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FinGym

Do Finger Gymnastics with Music

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1. Abstract

Rehab training will not have an immediate effect and therefore may lead into a lack of motivation for the patients to continue doing the exercises. FinGym is a video game to perform finger gymnastic exercises with LMC (Leap Motion Controller) to music. The expectation of this game was, that it will be motivating people with physical disease on their hands more to perform the exercises because of getting rewards while playing. The goal was to develop a working prototype but also to answer the question of the technical practicability of a game using the LMC and if it will work precise enough to fit the needs of a medicinal application. To find out if there is a need among affected people for an application like FinGym and if they would use it instead of doing the exercises regularly a usability test was done. While the test showed that even elderly people would use computer games for rehab the use of the LMC revealed a few technical issues according to the purpose of rehab.

2. Motivation

Yet Another Rehab Game

The first question was if there are already related projects or studies covering the use of the LMC in combination with rehab. There isn't much. LM (Leap Motion) provides an online store where users can search for apps and buy them but during the time FinGym was developed there was no app especially for rehab. The paper "Free Hand Interaction With Leap Motion Controller For Stroke Rehabilitation" [1] is about a study with 14 people with post stroke. The participants had to play a modified clone of the Fruit Ninja game and cut the fruits with the index finger to get as many points as they can. Each fruit counts one point. As a result the study "show a high correlation with standard clinical assessment scores such as Fugl-Meyer (FMA) and Box-and-Blocks Test (BBT) scores" [1]. While this study provides valuable data for further researches it does not answer the question if it is generally possible to perform rehab exercises with the LMC. Moving one hand just making a pointing gesture is simple in comparison with more complex movements normally done in rehab. More complex movements means that the patient has to roll, to stretch and to contract his hands and also that the hands can cover each other while moving. Therefore the LMC has to track the hands in different angles and will lose tracking information if one hand is covered by the other one. To show if this would be a problem FinGym was developed for.

User Group

FinGym was designed mainly for patients and the elderly, who are easy to suffer from the disease Limb Contracture.

A Limb Contracture is the lack of the ROM (Range Of Movement) due to joint, muscle, or soft tissue limitations. [2] It is caused by less agility of joints and muscles and malposition of an extremity.

A common method to prevent limb contractures is to move the joints and muscles. This can be done either active by the patient or passive by another person. A

movement often used for prevention of Limb Contractures in hand is to open the hand, stretch all fingers and then close the hand to a fist. Doing the extended hand and fist movements in cycles can make up a finger gymnastic exercise.

Current Situation

There are some aspects in the current situation of the finger gymnastics, that can be improved by FinGym.

1. It is location and time restricted. Patients or the elderly, who want to do a rehab exercise, must go to a rehab center on a fixed date. But some of them have problems on walking or ever are immobile people.
2. It is dull. Medical treatments are mostly boring. Patients and the elderly can’t do anything else at all except the exercises. Unfortunately, finger gymnastics is one of them.
3. It lacks of motivation. The effect of the exercises comes really late, probably after a few weeks or months. It leads to a lack of motivation from patients and the elderly for further treatments.

3. Concept

To improve the tradictional finger gymnastic exercises, FinGym was designed in the following ways:

1. It was built on PC/Laptop with LMC so that patients and the elderly can use it at home or anywhere they want.
2. It was designed with music to make patients and the elderly feel more interesting. And music has the effect of relaxing them.
3. To make finger gymnastic exercises more motivated, there were gaming elements in FinGym. Patients and the elderly can see what they have done by visualization of scoring immediately.

In a word, FinGym is an application to do finger gymnastic exercises in a music game with Leap Motion Controller to increase the agility of fingers and hands.

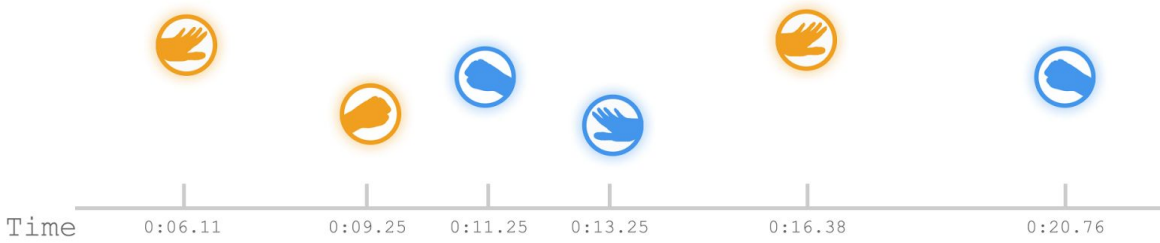
Gestures

In general the movements should be used to increase agility of the hands as a prevention method for Limb Contractures. Movements often used for prevention of Limb Contracture of hand are to open the hand, stretch all fingers and then close the hand to a fist. In finger gymnastic exercises patients and the elderly do these two gestures in cycles.

