Playware Ball – Initial Development Impressions of an Intelligent Ball

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Abstract

This paper investigates the use of barometric pressure sensors in combination with accelerometer data as a viable way to track the activity level of players in a fast-paced exercise game using a football to motivate the participants. A fitness game was developed along with a prototype intelligent ball with the aim of tracking both the skill level and the level of activity for the users. The initial findings indicate that the sensor fusion of barometric pressure data and accelerometer data proves reliable in the fast-paced setting of football games. Furthermore, the constructed prototype foam exercise ball proved a reliable container to house both the sensor and computational devices in a safe manner and could be useful for further tests on other aspects of combining gaming and physical exercise.

Keywords: Playful technology, Playware, Personal Health Technology, Adaptive Games, Football.

1. Introduction

Increasing the number of daily physical leisure activities performed by the elderly in nursing homes could prevent several diseases including dementia [1]. It is vital that no one spends too much time sitting down as research shows inactivity has a dramatic impact on potential risk factors such as cardiovascular disease, type 2 diabetes, metabolic syndrome, and obesity [2]. The simple solution to avoid those risk factors is to increase the daily level of activity. However, there is resistance from some of the elderly to sustain a healthy balance of daily routines with enough exercise as some psychological barriers hinder the elderly to join in. The natural physical limitations of old age can sometimes make them feel inadequate and prevent them from wanting to exercise. The mundane nature of repeating exercises can also be a factor that prevents them from raising their activity levels.

In an attempt to increase the overall activity level of the elderly generation in a fun and accessible manner, we developed playware [3, 4] focusing on play with intelligent artefacts to engage the users. Indeed, other playware such as Moto Tiles have shown to have a significant effect on the physical health of seniors [5-7]. According to the Playware ABC [8, 9], the hardware was developed to be usable in multiple contexts spanning various usage scenarios and developed for different user types with a large variety in their amount of previous experience with digital entertainment (see [10] for other playful rehabilitation use). In this work, the hardware was developed as a semi-autonomous robotic toy that could be self-explanatory in its intended use and that would require little to no instructions before being adopted. As a way to measure the activity and skill level of the users of the toy ball, the ball was equipped with a barometric pressure sensor and an accelerometer to provide reliable data for performing adequate movement analysis. The robotic exercise ball was developed to be expressive and fun. It was not developed using any specific expressive robotic models but analyzing it after its constructions phase using the MOAM model of affective expression modalities results in a point distribution of 3 for the sound modality which provides a coordinated effort to respond to user input [11].

The playware ball was preliminarily tested under different context circumstances to investigate how well the sensor combination of barometric pressure sensors and accelerometer sensors functioned with different pressure changes and different types of user handling. The form factor and sensor choice for the exercise tool proved a sensible combination usable for a large variety of purposes.

2. Physical construction and software setup

The physical object was a 20cm diameter, foam-body, semi-autonomous exercise ball. The outer layer of foam was selected for the following main reasons:

- It contained a penetrable surface that allowed air to travel freely to and from the barometric sensor so that it would provide robust readings.
- The foam protected the sensors in a flexible enclosure.
- The elastic body of the foam enclosure worked as a shock absorber to prevent damage as the ball would receive hard kicks during exercise games.
- The foam ball invited energetic activities as its morphology would resemble a non-harmful toy that you were not afraid of kicking around with the risk of hitting indoor furniture or other people in the vicinity.

Fig 1. The Playware Ball containing the electronics inside.

Inside the foam outer layer was a small embedded computer platform. The main system on a chip was an ESP8266 based platform with onboard wifi to provide connectivity and data transfer to and from a mobile application. To the SOC, the accelerometer and barometric pressure sensor were attached. To facilitate communication with the Arduino based ESP8266 platform, the I2C communication protocol was used for both sensors. To power the device a dual cell lithium-ion battery was used. Sufficient charging ports were added to allow a swift and easy charging process between the exercise games. The constructed morphology aimed to entice physical activity and to present the hardware in a reliable package. Figure 1 shows the complete form factor of the exercise ball.

