Exploring Different User Interfaces for Automatic Tracking of Free Weight Exercises Using Computer Vision

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Abstract: Several research studies have shown the importance of physical exercise. The global gym and fitness industry faced a transition from traditional gyms to virtual fitness training during the pandemic lockdowns. A proliferation of applications is available to provide different digital gym experiences. Advagym is one example that uses sensors to track and give feedback to gym goers. Sony's R&D Center Lund Laboratory has developed a Camera-based Tracking System (CTS) which aims to offer an automatic free weight exercise tracking solution with Advagym. The main goal of this paper is to align the Advagym application combined with CTS for free weight exercise (FWE) tracking and to conduct a comparative study of four different user interfaces presenting FWE tracking to increase the user experience. The main contribution of this paper is to elucidate knowledge about which UI feedback of FWE given for the "gym-goer" was preferred.

1 INTRODUCTION

Physical exercise is of significant importance for all adults and adolescents. It can, for example, improve their mental health, sleep, physical ability, weight control, decrease the risk of chronic diseases and ailments (Piercy et al., 2018). Therefore, it is in society's economic and social interests to help and encourage people to exercise and stay healthy. A growing data- and technology-based industry is looking into new ways to assist with this matter.

The global gym and fitness industry has seen its market size grow by over 43% from 2009 to 2019 ($67B to $97B) (Statista, 2020). However, the COVID-19 pandemic led to nationwide lockdowns and social distancing regulations and norms. Therefore, the transition from traditional gyms to virtual fitness accelerated instead. This transition has led explicitly to increased downloads and subscriptions of fitness applications. The global fitness application market size is valued at $1.1B as of 2021 and is expected to see a compound annual growth rate of 17.6% from 2022 to 2030 (Grand View Research, 2022).

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Different companies and entities have a clear incentive to support this growth and market expansion. There are currently a vast amount of fitness applications on the market that satisfies specific niches or needs of the user. Such conditions encompass everything from simple motivational applications to monitoring, planning, and logging applications to help users track their workouts' progress. However, some companies are aiming to offer the user a more "complete" solution, i.e., digitizing the entire gym-going experience. An example of such a company is Sony Advagym [1].

Advagym (2015) is a commercial solution already available in the market, which aims to use Internet of Things (IoT) devices mounted on existing gym machines to track performance data from users' workouts and digitize the gym experience. The IoT sensors serve to collect data, push the data, and share the data with a whole network of connected devices. IoT sensors are used to track the user's performance and movements (Gubbi et al., 2013). More recently, Advagym added velocity-based training to their application, which allows the user to easier keep a certain pace while lifting weights (Alce et al., 2021). However, Advagym does not currently support automatic tracking and logging of an essential aspect of

[1] https://advagymsolutions.com/

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the gym-going experience, i.e., the free weight exercises (FWE). Recent advances in computer vision and machine learning have presented possibilities to solve this problem.

Sony's R&D Center Lund Laboratory has developed a Camera-based Tracking System (CTS) that enables three-dimensional (3D) object tracking and can be trained to detect specific movement patterns. Through the use of this system, Advagym and Sony's R&D Center Lund Laboratory are jointly exploring implementations of an automatic free weight exercise tracking (FWET) solution. Since the CTS itself is "invisible" to the user, i.e., with no means of input or interaction. One can ask, how is the user supposed to use the system?

The main goal of this paper is to align the Advagym application combined with CTS for FWE tracking and to conduct a comparative study of four different user interfaces (UIs) presenting FWET to increase the user experience.

The main contribution of this paper is to elucidate knowledge about which UI of FWE given for the "gym-goer" was preferred.

The following section presents relevant related work. Then the Advagym system is described, followed by the evaluation, results, discussion, and conclusions.

2 RELATED WORK

Previous approaches for exercise detection and tracking include using wearables and instrumenting equipment. For example, wearables such as IMUs have been used to track user's exercise movements by Seeger et al. 2012. Example of instrumenting gym equipment to monitor its use, Velloso et al. 2013 can be mentioned who instrumented both the users and the equipment with IMUs and used the system to train a novice user. However, more recently research is being done in the field of computer vision and machine learning. For example, there have been numerous computer vision-based systems that have focused on rehabilitation. Ar et al. 2014 used a depth camera to recognize in-home physiotherapy exercises, and Anton et al. 2015 used a depth camera to track exercises for telerehabilitation. More recently, systems have employed deep learning-based approaches to track pose from an RGB feed by Cao et al. 2017, and Mehta et al. 2017. These results have slowly begun to become commercial products available to consumers.

