Real-Time Self-Directed Behavior and Intervention Management Framework

Capstone Design Project Final Report

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1. **Objective**

   This project aims to create a system that can use sensors to monitor the health of the user. This data can then be used in a virtual system to motivate the user to achieve good health habits.

2. **Introduction**

   Maintaining a healthy lifestyle is not simple in today’s world. When one lacks the resources or knowledge of how to maintain a healthy lifestyle, one’s health often begins to decline, and bad habits begin to form. Even when the person acknowledges that they can become more healthy, a trip to the doctor can be seen as an inconvenience, or, for some, impossible because of a lack of expenses. These patients can fall through the cracks and never recover from the bad lifestyle habits they have formed. If there were a way to more easily reach out to those who need help in creating a better life, this problem could be more easily overcome. We believe that technology today gives us the tools to solve this problem.

3. **Motivation**

   It is clear not everyone has the monetary means to take full advantage of the healthcare system, yet more and more people possess smartphones or other mobile devices. There must be a way to take advantage of the growing number of smartphone users to tackle the problem of limited healthcare. If healthcare providers could increase the amount of dialogue made through mobile phones, then perhaps people would be able to obtain more affordable healthcare.

   The only problem with this is that the healthcare officials would not be able to observe the problems of the patients in order to diagnose them. This is what this project aims to accomplish. Through the use of sensors, this project monitors the
user’s daily activity and fitness. Another issue is that the users may not want to increase their overall fitness, or even keep wearing the sensors at all.

This problem is solved through a virtual contingency management system. A normal contingency management system is a type of reinforcement that provides rewards for the user achieving a higher state of health. The objective of this project is to create virtual rewards that the user can achieve through their results in the real world.

4. Theory and Implementation

4.1. Contingency Management

The main theory behind this project is that of Contingency Management. Contingency Management is a type of treatment that rewards patients for good behavior. The goal behind the theory is to observe the patient’s progress along his or her proposed treatment, while rewarding them as they achieve better and better states of health.\[1\] Maintaining good habits must be reinforced, therefore the rewards are given to the patient as they transition to better and better states of health. Also, rewards are to be removed if the patient is showing signs of regressing back into bad habits. An example of some health states is shown in Figure 1:
While this is a basic example, it shows all that is necessary for an understanding of Contingency Management. The transition between states is simply if the user is following his or her treatment. If the user does, they move to a state that represents better health. The time between measurements of the patient can be any amount of time: hours, days, even weeks. Now that knowledge of Contingency Management is in place, it begs several questions: how can the patient’s health be measured, and what kind of rewards can we possibly afford to give the patients?

4.2. **Shimmer Sensors**

The answer to the first question lies in the sensors created by Shimmer. Shimmer is a company that produces lightweight sensors that can be worn on any part of the body, with minimal annoyance. Because these sensors are lightweight and attractive, they seemed like the ideal piece of equipment for this project.
However, because the sensors measure such concrete data, a declaration of what a “healthy lifestyle” is must be made. For the purpose of this project, we have decided (in simple terms) that a measurably healthy lifestyle consists of a healthy diet along with an amount of exercise per day. To measure these results, we have chosen to use the GSR and ECG Shimmer sensors.\[2\]

![Figure 2: Example of Shimmer sensor being worn on wrist](image)

The first sensor is the GSR, or Galvanic Skin Response, sensor, shown in Figure 2. This sensor measures the electrical conductance of the skin. Electrical conductance in this case varies by the amount of moisture on the surface of the skin, which means this sensor essentially measures the amount of sweat created by the user. Measuring the amount of sweat created would not alone suffice for monitoring health, since patients can perspire when not exercising. Because of this, the ECG Shimmer sensor was chosen to supplement the GSR.

