World of Workout: A Contextual Mobile RPG to Encourage Long Term Fitness

Joey Bartley
Department of Computer Science & Engineering
Texas A&M University
bart1739@tamu.edu

Jonathon Forsyth
Department of Computer Science & Engineering
Texas A&M University
jonathonforsyth@tamu.edu

Prachi Pendse
Department of Computer Science & Engineering
Texas A&M University
prachirp@tamu.edu

Da Xin
Department of Computer Science & Engineering
Texas A&M University
daxin@tamu.edu

Garrett Brown
Department of Computer Science & Engineering
Texas A&M University
gbrown09@tamu.edu

Paul Hagseth
Department of Computer Science & Engineering
Texas A&M University
pehagseth@tamu.edu

Ashish Agrawal
Department of Computer Science & Engineering
Texas A&M University
ashish1308@tamu.edu

Daniel W. Goldberg
Department of Geography
Texas A&M University
daniel.goldberg@tamu.edu

Tracy Hammond
Department of Computer Science & Engineering
Texas A&M University
hammond@tamu.edu

ABSTRACT

In today's digital world many individuals spend their day in front of a computer or mobile phone for entertainment. Individuals enjoy a more sedentary lifestyle from advances in technology. This is one of the leading factors contributing to a decrease in fitness level for large parts of the populations in developed countries. We want to design a mobile role-playing game (RPG) where the character evolves based on the exercises the user performs in reality. This design can motivate and persuade a potentially large demographic of users to engage in physical activity for an extended period of time through the enjoyment of an engaging game. This novel application has shown the capability of automatically identifying and counting the exercises performed by the user. This automatic activity recognition and numeration is performed solely through the accelerometer of a single smartphone held by the user while exercising. The type and amount of exercise improve the characters speed, strength, and stamina based on the type and amount of exercise performed.

Categories and Subject Descriptors

J.3 [**Life and medical sciences**]: Health; H.1.2 [**Models and principles**]: User/Machine Systems—*Human factors*; H.5.2 [**Information interfaces and presentation**]: User Interfaces—*User-centered design*; I.2.1 [**Artificial Intelligence**]: Applications and Expert Systems—*Games*

General Terms

Human Factors

Keywords

Exergaming, Motivation, Fitness, Activity Recognition, Pattern Recognition, Gaming, Smartphones, Wearable Computing, Location, GIS, Health.

Second International ACM SIGSPATIAL Workshop on HealthGIS (HealthGIS'13), November 5, 2013. Orlando, FL, USA
Copyright (c) 2013 ACM ISBN 978-1-4503-1703-0/12/11 ...$15.00.

1. INTRODUCTION

In the past decade mobile phone gaming has drastically increased, as smart phones now allow the inclusion of sensors and interfaces between the device and the user. These new mobile interfaces aim to tie games with actions in the physical world, encouraging users to avoid a sedentary lifestyle. The combination of mobile games with environmental interaction attempts to improve physical well-being by motivating exercise and significantly reducing the perception of fatigue. These types of applications attempt to combine exercising and gaming, and have been dubbed as "exergaming". Several clear examples of this concept include Nintendo's Wii Fit[1], Konami's Dance Dance Revolution[2], and Microsoft's Kinect console[3].

Most exergaming participants play the game for a short period of time due to lack of continuing motivation [13].

[1]http://wiifit.com
[2]http://www.ddrgame.com/
[3]http://www.xbox.com/en-US/kinect

The novelty of today's exergaming applications either wears off quickly or fails to provide the user with proper fitness guidelines. The specific types of exercises that integrate with these games are also limited to a few basic categories of motions [15]. A strong link between in-game progress and real-world progress needs to be enhanced in the exergaming market [10]. One-dimensional tracking systems have been designed in several types of exergames to track distance run or steps taken, but these do not provide a complete picture of physical activity, which is crucial.