In 2018, Amazon launched a new physical shopping concept called Amazon Go. With Amazon Go, customers first enter through a turnstile where their smartphone's screen with the Amazon smartphone application opened is scanned. Then, they walk around the store and put food items into their shopping cart and when they are ready they leave the store. The total purchase amount is automatically charged through the credit card registered with their Amazon account. No further interaction is required of the customer. This is done through multiple cameras utilizing computer vision and deep learning algorithms together with "sensor fusion," i.e., different sensors such as weight- and proximity sensors working in symbiosis (Wankhede et al., 2018).

GymCam is a proposed solution that detects, recognizes, and tracks exercises in a gym through computer vision and machine learning algorithms. The system utilizes a single-camera solution to track motion and assumes that most repetitive movements over time in a gym are regarded as exercises in progress, thereby differentiating random movements from exercises (Khurana et al., 2018). Khurana et al. (2018) claim to be able to track hundreds of users simultaneously while still being able to detect and track the individual exercises and the corresponding repetitions being carried out by the users. The system can also handle occlusion due to its focus on detecting repetitive movements in favor of accurately estimating body key points (i.e., skeletons) as with typical multiple-camera solutions. However, it does not focus e.g. on the user interface flow and experience.

3 ADVAGYM

Currently, users of Advagym's system interact with it by use of an application on their smartphones. By implementing a smartphone-based prototype application that can interact and communicate with Advagym's hardware (IoT devices) and Application Programming Interfaces (APIs), along with Sony R&D Center Lund Laboratory's CTS system, it will be possible to evaluate an FWET system.

To provide a complete digitization solution for the gym experience. One would simplify it down into the following required parts:

- **Hardware:** to somehow translate the physical world into the digital, you would need devices and sensors placed and mounted differently throughout a gym.
- **Software Platform:** interpreting/parsing the data recorded by the hardware requires different types of software to be written. Transmitting the processed data to where it is needed and handling a large number of users requires some form of

a flexible software platform to build various features/solutions.

- **Client/Application:** for a user to interact with the software platform and hardware, a client/an application of some form is needed, such as a smartphone application.

3.1 Sony's Camera Tracking System

Using both machine learning and computer vision, Sony's R&D Center Lund Laboratory has developed a Camera-based Tracking System (CTS) that enables 3D object-tracking, and that is trained to detect specific movement patterns.

The CTS employs a multi-camera solution to track multiple objects within a space accurately. This is done to minimize the issue of occlusion present in many single-camera solutions for object tracking (Zhu, 2019). Multiple cameras with temporally consistent video feeds allow matching of two-dimensional (2D) inputs, which in turn makes it possible to achieve fast individual 3D pose estimations of all humans present in the view of the cameras (Chen et al., 2020). The system can detect and track several exercises, including bench presses, bicep curls, deadlifts, situps, and squats.

Sony's R&D Center Lund Laboratory has set up a gym space to test and evaluate the CTS. The gym has many machines that Advagym uses to test its hardware and software solutions. There are also several types of free weights equipment available: barbells, barbell weights, and dumbbells.

3.2 User Interface for Onboarding

After testing and exploring the CTS, multiple brainstorming sessions took place to develop an overall concept for the smartphone application. The following constraints of the CTS were noted:

- The system does not have 100% accuracy in terms of repetition detection.
- Users need to carry out exercises within a specific gym area, covered by the cameras used.
- In certain use cases, the system can lose track of a user even though they are within the tracked area.
- Only the exercises the system can detect are tracked and logged, i.e., there is no possibility of custom exercises unless the system is re-trained.

From these constraints, it was determined that three main areas needed to be taken into account when devising the initial concept:

- **Connection:** How would a user connect to the tracking system?
- **User Interface Flow:** What steps would the user need to take to interact and use the system?
- **Feedback:** What modes of feedback would need to be in place for the user to be able to respond to errors?