- Fist: This way patients and the elderly has to perform a fist gesture where all finger joints are moving until the hand is nearly closed.
- Extended Hand: The opened hand and spread fingers. Performing this gesture all joints are moved in the other direction.

In FinGym these two markers (p. 1) were designed for these two gestures, and they were arranged one after another by the rhythm of music to simulate finger gymnastic exercises. The different colours and different directions are for the different hands.

Database

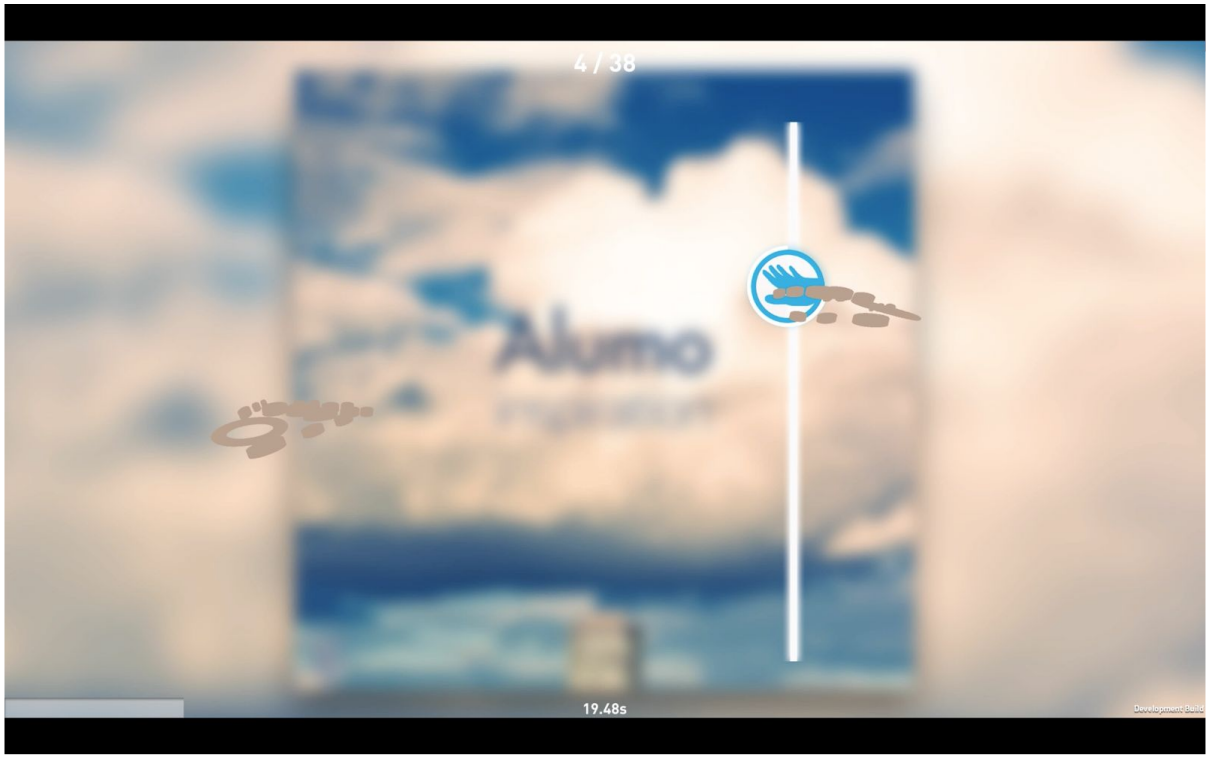


p. 2

In order to make the makers appear at the certain time point of the music according to the rhythm and show the gesture type to the user, a database (p. 2) was built for every marker containing the data of certain time point, the gesture type and the correct hand.

Interaction Techniques

Interface



p. 3

The white line here is the indicator to show the time point patients and the elderly should hit the markers. It repeats the movements from left to right and right to left. In the following screenshots the indicator moves from right to left. Markers will appear at the x-position according the database, which is based on the rhythm of music, but the y-position of them are random within a certain height zone. At the top of the screen is the score, the highest score is 38. And at the bottom is the timeline of the music.

