GyEEm Of the Future

Senior Design

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1. Introduction

What's the difference between engineers and business majors? Engineers have busy schedules, and business majors don't. What's the similarity between engineers and business majors? Neither of them likes to waste their time – albeit, this is for different reasons: engineers don't like to waste their time because they *don't have time to waste since they're so busy working as humble servants of the people constructing a better world*, and business majors don't like to waste time because they *don't like it when they have to miss an episode of the Flintstones* because they're behind schedule. On a serious note, though, nobody likes to waste their time - so it's important to have tools that allow us to plan an efficient schedule and stick to it. We consider that one activity that must be planned with care is going to the gym; this is not only because it involves spending a considerable amount of time (5 minutes to get ready, 40+ to work out, 10 to shower, and 10 in transit to and from the gym, totaling to at least 65 minutes), but also because one is likely to want to eat or to relax after this activity. Our objective is to develop a system that allows Notre Dame students to plan their workouts more efficiently, makes their experience at the gym more pleasant. We intend to keep scalability in mind when designing our system so that perhaps in the future it may be implemented at a grander scale.

2. Problem Statement and Proposed Solution

If you've been to the gym at a busy time, then you can probably relate to the problems this project will tackle. *Don't you just hate it when you're alternating between a bench and a machine and some foreign PhD student wearing jeans and a polo decides to use the machine right as your finishing using the bench and going back to the machine?* Perhaps not, but we are sure that you can imagine that sometimes the gym gets crowded, and that not everyone is an expert in gym etiquette or in gym awareness; maybe the PhD student wasn't being inconsiderate, maybe he just wasn't aware that you were still using that particular machine – wouldn't it be great if you had a way to let others know when you're using a machine? Consider for a moment a few reasons *why* people *don't* go to the gym: maybe they can't find the time to do so, maybe they feel uncomfortable working out in front of other people, maybe they have had bad experiences. Bad experiences come in different forms. A bad experience could be going to the gym knowing that you can only really afford to spend 45 minutes there, finding that a lot of machines or benches that you need are occupied, and realizing that you're going to either (1) have to go back home, (2) settle for a sub-par workout, or (3) spend more time there than you can afford. Another bad experience could be being only a beginner at weightlifting, going to the gym and finding that there are a lot of "meatheads" there that intimidate you and make you feel uncomfortable. It is evident that timing is key in exercise, in respect to both the development of one's body and one's busy schedule and/or preferences while exercising. The problem is that it is hard for one to plan around busy hours at the gym if one doesn't know when busy hours are!

Our proposed solution to the problem of scheduling workout times is to develop a system that not only allows gym members to check how busy the gym is at a given time, but also allows them to let others know when they are using a particular machine, and even provides a means for gym members to know whether their peers went to the gym or not on a particular day, thus laying down the groundwork for some friendly competition. To accomplish this, we will implement a framework of sensors that can be installed on gym facilities that will keep track of which pieces of equipment are in use. These sensors will be linked up to a centralized microcontroller that will communicate with a gym administrator's computer, which will in turn make that information available on a web site. This way, gym members will be able to check how crowded the gym is in real time. We'll develop the website interface, and it will be designed to have time series graphs showing past and current statistics on gym usage; if time allows, we'd like to expand on this and use time series analysis to provide a "forecast" for future times, so that gym members might know what to expect. Our solution to the problem of not having a way to let others know when a particular machine is in use will be a simple red light/green light system which will be implemented by having a button on various pieces of equipment (tread mills, benches, weight machines, etc.) that a gym member can press to let others know the machine is occupied (the light will turn red). This feature will be designed in such way that it will utilize the sensor on that machine to continuously check whether or the machine is in use. After a certain time period of not sensing anyone (two minutes, for example), the light will turn green.

3. System Requirements

To develop our system, we're going to need to have sensors to detect whether or not a particular machine is actually in use and a means for sensors and microcontrollers to communicate with a centralized computer; this should be done wirelessly – we don't want to put cables in the middle of the gym. We're also going to need a way for the information about which equipment is in use to be sent out to a website and made available for everyone as an output once this information is inputted into the computer from the different microcontrollers. To make the aforementioned components work, we're going to need to have a way to power the centralized microcontroller and sensors; we'll be using batteries. We're also going to need to provide a means for gym members to let others know when they are using a particular machine. To make the website work, we're going to need to have a user interface with which the user can answer questions on a particular piece of equipment – *I wonder if the leg press machine is in use?* One last thing that needs to be addressed is that fact that we'll need to have a convenient spot to place our sensors next to each piece of equipment; while this is easy to determine for things such as treadmills or an elliptical, it is a bit more tricky for thinks such as benches in front of the weight rack, or bars that are used to do pull-ups. Another important thing to consider is that we're going to need our sensors, microcontroller, buttons, and cables to be out of people's way and to not be exposed and vulnerable to accidents. In addition to this, though, we're going to need support from the Rolf's staff; we feel that we can provide a service satisfactory enough with the system of sensors and the web interface to convince them to let us install it on their gym, but are going to need them to let us test our system out in their gym.