3.2.1 Connection

For a user to connect to the FWET system and to start using it, one would somehow need to bind (link) the "skeleton" shown in the visualization of the CTS with the user. Three different UIs regarding how a user would bind were proposed:

1. **Gesture:** if the user performs a specific gesture such as holding both arms above their head. The system can see which skeleton is making that exact gesture and bind the user.
2. **Waypoint:** if the user presses a connect button on their smartphone application while standing at a specific location in the tracking area. The system would know that the skeleton at that specific location, at that very instant, is the user.
3. **Puck:** works identically to the Waypoint method, but the user taps a Puck with their phone instead of pressing the connect button on their smartphone app.

The prototype's goal is to be integrated with the current Advagym application. Therefore, we used the current version as a baseline for the user interface flow.

3.2.2 User Interface Flow

The User Interface Flow (UIF) was created in a digital Lo-Fi version. Due to the COVID-19 pandemic and its subsequent restrictions and regulations in Sweden, it was impossible to meet with potential usability test participants in person. Therefore, the goal of the digital Lo-Fi prototype was to create a digital smartphone prototype that test participants could use and interact with over the internet. Since three different connection methods were proposed, three distinct prototypes were evaluated, each with varying connection methods.

The UI was inspired by the current Advagym application. The different screens constructed were interactable in terms of being able to click/tap on specific UI components, scroll through list views, and move and navigate back and forth throughout the application. The screens and screen transitions were also animated to resemble the current Advagym application closely.

The FWET UI was integrated with the Advagym UIF. The Gesture connection method implies that the user performs a specific gesture, which the CTS can detect and link the tracked skeleton with the user performing the gesture.

The second connection prototype was referred to as Waypoint and implies that the user walks over to a specific location in the gym that is clearly marked with the help of signage, paint, or some other material or objects. Since the CTS has the exact X, Y, and Z coordinates of the Waypoint stored in its system, the CTS can determine that the skeleton is inside the specified Waypoint boundary and can be bound to the specific user.

The third connection prototype was referred to as Puck and implies that the user taps a specific Puck in the gym with their phone. To differentiate the FWET Puck from the other Pucks which are placed on the gym machines, there should be additional signage accompanying the free weight connection Puck or affording the Puck a different color signifying the different use case.

3.2.3 Lo-Fi Usability Test of the User Interface Flow

The goal of the usability test was to evaluate which of the three proposed connection methods showed the most promise regarding quantitative and subjective metrics.

Setup. Due to the COVID-19 pandemic and its restrictions and regulations in Sweden, all test session parts were conducted online using Google Meet.

Participants. Twelve participants (three females, nine males) conducted the online test. The average age of the participants was $M = 27.0$ and ranged from 25 to 30 years.

Procedure. At the start of the test session, the participants were asked to imagine being in a gym environment and to place a smartphone in front of them. Depending on what prototype was used, a further description of the gym area and what objects/things were available was presented. When the participants were ready, they were asked to perform specific tasks using one of the proposed Lo-Fi prototypes, 1) Gesture, 2) Waypoint, and 3) Puck. The order in which the prototypes were presented to the test participant was counterbalanced. After all test scenarios had been completed, a semi-structured interview was conducted, and the participants were asked to rank the prototypes. Each session lasted about 30 min.

Results. All twelve participants managed to accomplish the usability test. A summary of the preferred prototype can be found in Table 1. The semi-structured interviews found that the UIF of starting an exercise was not straightforward; there was more than one way of getting there. Many non-interactable/functional user interface elements and components made navigation confusing.

Table 1: Preferred prototypes.

Prototype	1st place	2nd place	3rd place
Gesture	3	1	3
Waypoint	4	1	2
Puck	5	4	0

3.3 Hi-Fi Prototype

Based on the results found during the Lo-Fi prototype, it was decided not to proceed with the Gesture connection and only focus on Waypoint and Puck. Moreover, it was decided to focus on creating pure free weight training rather than getting stuck with integration to Advagym. However, still, the same color scheme and fonts were used. It was decided to develop the application in React Native[2], since it allows cross-platform development.