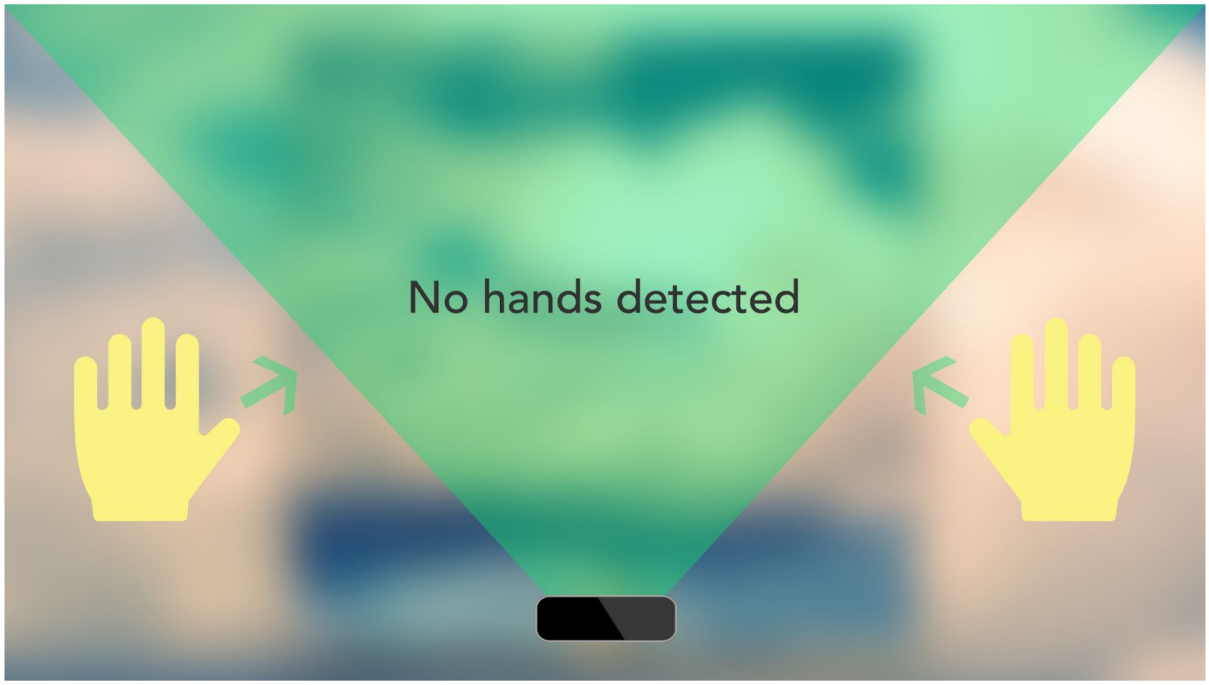
Interaction Process

The interaction processes could be divided into 4 parts:

1. Pre-Ready

   At the beginning, patients and the elderly put their hands above the LMC (p. 4) to get ready. Then the music will be played. They listen to the music and wait

for the markers to come. When it comes, they should hit it by moving his hands forward (p.5).

