Provide reliable feedback during fitness derived from online activity matching

Sandra Drenthen
University of Twente
P.O. Box 217, 7500AE Enschede
The Netherlands
s.drenthen@student.utwente.nl

ABSTRACT
This paper will explore whether it is possible to provide real-time, useful and reliable feedback to trainees that helps improving their movement using online activity matching. If this is possible, trainees would not require constant monitoring by the coach, but can instead correct their movement themselves using online activity matching.

An experiment is set up that gives feedback about the fitness exercise named ‘Concentration Curl’. SunSPOTs are used as sensor nodes and a computer screen as feedback device. The free range sensor node compares the movement of the trainee with the baseline, which represents the correct movement. From this comparison, the free range sensor node selects the desired feedback that should be given and sends it to the computer, which displays the feedback on its screen. The results of the experiment show the sensor is comfortable to wear and the generated feedback is reliable and helps the users to improve their movement.

Keywords
online activity matching, movement comparison, movement correction, feedback, sensor node, SunSPOT, concentration curl.

1. INTRODUCTION
To prevent injury during a sport exercise, the correctness of the executed movement is very important. Learning to correctly execute these movements usually requires personal training from a coach. With a lot of research already performed on online activity matching, it is likely that this technique can assist the coach in managing larger groups of trainees by providing useful and real-time feedback. This way, trainees would not require constant monitoring by the coach, but can instead correct their movement by themselves. Also, it can allow a trainee to improve their skills in their own time, so he or she can practice even when their coach is absent.

Online activity matching means that sensor nodes are used for activity matching. A sensor node is a small node in a wireless sensor network, which is capable of gathering information, performing some processing and communicating with other connected nodes in the network. Activity matching can be performed with different kinds of sensors, for instance with 3D accelerometers that register the movement using the acceleration or with cameras that register the movement using online image processing.

The research applies online activity matching to the area of fitness training: a heavy, physical sport where the correct execution of the executed movement can not only prevent injury but also increases the efficiency of the exercise. The sensor node gathers information about the movement that is performed and compares it to a baseline. In this experiment, the baseline is a set of rules that represent the correct movement. After the comparison is completed, the sensor node generates the feedback. This research will find out whether it is possible to generate feedback that is real-time, useful and reliable.

2. PROBLEM STATEMENT
2.1 Related research
A lot of research has been done in the field of movement detection and comparison between movements, but there’s not much known about presenting the trainee with useful feedback.

For instance, technology using 3D accelerometers to accurately detect movements and match these onto an activity has already been researched previously [2]. The resulting conclusion that movements can be accurately detected and classified, paves the way for the derivation of meaningful feedback with this technique. The technology to compare the movements of a coach to those of the trainees has also been thoroughly researched [5]. It has been shown that it is possible to discriminate between spatial and temporal differences and derive feedback from those differences. Technology to match activities to an offline stored baseline has also been researched before [9].

In sporting areas where distance is used to measure performance, some applications and devices giving feedback to the trainee are already widely available. For instance, FitnessKeeper has made an application for the iPhone and Android smartphones named ‘RunKeeper’ that keeps track of the distance progress by using the GPS sensor of the phone. It can be used for activities like running, cycling, skiing and rowing. During the training, the application gives feedback about the distance, pace and the total distance that has been covered. The RunKeeper application can also be extended with a special heart rate sensor that combines the heart rate information with the training. Afterwards, the trainee can go online to see the progress that has been made. As a bonus, exercises performed on a machine like on a treadmill, can also be uploaded by hand, making indoor trainings also visible in the progress overview [4].

Some research has also been done on using 3D accelerometers in combination with a GPS sensor for giving feedback to the trainee while running. The 3D accelerometers are used to
minimize the measurement errors of the GPS sensor and help establish the correct running speed and distance covered by the trainee [7].

Online activity matching with cameras that register the movement using online image processing is the most complex option of activity matching. Research has shown that moving objects can be tracked using this technique with small errors, even when the angle between the cameras is significantly different [3].

2.2 Research questions
This paper will focus on the correction of movements using feedback derived from online activity matching. This research answers the following question:

How can useful, real-time feedback be derived from the comparison of the trainee’s movement and a stored baseline to improve the trainee’s movement?