In this paper, we aim to provide a complete physical activity system with continual motivation through our exergaming model, developed into an application called World of Workout. This game provides a large selection of exercises using sensors widely available in smartphones, allowing physical activity recording on a wide selection of devices. We also provide several channels of feedback for both long and short-term drive, which encourages users to exercise regularly. A strong tie between a user's workout routine and gameplay makes the incentive of exergaming more direct.

By having a correlation between game play and the exercises performed by the user, we encourage progress in multiple aspects of a proper fitness routine while keeping the user entertained. This correlation improves the previous single-focus models, such as track only cardiovascular statistics. We consulted health care professionals during the development process to verify the quality of exercise and to make sure the recorded activities are appropriate. Finally, we implement methods such as triggers, randomization, and accelerated progress for continued motivation.

2. RELATED WORK

Many applications have been released on the smart phone market to encourage exercise activities but either focus solely on short or long-term motivation. For full benefit to the user, the application utilizes both forms to encourage the user to become and stay fit. The key is to find a balance using a myriad of motivation techniques in an integrated system to captivate the user[5][6].

2.1 Computer-Based Motivation

The use of computers for the purpose of behavior modification was originally considered science fiction [14]. The inability of a static-state system to measure the user's activity patterns played a major role in supporting this paradigm. However modern studies have started building behavioral modeling to help encourage and measure sustained use[3][11]. Motivational applications can be divided into three model categories of analytic, social, and affect. Our system borrows from all three, but is mainly designed as an affect model where the user's progress affects an avatar to represent the progress of the user and increase retention [9]. The system includes social model aspect where users can play with friends, but does not include a global leader board since many users may become discouraged with high performing individuals who can work at an elevated pace. The final behavior model is a factual model where users see statistics, which this system enables, but it is not the focus.

2.2 Existing Applications

ZombiesRun! [1] is a mobile application designed to add entertainment value to running or jogging. The game works by playing the sounds of a zombie apocalypse to the user as he or she runs. It encourages the user to run faster and farther through a scenario of critical danger. This approach lacks a long-term motivation component because the application cannot adapt for long-term effect. This means that the runner can become quickly bored of the once-novel zombie environment. Another famous application that suffers from lack of long-term use is Nike Run, which has prerecorded statements from famous athletes to encourage the user.

Walk2Build [8] is another application on the market that encourages fitness but unlike ZombiesRun! [1]. This application lacks immediate motivational feedback. The game records the number of steps taken by the user and converts this number to currency in a Sim-style world, building a city. The more the user walks or runs, the bigger the city gets, showing the user the results of his or her efforts. However, getting to a large city takes a long time, and users can fall short due to lack of immediate reward [7].

3. IMPLEMENTATION

3.1 System Architecture

The World of Workout system architecture divides the project into three main levels as shown in Figure 1. The user level demonstrates how the individual actually interacts with the system, which is performed through mobile phones, a web page, and sensors. The logic level demonstrates how the application works and is divided into the exercising and gaming engines respectively with added components. The last level is the data level that stores all information and interacts with the program through HTTP and a server.

3.2 User's Perspective of the Application

From the user's perspective the World of Workout application is divided into three separate components. The webpage, which runs on Apache Server and PHP, is used for all server side scripting. It acts solely as an interface to the MySQL database from which the user can check his or her statistics and information. The webpage provides a convenient way to modify the user profile and allows the individual to review his or her data on a monitor instead of a small phone screen. Through the website, the user can have a larger display of his or her progress easily accessible via a web interface to update his or her current workout regime.

The second component is the game itself. It is built using the libraries and structures of AndEngine[4], which is an open-source Android game platform. The game play entails the user exploring and trying to survive in a post-apocalyptic world, fending off monsters and other survivors. A unique avatar is controlled by the user. This avatar becomes stronger based on the real world exercises the user performs.

The exercise engine monitors users' activities and uses those activities to improve the strength, speed, and stamina of the avatar. It contains a robust user interface that allows the user to navigate and choose from a variety of exercises to perform. The engine connects to the server and is able to access and modify each user's exercise data in the database so that new physical activities can be made available to the rest of the application.