3.3.1 State Handling and Application Settings

For the application to understand what information to display to the user or what feedback to provide in response to system errors or actions taken by the user. The application would need to handle the following states: 1) **LoggedIn**: is the user logged in or not? 2) **UserID**: what is the logged-in user ID? 3) **UserType**: is the user an admin/tester? 4) **Connection**: this state consists of the following child-states: - *Connecting*: is the user attempting a connection? - *Connected*: is the user connected to the CTS? 5) **Error**: an error of some kind occurred.

The state handling was implemented through the use of React Redux[3]. Redux allows you to read and be notified of any changes made to the state(s) through the use of "Hooks" from anywhere inside the application. This was used to update the appearance or functionality of components or the layout of different application parts. The states were stored either as boolean, string, or number types.

Some data needed to be stored in memory that the application could read and write to. Redux allows for a "store" which can save and handle data of different kinds. This was used extensively throughout the application. Some of the data stored were as follows: 1) **skeletonID**: the user's current id according to the

[2]https://reactnative.dev/
[3]https://react-redux.js.org/

CTS (saved as a string). 2) **latestMessage**: the latest MQTT message received from the CTS (saved as a string). 3) **repNumber**: the current number of repetitions in the set (saved as a number). 4) **exercises**: an array of all exercises performed by the user, and the accompanying data of each exercise, including the number of sets, repetitions, and weight lifted.

3.4 CTS Connection

For the user to connect and interact with the CTS, the prototype smartphone application needs to be able to: 1) Connect and listen to the CTS broker's modified topic and parse its MQTT messages. 2) Know when to listen for certain MQTT message types. 3) Know what Skeleton ID(s) are within the Waypoint boundaries in the tracked area.

This was the key part of the solution for connecting and using the CTS. For the CTS broker to send out the *closest* MQTT message type, it needs to know two things: 1) The X, Y, and Z coordinates of the Waypoint. 2) Detect a skeleton (tracked human) within a certain distance of the Waypoint, i.e., within the Waypoint boundary.

The Waypoint location could be anywhere as long as it was inside the CTS's tracked area. To define a Waypoint, the following was done: 1) Make sure the tracked area has no other humans in it. 2) Stand at the exact location of where you would like the Waypoint to be. 3) Record the X, Y, and Z coordinates of the Skeleton IDs present in the scene reported by the CTS. 4) The recorded X, Y, and Z coordinates of the single, stationary "Skeleton" is your Waypoint location.

To determine that a skeleton is within the Waypoint boundary, the formula for calculating the distance, d between two points $P_1 = (x_1, y_1, z_1)$ and $P_2 = (x_2, y_2, z_2)$ in 3D-space (xyz-space) was used (Equation 1):

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \qquad (1)$$

If the distance d between the Waypoint and a skeleton was calculated as less than $0.5m$ a closest message was sent out by the CTS broker containing the Skeleton ID of the tracked/detected skeleton.

After the development and implementation had concluded, a fully functional Hi-Fi prototype smartphone application was developed.

Four different connection states of the application make the top of the Exercise screen change its appearance (Figure 1). Additionally, two different feedback alternatives were added when the user was successfully connected to the CTS, 1) tactile feedback in the form of vibration or 2) auditory feedback in the form of a human voice stating "Connection successful!". When the user starts to perform the exercise, the application changes the user interface and shows a counter counting the number of completed repetitions.

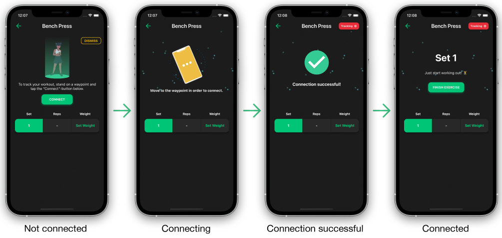

Figure 1: The Hi-Fi prototype's four connection states.

Four different prototypes were developed:1) Waypoint with auditory feedback, 2) Waypoint with tactile feedback, 3) Puck with auditory feedback, and 4) Puck with tactile feedback.

4 EVALUATION

A user study was conducted to evaluate the different prototypes by letting all participants perform tasks in the office gym.