To completely answer this question, the following underlining questions have to be answered:

How reliable is the feedback derived from real-time comparison between a stored baseline and a trainee’s movement?

How useful is the derived feedback in the process of improving movement and how fast is this feedback presented?

2.3 Research area
This research will use the movement of a fitness exercise named ‘Concentration Curl’. It is a perfect basic exercise, performed with one halter, training two muscles in the upper arm; the biceps and brachialis [1].

The trainee can perform the exercise while standing or sitting down. Firstly, the trainee has to lift the halter slowly to the front of the shoulder and followed by slowly lowering the halter until the arm is fully extended. The trainee should exhale when lifting and inhale while lowering the halter. This movement is repeated multiple times to perform the whole exercise.

Figure 1: Two products of Technogym: Arm Curl (left) and IsoControl (right)

Currently, feedback options are available for people performing the Concentration Curl exercise on a regular fitness device. For instance, the fitness device called ‘Arm Curl’ from Technogym can be upgraded with ‘IsoControl’; a small screen where feedback is shown to the trainee (Figure 1). The feedback is given by a moving bar that indicates the movement of the trainee and another moving bar that indicates how the movement should be done. The trainee can adjust his speed by comparing the two bars themselves [8].

However, when the trainee prefers to use weights instead of the regular fitness device, there is no similar device that presents feedback to the trainee. Therefore, this research aims to give feedback for this fitness exercise using 3D accelerometers.

3. TECHNOLOGY
Since human movement is performed in all directions and detecting and correctly classifying this movement is necessary for this research, it requires the use of one or multiple sensor nodes with a 3D accelerometer or a camera and the ability to communicate. There are a couple of options for the sensor nodes: modern day smartphones with 3D accelerometers, a sensor node like the SunSPOT, or camera’s with online image processing.

Modern day smartphones are capable of detecting movement using 3D accelerometers and performing complex calculations. A big advantage of using smartphones is that many people already own a smartphone, making this technology available for a big group of people at no additional cost. A disadvantage of using smartphones is their size and weight. They are probably not comfortable enough to be attached to body parts.

![Figure 2: The SunSPOT device](image)

An alternative for the 3D accelerometer is the use of SunSPOT devices (Figure 2). They have a more manageable size of 41 by 23 by 70mm and weigh 54 grams. This is thicker, but much smaller and lighter than conventional smartphones, making it more comfortable to be attached to body parts. Furthermore, SunSPOT's have the ability to communicate with each other and can also act as a base station when it is attached to a computer. As a base station, the SunSPOT provides the data link between one or multiple free range SunSPOT’s and the computer. The computer can be used to present the feedback.

The last option is to use cameras with online image processing. This is a very complex technique. This complexity also means that it will take more computation time and therefore the feedback will be slower than when 3D accelerometer sensor nodes are used. Furthermore, the prices of camera’s and image processing software are much higher than those of the 3D accelerometer sensor nodes.

Considering all the reasons stated in this research, SunSPOT technology is the best technology to perform this research with.

4. METHODOLOGY
One, two or even three sensor nodes can be placed on different positions on the arm, such as the wrist, the elbow and the upper arm. Using more than one sensor node gives the opportunity to measure more detail of the movement, but it also introduces more complexity: one sensor node has to be the master, which measures his own data and collects all the data of the other sensor nodes. The master node then needs to synchronize the data in order to generate feedback. How many nodes are needed and where they should be located will be tested in a
small experiment. It is desired to use as few nodes as possible, due to the computational complexity and the user’s comfort.

After the amount of sensor nodes is concluded, the performed movements have to be compared with the correct movement, requiring that the baseline should be defined and programmed in the sensor nodes. The computations necessary for the comparison between the performed movement and the baseline will be executed on the sensor node itself.

Once the comparison is completed, the sensor node sends the desired feedback to the base node, which is attached to a computer. The resulting feedback should then be provided to the trainee, which could, for example, be established through a visual or an audio cue.

5. IMPLEMENTATION

5.1 Implementation of the baseline
There are no explicit rules or standards defined for the speed at which the exercise should be performed, though research has shown that a 2 second take-off phase and a 2 second landing phase gives the highest total muscle activation for the biceps and brachialis [6]. The rules in the baseline about the speed of the exercise are based on those values.

