ProCardio - Running in Central Park on a treadmill

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Abstract - With the increasing demand of at-home workout, runners become more interested in experiencing live-scene running indoors. However, there is a lack of treadmills that can synchronize the inclination and speed changes from a video with a specific route. We present a solution with a control system and a software that allows the treadmill to synchronize with a live-scene video. With the expectation of minor delays, the system provides the users with a more immersive way of running as well as recording useful health data for them.

1 Introduction

There are many benefits of physical exercise. Research has proven that exercise reduces risk of multiple conditions such as coronary heart disease, stroke, cancer, diabetes, depression etc. Experts recommend 150 minutes of heart-rate increasing activity per week [1], and a treadmill can be of help to reach that goal.

Modern gym equipment incorporates many technologies to enhance the user experience of exercising. Gyms often attempt to simulate a pleasant and entertaining environment for running exercises, something that can often be seen on treadmills with interactive touchscreens. One way of doing this is to play a video when running or walking on a treadmill. However, there are limited options for video playback with accurate elevation and speed changes to simulate running in the location of the video.

Companies such as Zwift [2] and Technogym [3] have developed technology to combat this issue. Zwift however focuses more on bicycle training, as well as a virtual map, rather than a video shot in the real world. It also required a subscription in order to use their virtual maps. Technogym provides video playback from actual locations but without the possibility to synchronize video with the treadmill.

Figure 1. ProCardio system in use.

The aim of this work is to construct software that will synchronize the elevation changes in the video and the incline of the treadmill by using elevation data collected from Google Earth. Our goal is to provide the user with an interactive interface where you can choose a video from a library of predetermined routes with corresponding elevation data.

2 Design

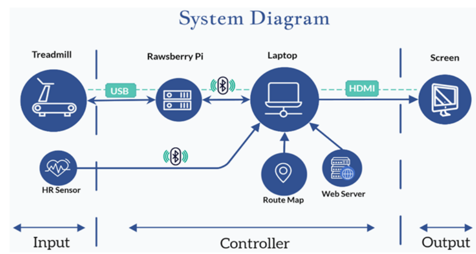

Figure 2. System Diagram

Figure 2 illustrates the connections for the system design. Since the treadmill doesn't have an available wireless module, a Raspberry Pi controller that functions as a transit station is placed between the input side and the controller with one side connected to the treadmill by USB cable and the other side connected to the laptop through Bluetooth service. This design builds a bidirectional communication which allows speed and inclination modification orders made by both devices. On the output side, a screen is connected to the laptop by HDMI cable. Optional input sensors such as the HR sensor can also be added into the system through Bluetooth service to monitor the users' health condition during running. Functions for exchanging data through Raspberry Pi and speed control are based on Python programming and the main control program is in JavaScript.

The basic working principle of the system design is to realize synchronization between the treadmill and the video of a chosen route. The synchronization can be further divided into two parts which are the reoccurrence of real scenes and the synchronization of real-time feedback. According to the running video, geometric information is extracted from the map. Based on the generated GeoJSON file, the main program calculates distances between adjacent samples with geometric coordinates. After combining with the ratio of current time and the time interval between samples, the distance and inclination changes become real-time speed and inclination. These two parameters will be continuously transmitted so that the chosen route will reappear on the treadmill. However, treadmill users have individual preference for the pace and uneven levels of running capability which means that they are supposed to increase or decrease the current speed of the treadmill according to their demands. This indicates a need for synchronization of real-time feedback in the system design. Benefiting from the bidirectional communication between the input and the controller, the laptop can receive newly updated speed parameters from the treadmill and convert them to a changing ratio. The ratio is used for relating the current speed of the treadmill with the play speed of the video so that the experience of running in real scenes is aligned with runners' personal preferences.

With the screen on the output side, the users will receive all the information visually during running. The screen shows the chosen video and essential real-time feedback including inclination, speed and route information in a concise way with an integrated HTML webpage. The entire design brings runners an immersive experience of running in any selected real scene on the treadmill.

3 Results

The system was tested in two different ways, with performance and usability tests[1].

The performance tests are quantitative tests that help evaluate how well the system performs with a chosen route and secondly the usability tests are quality tests that help evaluate learnability, efficiency, memorability, errors and satisfaction of the system[4].

3.1 Performance tests

The performance tests performed were inclination tests. The test is used to evaluate how well the treadmill can keep up with inclination change.

As we can see on Figure 3 the treadmill can follow the real inclination change of the route for most landscapes.

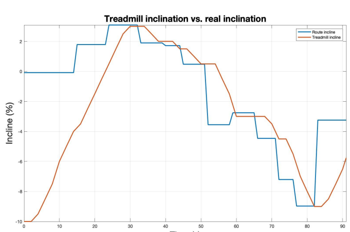

Figure 3. Comparison between treadmill inclination and real inclination collected from Google Earth.

The treadmill starts at -10% incline (minimum incline) and initially it needs to catch up with the real inclination.

From the first 30 seconds on the graph we can see the treadmill is limited to an incline change of approx 0.44% per second. The largest error is in the start and when the treadmill meets a fast inclination change because of the limitation in inclination change rate.