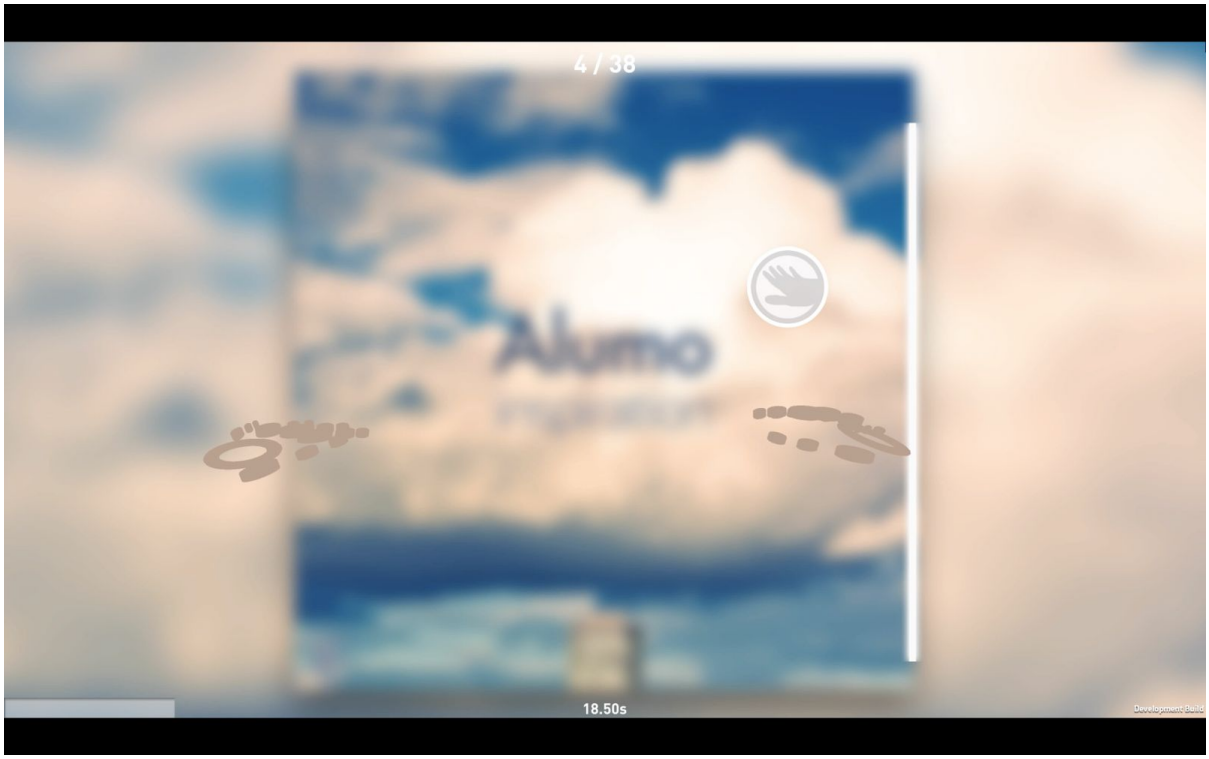


p. 4

p.5

2. Markers pop up

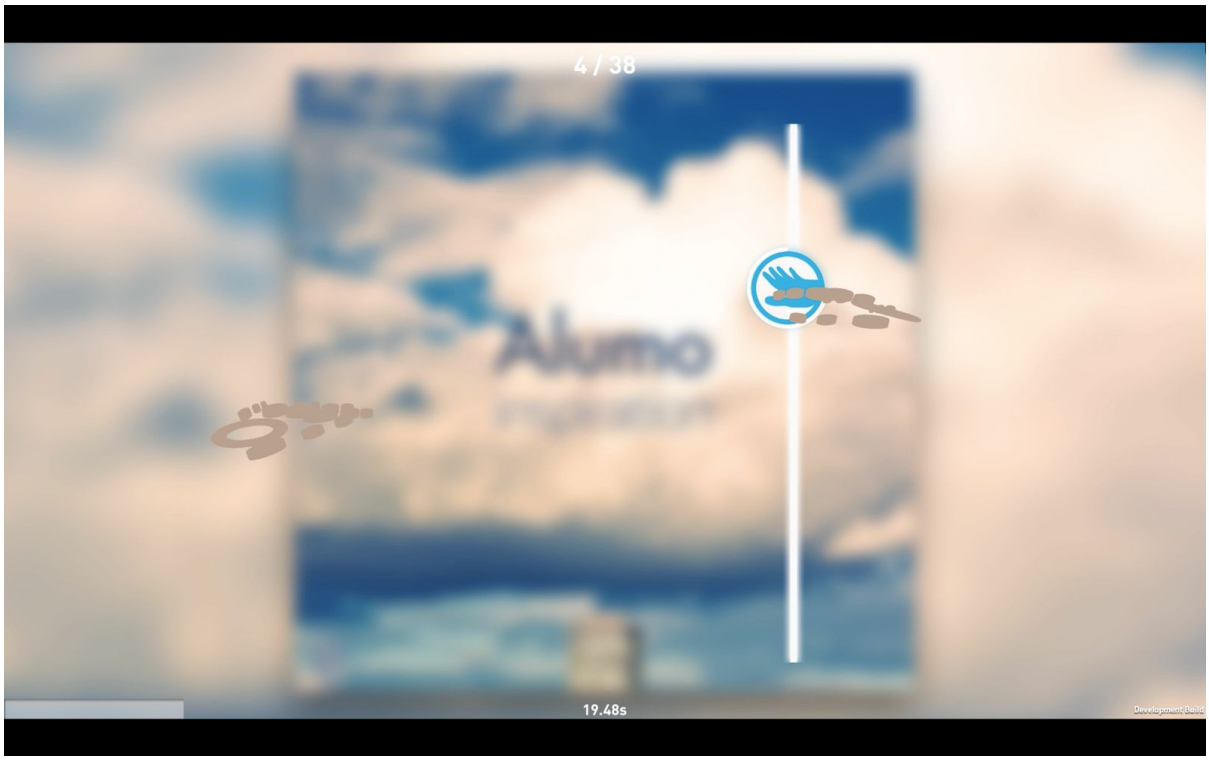
   Marker will appear about 2 seconds before the time point in the database, but it is inactive with the colour grey (p. 6). It only shows the certain position and the certain time point of this marker, so patients and the elderly has the time to know when they should hit the the marker and where to hit it with which hand and which gesture.



