GRow
“Feel More, Row More!”

HCI project

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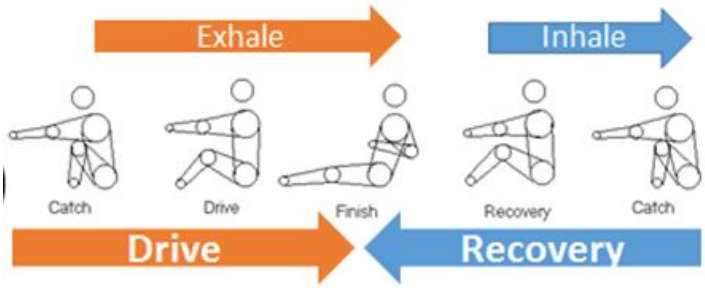
Abstract:
Sport is an integral part of human life. Sport activities are quite diverse and are followed by a growing number of people across different genders, countries and social levels. The US statistics has shown that more and more people are becoming involved into sports each year, in particular women engagement is increasing rapidly [6]. One of the main reason why it is so popular is the fact that it helps people to keep fit. Moreover, it strengthens our health, builds solid character values and, of cause, assists in socializing.
Thus, it has been a trend for some time for research and industry to study and develop technological gadgets and applications that target this aspect of human activities with different goals set: ensuring safer, easier, more efficient, more effective, more enjoyable, and friendlier experience for users.

In this work we present an improved solution that aims at exploring,facilitating and improving rowing activities. While some solutions already tried to target rowing sport and still mainly focused on professional rowers by means of improving performance and strokes per minutes, we believe it is equally important to help beginners to realize correct and accurate movements. Furthermore, deep market and system analysis in addition to leveraging the proven practices in multimodal interface design have shown that the right combination of different sensory channels, such as auditory and haptic, can lead to enhanced user experience.

The document is divided as follows: in the first section we introduce the rowing scene and define the application scope. Next we systematically review some of the most notable theoretical work along with related examples currently in use to identify key features and limitations that we will try to address in our solution. After that the user,task and domain analysis are performed in order to deeper understand the requirements and possible alternatives for further design phases.

1- Scenario and problem definition:
Any kind of sport requires precise and coherent body movements. Since the rowing activates all body muscles it also requires physical strength, flexibility, cardiovascular endurance and strong core balance. Although it is easy to learn, high coordination between different body parts motion is required, in addition to the synchronization that should emerge among the rowing team members [7].



Among the olympic settings of rowing sports several alternatives exist including different players number within a single boat and different stroking strategies with single hand vs double hand stroking.

While it's granted that the visual senses of the rowers is occupied, it's suggested to use other senses in order to guide and assess the motion quality of the rowers.

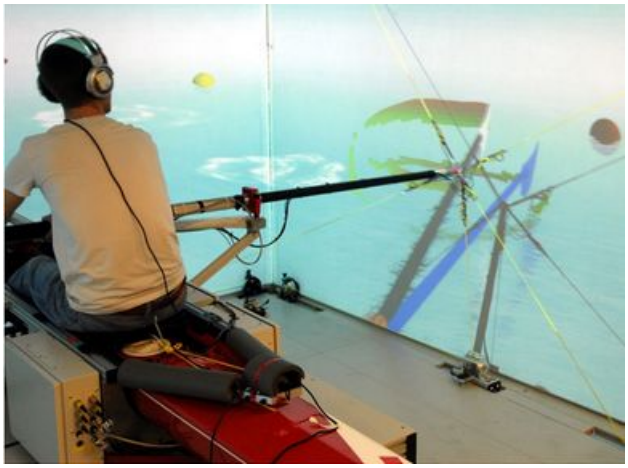
2- State of the art:

In this section we present the notable work that tried to assess the problem of computer aided rowing coaching, in which often audio feedback is suggested to allow the rowers to understand different aspects of the rowing performance.

In this work [1] the authors of the paper designed a sonification solution targeting mainly one rower. First the boat acceleration is recorded using dedicated sensor hardware Sofirow, and then remotely analysed. Based on the acceleration value an audio feedback is delivered through loudspeakers to the athlete user. The pitch is used in order to encode the acceleration feedback. After the experiments, athletes confirmed the system to be functional and supportive. The system settings can be seen in the following picture.

In this work [2] the team scenario is considered. The Mobile Measuring System (picture below) ,gauge attached to the oars, Sofirow and HR monitors are used to collect all necessary data, in particular force applied to the oars, angle of movement, velocity, acceleration, heart rate and blood lactate. The real-time audio feedback is delivered through pitch based on the boat acceleration that takes into account the team synchronization. The professional sportsmen were satisfied and pointed out the synchronization improvements.