4. System Block Diagram

4.1 Overall System:

Our overall system can be broken up into three parts: hardware, software, and human interaction. The hardware components will provide a means to implement the communication between electronic components with a computer, while the software will perform operations on the data available and make relevant information available to gym members; all of this will rely on human interaction (both with the hardware at the gym, and with software outside of the gym). This is summarized in Figure 1, shown below.

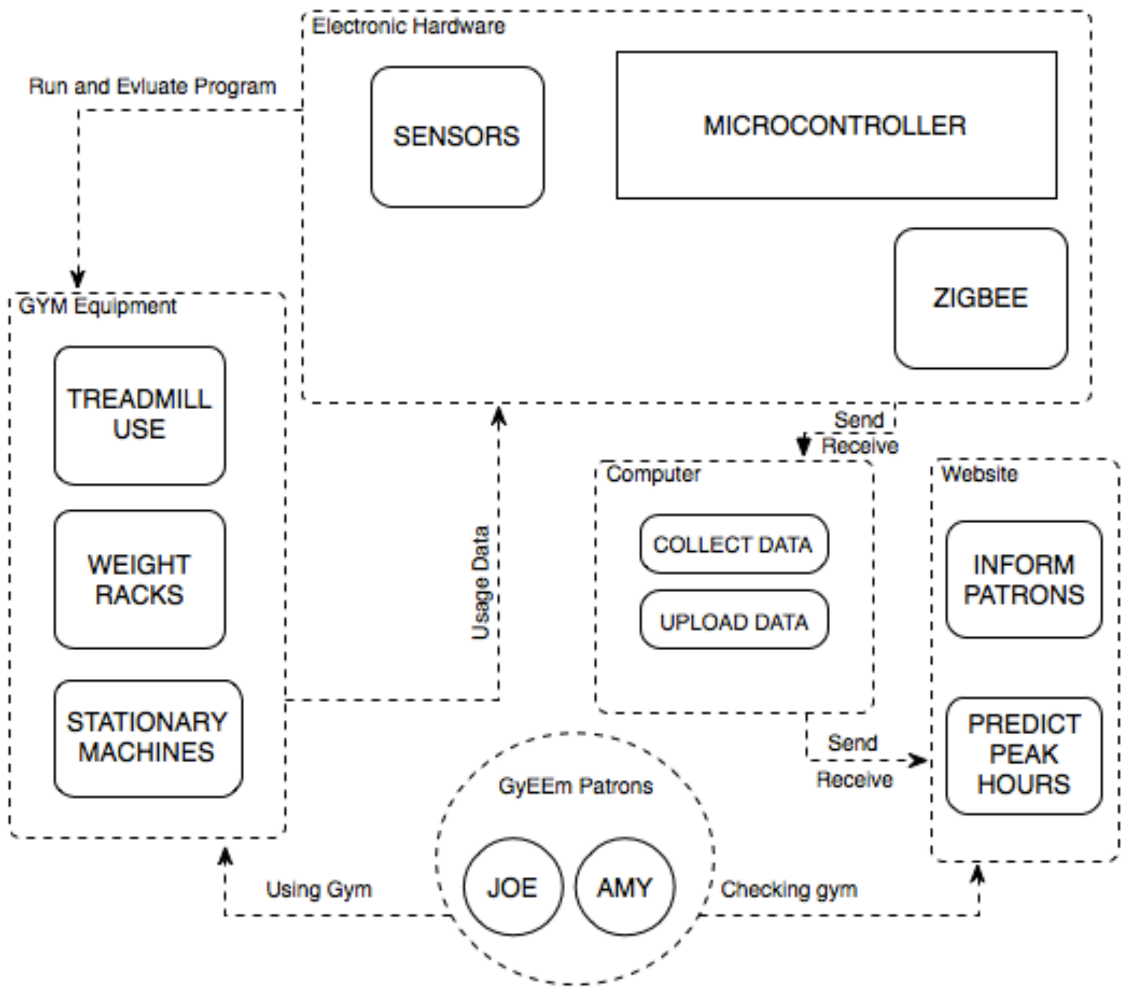

Figure 1: A block diagram describing the general functionality of our system

4.2 Subsystem and Interface Requirements:

Now we take a closer look at the requirements for each subsystem. It makes sense to look at ZigBee independently, so we consider it separately. We've broken up our subsystems as: hardware (sensor/microcontroller and computer), and software (website, data analysis). The subsystem and interface requirements are outlined in Table 1, shown below.