The sensor processing and game initiation controls were controlled by a companion mobile application. The game would connect to the ball via a shared wifi connection and would receive sensor data with a refresh rate of 200hz. The refresh rate was chosen as the best compromise between high granularity of sensor measurements and high power consumption for both transmitting the data as well as post-processing the data on a mobile device. Figure 2 shows the application's main window and activity selection screen. To make sure the height estimations were as accurate as possible, the game would auto-calibrate the height measurement base of the barometric pressure at the start of each physical activity game. The software would assume that the ball was placed on the ground as the game was initiated to establish the lowest possible readings within each game. To process the data the following post-processing filters were applied to the stream of incoming data. All data points were averaged and the current height estimation was only affected through a low pass filter with high perseverance of the existing value. To focus the data measurements and filter unnecessary readings from the stream, the accelerometer data was used to detect when the ball was kicked and when the ball was descending towards the ground with detected expected gravity speeds. The accelerometer data was also employed to detect when people kicked the ball and whether the ball was moving or was kept still. The audio-based expression modality of the physical setup was also provided through the app and the audio would automatically select speaker mode and increase the volume to ensure the users could hear the intended audio cue throughout the exercise sessions.

3. Fun in the game

The games developed for the exercise ball was created with the intention of being easily understandable, fun to play and also fun to watch. The games should be explainable in a single sentence to ensure the users maintain a flow in the exercise routines by avoiding that anyone would stop in the middle of an exercise confused by the rules of the game. The games were challenging and fun as a means to keep the users coming back for repeated exercise sessions. The reason for making the games entertaining to watch as well was done in an effort to entice new players to join in.

From a health perspective, the games focused on two different types of activities with an emphasis on different body aspects to strengthen:

- The cardiovascular system.
- The fine muscle movement and eye-leg coordination.

Fig 2. The interface on the tablet when playing the rehab game for upper extremity training with two playware modules.

The first game, which emphasized cardio strengthening exercises, was a game that enticed the participants to keep moving at a steady pace throughout the exercise session. The premise of the game was that the exercise ball would sense whether it was moving or standing still and communicated those different states to the users through each exercise session. To force the users to move during the game, the software would also keep track of each time the ball was kicked sufficiently hard. A hard kick meant that the users would have to chase after the ball and prompt further cardio strengthening activities. If a certain playing time had passed with no one kicking the ball (e.g. 4 seconds), the ball would play an explosion sound to convey that the game had ended. The premise was to keep the ball moving for as long as possible. High-scores would be gained if you could top the previous players' overall exercise time.

The second game attempted to improve the finer muscle movements in the user's legs and to strengthen the eye to leg coordination. The premise and goal of the game was to keep the ball in the air as much time as possible and avoid it hitting the ground. The sensors would register whether the ball was kept still, to make sure the users were not resting the ball on their feet during an exercise session. The barometric pressure was used to ensure that the ball would not stay beneath a threshold user-adjustable height for too long. If that happened, a sound would convey to the user that the game had ended.

4. Prototype verification

The developed prototype hardware and game software were tested by 5 faculty staff members of the playware lab at the Technical University of Denmark. The early testing with the foam ball indicated that the users often accidentally stepped directly on the critical center parts of the construction. To ensure this part would work in extended exercise sessions we attempted to perform tests where we put some physical strain on the equipment. This included the following tests:

- Hard-kick tests, in which we performed multiple subsequent hard kicks directly aimed at the center mass of the ball where the electronics were housed.
- Step-on tests, in which we stepped on the ball from several approaching angles.
- Drop tests, in which we dropped the ball from different high altitudes between first to the third floor of the university building.

It was important to make sure the ball would work across several different contexts. The final product was aimed at working both outside and inside, in high humidity, and warm and cold weather. The foam enclosure needed for the barometric pressure sensor to work excluded the construction from working in scenarios where it would get wet so it was only tested in dry conditions. To ensure the barometric sensor worked in less than ideal conditions, we attempted to introduce some sensor noise to occlude the sensor data during test exercise games. This included changing the local pressure in the room by opening a window during a game session and by moving the ball while it was calibrating the low height measure during game initiation. Different heights were tested and a different pace of height changes was tested to investigate the limits of these sensors in this specific setting.