[4]http://www.andengine.org/

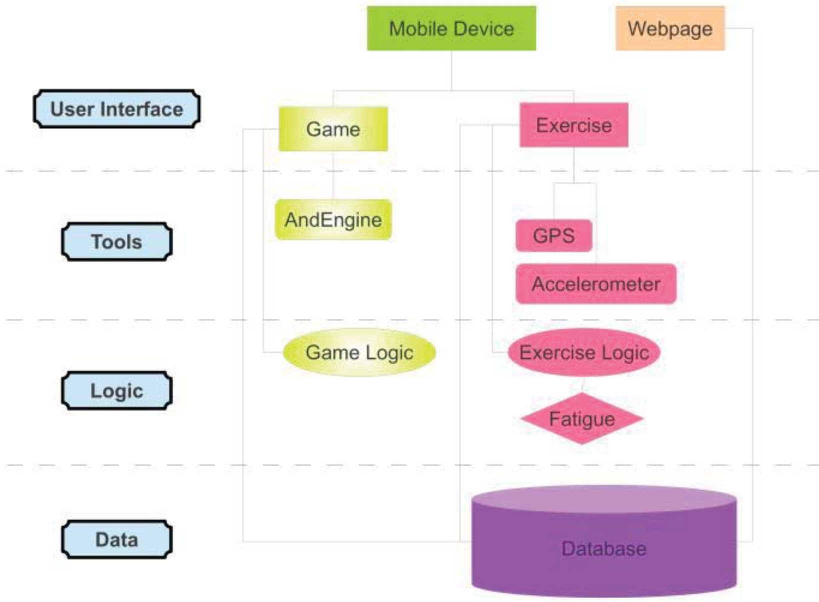

Figure 1: System architecture representation with game and exercise parts highlighted.

The application uses GPS and accelerometer in user's smartphone to record and identify exercises. We separate the activities into two groups stationary and moving. Pushups, jumping jacks, and sit-ups are considered stationary as they have a little to none user displacement and exercises like walking, running and sprinting are considered moving. We use accelerometer to recognize stationary exercises and moving exercises are recognized by analyzing GPS information.

When the user wants to exercise, he or she will either browse and select a particular activity or let the engine pick a random activity. The engine will use the appropriate sensor to track the number and intensity of the chosen exercise. Once the activity is completed, the user will be shown his or her results and the database will be updated giving the user credit for exercises performed. The system can also automatically detect self-imposed exercise as described in the activity recognition section below.

3.3 Interactions within the Platform

The exercise and game engines themselves interact with each other through three statistics: speed, strength, and stamina. Each of these values increases when the user performs corresponding types of exercises. For instance, running long distances increases stamina while sprinting increases speed. The values that are recorded through the phone sensors go through a logic algorithm located on the server that determines new statistics for the character[12]. When the game starts, it reads these statistics and alters the user's avatar accordingly (Figure 2). This direct correlation allows users to see how each exercise helps their personal fitness by noting what attributes are increased.

Our logic algorithm is based on a logistic function based on two attributes. The first attribute is accelerated improvement when the user is initially increasing his or her amount of exercise, so the user can see improvement quicker in the game than in real life and will be encouraged to keep working out. This technique was designed to persuade the user to keep using the app past the initial period of use where the benefits of exercise are not readily seen [2]. This way, users can see the improvements in the early timeline, keep their motivation, and press on with more rigor.

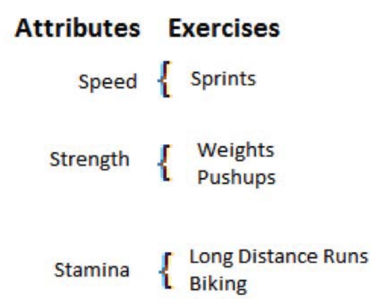

Figure 2: In-game avatar attributes.

The second attribute is an imposed bound past which additional exercise does not improve the user's in-game character statistics. Studies show that falling into the same routine lowers the benefit of that particular exercise, thus the system encourages users to change it up or work harder[4]. This attribute represents a fatigue factor, discussed below.

