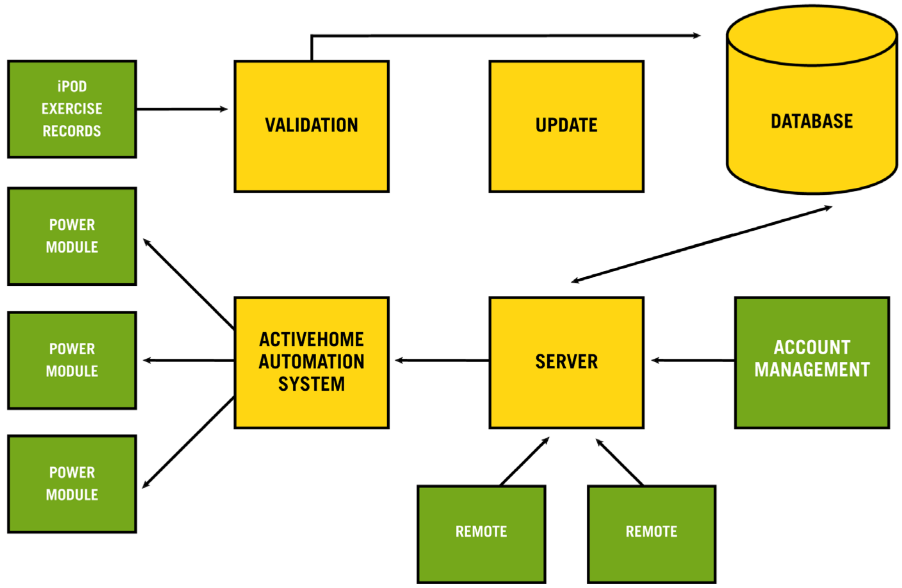


FIGURE 4
SYSTEM BLOCK DIAGRAM

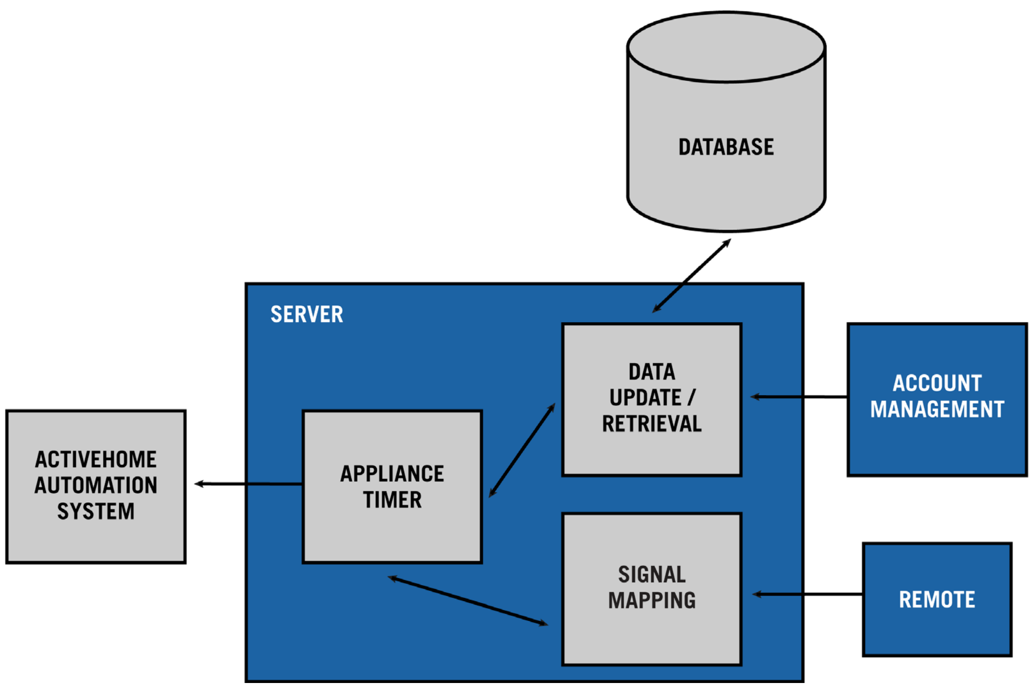
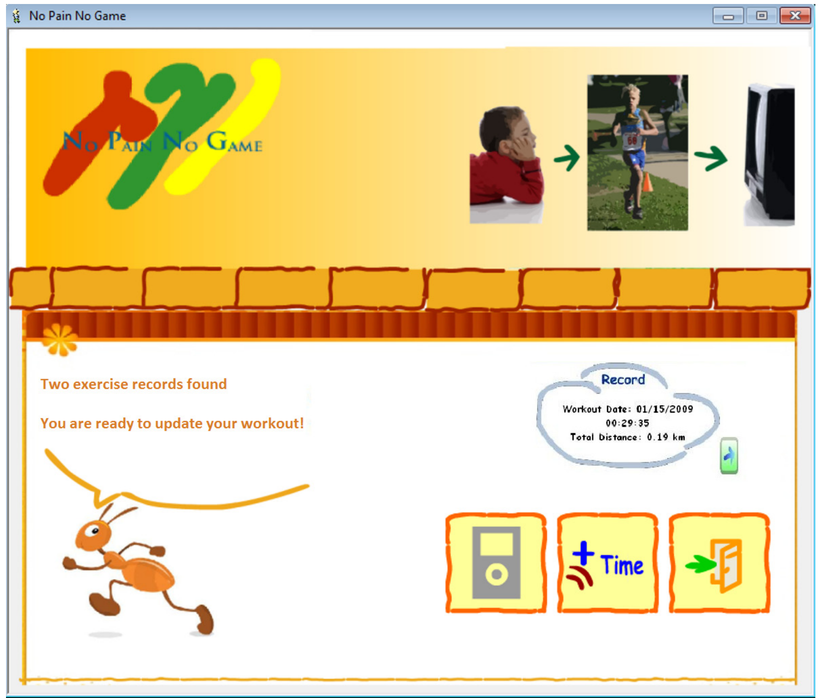