4.1 Setup

The evaluation was conducted in Sony's office gym. The gym was already equipped with Advagym technology. It also has a wide range of gym machines, along with free weights such as barbells, dumbbells, and different benches. Throughout the gym and along the ceiling, small cameras were placed that created the tracked area of the CTS. Both quantitative and qualitative data were collected. The active session was documented through video recordings from a Sony smartphone as an overview camera. Participants who use an Android phone daily conducted the test with a Google Pixel 2 XL, and those who use iOS tested with an iPhone 13 Pro. An orange Puck was placed in the middle of the room, adhered to a larger gym-machine assembly. On the floor beneath the Puck, a large circle was outlined with the help of tape. The circle functioned as the Waypoint area.

4.2 Participants

Advagym is an application with a very broad user group that consists of both young and elderly users. It can be beginners as well as elite trainers. The one thing they have in common is that they are training at a gym. However, we had some restrictions, such as being able to perform the test physically, i.e., the participant should be able to perform squats exercise without any weight and without any pain.

An online questionnaire using Google Forms was used to recruit participants more easily. The online questionnaire served two purposes; to gather relevant demographic data about the participant and book an available time slot. The sign-up questionnaire was spread through different channels, both in digital and physical form. The physical form consisted of a poster with QR-code links that were placed in several crowded areas within the campus of Lund University. The digital form consisted of a link and an accompanying description of the test and its purpose, that was distributed through Sony's social media groups.

In total, 32 participants (17 female, 15 male) were recruited. The age of the participants ranged from 19 to 60 years (M = 31.1, SD = 10.42). To estimate and grade the training skill of the participants, a sequence of calculations was made based on their sign-up questionnaire answers. The following parameters: weekly training frequency and time kept with current training frequency. This was graded on a scale of one to five, where the interval of one to three was graded as beginner/novice training skill and 4 to 5 was graded as advanced training skill. 32 test participants meant that the participants would be evenly divided between the four Hi-Fi prototypes, meaning each prototype would be evaluated eight times.

4.3 Procedure

The test session was divided into three parts: The preparation stage (Pre Test), the Test session, and Post-test. The Preparation stage includes the initial contact with the participants. Participants signed up for the test with the help of an online questionnaire. The COVID-19 pandemic regulations and restrictions had been removed in Sweden by the time of the evaluation of the Hi-Fi prototype. Therefore, all test participants could conduct the evaluation in person at Sony's office gym. Participants were welcomed and escorted to the office gym when they arrived at the test location. In the office gym, they were given a brief introduction to what Advagym is and the purpose of the evaluation. Moreover, they signed a Non-Disclosure Agreement (NDA) and an informed consent form. Next, they were asked to start with the test scenario, which included seven tasks: 1) Carry out two sets of Squats, five repetitions each, with the help of the application and the automatic tracking feature, 2) Go over to a table outside of the tracked area, to get some water and then return to the exercise area, 3) Carry out one set, ten repetitions of Biceps curls, with the help of the application and the automatic tracking feature, 4) Carry out two sets, five repetitions of Bench Press with the help of the application and the automatic tracking feature, 5) Carry out a couple of Biceps curl repetitions but do it without the application automatically tracking the repetitions/exercise, 6) Carry out a couple of additional Biceps curl repetitions with the help of the application and the automatic tracking feature and finally 7) Finish/end the workout. All tasks were designed to understand whether the participant will know how to use the application and whether they are being tracked. After all tasks had been completed, the test participants were asked to fill out a SUS questionnaire regarding that specific prototype, followed by a semi-structured interview including questions about if they have used any gym application before and their initial thoughts regarding the FWE system. Each session lasted about 45 minutes, and the participant was given a movie ticket as a reward. The whole procedure of the test session is visualized in block diagrams.

4.4 Results

In the following section, the results from the SUS scale and the structured interview are presented. All 32 participants managed to accomplish the exercises. We used an alpha level of 0.05 for all statistical tests.