A final feature of the app is a random-reward function. After a given length of time, the game recommends a particular exercise to the user for him or her to perform. This helps remind the individual to work out as well as expand

Figure 3: Screen shot of example world.

his or her knowledge of what activities benefit progress in the game. This trigger gives a reward by unlocking bonus statistics for the avatar to compel the user to stay active.

3.4 Activity recognition

In order to provide the user with additional motivation to exercise, our system can automatically recognize and count a user's activities, such as jumping jacks and sit ups, without having to specifically specify the exercise being performed. The user must first calibrate each exercise by labeling specific exercise. Each exercise is classified using accelerometer data. By automatically recognizing activities performed by the user, we provide a better game experience, as hand-entry of exercise can be problematic, and users will lose focus.

3.5 Gameplay

The game itself is designed to be a never-ending survival story that is based on the style of gameplay from previously successful games such as World of Warcraft and Diablo. These games have been shown to retain users for extended periods of time by adding the element of investment and individuality. We took some of the concepts and developed them into our game. We created several zones where characters with certain statistics can thrive to better accommodate the wide variety of users we plan on reaching. Some individuals will inevitably build stronger or faster avatars than others, and our system creates a positive incentive for everyone by rewarding exercise from a variety of approaches. Random rewards can also boost characters so they can enjoy new realms they were not able to previously. The end goal of the system is to encourage the user to improve through positive feedback that continues to entertain. Hence, the game map itself mirrors increasing difficulty and rewards for the users in game characteristics as they become faster, stronger, and able to endure longer.

3.6 Technical Considerations

To ensure a smooth user experience, we isolate each of its components to reduce background consumption of resources. Both game and exercise engines read and update from the database only at startup and at closing. The exercise application and the game application currently run separately, with the game receiving the values of strength, stamina, and speed, as well as relevant game data such as status and current bonuses only when the user begins or switches to game mode. The exercise component has a logic system included within the engine that updates the database with improvements recorded at the end of each workout. The logic rules were designed based on input from consultation with the Texas A&M Kinesiology Department. This is critical for our system since a large quantity of health applications on the market today have no oversight from health care professionals. In this way we have accounted for the application's accuracy and user's safety.

3.7 Fatigue factor

Our application utilizes a novel approach to balance a user's workout through the system's automatic calculation of a fatigue factor. A system of diminishing returns encourages the users of the application to exercise in a safe manner. Diminishing returns from performing the same exercise helps to make sure the user does not overwork themselves. The app gives less credit for the same exercises if the user is performing or increasing these exercises at unsafe levels. For example, running 20 miles every day non-stop without letting the body rest is an unsafe exercise and the user will see little to no more improvement in avatar statistics for the 21st mile after the 5th mile. This also attempts to discourage users from cheating the system. If a user tries to trick the system by simply moving his or her foot while sitting down to simulate running, the application will eventually give no credit for this. The last advantage of fatigue correlates with the accelerometer and the ability to see when certain activity thresholds are reached. As a person works out, he or she gets tired and their actions are not as accurate. For example, the user may not reach a 90-degree angle between biceps and forearms when doing the last pushup in a workout. The system attempts communicate to the user whenever form decomposes in a way that makes sense and describes how to improve.

4. EVALUATION

We conducted a user study on ten students at Texas A&M who are currently working on their undergraduate degrees. During the study, we collected demographic information and to help baseline fitness levels for our sample users. About half of these individuals work out more than once a week, while the rest were more sporadic. A few had prior experience with fitness applications. Examples of these applications include GPS Run Tracker, World of Fitness, and My Fitness Pal.

Additionally, we performed several experiments testing our automatic identification and numeration of various exercises.

5. RESULTS

In terms of in-game character statistics, users rated stamina as the most important and speed as least important to their perspectives of fitness. They also rated a series of 15 questions on a scale of one to five. The two highest rated questions, both with ratings of 4.8 out of 5, were ease of use of the GPS exercise tracking and the variety of activities that the application supports. The average ratings from the questionnaire are listed in Table 1.