FIGURE 5
DETAILED BLOCK
DIAGRAM OF THE SERVER.



MICHELLE's Exercise Data

	Exercise Date	Calories	BMI	Description
▸	2008/6/12	7.093334	19.53125	At risk of overweight
	2008/11/11	233.96917	19.53125	At risk of overweight
	2008/11/11	233.96917	19.53125	At risk of overweight
	2008/11/13	14.407499	19.53125	At risk of overweight
	2008/11/13	14.407799	19.53125	At risk of overweight
	2008/11/13	14.407799	19.53125	At risk of overweight
	2008/11/25	12.25	19.53125	At risk of overweight
*				

FIGURE 6 (TOP)
A TYPICAL SCREENSHOT OF THE CLIENT GUI IN *NO PAIN NO GAME.*

FIGURE 7 (BOTTOM)
AN EXAMPLE TABLE OF THE EXERCISE DATA.

provide the children with more options to perform physical exercise. Also it should be noted that the server side and client side of the system (Figure 3) can run on two networked computers, or they can run on a single machine.

A new method of gaming can be designed in order to make players benefit from doing physical exercise in the real world. This can be achieved by extending the system to a server maintained by game companies. Similar to the design for the Home Automation System, the system now rewards children who have performed a sufficient amount of exercise with the profit in the game. For example, a child's character in the game becomes stronger and thus is able to carry better weapons. It is anticipated that this idea gives encouraging incentives for children in exchange for performing physical exercise.

No Pain No Game can also cooperate with a children's health organization to advocate formulating an exercise plan, encouraging children by a competitive display record on the organization's website. A child can upload his/her exercise progress and get ranked, accordingly. Further, the exercise data collected from children can be a useful resource for related research institutes. People in health-related organizations can analyze how the trend of health data progresses during the exercise.

CONCLUSIONS

Childhood obesity has been a public concern as people expend money and resources in order to maintain their children's physical fitness and overall health. As such, it is necessary to build an application that continually encourages children to perform physical exercise. Several parental control units have been designed, but few of them can effectively impact children. With home automation system technology ever improving and with the number of related research projects growing, the proposed system is built on the idea of home automation systems. In this system, called *No Pain No Game*, children have to perform exercise for enough time in order to be able to activate any entertainment appliance. The activity level of children is monitored using a Nike + iPod Sport Kit, which is becoming more popular. It records the number of steps taken and time elapsed. Therefore, the application can calculate calories and other related data from the records. A database is utilized to store the exercise records and the time budget for every registered child.

No Pain No Game lowers the risk of being cheated by means of its validation process. Also, its user-friendly GUI easily allows children to learn how to extend their entertainment time. Children can obtain a sense of achievement, while parents can let the system automatically monitor the ac-

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tivity level of their children and the status of the appliances. It is believed that a complete *No Pain No Game* product would enable the parents to supervise their children's exercise and entertainment inexpensively and in a completely unobtrusive fashion.

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For further reading: *http://bit.ly/kLTVD3*

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