Overall the combination of barometric pressure and accelerometer sensor data worked very well to determine the different states needed in the exercise games. They determined the altitude and movement amount with a high enough confidence level to be usable even in this fast-paced exercise context. The sensors often showed some erratic behavior where it would return outlier data such as jumping to a very high or low altitude level during the games but using basic filtering methods these wrong measurements were easily discarded. Once in a while, the local pressure would change in a given room. This changed the minimum height threshold defined in the game. By changing the calibration to occur at the start of each game we countered this effect with some success. However, this required the users to keep the ball still at the ground at the start of each game, which sometimes proved difficult as the test users had a hard time leaving the ball alone. We see that as a positive indication that the chosen morphology invites physical interaction.

5. Discussion - improvements

Our testing phase showed that the next prototype could benefit from including more onboard expressive features. This includes both more expressive features employed mid-game and also pre-game explanations and during game selection. Although the mobile application is a great platform to deliver written instructions and to provide processing power to analyze the sensor data, using it subtracts from the experience of having an intelligent ball that works alone without the need for tethered connections.

The expressive sound used throughout the exercise games makes the ball seem alive and should be coming from the ball, not the app. It was a clear indication through the tests that the users wanted to forget the app and just focus on the ball. This resulted in users kicking the ball to a distance about ten meters from the app, at which point it proved difficult for the data connection to remain active and which also made it difficult for the users to hear any game-related audio cues coming from the app. Moving to a standalone platform in the ball would also make it easier for people to interpret the exercise ball in an anthropomorphic way which might improve how people interacted with it. If people would see it as a viable partner during the exercises it could make them more eager to exercise alone with the ball. However, moving the electronics and adding necessary processing power to facilitate a standalone decide might be difficult as doing so will be a tradeoff between having the robustness and reliability of using simple electronics inside the ball vs using a more complex setup using powered speakers and more processing.

In the preliminary testing phase, there was a tendency for people to view the playware ball as an intelligent entity. (E.g. some people expressed that the ball tried to trick them). This anthropomorphic interpretation may be utilized in further prototypes. This could maybe amount to making the ball laugh when people kick it or otherwise taunt them to interact with it. The responsive nature of the interactive exercise ball seemed to fit the scenario of enticing exercise well and it made people see the ball as a tool that was both energetic and alive.

Further improvements in future prototypes might also benefit from including better haptic feedback to the users. This is needed to make the ball an untethered standalone device. The haptic feedback could provide a way to provide feedback when the users initiate games or attempt to stop current activities. E.g. it might vibrate to give feedback or the users could shake it to change activity. Our current knowledge from developing this and other playware devices tell us the more simplistic we make the device, the more it will entice people to use it.

Using an app with the ball might also make people scared of trying it as the mobile device itself represents high levels of complexity and demands a steep learning curve from people who are not already familiar with smart devices. In development phases for new technology, we cannot per default assume that the elderly generation is comfortable with using mobile platforms or computers. Our preliminary testing shows that simplicity might be a viable way to appeal to a large variety of ages - when combined with a device that resembles a common object such as a football it makes it easy for new users to approach and start using it.

6. Conclusion

The sensors and the hardware proved reliable during our preliminary testing phases. The playware ball itself was a successful prototype that gave us knowledge on the type of material and enclosure needed to proceed in building further prototypes. The morphology proved enticing for people to pick up and start using and the expressive nature of the audio cues was interpreted as fun and informative during the exercise games. This was a preliminary investigation into the development of an intelligent piece of a playware exercise equipment to facilitate more enjoyable physical activities for the elderly generation and as such the prototype accomplished a lot with simple sensors in a complex scenario. The prototype platform managed to get reliable information on all the discrete ball states needed to provide a good experience for the test users and the expressive features of the playware ball made the ball fun to use. The platform proved a viable foundation to continue development for further testing of combining gaming and physical exercise.

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