5.1 Exercise engine

Table 1: User Study Results

Feature	Average Rating
Accuracy of movement tracking	4.67
Ease of GPS Use	4.83
Likeliness of GPS re-use	4.39
Jumping jack measurement accuracy	4.13
Push-up measurement accuracy	3.50
Cruches measurement accuracy	4.00
Ease of Accelerometer Measurement	3.83
Variety of Activities	4.83
Recognition of Character Improvement	4.61
Game Enjoyment	3.89
Likelihood of Future Gameplay	3.72
Recognized Correlation of Exercise to Game	4.06
Likelihood of Future Exercise	4.06
Motivation to Exercise	3.94
Rating Compared to Similar Apps	4.25

Our exercise engine tracked a distance activity with the GPS. The GPS logs the distance traveled and saves a set of points to keep the route using the Google API 4. In our study, we wanted users to simply move around campus and see if they were happy with the tracking capabilities.

The accelerometer was successful in recording data that can quantify the numbers of exercises completed. The application can also identify "weak" performance activities in a set or ones that have a low-recorded threshold (such as a jumping jack from a fatigued user). The ability to differentiate particular activities proved difficult due to the variable sizes of users, emphasizing the need for user calibration. The following figures display sample data from various activities that were successfully automatically identified and counted. Future work includes developing an automatic identification algorithm that works for users of a variety of sizes, shape, and form. Additional devices placed on the body may help unify user performance, as currently different users may place the phone in different parts of their body when exercising (such as in their hand versus in their pocket).

5.2 Recognition Results

After collecting accelerometer data from activities we have found two key patterns. We have designated these patterns W and M patterns respectively. The W pattern results from an activity that has a spiked motion or quick linear motions. Weight presses are examples of a spiking motion activity where the user quickly lift weights straight up and down. Figure 7 and 8 show the complete accelerometer data followed by a clean W pattern for recognition.

The second pattern is the M pattern that comes from circular activities where the phone follows a circular path. Lunges register as a circular activity since the phone travels in an oval circuit. Figure 9 and 10 show a simple circle pattern of the phone to make it easy to visualize.

By identifying these particular patterns, the system can classify activities into subsections for analysis. Classification is much preferred to user-performed identification and can help increase the accuracy of our application and expand the variety of exercises that the user can perform. To illustrate