The SunSPOT keeps track of the time passed between the beginning and the end of both the upward and the downward movement. When the movement is completed, the SunSPOT compares the time passed with a timeslot that is considered the correct speed. The speed of both the upward as the downward movement is considered correct if the movement is performed between 1.5 and 2 seconds.

Another rule in the baseline is programmed about keeping the weight straight during the exercise. The device is considered to be held straight when it is held upwards, taking into account a positive and negative error margin of 15 degrees. This error margin is required to overcome small differences between the placement of the sensor and the position of the weight. When the sensor can be placed in the weight, this error marge could most likely be decreased.

5.2 Implementation of the feedback
As mentioned before, the SunSPOT sensor node will transmit the generated feedback to a SunSPOT base station, which is attached to a computer. There are two main options to give feedback: using the screen or using sound.

![Feedback Screen](image)

Figure 3: One of the possible feedback screens

When utilized within a shared fitness centre, the audio option may be considered distracting and annoying by others. Consequently, this research will only use visual feedback. A simple feedback option is chosen that only gives very basic feedback (Figure 3).

After the user has lifted the weight, the screen will display whether the speed of the upward movement of the user was executed correctly, too slow or too fast. Similar feedback is given for the descent negative lift. It also informs the user immediately when the weight is not held straight.

The user gets positive feedback if the movement is executed correctly and negative feedback otherwise. The positive feedback is presented by green text and negative feedback is presented by red text. This helps the user to quickly interpret the feedback while performing the exercise. Additionally, a small gif animation is shown at the bottom of the feedback window, showing in a very understandable way how the exercise should be performed.

5.3 Time and computation complexity
Because of the simple baseline, the computational complexity of calculating the performance of the trainee is very low. Therefore, very little time is required to compute the feedback: approximately a few milliseconds. Sending the data to the base node and displaying the feedback on the screen is not very complex either and is also taken care of in a matter of a few milliseconds. The low complexity enables the feedback to be real-time.

6. USER EXPERIMENT
The user experiment will be performed with 21 students of the University of Twente, with different kinds of fitness experience. In this experiment, the user is asked to put on the sensor node and turn it on. The feedback screen then provides instructions about which kind of exercise should be done and indicates that the user can start performing the exercise.

When the user starts performing the exercise, the screen provides feedback to the user. The user performs the movement a couple of times to see roughly all the different kinds of feedback. When the user immediately performs the correct movement, the user is asked to try doing it wrong, so the user is introduced with the different types of feedback.

Afterwards, the user will be asked to fill in a simple questionnaire with, in addition to questions concerning some basic personal details, the following questions:

- How much experience do you have with fitness training?
- Does the feedback feel reliable?
- Does the feedback help to improve the movement and perform it better the next time?
- Is the sensor comfortable to wear and does it not hinder?
- Would you use a similar product if it is available?
- Would you like to have a different kind of feedback?

The first question is asked to give more details about possible differences between experience levels in fitness training. In the second through fifth question, the user is asked to give a grade between one and five. Here 1 stands for definitely disagree, 2 for disagree, 3 for neither agree nor disagree, 4 for agree and 5 stands for definitely agree. The sixth question is an open question, which gives the opportunity to point out some possible improvements of the feedback.

Expectations are that the feedback is reliable and it does help to improve the movement and the sensor will likely be comfortable, due to its small size and weight. It is hard to predict whether or not people want to use a similar product or prefer other products. The feedback will likely be alright, although it is possible some improvements of the feedback are pointed out by the users.
7. RESULTS

7.1 Small experiment
For the amount of sensor nodes and their location, a small experiment was set up. The small experiment has shown that using one sensor on the wrist gives enough data about the movement to be able to give proper feedback. The most optimal location for the sensor node is on the weight itself. However, due to the dimensions of the SunSPOT, it is not very comfortable to put the node on the weight. As an alternative, the wrist is chosen. Placing the SunSPOT on the wrist makes it comfortable to wear, while keeping it very close to the weight and making it possible to measure if the weight is kept straight or not. Another benefit of this location is that the user can easily attach the node with the use of a wristband (Figure 4).

![Figure 4: The SunSPOT attached to a wrist](image)

7.2 User experiment
The results of the user experiment are measured by the given answers to the questions in the questionnaire, given after the experiment.