4.4.1 SUS Score

The results obtained from the SUS questionnaire for the Puck-NoSound present a mean score of M = 81.3, SD = 4.23, with a minimum score of 75.0 and a maximum score of 87.5. For the Puck-Sound, a mean score of M = 73.8, SD = 11.10, with a minimum score of 50.0 and a maximum score of 87.5. For the Waypoint-NoSound, a mean score of M = 72.8, SD = 9.86, with a minimum score of 60.0 and a maximum score of 90.0. For the Waypoint-Sound, a mean score of M = 70.6, SD = 11.78 with a minimum score of 52.5 and a maximum score of 90.0. A one-way ANOVA for dependent measures between Puck-NoSound, Puck-Sound, Waypoint-NoSound and Waypoint-Sound showed no significant relation: $F(3,28) = 1.81$, $p = .169$.

4.4.2 Semi-Structured Interview

During the semi-structured interview, 15 out of 32 test participants said that they would like to use a system such as the one proposed during the test. 10 out of 32 test participants said they would like to use a system like the one presented during the evaluation if some changes were made, such as more stable tracking, if more exercises were added, and if they had more interest in tracking their exercises. Seven out of 32 test participants said they would not like to use a system like the one proposed during the test. However, 25 of 32 were positive in regards to using an automatic free weight exercise tracking solution.

The test participants provided a lot of feedback regarding the prototypes' features/functionality and user interface. Examples of such feedback include: - It was not clear that you could step out of the "Waypoint" when performing exercises. - It was not clear where and what the "Waypoint" was supposed to be in the gym. - It was not clear if you had to bring your smartphone with you in order to be tracked by the system. - It was not clear where the orange "Puck" was in the gym. - The solution needed to be even more "automatic," i.e., less interaction would be required by its users. - The repetition tracking was sometimes not accurate, i.e., the system missed some repetitions, and at other times the tracking system did not work. - The ability for the application to "guide" the user in the sense of offering programs with different exercises that the application would then "fill in" as the user was performing the different sets and repetitions. - In the case of the "Puck" prototype, when asked to reconnect to the system after having left the free weight training area to get a drink of water, it was not clear which Puck that the test participants needed to tap with their phone to reconnect. Test participants (correctly) observed that tapping whichever Puck was available to them in the gym, such as Pucks found on gym machines, did not initiate an automatic FWET connection attempt. Some form of animation of the illustrations when it came to instructing the user on how to connect to the system would help with understanding.

5 DISCUSSION

In this section, we will discuss the "takeaways" of the evaluation and the limitations of the prototypes.

5.1 SUS Score

There was no significant difference regarding the SUS score. All four had a SUS score above 68, which is considered above average (Brooke, 2014). The Puck-NoSound had a mean slightly larger than the other ones. The SUS score measures cognitive attributes such as learnability and perceived ease of use. The result indicates that all four UIs are considered to be easy to use and easy to learn.

Both Puck prototypes had the highest mean SUS score. People, in general, are already quite experienced with tapping on things in different contexts, such as when tapping one's credit card or smartphone using Apple/Google pay to a register when paying at a store or when tapping one's transit card when using public transport. This perhaps made this form of interaction feel more intuitive and natural to the user. Building upon already-established interactions could be helpful when users need to interact with a new piece of technology.

5.2 Semi-Structured Interview

One of the main reasons for not being interested in the FWET system is the need for more stable tracking and more exercises. The CTS's human tracking and exercise detection do not have 100% accuracy. When the CTS did not detect repetitions, the repetition counter displayed on the prototype or communicated to the user by way of audio was not incremented. One of the usability test tasks instructed the user to go to the far corner of the gym and do sets of Bench Press exercises. This activity was specifically chosen since prior knowledge of the CTS in the gym had shown that the far corner combined with the Bench Press exercise led to the system losing track of the user and, therefore, not registering their repetitions. The non-registered repetitions and loss of tracking frustrated several test participants. This might have led them to believe that the prototype and system were difficult to use and complex, which was different from the intended effect.

Adding more feedback in the form of auditory and haptic feedback in the prototypes did not correlate to higher mean SUS scores. One possibility could be that the modes of feedback needed higher affordance or be sufficiently explained/put into context for the user. On the other hand, several test participants that used the prototypes without the additional feedback explicitly asked for the addition of such forms of feedback during their Post Test short interviews, which indicated that such additions would be positive.