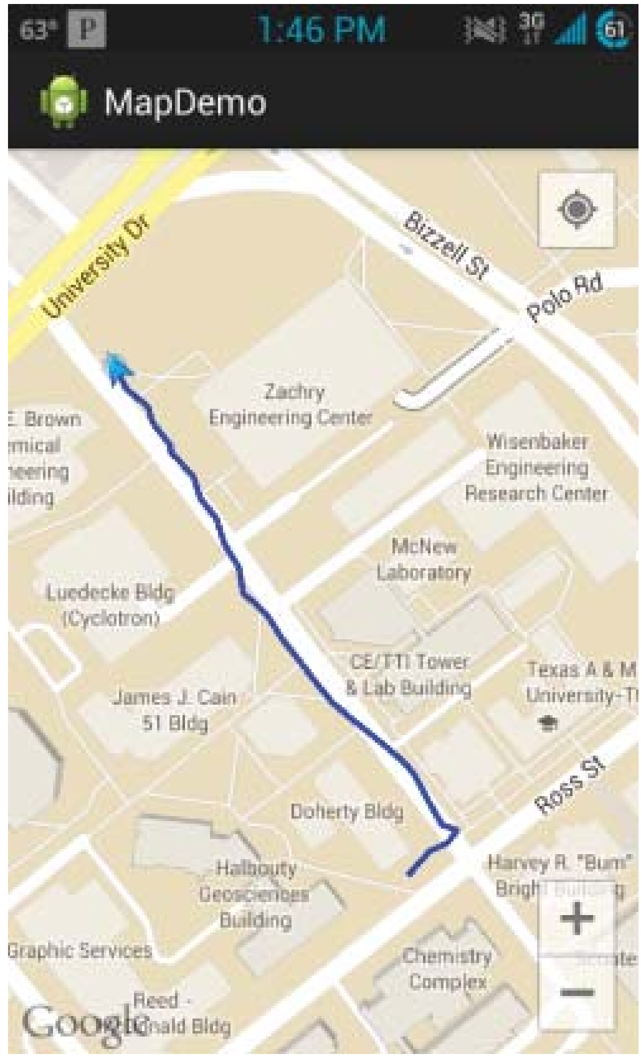

Figure 4: Distance demo.

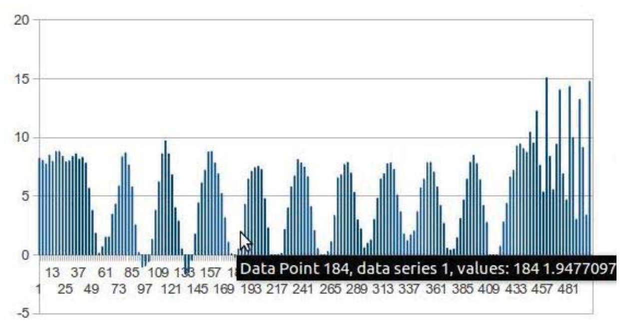

Figure 5: Z-axis change for various activities.

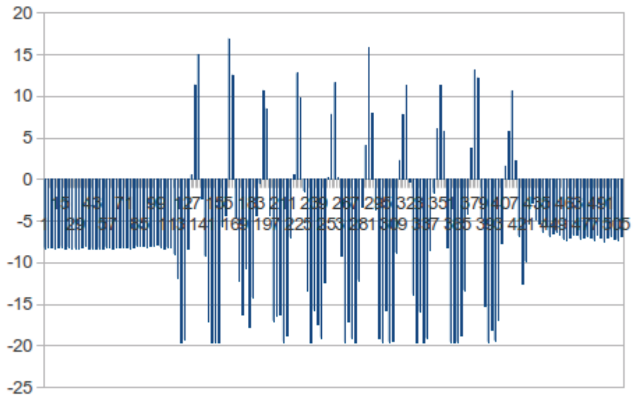

Figure 6: Data from pushups.

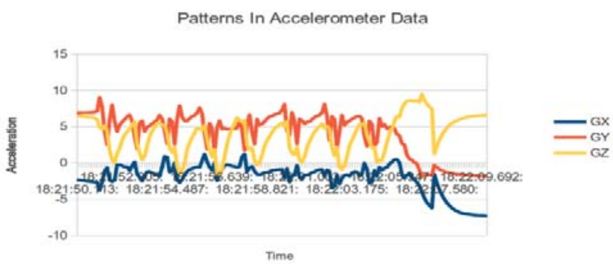

Figure 7: Spiked activity data.

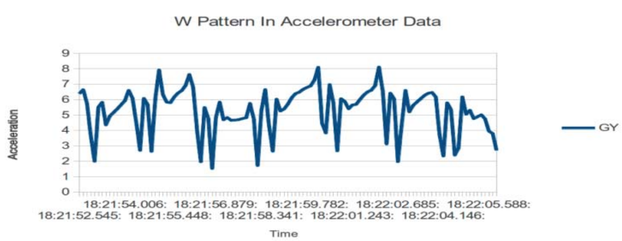

Figure 8: W pattern in Y direction.

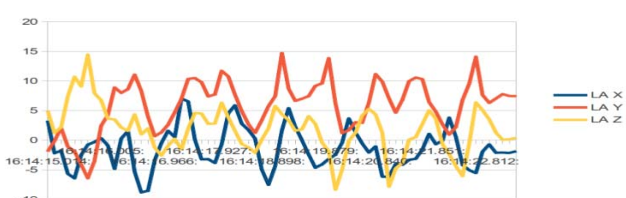

Figure 9: Circular activity data .