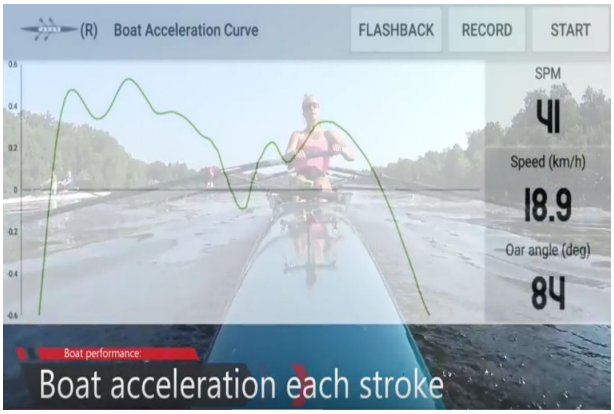
In this work [4] a virtual reality environment is set and a number of participants are exposed to a virtual rowing experience in which the trajectory of the movement is measured and different visual, auditory, and haptic feedbacks are delivered, according to the authors the use of multimodal feedback enhanced the ability to learn for the participants rather than using only one channel.



3- Market analysis:

As for the current relizations for rowing applications most applications are mobile-based leveraging the already-existing sensing capabilities.

In Rowing Performance application additional sensors are used and interconnected to collect different measurements some are boat-mounted, others are oar mounted, and they collect speed, acceleration and oars trajectory and these data is stored and synchronized to a coach device for later analysis and assessment. Although no real-time feedback is delivered, the records can be useful to improve quality and performance of rowing. Currently, the application is available only for Androids.



Another application, Rowing in Motion, records the acceleration of the boat, speed and stroke rate using the accelerometer and GPS sensors. A real time auditory feedback is provided based on the acceleration. Both IOs and Android applications are available for download. Furthermore, it provides two different interfaces for rowers and coaches.

4- User Analysis:

It's our target to support different types of users with different experience in both rowing and technology usage.

During our exploration of users needs we analysed a tend to simple interfaces that don't intervene with the rowing experience and at the same time provide intelligent guidance according to the rower definition.

For beginners it was important to remind and assess the full range movement accuracy from body to legs to arms rotation, and it's important for them to be alerted when releasing the oar as it would result in flipping of the boat.

Hands synchronization (in the case of double stroking) and team synchronization is a tricky part for the beginners -according to the people we've met- and they would prefer if a solution can tackle this issue.

As for more advanced users, the synchronization is still important, but they care less about movements accuracy as they developed an long experience in rowing and movements are now unconsciously controlled, but for them it's important to track the performance by means of time and distance of trip, and in order to detect performance inefficiencies they want to constantly address their stroke-per-minute rate and acceleration cycle (acceleration - deceleration).

4.1- Personas:

According to the interviews we have conducted, we have categorized two personas who capture the users expectations from a rowing solution:

a- User 1(Paola)

Paola is a beginner rower, she has been practicing rowing for a year and a half but not on tight schedule, she takes rowing more as a hobby, but she would like to improve her experience using a solution that can feel like a coach.

Goals:

Rowing correctly and with other teammates who are also beginners.

Having a simple interface, as her experience with technology is limited.

Frustrations:

Sometimes when the boat stops for a break she forgets holding the oar and the boat flips

It's tricky for her to keep the balance between her arms, torso and legs movements especially when trying to speed up stroking.

b- User 2(Steven)

Steven is enrolled in the local team, and he spends a lot of hours training for participating in rowing events and local championships, his dream is to represent his country in the olympics one day.

Goals:

Increasing the rowing performance by means of time and speed

Work with his teammates to better communicate during rowing sessions

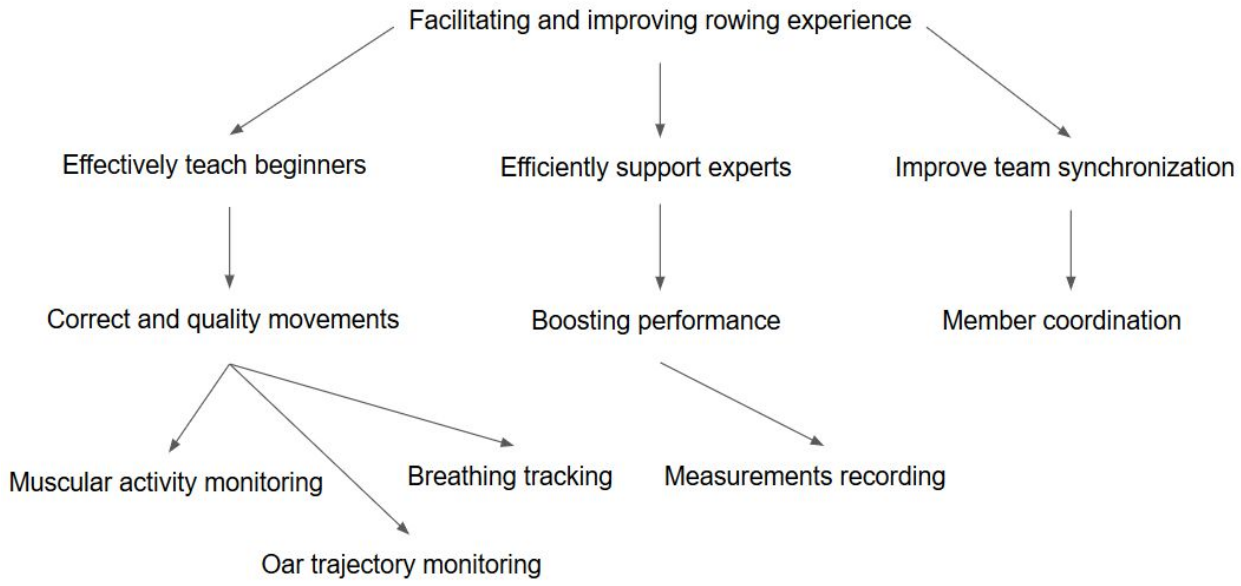
Frustrations:

The difficulty of using other solutions he had tried and the limited functionality

Miss-synchronization among team members affects the boat acceleration and wastes other members efforts.

5- Task Analysis:

Our global task is to facilitate and at the same time improve rowing experience in both beginner and expert users taking into account the possibility of team rowing. Since the above task is quite complicated, we are going to represent it as a hierarchy of subtasks.



With regards to the beginner task, our goal is to facilitate the learning process and ensure the correct and quality movements. This can be decomposed into three main subtasks: muscular activity and breathing tracking, and oar trajectory monitoring. The main precondition is to choose the stroke strategy. The task can be performed on a canal,river,lake or other large bodies of water. The learning is done by trying and perceiving the feedback which will help to row in a correct and effective way. Therefore, no instructor is needed. In general, the task is advised to be performed twice a week in order to master the necessary skills.
The professional user task aims at efficient support targeting the performance boost. The very important precondition is that the user should already know how to row correctly. Moreover, he/she wants to monitor and overcome obtained results. In other words, the expert is focusing on time and speed improvement by setting the desired clock time. This task can also be performed on different large bodies of water and the learning is done by trying and receiving the real-time feedback. The couch can be involved in order to analyse the measurements and performance in real time, otherwise, the sportsman himself can analyse it later, since all the sensors data will be recorded. The task is recommended to perform every day, however it depends on professional goals of the athlete.
The team synchronization task focus on helping the team of rowers to row as a single organism. To obtain that the high coordination between the members is needed. The precondition of this task is the strategy of stroke chosen by the team. The task can be done on different big water surfaces. The learning process is achieved by trying and perceiving the haptic feedback which will coordinate the work of each rower in line with the others. In the scenario when there are 4 or 8 rowers, the desired speed can be set to avoid the person which usually coordinates the whole team speed. The task can be performed frequently due to the team goals.

6- Domain Analysis:

In order to understand better the elements of our domain and the relations between them we need to perform a domain analysis.

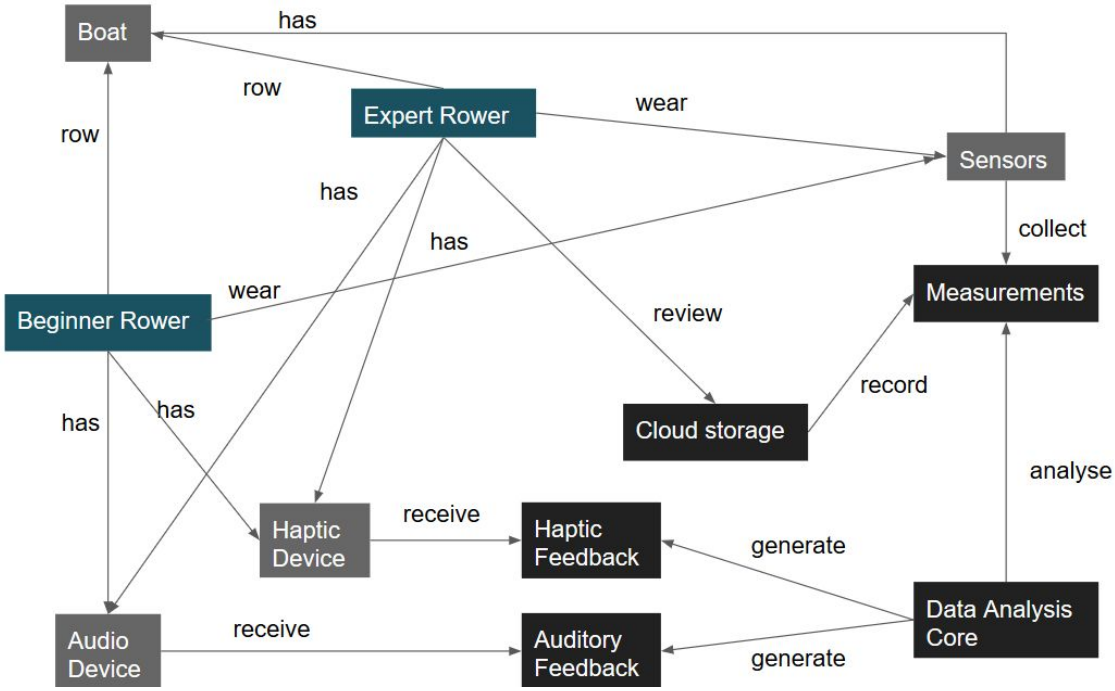
Having analyzed the domain, we identified the following entities.

