CHAPTER ??

Skill modeling and feedback design for training rowing with virtual environments

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ABSTRACT

This chapter presents the models of rowing skill and the feedback design principles behind the rowing training system SPRINT developed in the context of the SKILLS project. This system has been designed for training multiple sensorimotor and cognitive abilities of rowing, addressing efficiency of the technique, coordination and energy management. SPRINT is characterized by a portable mechanical platform that allows realistic motion and force feedback that is integrated with real-time simulation and analysis of athlete performance. The system is completed by training accelerators based on visuo-haptic feedbacks.

Keywords: Training Platform, Skills, Multimodal, Virtual Reality, Rowing

INTRODUCTION

The creation of a multimodal system for training a specific skill is a task that starts from the analysis of the skill itself, the identification of the relevant tasks, the associated skill components and the relevant variables for sensori-motor or cognitive training. This analysis phase allows taking decisions in the context of the training platform, in particular relatively to the simulation part of the platform and the training feedback part. The former part of the training system provided by means of virtual environment technologies, deals with the stimuli that are part of the real task and is constrained by realism requirements and technological limits. The latter part deals with the identification of the types of multimodal stimuli that can be adopted for training in the virtual environment. For a given training system, which are the correct stimuli that can be provided? How we can exploit at most features of Virtual Environments?

There are indeed several aspects of Virtual Environments and multimodal technologies that can potentially improve the training of motor tasks. This work discusses the aspects connected to sport training by introducing a training system for rowing that has been developed in the context of the EU SKILL Integrated Project (http://www.skills-ip.eu/). This system is called SPRINT (Ruffaldi 2009a). The SPRINT system is a platform for in-door rowing training that is aimed at improving specific sub-skill of the general rowing skill. The system has a basis of simulation component that recreates the motion of the user and provides a haptic feedback of the interaction with the water. Over the simulation basis is built a set of exercises based on multimodal feedback for training specific sub-skills, in particular: technique, strategy and coordination. The capturing is performed not only in real-time but in particular during the system design phase for characterizing the model of experts respect given sub-skills. The model is then used, in a user personalized form, for training the user during the execution of the specific training exercises.

This work discusses the modeling of the skill, and the how the feedback is selected and integrated in the multimodal experience of the training system. In particular we discuss the capturing system and the design of feedback based on visual and vibrotactile technologies.

ROWING SKILL

Rowing is a sport that can be can be competitive or recreational, where 1 or 2, 4 or 8 athletes row in a boat on flat water, facing backwards and using oars to propel the boat forward. Rowing is a demanding sport requiring both physical strength and cardiovascular endurance, and involves both lower and upper limbs as well as the trunk, determining the use of almost all human muscles. Rowing task is cyclical, since mainly consists in repeating efficient oar strokes for 6-8 minutes. The most effective measure of efficiency is the distribution along time of the ratio between power output and resulting velocity. For obtaining such efficiency several abilities are involved like cyclical repetition of the most efficient gesture, management of the posture, perceptual abilities for controlling external stimuli, coordination between limbs and with partners, and management of the energy expenditure during the race. In the context of a training system for rowing it is fundamental to correctly identify the above aspects and formalize them with the help of mathematical formulation. In particular after analyzing, with the help of expert coaches and rowing manual, the typical errors and tasks in rowing we have selected the elements that are more relevant for training intermediate rowers. In particular the factors affecting the efficiency of the technique, like errors in the entrance and exit from the water, coordination between limbs, and finally the profile of effort/velocity adopted during the race.

SPRINT SYSTEM

The SPRINT system has been designed around a mechanical platform that allows reproducing out-door features of rowing movements. Both sculling and sweeping tasks are possible and the platform can be adapted to different users. The complete experience of the system is show in Figure 1, in which is presented the mechanical platform in blue, with the force feedback fan highlighted, and the frontal LCD display for the visual feedback. The platform is completed by the sensing components and vibrotactile actuators placed around the wrists of the user (Ruffaldi 2009b). The major difference respect existing commercial solution like Concept2 is first in the possibility of performing a realistic motion, then the use data analysis techniques for characterizing the performance of the user and finally in the integration of multimodal feedback for training the athlete in different aspect of the rowing skill. Respect existing immersive solution like (von Zitzewitz 2008) this system has been designed to be adopted in real rowing contexts and providing the required flexibility for training athletes.

The motion of the user is acquired by means of encoders recording position of the oars in the two main axes, and one infrared sensor that tracks the seat displacement, at the rate of 120Hz. The integration of this information with a simplified kinematic model of the user allows identifying the most relevant motions of the user's body (Filippeschi 2009, Garland 2005). The kinematic model has been validated and corrected by an acquisition session inside a motion capture system (VICON by

OMG plc) in which the information obtained from markers has been related with the sensing data of the SPRINT system.