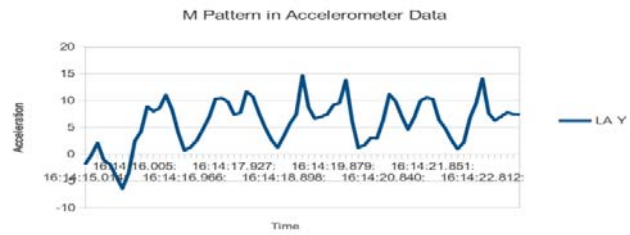

Figure 10: M pattern in Y direction.

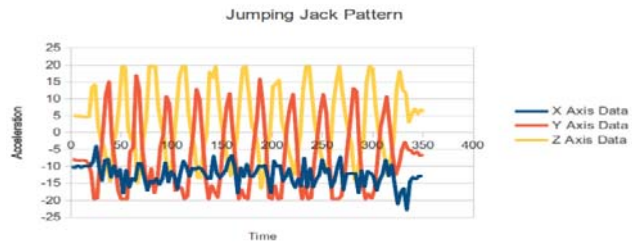

Figure 11: Jumping Jack data.

this point, jumping jacks have a spike motion as the user is rapidly moving in linear paths if the user holds the phone in his or her hand. The phone however travels in an arc, which means we should expect an M pattern influence. Figure 11 represents an actual result from jumping jacks.

As we hypothesized, experimental results confirm an evident W pattern in the Y and Z axes. However looking at the X-axis shows an M pattern intertwined with the W pattern since the activity follows an arc path. Our ability to classify these patterns allows for easier addition of new activities and analysis of their results since the output usually follows a predetermined graphical outline.

The most obvious patterns extracted from varying exercises have given us the ability to implement simple classification algorithms directly on the phone. The system readily identifies the difference between crunches and jumping jacks, for example. Moreover, this activity identification works in tandem with the live character statistics to deliver an instant bonus to the player. As we have noted, an exercise like jumping jacks can, not only be identified, but also improves the corresponding aspect of the character's in-game abilities.

6. FUTURE WORK

As a consequence of our user study, we have identified that the draw of the gameplay is an important aspect of this project. The effectiveness of gamified workout applications directly ties to the interest generated by playing the game. Numerous sedentary games exist that allow the avatar to improve in multiple dimensions, but no exergaming games exist that allow the avatar to improve in multiple dimensions based on different types of exercises performed by the user.

7. CONCLUSION

This project aims to improve upon existing exergaming mobile applications by developing an addictive role-playing game where a player's in-game character evolves in response

Figure 12: Game user interface.

to exercise in real life. Expansion of the concept of exergaming in our research involves the combination of short- and long-term motivation. We see the achievement of this through the instant gratification of gameplay and the cumulative increase in avatar abilities.

The results of both our study and previous work in mobile gaming show not only that this market is competitive, but also that it has an edge on console games in the realm of fitness applications. The system has a low price of entry for users due to the ubiquity of smartphone hardware that supports sophisticated sensor integration like GPS, accelerometer, electronic compass, and hi-resolution sound and imaging. Data from our investigation also shows how insights pulled from accelerometer readings provide a high level of detail.

Incorporating this information into fitness applications can benefit the mobile exergaming market. Given that users hold the phone in a variety of manners during exercise, we believe our system would benefit from additional wearable sensors to improve activity recognition. Our study shows that the combination of multiple input channels from various types of sensors allows improved accuracy for recognizing input from physical activity.

Overall, we found that a direct connection between exercise and in-game progress creates an effective motivational basis for exergaming. Although users pointed to several areas for improvement in our gaming and tracking systems, their response to the incentive method gives us confidence that mobile fitness applications will benefit from shifting to a reflective representation of progress. Through our test application, World of Workout, we have found reason to augment exergaming with reward and feedback concepts from persuasive technology, real time responses on a mobile platform, fatigue considerations from sports medicine, and an addictive gaming context in a way that keeps users engaged in long-term fitness.