People: Beginner, Expert

Physical objects: Boat, Sensors, Haptic Device, Audio Device

Informational objects: Measurements, Data Analysis Core, Cloud storage, Auditory and Haptic Feedbacks.

The relationship between the above entities are shown in the Entity Relationship Diagram.



Every type of users (Beginner and Expert) rows a boat and wears some sensors that collect user measurements such as muscular activity and breathing. The boat facility itself contains some other sensors that measure the oar trajectory and the performance metrics. All the data collected from the sensors are then analyzed in real time by Data Analysis Core in order to decide when and what type of feedback should be generated. The measurements are also recorded and stored on Cloud in order to give the possibility to the professional user to review his/her performance and related results later. The feedbacks are received by specific devices and propagated to the user aiming at movements coordination in single rowing and also motions synchronization in team scenario.

7- Requirements:

According to the previous analysis, we show here the functional and nonfunctional requirements that have to be fulfilled in the application.

Functional Analysis:

The solution is to be used by a single or a set of rowers in one team, using a mobile and web interface for different purposes.

The mobile interface is meant for on-site interaction, for instance, starting and ending the rowing session,setting up the parameters etc.

The web interface is used for retrieval and management of rowing sessions with the ability to analyse the recordings (by a coach or by an athlete himself).

The solution provides two possible operation modes, configurable using the graphical interface. The first one is for beginners, which allows the user to learn the rowing in a more controlled way, and the second is for experts in order to achieve more specific time or speed framed goal.

The solution must include suitable technological gadgets that are able to collect the necessary measurements required for the application to operate; Namely:

- Body measurements: breathing activities, upper and lower body alignment, muscle activation.
- Boat Measurements: acceleration.
- Oar Measurements: oar trajectory.

The application has to be able to interface with the mentioned gadgets and collect signals from all of them. In order to decide which feedback is going to be generated and in which instance of time the system should perform on-the-fly data analysis.

The feedback has to be then propagated to the user in real time by means of specific devices.

The application must respond with a relevant feedback as follows:

- Auditory feedback based on the quality and correctness of the rower movements and oar handling, or based on the boat acceleration according to the selected setting.
- Tactile feedback based on the synchronization with other team rowers and the synchronization between the two hands of the rower.

The application must synchronize the measurements with a cloud storage for later analysis and retrieval.

Nonfunctional Requirements:

The mobile user interface should be minimal,intuitive and easy to use, and suitable for high lightning conditions (sun).

The gadgets and sensors should be selected such as to require minimum set-up hassle. The size and location should be chosen in a way that do not interfere with the rower experience and range of movements. In particular, the sensors attached to the oar should be of minimal weight in order not to change the oar resistance.

Not only the sensors, but also the feedback propagating devices must be chosen in a very careful way such that not to impede the rower attention.

Thus, the auditory feedback should be delivered in medium and with a characteristics that minimally intervene with the environment important sounds (rowers vocal communication).

The feedback should be delivered in real-time and with minimum possible latency.

Uploading the measurements to the cloud should be of high throughput but not to interfere with the feedback operation of the system. Thus, this task is given a second priority.
The collection of measurements should be synchronized and reliable.

8- Further steps:
After deep analysis of the requirements of the application we will start the Design phase. We plan our future work as follows:

- Choice of technology
- Setting design (where to put the sensors and devices)
- Mobile and web application design (sketching the visual interface)
- Sound design
- Haptic design
- Mapping the data into feedback

9- Design:

Starting from the user analysis and requirement analysis we will define the following scenario that corresponds to a set of users (beginner users).

9.1- Beginners Scenario
According to the user analysis, beginners are mostly interested in learning the correct movements, and thus the design will focus on this aspect along with providing an easy-to-use interface.
It has been shown in [8] that using vibrotactile feedback as an error correction targeting the wrongly moving body parts have a good effect in stimulating motor learning.
Multimodal Interface Elements:
Each rower will be equipped with the following gadgets:

- A set of body-mounted sensors used to track the 3D body motion of the rower
- A set of body mounted vibrotactile motors used to deliver tactile feedback
- A bluetooth headphone that delivers auditory feedback

- Smartwatch as a user interface and the controller of the whole system during the rowing session.