According to the first question in this research, 9 users have little experience, 6 users have medium experience and another 6 users have much experience with fitness training. The amount of experience is used to group the answers of the following questions, to see if the different experience groups have different opinions.

The second question (Figure 5) is about the reliability of the feedback. An average score of 4.24 out of 5 is given. The little experienced users have given the highest score, the medium experienced users gave it a bit lower score and the much experienced users gave it the lowest score of the three groups.

![Figure 5: User experiment question 2](image)

The third question (Figure 6) is about whether the feedback helps to improve the movement and performance. It is given an average score of 4.19 out of 5. The much experienced users rated it about a half point lower than the little and medium experienced users.

![Figure 6: User experiment question 3](image)

The fourth question (Figure 7) is about the comfortableness of the sensor. It is given an average score of 4.29. The users with much experience gave it a rating of almost a point lower then users with little and medium experience.

![Figure 7: User experiment question 4](image)

The fifth question (Figure 8) is about whether the user will use a similar product if it is available on the market. It is given an average score of 3.10. A remarkable difference is given between the different experience groups. Users with little experience graded it with a 4.22, while users with medium experience rated it with a 2.83 and users with much experience graded it with a 1.67.

![Figure 8: User experiment question 5](image)

The sixth question is about the presentation of the feedback. 20 of the 21 participants (95%) do like the use of a screen and 1 of the 21 participants (5%) would prefer the use of sound. Furthermore, 9 of the 21 participants (43%) mentioned they would like to have more detailed feedback about the speed during the upward and downward movement.
8. DISCUSSION
The results of this research are promising; the average scores of the reliability, improvement of the movement and comfortableness were all bit above the 4 points out of 5 points possible. This is a good score for all of those components. The sixth question shows that such a product will probably only be used by users with little fitness experience, because they indicated that they will use a similar product if it is available, while the other groups indicate they will probably not use it. Almost half of the users (43%) would like to have more detailed feedback during the upward and downward movement. This is something that is definitely possible and programmable in the SunSPOTs. The use of a screen is considered as a nice way to receive feedback, although the users did not experience the use of sound in this research, giving them not much material to compare between the use of a screen and the use of sound.

The results are in line with the expected results. It is interesting that the users with little experience indicate they would like to use a similar product to learn the movement, while users with more experience don’t see the value of the product, possibly because the more experienced users already know how to perform the movement.

It should be pointed out that the research has been tested only by a single group of people. This makes the result a bit weak for doing general conclusions.

9. CONCLUSION
9.1 Answers to the research questions
In order to draw a final conclusion of this research, we start with giving an answer to the sub questions given in paragraph 2.2.

The first sub question is about the reliability of the feedback. In the experiment, the users indicated the feedback feels reliable to them. The results therefore show that the reliability of the feedback is good enough to give proper feedback.

The second sub question is about the usefulness of the feedback in the process of improving the movement. In the experiment, the users indicate that the feedback does indeed help to improve their movement and perform it better the next time. The results show that the feedback is considered useful, although only the less experienced users would like to use a similar product if it is available.

We are now able to answer the main question of this research. In order to derive useful, real-time feedback from the comparison of the trainee’s movement and a stored baseline that helps to improve the trainee’s movement, the use of sensor nodes can be a solution. Even with one free range sensor node, much information about a simple movement can be derived. The sensor node is capable of comparing this information with the stored baseline in such a way that it is able to select the feedback that should be given. The sensor node then sends the feedback to a base node, which gives the feedback information to a computer, which in turn displays the feedback. The use of a screen is considered as a good way to receive feedback.

9.2 Future work
This research leaves a couple of things open for future research. First of all, similar research should be done with people that have more different backgrounds. Now, only the opinion of students with different kinds of experience with fitness training were gathered, but how do, for example, older people experience such a product?

Secondly, the results have shown that the users would like to have more detailed feedback about the speed during upward and downward movement. This is something that the SunSPOTs are definitely capable of measuring and can be programmed onto the baseline and feedback module if desired.

Furthermore, the use of different kinds of feedback should be researched. This research indicates that the use of a screen is considered as a nice way to receive feedback, but other possibilities should be explored and tested as well to confirm the most appropriate feedback type.

Finally, more sensors should be used with proper synchronization between them, to be able to give useful and real-time feedback about more complex exercises.

10. REFERENCES