p. 6

3. Indicator moves over the marker

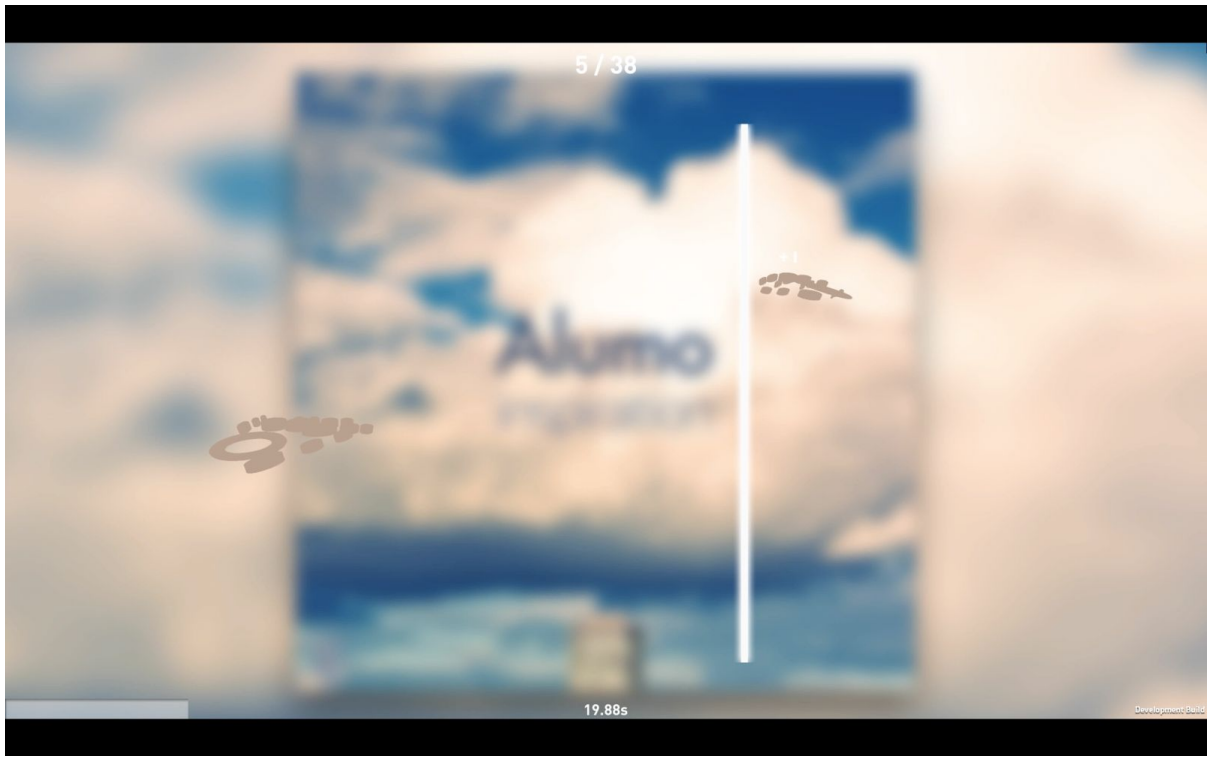
   Then the indicator continues moving from right to left. When the indicator moves on the marker, the marker will be active with colour (p. 7) about 1 second. This 1 second is the time for patients and the elderly to hit it. In this case they should move his right hand forward with the extended hand gesture at this position.



p. 7

4. Score or not

   If patients and the elderly succeeds doing this (p. 7), they score (p. 8). Otherwise, they lose this score of this marker.



p. 8

4. Technical Implementation

FinGym was made with the game engine unity and the programming language C#. The framework and the API of unity is based on the Mono framework - the open source pendant of the .NET framework. LM provides packages for common game engines containing the API (Application Programming Interface) to the LMC and a wide variety of programming examples. The coed is mainly based on the MVC (Model View Controller) Pattern.

Data storage

The data are stored in a SQLite database using the schema shown in Fig. 1. The song contains the title of the audio file and the path to the file and can have one or more tracks. The track was meant to provide variations of gestures for one song to try out different combinations but is not used for now. The gesture finally contains the actual data (start time, end time and the gesture type) for the exercise.