The technology is chosen to have a minimum weight and effect on the rower, while obtaining high precision measurements and the most helpful feedback.

Smartwatch user interface design:

The user interface is designed to fulfill the required task with a both simple manner and with a visual elements that are easy to interact with in a smartwatch form factor.
Starting the rowing session requires three steps only:choosing whether to create or join a session, choosing the difficulty mode and choosing the team size and style.
For single rowers the steps are straight forward, while for team rowers special care is also given to simplify the setup; the team leader sets up the session properties as noted before, then each of the team members within their seating order joins and confirms his joining order.
The team leader when ,the session is full, starts the session, and ends it when required.
The following sketches clarify the user interface design.

Feedback Design:

In this section, we discuss the feedback we provide in the beginner mode, that faithfully builds upon the user analysis and users priorities.
Two types of feedback are provided, an auditory feedback mainly intended to help with synchronization, and a tactile feedback that targets specifically movements quality.

a. Auditory Feedback

Two types of synchronization can be realized, team synchronization and hands synchronization in the context of sculling. To better address both cases, we will consider the single rower scenario first.

In this scenario, no team synchronization is required, but for addressing hands synchronization we deliver auditory feedback that resembles the oar sound as it hits and dives into the water, and then above the water, the sound is phased with the actual motion and to be damped in one ear if the corresponding hand is late.

While in the team scenario, the leader's motion is tracked and the oar sound is played to all the rowers with a matching phase.

Here hands synchronization is achieved by the rowers themselves, by comparing the sound feedback and their hands movement. Because the sound is easily relatable to different rowing phases, they can understand if both or one of the hands is late and try to catch up.

b. Haptic feedback

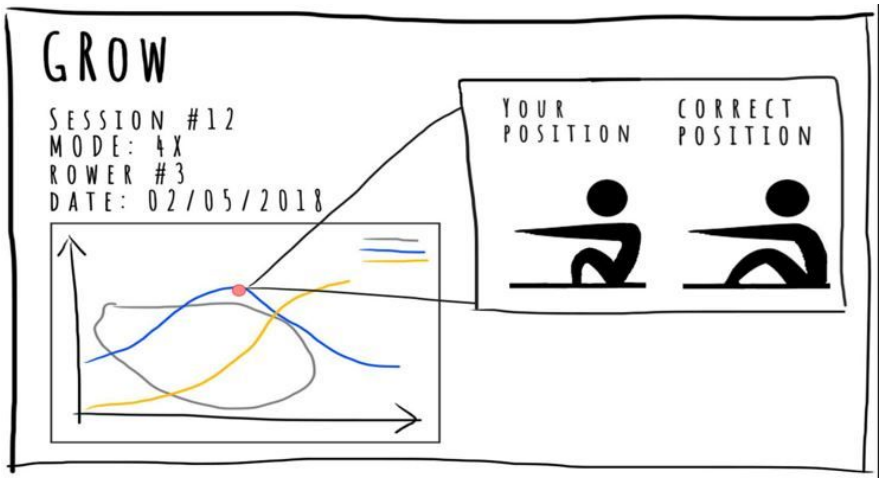
The main requirement of the beginners is to assess movement correctness. Thus, and with the use of the sophisticated different sensors, the system is able to accurately detect any fluctuations and deliver the appropriate vibrotactile feedback.

Two aspects of movement correctness are assessed; the first one is the hand trajectory during the drive phase. To ensure smooth horizontal movement, two vibrotactile motors are places on the wrist and a feedback is delivered if the trajectory is shifted upwards or downwards using the corresponding motor.

The second aspect is the hand position with respect to the body at the end of the drive phase, and for assessing this aspect we use a vibrotactile motor on the elbow and on the wrist to indicate if the hand is to close or too far respectively.

Web Interface Design:

The application offers analysis ability for beginners through a web portal, in which the user can browse previous rowing sessions and assess his movements correctness and observe his mistakes across time. The following sketch shows how will the web interface will look like this:



9.1- Expert Scenario:

The emphasis of experts users, following the user analysis and related requirements, is performance. Thus, we have focused in the mode of operation on delivering offline and online performance insights while also taking into account synchronization as a key characteristic of rowing efficiency.

Multimodal Interface Elements:

Each rower will be equipped with the following gadgets:

- A couple of head mounted sensors mainly targeting legs for calculating knee angle
- A couple of vibrotactile motors located at the ankles
- A boat mounted speakers that delivers the auditory feedback.
- Smartwatch as a user interface and the controller of the whole system during the rowing session.
- Smart oars that are able to track the force and the rotational movement aspects of the oar, chosen to have a minimal weight.
- Boat-mounted sensors able to record 9-axis motion in terms of linear acceleration and rotational movement around both the vertical axis and the surface plane.