8. ACKNOWLEDGMENTS

This application was developed as a senior design project at Texas A&M University. We would like to thank Paul Taele, Manoj Prasad, Dustin Joubert, and our fellow senior design classmates for giving us helpful feedback. We would also like to thank the Department of Computer Science and Engineering at Texas A&M for funds and equipment they provided.

9. REFERENCES

[1] Zombies run! https://www.zombiesrungame.com. 2011.

[2] S. Berkovsky, J. Freyne, D. B. Mac Coombe, and N. Baghaei. Physical activity motivating games: you can play, mate! In *IHI '12*. Proceedings of the 2nd ACM SIGHIT International Health Informatics Symposium, 2012.

[3] P. Bielik, M. Tomlein, S. M. Peter Kratky, M. Barla, and M. Bielikova. Move2play: an innovative approach to encouraging people to be more physically active. In *IHI '12*. Proceedings of the 2nd ACM SIGHIT International Health Informatics Symposium, 2012.

[4] L. T. Cowan, S. A. V. Wagenen, B. A. Brown, R. J. Hedin, Y. Seino-Stephan, P. C. Hall, and J. H. West. Apps of steel: Are exercise apps providing consumers with realistic expectations?: A content analysis of exercise apps for presence of behavior change theory. *Health Educ Behav*, 2012.

[5] B. Fogg. A behavior model for persuasive design. In *Persuasive '09*. In Proceedings of the 4th International Conference on Persuasive Technology, 2009.

[6] B. Fogg. Creating persuasive technologies: an eight-step design process. In *Persuasive '09*. In Proceedings of the 4th International Conference on Persuasive Technology, 2009.

[7] L. Gorgu, A. G. Campbell, K. McCusker, M. Dragone, M. J. O'Grady, N. E. O'Connor, and G. M. P. O'Hare. Freegaming: mobile, collaborative, adaptive and augmented exergaming. In *MoMM '10*. In Proceedings of the 8th International Conference on Advances in Mobile Computing and Multimedia, 2010.

[8] I. Hamilton, G. Imperatore, M. D. Dunlop, D. Rowe, and A. Hewitt. Walk2build: a gps game for mobile exergaming with city visualization. In *MobileHCI '12*. In Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services companion, 2012.

[9] A. C. King, E. B. Hekler, L. A. Grieco, S. J. Winter, J. L. Sheats, matthew P. Buman, B. Banerjee, T. N. Robinson, and J. Cirimele. Harnessing different motivational frames via. mobile phones to promote daily physical activity and reduce sedentary behavior in aging adults. *PLoS ONE*, 2013.

[10] G. K. Nee and M. S. B. A. Bakar. Android- based exercise application. In *ICCIS '12*. International Conference on Computer and Information Science, 2012.

[11] K. G. Stanley, I. Livingston, A. Bandurka, R. Kapiszka, and R. L. Mandryk. Pinizoro: a gps-based exercise game for families. In *Futureplay '10*. Proceedings of the International Academic Conference on the Future of Game Design and Technology, 2010.

[12] K. G. Stanley, D. Pinelle, D. M. Alan Bandurka, and R. L. Mandryk. Integrating cumulative context into computer games. In *Future Play '08*. In Proceedings of the 2008 Conference on Future Play: Research, Play, Share, 2008.

[13] G. B. Svendsen, Y. Soholt, A. Munch-Ellingsen, D. Gammon, and A. Schurmann. The importance of being useful and fun: Factors influencing intention to use a mobile system motivating for physical activity. In *HICSS '09*. 42nd Hawaii International Conference on System Sciences, 2009.

[14] H. Tobiasson, A. Hedman, and Y. Sundblad. Design space and opportunities for physical movement participation in everyday life. In *OzCHI '12*. In Proceedings of the 24th Australian Computer-Human Interaction Conference, 2012.

[15] A. Whitehead, H. Johnston, and a. J. W. Nicole Nixon. Exergame effectiveness: what the numbers can tell us. *Proceedings of the 5th ACM SIGGRAPH Symposium on Video Games*, 2010.