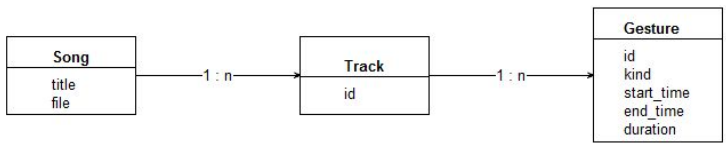
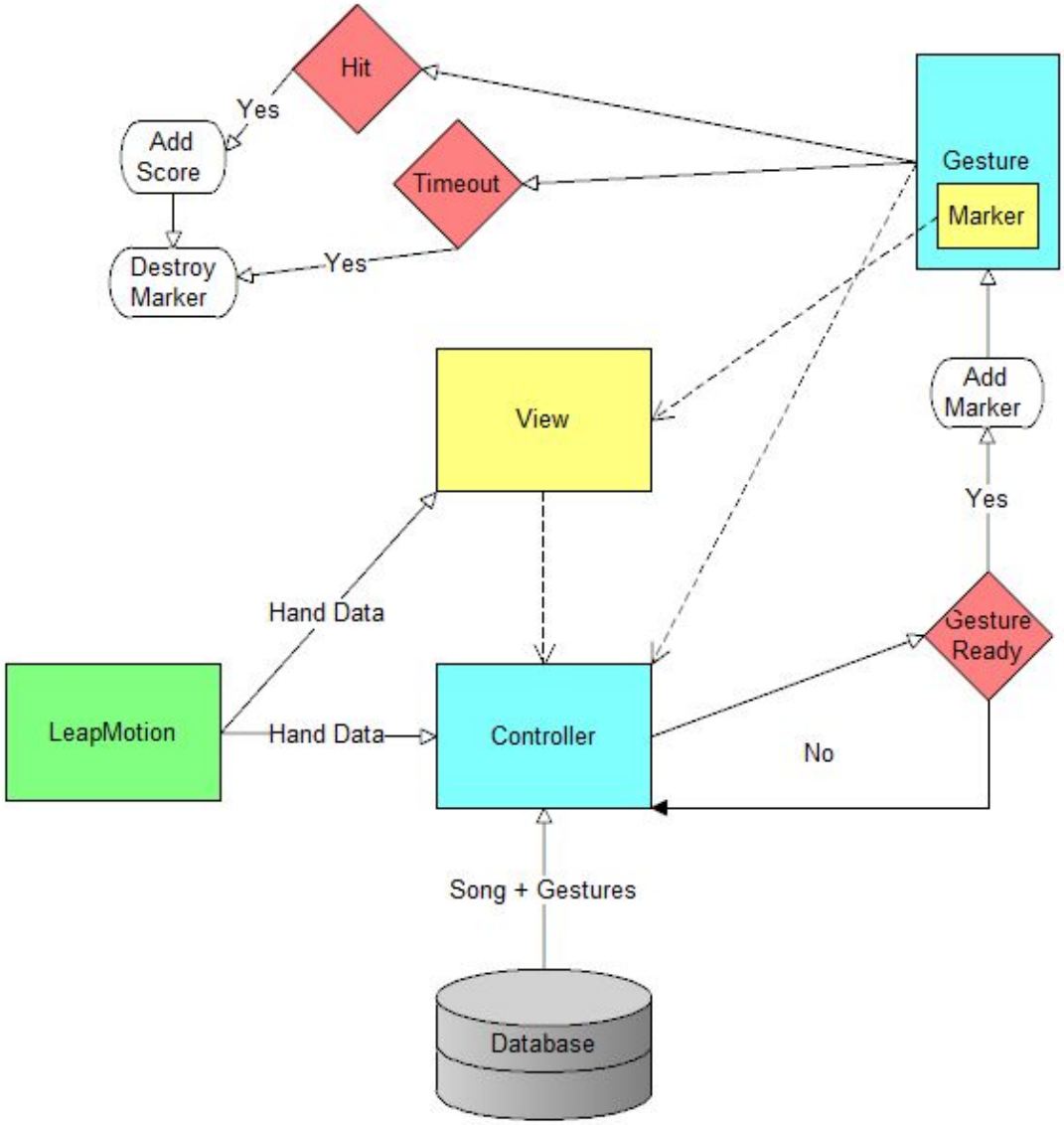