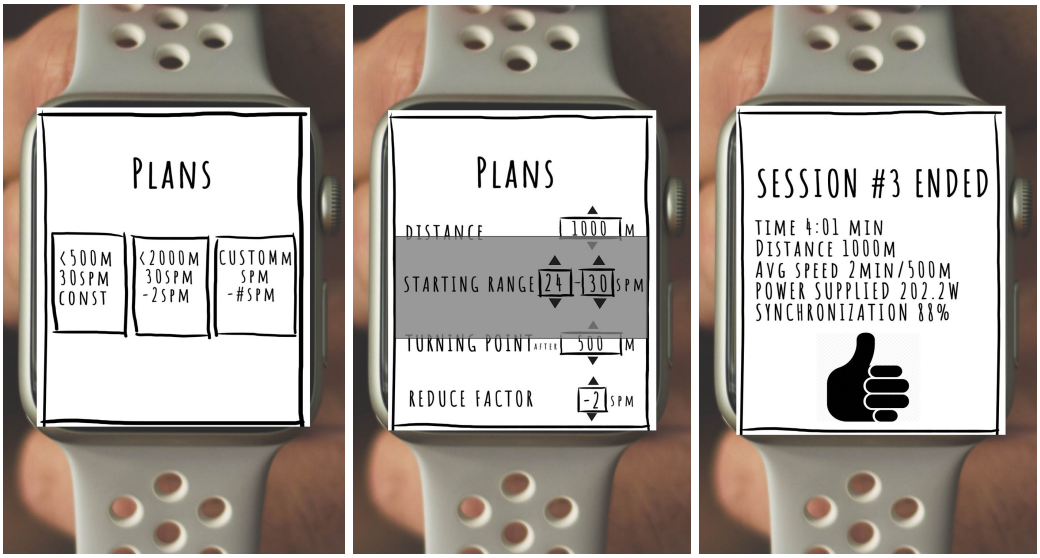
The choice of using loudspeakers was based on experts feedback which favored having no obstacles on the ear in order not to degrade balance sense, and since we provide the same feedback for all rowers, the use of loudspeakers makes sense and will not cause any interference.

Smart watch user interface:

Keeping the rowing session creation steps as simple as the beginner scenario, we notice the need for more configuration that helps the experts in better understanding and measuring their training goals and achievements.

The interface allows the leader to set the targeted rowing speed(strokes per minute) as well as the rowing distance and speed reduction among many predefined common plans, or allowing the rower to define his/her own plan.

After the end of the session, more in depth performance measurements are displayed, like distance, time, average speed, power applied, and synchronization accuracy.



Feedback Design:

The main goal of the feedback is to enhance the efficiency of the training session in terms of meeting a training target and supporting team synchronization.

a. Auditory feedback:

It's common in the literature to use audio channel to stimulate and reinforce motor system performance, we followed a similar strategy and relied on the previously designed sound to encode both acceleration and stroke period. Namely, the sound domain is stretched to match the stroke period preset of this session, and the amplitude is mapped to the acceleration achieved during that stroke.

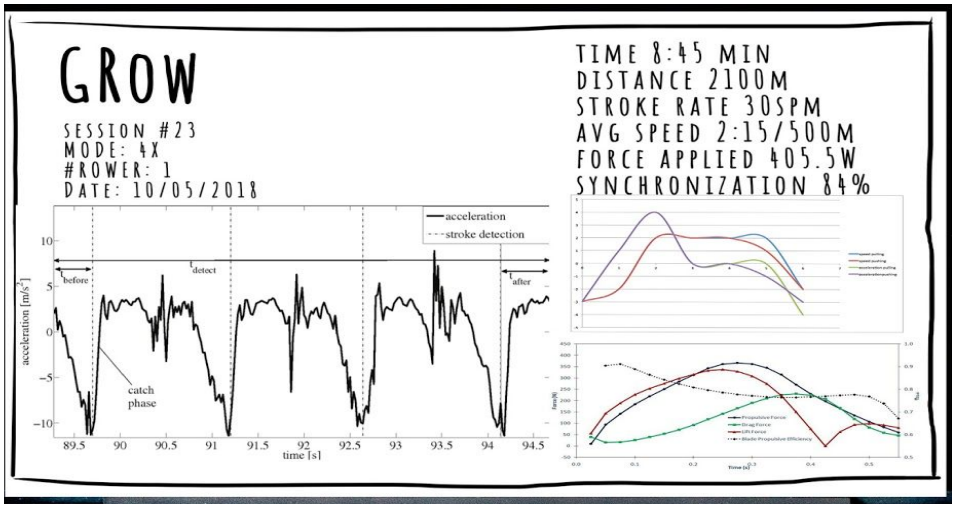
b. Haptic feedback

We use the leg sensors to track the knee angle, and the vibro-tactile motor is used to signal the reach of the optimal push-back angle at each stroke.

This signal is useful for both performance and synchronization considerations.