The ECG, or electrocardiogram, sensor measures the heart rate of the user. This sensor is slightly more involved, as it requires three attachments to the chest of the user. The electrodes placed on the chest are wired directly to the sensor in order to achieve the most accurate results. Additionally, both sensors are able to measure 3-axis accelerometer values.
We believe that through these two sensors, the user’s health can be monitored very easily. The Shimmer sensors log the data throughout the day, which allows for observations to be made on the stored data. For example, if the user’s heart rate increased at the same time that the user was producing sweat over an interval of 30 or more minutes, we can conclude that the user had been doing rigorous activity during their day, which in this case constitutes exercise. This, along with dietary input can allow us to observe if the user is truly making progress in achieving a healthy lifestyle.

4.3. **Shimmer Application**

The question remains as to how all of this data is made available to the user. Smartphones are becoming more and more prevalent across all areas of the world, as it gives you a wide array of information at your fingertips. We want the access of this system to be as painless as possible, to keep the user engaged. Therefore we have created the entire system on the Android operating system. This allows the user to observe his or her progress in a matter of seconds, whereas a program online may take several minutes to access. Creating an easy to access system is important, as it is the goal of the system to keep the user involved and motivated to reach a healthy lifestyle. If it took too long to access the system, the user may become disinterested, and they may even stop following their treatment guidelines.

Shimmer provides extensive documentation to observe the data obtained by the sensors via a computer, but less so via a mobile device.\[2\] Because of this, a new mobile application had to be created. This application is able to connect to the sensors via Bluetooth, and it can monitor them in real time. This application can also observe the stored data, and make checks to see if the user has been exercising.
4.4. Virtual Rewards

Now that we know that the patient’s health can be monitored remotely, this still leaves the question of rewards. Normal Contingency Management systems give monetary rewards, such as coupons, or vouchers. This is clearly not an optimal solution for the long run, or for large systems with many users. Because these real life rewards seem implausible to give out, the concept of virtual rewards was explored. If there is a way to motivate users by giving them virtual rewards for their real life accomplishments, then the overall cost of the system decreased dramatically.

There are many ways that virtual rewards can be given out, but for this project, we chose the concept of a mobile game. Mobile applications are becoming one of the hottest markets, with week old games sometimes achieving download
numbers in the millions. We want our product to be able to reach as wide of a demographic as possible, and a mobile game seems like a perfect route to do so. The virtual rewards in this case become very simple in concept. As your health increases, you achieve more upgrades in the game, and, ideally, as you obtain more upgrades, you have more fun playing the game, encouraging you to increase your fitness and obtain even more upgrades.

The game chosen is created based off of a sample game in the Unity game engine. The “Space Shooter” game created is simple enough to draw the user in with little introduction, yet deep enough to allow the user to rack up more and more points based on their skill and dexterity.

The open source version of the game is made for personal computers, so it had to be ported over to android. After this, adjustments were made to allow the user to control the ship using the gyroscope inside the mobile device, tilting the device to move the ship. Again, adjustments were made to allow the ship to fire whenever the touchscreen was pressed. The original game came with only one level, and the final version now has a far greater number of levels, with enemy boss ships thrown in to add more depth to the game. The upgrades available also add more depth to the game, some changing the way the ship fires its shots, to bombs that can clear the enemies on screen in a pinch. Some of these upgrades are shown in Figure 4. Again, these upgrades can only be obtained by achieving a healthy lifestyle.
Another form of virtual motivation is achieved through Facebook integration of the mobile game.\textsuperscript{[4]} If the user is simply playing the game by his or herself constantly, they may feel lonely or demotivated. The Facebook integration of the game makes sure the user will not feel alone in their situation. The user can check if they have any friends who are using the mobile game, and in addition, they can find other users who are undergoing the same specific treatment as them. This allows the users to form a kind of community between themselves, showing them that they are not the only ones going through hardships. Through Facebook, users can share their scores with their friends and communities, and achieve smaller upgrades by doing so. If a user sees that their friend has a higher score than them, they may try harder to achieve their fitness goals to get the upgrades they need to score higher. The friendly competition created can provide an additional way to motivate users to become healthier.
4.5. Integration

The individual parts of this project have been outlined earlier, but their integration has not been mentioned as of yet. The basics of the integration can be seen in a simplified UML diagram, shown in Figure 6.