Fig. 1

p. 9

Modules

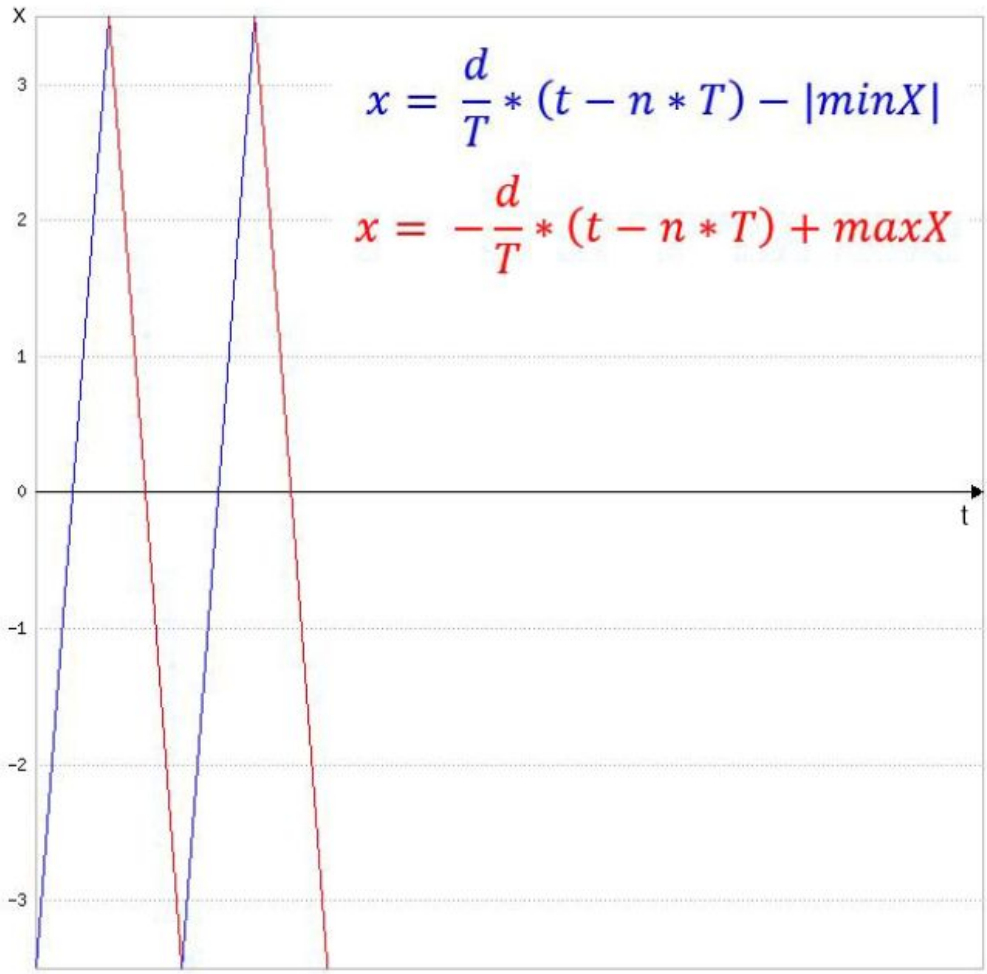
The controller loads that data from the database and also gets the data from the LMC. As soon hands are detected the controller starts the playback of the music and compares the playback time with the start time of each gesture and also triggers the view to update the position of the indicator based on the playback time. If the start time minus one second is equal or less than the playback time the controller triggers the view to add a new marker in an inactive state. If the start time is equal or less than the playback time the marker becomes active. Then the active gesture runs a countdown for one second. If the time runs out or the marker was hit within this time either a timeout event or a hit event is triggered.


Hit
Yes
Add Score
Timeout
Destroy Marker
Yes
Gesture
Marker
View
Add Marker
Yes
Hand Data
Gesture Ready
LeapMotion
Hand Data
Controller
No
Song + Gestures
Database

p. 10

Calculating the x positions

To set the x position of the indicator and markers in relation of time, two mathematical terms were used.



p. 11

Applying the conditions:

- maxX > minX; T > 0; Time unit = ms

The following takes effect:

- d = maxX - minX
- T = Constant timespan for each cycle (E.g. time the indicator needs to move from one side to the other)
- n = integer part of t / T

The blue term shown in the figure above is for the movement from left to right and the red colored term vice versa.
One cycle is the movement from one side to the other. The value of ***n*** increases on each cycle. If ***n*** is even the blue term is used and if it is odd the red one is used.
For a constant flow from left to right and back the whole term needs to be moved in right direction on each cycle. This is done by calculating ***t - n * T***.
Passing any time value in milliseconds into this function a x coordinate within the visible area between minX and maxX is calculated.

5. Evaluation

The LMC would be a great device to perform rehab exercises but unfortunately has still some technical issues making it inappropriate for this purpose at the moment. During the development it was observed that the tracking sometimes does not work anymore. Either the hand suddenly was twisted to 180 degree without a reason or was completely lost. To get the hand back it has to be moved outside the area of the LMC and then moved back inside the trackable field again. This issues will disturb the exercise. Furthermore the LMC has a sluggish response. There is a short delay between the actual movement of the hand and the movement on the screen which could be a bit irritating for the patients.
Taken as a whole the prototype works with some restrictions e.g. less complex gestures like a fist or an extended hand.

User Study

There was also a user study done with five participants (3 Male, 2 Female) with a minimum age of 50 years, all were right handed and had physical disabilities on their hands. There was a maximum score of 38 points to collect.
Since I did an apprenticeship as a geriatric nurse and being the programmer of FinGym the study was managed by me in cooperation with Die Pflege-Partner - an outpatient nursing service - and was guided by Mr. Georg Spriewald-Makedonsky who is also a geriatric nurse.