3.2 Usability tests

To test the usability of our system, two testing subjects followed a task list (Table 1) to try out the system. While the subjects were performing the tasks, the examiner documented results by writing down errors (see Appendix) made by the subject and evaluating the severity (Table 2). From the testing results we can find out how easy it is for the subjects to learn to use our system (learnability). Both subjects were timed for how fast they solved each task so that we can know which step may cause confusion to our users (Table 4 and 6). The average time for accomplishing the whole procedure is around 3 minutes and 45 seconds which indicates a good efficiency of the system. The bluetooth connection is the most time-consuming part as the bluetooth devices are often not discovered fast.

All errors that subjects made have been documented in Table 2. Both subjects had a hard time going between the treadmill and the computer running the software. None of the errors are classified as severe and the testers could recover from all the errors they made. However, it still shows a possible direction of improving our system. In the last task, the subjects are asked a question about how satisfied they are with the system. Both subjects were satisfied with the system with an average satisfaction score of 7.5 out of 10.

4 Conclusion

We have developed a controller system with software that provides the runner real- scene experience throughout physical exercise. Based on extracted geometric information from the map, a chosen route can reappear on the treadmill with real inclination and speed changes. Additionally various sensors which monitor the users' health condition can be embedded into the system for further data processing. For future project development, we suggest creating user accounts so users can have their own place with their workouts. Also another improvement is an app that allows users to record and upload routes. For additional development, we recommend adding a tutorial on usage for easier usability for a new user.

5 References

[1] *Benefits of Exercise, NHS* (2021). https://www.nhs.uk/live-well/exercise/exercise-health-benefits/. Accessed December 7th 2022.

[2] https://us.zwift.com/. Accessed 11th of October 2022.

[3] https://www.technogym.com/us/. Accessed 11th of October 2022.

[4] Nielsen, J. (2012). *Usability 101: Introduction to Usability*. Nielsen Norman Group. https://www.nngroup.com/articles/usability-101-introduction-to-usability/. Accessed 11th of October, 2022.

[5] Github Page. https://github.com/asmundur31/ProCardio/commits/main

6 Appendix

Usability tests

System	ProCardio
System version	2.0.0

Tasks for subject to perform:

Task nr.	Task name	Task description
1	Access our software	On a computer open a browser with bluetooth support (ex. Google Chrome) and go to https://treadmill.dev.kthcloud.com. You should see our home page.
2	Choose a route	Choose a route to run, select routes and from there select a route of your choice. You should see the video you chose.
3	Connect to the treadmill, heart rate device and start	Now you need to connect to the heart rate device by choosing 'Connect HR'. A list of bluetooth devices comes up, choose the Polar device. Next connect to the treadmill by choosing 'Connect treadmill'. A list of bluetooth devices comes up, choose 'raspberrypi'. You should see a message with a successful connection. To start the route you press 'Start'. Go to the treadmill and start running.
4	Speed change	While running select any speed you can handle. You do so by pressing the speed controls on the treadmill. Enjoy the view while running and feel the inclination change.
5	Stop running / Cool down	When the route finishes you automatically enter to cool down. If at any point you want to stop, press the 'Start/Stop' button on the treadmill and wait for it to stop.
6	Results	Go into recordings on top of the page. Here is a list of all recordings. Find your recording and view your results.
7	Question	How satisfied are you with the system? Answer from 0 (not satisfied) to 10 (completely satisfied)

Table 1. List of all tasks the subjects have to perform.

We classify the severity of the errors:

Small error (S)	Has no big impact on the subject, he becomes slightly irritated.
Medium error (M)	The subject is able to finish the task but has to take a detour or takes an unusually long time finishing the task.
Large error (L)	Subject cannot finish the task and/or loses data.

Table 2. Classification of how severe the errors are.

Usability test results

List of all errors, where we combine similar errors.

Error nr.	Error short description	Task nr.	Name	Severity (S,M,L)
1	Heart rate sensor slow	3	Melker B	M
2	End route	5	Melker B	S
3	Start route	3-4	Skylar	S

Table 3. Overview of all errors made by all subjects

Usability subject 1:

Date	2022-12-06
Examiner	Us
Location	Integration Lab - KTH Flemingsberg
Subject	Melker B

Task nr.	Time (mm:ss)
1	20 s
2	20s
3	3 min
4	30s
5	10s
6	30s
7	7 (Add pop ups or a tutorial)

Table 4. Time for subject 1 to finish all the tasks and satisfaction score.

Errors:

Error nr.	1
Short description	Heart rate sensor slow
Subjects likely problems	When the subject put the sensor on, he had it outside his t-shirt so the sensor did not turn on.
Location of error	Connecting heart rate sensor to software
Reason for error	Sensor not turning on
Severity	M

Table 5. Error 1 for subject 1.

Error nr.	2
Short description	End route
Subjects likely	When the subject wanted to end. He forgot to end the route in the software even

problems	though he stopped the treadmill.
Location of error	When the video is still playing.
Reason for error	Subject wanted to end the route earlier.
Severity	S

Table 6. Error 2 for subject 1.

Usability subject 2:

Date	2022-12-06
Examiner	Us
Location	Integration Lab - KTH Flemingsberg
Subject	Skylar

Task nr.	Time (mm:ss)
1	10s
2	20s
3	1 min 10 s
4	40s
5	10s
6	10s
7	8 (Hard to run between the devices computer and treadmill)

Table 7. Time for subject 2 to finish all the tasks and satisfaction score.

Errors:

Error nr.	1
Short description	Start route
Subjects likely problems	The subject didn't realize that the treadmill would start automatically.
Location of error	Starting the treadmill
Reason for error	No knowledge about the software before
Severity	S

Table 8. Error 1 for subject 2.