Table 1: An outline of subsystem and interface requirements

SUBSYSTEM AND INTERFACE REQUIREMENTS	
Hardware Requirements – Sensor and Microcontroller Combination	
General	Must be able to determine the state of the gym equipment that it is fixed to (in use or not in use)
Size	Must be packaged together in a small container in order to not interfere with the natural operation of the GyEEM
Batteries	The sensor will be powered by the microcontroller, which will use AAA batteries
Software Requirements	
Website Operation - General	Must be able to quickly and accurately display which pieces of equipment are in use and which are not
Website Operation - Display	The website must be configured in a clear manner that informs gym members of gym occupancy
Data Analysis	Must have a way to perform time series analysis on the data acquired from the sensors
Zigbee Requirements	
General	Must allow the microcontroller to efficiently transmit data to computer which will then upload all of the necessary information to website
Range	Must be able to cover range of a standard gym
Reliability	The ZigBee and its transceivers must have a long lifetime; unreliable wireless transmitter is not acceptable
Gym Equipment Requirements	
General	Must have surface to mount the sensor/microcontroller package onto
Equipment Location	Must not be close to water to ensure safety of the sensor

4.3 Future Enhancement Requirements:

We foresee that a way in which we could take our system to the next level would be to create an app for it. In this app, we'll allow gym members to have access to the same schematic that would be shown on the website displaying which pieces of equipment are in use, and which are available, and also the same times series plots showing current GyEEm usage statistics as well as the projected 'forecast.' In addition to this, we'd like to provide gym members with a way to engange in some friendly competition; our vision for this is a 'fantasy football' type system in which patrons and a selected group of friends receive points for going to the gym, and lose points for not going to the gym. This way, friends can agree to pitch in to a common pool of money at the beginning of the month and to have one point be one dollar – at the end of the month, a designated person distributes the money accordingly. The requirements for these enhancements are outlined in Table 2.

Table 2: An outline of requirements for future enhancement of the GyEEm

FUTURE ENHANCEMENT REQUIREMENTS	
App – User Interface Requirements	
Equipment Currently In Use Screen	Screen must show schematic of GyEEm equipment: displaying available equipment in green, and occupied equipment in red
Current Gym Usage Screen	Screen must show time series graphs displaying current usage statistics as well as a projected 'forecast'
'Fantasy Football' Screen	Screen must show which friends went to the GyEEm.
App – Core Logic Requirements	
Input Data – GyEEm Website	App must be able to pull usage data from the GyEEm website
Input Data – GyEEm entrance logs	App must have access to the GyEEm's logs to keep track of who worked out and who didn't on a particular day (for the 'Fantasy Football' feature).
Saving data	App must have a way to save data, so that day after day, points can be added or taken away from a particular GyEEm member (for the 'Fantasy Football' feature).
Connecting Friends	App must have a way to know who is a friend of who (for the 'Fantasy Football' feature).

5. High Level Design Decisions

5.1 Hardware Decisions:

The first decision we're going to have to make is what sensors we're going to be using, and whether we'll have (a) each of those sensors will communicate with a corresponding microcontroller and then to a centralized computer, or (b) all sensors communicate with one centralized computer. We've decided to use Sharp Proximity Sensors (GP2Y0A02YK0F), and the AT32UC3C1128C-AUT microcontroller by Amtel because it has an ADC module and allows us to communicate via an SPI interface. We'll need the ADC module because the signal from the sensor is an analog signal that needs to be converted into a digital signal in order to use the SPI. For the sake of practicality, we also decided that we'll have each sensor wired up to its own microcontroller; this is because we're confident that we can make the microcontrollers small enough for the combination (sensor and microcontroller pair) to be packaged in a small container that can be strategically placed on a piece of equipment at the gym, and that this would also make the presentation neater. We've decided that this small container is something that we can build a prototype for using the 3-D printers in Stinson Remmick – one of our team members has experience using it. From there, we decided that each of those sensor/microcontroller pairs would report to a centralized computer via ZigBee. The transceiver device that will be used is the AT86RF212B, which is compatible with all of Amtel's AVR microcontrollers (and the AT32UC3C1128C-AUT is one of them, so our microcontroller is supported by this transceiver device). The centralized computer would then use a shell script that would be ran as a chron-job (every x minutes) to get the information from the input to the website; every certain amount of time, a series of commands specified in the aforementioned shell script will be executed to take the data from where it's inputted into the computer and move it onto the website.

5.2 User Experience Decisions:

Another decision we had to make was how to provide gym members with a means to let others know that they are using a particular piece of equipment, and will be right back. We decided to implement this using a system of red/green lights, in such way that when gym member was using a particular piece of equipment, but needed to step away from it momentarily (either to do complementary exercise on another piece of equipment or to go to the bathroom, answer an important phone call, etc.), that gym member could press a button, which would in turn cause the red light to turn on. Then, the sensor and microcontroller would be used to continuously check whether there was somebody there using the equipment or not; if the gym member didn't return to that particular piece of equipment after three minutes, then the microcontroller would cause the red light to turn off, and a green light to turn on in its place.