At the end each participant answered 5 questions according to their feeling about the application.
Because the study took place in the homes of the participants there were unequal conditions according to the tables and chairs.
Each participant did the exercise with the right hand and had three rounds to get familiar with the LMC. Then each participant performed the exercise to the end.

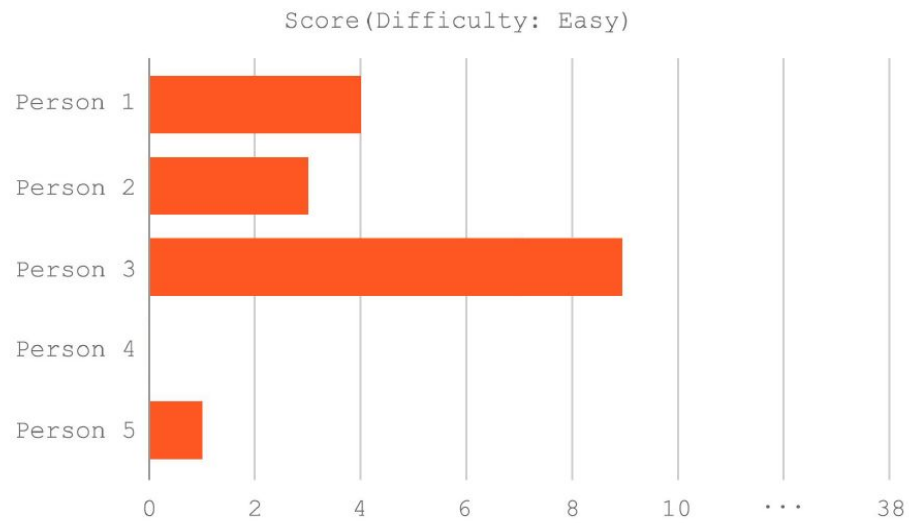
Problems

The study showed that the conditions at home may not fit the needs to work with FinGym. P1 was sitting in a wheelchair. The table on which P1 would normally do the exercises was too tall. Therefore the hands were too close to the LMC and could not be recognized. Because of the disability, P1 was not able to lift the arms any higher. With a lower table there was the problem that the footrests in front of the wheelchair blocked so it was not possible to get close enough to the table. At the end the laptop was placed on a chair and I held the LMC for P1 in my hand.

Because of this interference the whole study may have to be repeated but in a clinical surrounding to avoid inconvenient conditions. Nevertheless this points a central issue an application like FinGym has to be aware of. Especially elderly people being dependent on the help of others will not be able and perhaps will also be not willing for different reasons to buy a new table that fits the needs of such an application just to perform rehab exercises.
A possible solution would be to connect the computer to the TV and place the LMC on a rest table in front of the wheelchair which should be normally available.

Results

In the end, none of the participants got more than 9 of 38 points.



p. 12

Each participant also answered 5 questions:

1. Do you find the application useful? (5 yes)
2. Would you use the application? (3 yes, 2 no)
3. Do you believe that the application may have a positive effect on your disease? (5 yes)
4. Was the coordination of your hands a problem? (1 yes, 4 no)
5. Was it easy to hit the markers? (5 yes)

The results of the first three questions shows, that even elderly people would use an application like FinGym. P4 mentioned that he would use the application if he had a laptop but is not willing to buy one.

The answers of questions 4 and 5 are very interesting since none of the participants got more than 9 points during the test. P4 also said “it is surely easy to hit the markers but would need more practice”.

It seemed that hitting the markers was not the main goal of this 5 participants. At least there was no obvious frustration about it. All moved their hands in the direction of the markers and did the gesture shown on it. P4 even asked to try again when the test was already over.
In this sense FinGym achieved its goal because the focus lays on the rehab and not on the highscore.

With the words of Mr. Spriewald-Makedonsky: “There are many lethargic patients. The loss of agility often leads to a lack of social contacts and many are suffering on a depression therefore. It is very difficult to motivate this people to do anything. If they would just do one movement with this application it would be 365 movements per year the patient would not have done otherwise”.

6. Conclusion

Because of the results of the user study one question is where the problem was. To find out if patients would get a higher score and would have less problems controlling their hands with the LMC the test should be repeated in a clinical surrounding as already mentioned. This would clarify if the conditions at home - mainly the furniture - affects the performance of the users.

The scoring and the answers to the questions are in a very high contrast. It would be interesting to find out why and raises a few questions. Did the participants not apperceive the low score as a fail? Was it embarrassing for them to admit that they may have failed?

From the technological point of view the LMC is not precise enough for complex rehab exercises but it actually a great device for. A further research could also be to find out ways to improve the tracking.

7. References

[1] 2014. *CHI '14 Extended Abstracts on Human Factors in Computing Systems*. ACM, New York, NY, USA.
[2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3482407/