Web Interface Design:

The application offers in-depth analysis of the rowing sessions throughout a web interface, different graphs are presented leveraging the wide range of sensors present at the session with the possibility to track performance across many sessions and draw comparisons.



10 - User Evaluation:

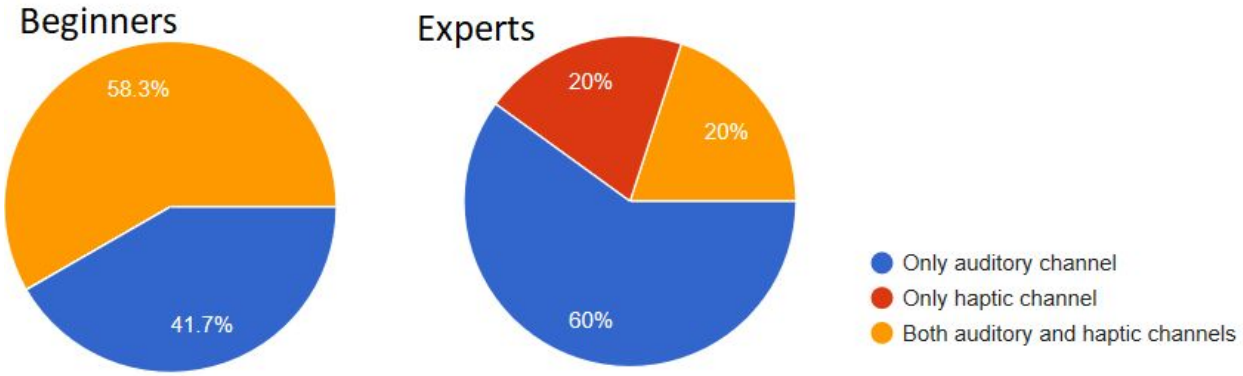
Following the initial design and sketches, we conducted a series of experiments in order to verify the options we've made and to properly guide further design efforts.

To do that, we targeted two user groups which are a set of rowers who have been rowing for at least couple of years, and a set of users who are learning rowing recently or wish to learn it.

We preceded the assessment by a brief presentation focusing on the interface of the related user mode, and allowing the users to experience the feedbacks, then we used for collecting user opinions both Q&A and a Google Forms questionnaire in which we included some chosen specific questions about some choices that were made and a section that tries to measure the overall user experience according to a well known questionnaire in the field of interaction design [10].

The questionnaires are available here for beginners and here for experts.

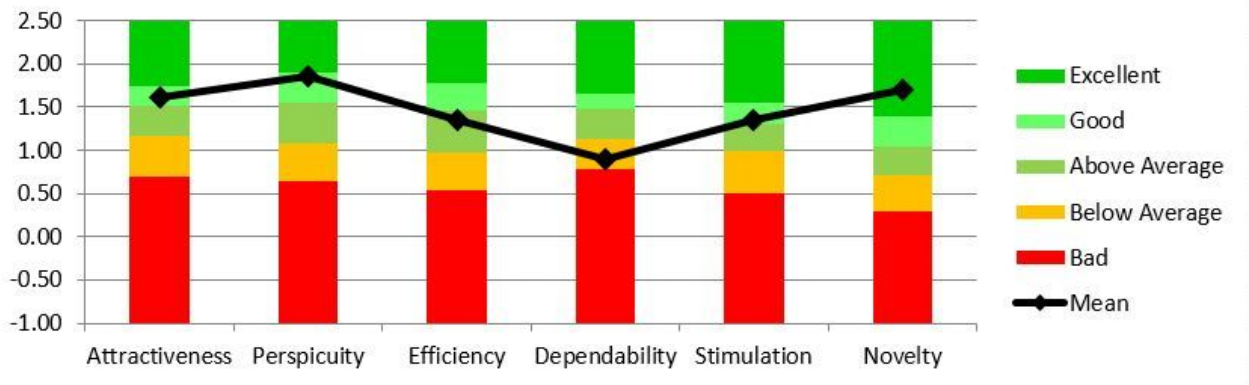
The following result was collected using 5 expert rowers and 12 beginner rowers:



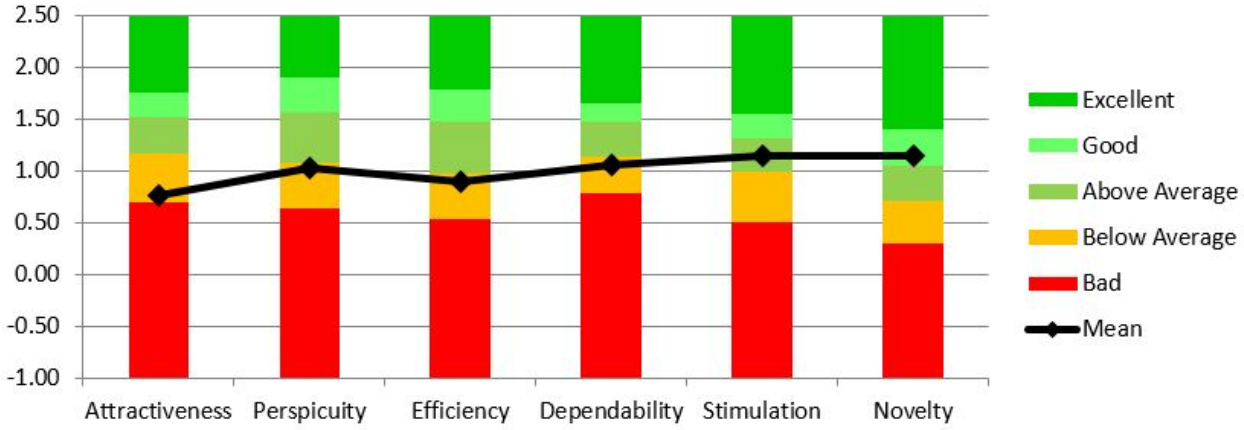
The charts show that, in general, users prefer the multimodality aspect of feedback, which coincides with the cognitive and physiological findings about motor learning and sensory feedback.

UEQ questionnaire uses a set of 26 questions that contains correlation, and uses the correlation to estimate a confidence measure of each response, here we show an overview of the results, and the detailed results are available in the Excel files Beginners.xlsx and Experts.xlsx attached with this document.

Expert Results:



Beginner Results:



While more samples will yield more stable and reliable results, the graphs show a promising novelty in the application, and indeed the dependability concerns that were shown in the results and that were raised by the users had led us to make changes in the design choices, especially the use of loudspeakers for auditory feedback in expert mode.
We believe that a running prototype tests will further lead to more accurate findings and it might lead to changes however not costly.

11- Further Development:

Based on the positive feedback we received, we can conclude that the current scenarios can be further developed to build an initial prototype with a low risk of major changes later. According to the requirements section, we expect that further design and assessment activities will require 3-6 months depending on the resources allocated, both workforce and other resources.
Some parts can be developed in parallel like the smartwatch interface and the web application interface.
The Data analysis core will require a considerable time and care and will include conducting actual rowing experiments feedback design implementation.
With the current market focus on expert rowers, we believe that this solution will provide a competitive option that covers a wider range of requirements and target users along surpassing the current applications in terms of a richer features for the expert rowers.

References:

[1] N. Schaffert and K. Mattes, "Interactive Sonification in Rowing: Acoustic Feedback for On-Water Training," in IEEE MultiMedia, vol. 22, no. 1, pp. 58-67, Jan.-Mar. 2015.
[2] S.Nina & M.Klaus, Influence of acoustic feedback on boat speed and crew synchronization in elite junior rowing. International Journal of Sports Science & Coaching. 2016.
[3] C.Daniel, S.Nina, M.Carlo, M.Klaus, A. Marco. AccrowLive: A Multiplatform Telemetry and Sonification Solution for Rowing. Procedia Engineering, 2014.
[4] S.Roland, R.Georg, M. Laura, R.Robert, W.Peter “Sonification and haptic feedback in addition to visual feedback enhances complex motor task learning”, in Experimental Brain Research vol. 223, pp. 909-925, Mar.2015
[5] G.P. Kenyon and M.H. Thaut, “Rhythmic-driven Optimization of Motor Control”.

Rhythm,music and the brain: Scientific Foundations and Clinical Applications, M.H. Thaut, ed.,New York: Routledge Chapman & Hall, 2008, pp.85-112.
[6]https://www.statista.com/statistics/189562/daily-engagement-of-the-us-poppulation-in-sportsand-exercise
[7] https://crossfitrowingblog.com/2015/04/24/breathing-technique-for-rowing/
[8] E. Ruffaldi, M. Bergamasco, and S. S. S. Anna, “Vibrotactile Perception Assessment for a Rowing Training System,” pp. 350–355, 2009.
[9] M. Rauschenberger, M. S. P. Medien-systempartner, M. Schrepp, S. A. P. Ag, M. P. Cota, and S. Olschner, “Efficient Measurement of the User Experience of Interactive Products . How to use the User Experience Questionnaire (UEQ). Example : Spanish Language Version,” Int. J. Interact. Multimed. Artif. Intell., vol. 2, pp. 39–45, 2013.

Useful Links:

http://www.sofirow.de/english.html
http://www.accrow.de/englisch.html
https://www.rowinginmotion.com/pricing/
http://www.rowingperformance.com/user-guide-and-q-and-a
http://www.concept2.com/service/software/other-apps
http://www.technologist.eu/the-sports-revolution/
https://www.statista.com/statistics/189562/daily-engagement-of-the-us-poppulation-in-sportsand-exercise
https://crossfitrowingblog.com/2015/04/24/breathing-technique-for-rowing/