The process begins with the Shimmer sensors collecting data from the user throughout the day. The sensors constantly send the collected data to the Shimmer application on the mobile device. This application then does transformations on the data to check if the user had undergone exercise during that day. Based on this data, the Shimmer application changes the state of the user. If the user had shown healthy lifestyle choices, then he or she moves to a higher state of fitness.
Otherwise, they move to a lower state. The difference in state is then sent to the mobile game, which will give upgrades based on the current state compared to the previous state. The changes in the game, good or bad, should motivate the user to perform better or to maintain the healthy lifestyle that they have achieved.

![Figure 6: UML Diagram](image)

5. **Cost/Sustainability Analysis**

The set costs of this system are the sensors and necessity of a smartphone or tablet device. The Shimmer sensors each cost around $300, with a $30 cost for electrodes every few weeks (for this case, say, every two weeks). There also lies the fixed cost of actually obtaining a smartphone or tablet device. These devices can cost anywhere from $100 to $400 for current generation devices.

One issue about the sustainability of this system is the necessity to integrate medical facilities with the application. In order for the application to have a purpose, it needs to be first recommended by a healthcare official to the patient. Furthermore, the healthcare official needs to be able to monitor the patient’s health.
through the application as well. This creates two barriers that need to be crossed for the application to become worthwhile.

The variable costs are more difficult to calculate. In the case that the user does intend to use the sensors, there are still some healthcare costs involved. There needs to be an initial visit to the healthcare official to prescribe a treatment plan for the user. After this, there only needs to be rare correspondence between the user and healthcare official, mainly if something goes wrong with the treatment. Otherwise, the majority of the healthcare costs are eliminated in this case, because the patient is chosen to maintain his or her own health.

In the case that the user elects not to use the health monitoring services this system provides, there are other costs involved. There will still be the initial visit to see what kind of treatment plan the patient should follow, however there will be more follow up visits as well. In fact, there may be even more follow up visits than necessary, for the patient may not be following their treatment as they should. If the patient does not have the motivation to follow his or her treatment, there will be even more follow up visits than necessary, increasing the overall price they are paying.

The choice between using the materials this system provides versus not using them largely hinges on the availability and price of health care. If healthcare is largely inexpensive, not using this system may be the correct option. However, if healthcare is expensive, or even simply not widely available, this system may be worth the ~$800 investment so that the patient will not have to make more than a few total visits to see healthcare officials. Additionally, as the price of these sensors decreases, the more attractive this system becomes. If healthcare officials were able to easily observe the actions of their patients via these sensors, they
would be able to treat a larger number people in a much shorter amount of time, giving more attention only to those who are not exactly following their treatments.

6. Conclusion

Our project has shown that there is a definite application for sensors such as those made by Shimmer in the use of health monitoring. The ease of measurements and ability to make transformations based on the data makes Shimmer sensors very attractive for any project that plans to observe the health of patients daily.

We are happy with the concept of Virtual Contingency Management, and we solidly believe that giving virtual rewards for real life actions can be a valid way to reward consumers in today’s world. In fact, members of this generation are thoroughly involved with the virtual world already, so virtual rewards may be just as good as real life rewards.

We have also seen that there are many possibilities for creating a virtual reward system, specifically ones that give rewards through mobile devices. The game we created is a good starting point to show how rewards can be given out, but we believe that there are even more intelligent ways to allocate rewards yet to be discovered.

In the future, we would like to work on this project again if there is progress made in the area of sensor development. The current sensors are a bit expensive, and they are still somewhat large. If the price and size of the sensors decrease, this project may soon become a reality. The virtual world is here to stay, and the first team to integrate health monitoring systems with mobile devices will be very successful.
7. References