It was also clear that the small outlined circle on the floor in the gym, representing the Waypoint, needed more discoverability and could be afforded more mapping to free weights. This could be done with additional signage or ensuring that the exercise screen's illustration was mapped to the circle on the floor. A lot of test participants did not find the Waypoint and some participants also chose to stand within the circle on the floor during their exercises. The prototype needed to sufficiently explain to the user that they were free to move around the gym area when performing exercises. Several users suggested that it would be a good idea to have a more thorough and comprehensive tutorial on how the system functioned before using it for the first time.

6 CONCLUSIONS

The findings presented in this paper expand the knowledge base of HCI research in the context of using a mobile application to support free weight exercise tracking. The result of the prototypes has been very impressive overall. All of the prototypes have performed very well regarding the usability scores. All of the prototypes were above the average score of 68 for the SUS-based questionnaire, which indicates that the proposed user interfaces are easy to understand and use. The majority of participants would also prefer to use one of the proposed prototypes in their daily training with free weight exercises. This is a good indication that the feature itself is interesting for users.

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REFERENCES

Advagym (2015). Advagym - for a connected gym experience. http://advagymsolutions.com.

Alce, G., Håkansson, J., and Espinoza, A. (2021). Exploring different user interfaces for velocity based training using smart gym machines: Pilot study. In *ICT4AWE*, pages 113–120.

Antón, D., Goni, A., and Illarramendi, A. (2015). Exercise recognition for kinect-based telerehabilitation. *Methods of information in medicine*, 54(02):145–155.

Ar, I. and Akgul, Y. S. (2014). A computerized recognition system for the home-based physiotherapy exercises using an rgbd camera. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 22(6):1160–1171.

Brooke, J. (2014). Sus—a quick and dirty usability scale. 1996. *URL: http://cui. unige. ch/isi/icle-wiki/_media/ipm: test-suschapt. pdf [accessed 2015-10-14][WebCite Cache ID 6cGs6wGeu]*.

Cao, Z., Simon, T., Wei, S.-E., and Sheikh, Y. (2017). Real-time multi-person 2d pose estimation using part affinity fields. In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pages 7291–7299.

Chen, L., Ai, H., Chen, R., Zhuang, Z., and Liu, S. (2020). Cross-view tracking for multi-human 3d pose estimation at over 100 fps. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pages 3279–3288.

Gubbi, J., Buyya, R., Marusic, S., and Palaniswami, M. (2013). Internet of things (iot): A vision, architectural elements, and future directions. *Future generation computer systems*, 29(7):1645–1660.

Khurana, R., Ahuja, K., Yu, Z., Mankoff, J., Harrison, C., and Goel, M. (2018). "gymcam: Detecting, recognizing and tracking simultaneous exercises in unconstrained scenes". *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, 2(4).

Mehta, D., Sridhar, S., Sotnychenko, O., Rhodin, H., Shafiei, M., Seidel, H.-P., Xu, W., Casas, D., and Theobalt, C. (2017). Vnect: Real-time 3d human pose estimation with a single rgb camera. *Acm transactions on graphics (tog)*, 36(4):1–14.

Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., George, S. M., and Olson, R. D. (2018). The physical activity guidelines for americans. *JAMA*, 320(19).

Research, G. V. (2022). Fitness app market size, share & trends analysis report by type (exercise & weight loss, diet & nutrition, activity tracking), by platform (android, ios), by device, by region, and segment forecasts. https://www.grandviewresearch.com/industry-analysis/fitness-app-market [Accessed: 2022-04-19].

Seeger, C., Buchmann, A., and Van Laerhoven, K. (2012). Adaptive gym exercise counting for myhealthassistant. In *6th International ICST Conference on Body Area Networks*.

Statista (2020). Market size of the global health club industry from 2009 to 2019. https://www.statista.com/statistics/275035/global-market-size-of-the-health-club-industry/ [Accessed: 2022-04-19].

Velloso, E., Bulling, A., and Gellersen, H. (2013). Motionma: motion modelling and analysis by demonstration. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1309–1318.

Wankhede, K., Wukkadada, B., and Nadar, V. (2018). Just walk-out technology and its challenges: A case of amazon go. In *2018 International Conference on Inventive Research in Computing Applications (ICIRCA)*, pages 254–257. IEEE.

Zhu, C. (2019). Multi-camera people detection and tracking.