We also had to decide how we would develop the user interface of the website. The key issue to address on this matter is that we're going to need to have the interface be designed such that the user can answer questions on a particular piece of equipment – *I wonder if the leg press machine is in use?* This would imply either providing a list of pieces of equipment and a color next to each listing to help the visitor to the website answer such a question or providing an interactive map of the gym in which the visitor can see whether a particular piece of equipment is in use, depending on its color. (The latter would be a better approach, because it's effectiveness wouldn't depend on the visitor knowing the name of the equipment he or she wishes to use.) We're going to put our microcontroller at the counter in which gym staff works; we feel like this is a good option because it's a centralized location.

5.3 Setup Logisitics:

One last issue we had to address was where we would put our sensor/microcontroller pairs. This is pretty straightforward to figure out for most pieces of equipment, but there are a few that are a bit trickier. We decided that for machines in that already have a user interface (such as a dashboard), we would take advantage of this and place our sensor/microcontroller package on that dashboard. For the benches in which people exercise using free-weights from a rack of dumbbells, we decided that we would place a two or three sensor/microcontroller pairs evenly distributed throughout the weight rack.

6. Open Questions

6.1 ZigBee Chip Transceiver

We are currently uncertain of the transceiver we will use. It would be ideal if we could find a transceiver that was able to communicate with the pic32 microcontroller family and this way use some of the initial setup from our demo presentation. Once we are set on the exact transceiver, we will have to decide if it would be ideal to have each microcontroller communicate directly to the web or to a centralized computer. This is indeed our major concern, and the one we have to resolve promptly.

6.2 Communication Method

The communication method between our microcontroller ant the transceiver is also dependent on which transceiver we use. Ideally, as we have mentioned before and from the research we have conducted most interfaces are done using SPI and that is the one we are planning to use as of now.

6.3 System Power Source

The system power source that we choose from our sensors can vary depending on the type of machine it would be mounted on. Most elliptical machines and treadmills are now connected straight to the wall. We could be able to figure an ingenious way to power our microcontroller and sensor directly from this source, rather than using batteries which is the initial plan for all of our sensors.

6.4 Delay Button

We are currently contemplating the possibility of adding a hold or delay button for each sensor. This button would add the feature of setting a machine as occupied for a couple of minutes in case the user is alternating between machines, has to go for a drink of water, etc.

6.5 Sensor Location and Mounting

The mounting of the sensor and its location on some machines seems fairly simple and non-dangerous. However, there some machines such as the weight benches or the weight racks were we have to be a little more careful on where we place our sensor. On the movable weight benches we have to be able to put our sensor in a location where it will not fall or break.

7. Major Component Costs

Our sensor/microcontroller pairs should cost about $30 (including shipping), and the cost of putting these two components together in a package would be about $2 per package; that totals to be about $32 per piece of equipment. We also have to take into account the ZigBee hardware; each AT86RF212B transceiver costs about $4 (with shipping). In conclusion, our total will be about $36 per piece of equipment; our final costs would thus depend on how many pieces of equipment we implement our system on. For now, we’ve decided that we’ll implement our system on 5 pieces of equipment. Nonetheless, we could change this in the Spring semester; the cost of components for our project summarized in Table 3 (shown below) are only an approximate of what we expect to be spending.

Table 3: Component Costs

SUMMARY OF COMPONENT COSTS	
Component	Price ($)
Sharp GP2Y0A02YK0F Sensor	5x5
Amtel AT32UC3C1128C-AUT Microcontroller	5x10
Amtel AT86RF212B Transciever	5x4
Enclosure Packaging	5x2
Led Bulb	2x5x2
Button	5x2
Total	135

8. Conclusions

We're confident that our work will be fruitful and hope that our system will end up providing a service that Notre Dame students will appreciate. In brief, we have a clear idea of how to go about implementing our system, but still need to figure out the details as to where we will place a couple of our sensor/microcontroller pairs; we feel, however, that this is something which would be much more practical to address once we have prototypes of our packaging built. We anticipate that we'll have to invest a considerable amount of work in figuring out how to use ZigBee to get the different microcontrollers to communicate with a computer, but also think that this will be our biggest challenge – once we've gotten over that hurdle, we'll have made a major breakthrough. In conclusion, we're ready for the next step, and are excited to proceed.

References

We consulted multiple websites for multiple electronics sellers including Digikey, Arrow Electronics, and All Electronics Coorporation. We also consulted the Atmel website in order to be able to look at the different microcontrollers and transceivers available, and pick one out in accordance to what was shown on their respective data sheets.