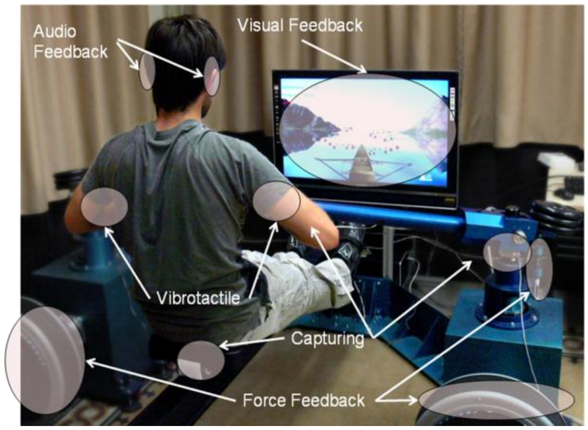

Figure 1 The user's experience in the SPRINT system

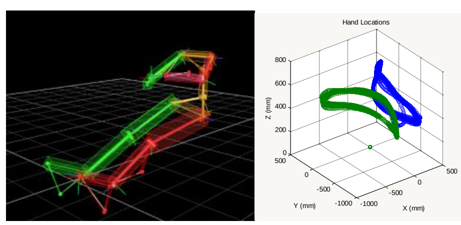

Figure 2 Acquisition session inside the VICON system
for validation of user's motion

Depending on the task being performed over SPRINT, additional sensors can be integrated, like biometric sensors for muscular activity (namely surface ElectroMyo Graphic sensors), Heart Rate sensing, Oxygen consumption devices and detailed motion capturing based on cameras. All the above information is being collected by a single computer that records synchronized data for later analysis and computes the proper feedbacks depending on the training scenario. The software core of the SPRINT system is the simulation of the rowing experience, dealing with the kinematic model of the user, the interaction of the oar with the water and the resulting motion of the boat. A correct simulation of the motion in the environment is motivated by providing the athletes a correspondence between their self-motion and the motion in the environment. In addition the simulation allows to realistically compute energetic parameters of the motion and to experiment the consequences of motions and errors on the rowing experience.

The knowledge about rowing skill and design constraints has allowed designing the SPRINT system as discussed above. In this section we are going to discuss how the different feedback components have been designed and how they participate at different training scenarios. The overall feedback design and the relationship with training have been based on the information flow model depicted in Figure 3. In this model the Environment is intended as the combination of the Virtual Environment, in which the simulated action is taking place, and the Real Environment, that is perceived by the user. Effectively every Virtual Entity is associated to one or more Physical instantiations in the form visuo-haptic feedback. On the left part of this model we have the Digital Trainer that has the role of coordinating the performance evaluation and providing the correct feedback depending on the scenario.

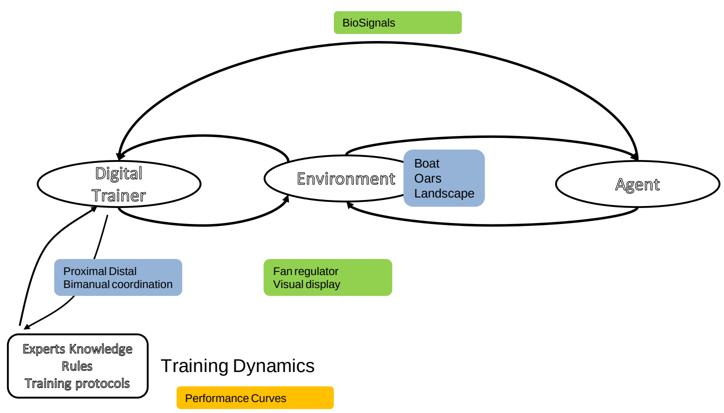

Figure 3 Information flow model of the interaction between the User and the Environment.

FEEDBACK FOR SIMULATION

The first type of feedback we are taking into account is oriented to the realism of the rowing experience, with the two fold objectives of not introducing disruptive effects in the training process and keep the user immersed in the training task. We have addressed two aspects in particular, the first is the force feedback while the second is the visual feedback.

Haptic Feedback

One of the main features of the SPRINT system is the capacity of providing a force feedback that has characteristics similar to the ones of the real rowing task. In particular we have adopted two energy dissipaters of the Concept2 ergometers that have been connected to the oars by means of a mechanical transmission. Such setup has been characterized using force sensor and compared against known profiles of forces measured on boat. The device is effectively a haptic interface because it produces but a force resistance depending on the user task, although in this version of the system it is not possible to tune such resistance during the task execution. The system measures the resulting resistance force from the speed of the fan of the dissipater that has calibrated by means of a force sensor applied on the transmission.

Visual Feedback

The visual feedback is provided by a Virtual Environment in which the user is placed with the boat in a typical rowing basin surrounded by various types of objects. Depending on the scenario the basin is populated with floats, that give the user distance references or the boats with opponents, whose avatars have a motion that is procedurally generated based on behavior schemes. A fundamental aspect in this part of the system is the type and position of the virtual camera that determines the point and field of view. In terms of camera position there are several possibilities (see Bailenson 2008 for an evaluation): the most immersive is first person with or without representation of the athlete limbs, then we have third person just behind the avatar of the athlete, and finally we have a third person facing the avatar and aerial point of views. In the first two cases the visual flow is the same as in the real scenario, although the presence of the avatar of the second case covers most of the visual field. Finally the last two points of view are more adequate for gaming, being easier for reaching the opponents. In the SPRINT system we have adopted the first solution, without the display of limbs, because they are only introducing occlusion in the view. The decision about the point of view is relevant for providing a match between simulated and perceived distances and velocity. For a discussion about distance perception see also (Vanni 2009). Respect other types of simulators, like racing and flight simulators, the perception of distance and velocity is provided both by the physical motion over the device, associated to the resulting fatigue, and by the visual component. For removing the introduction of scaling factors we have decided to follow a projection metaphor that is more common to augmented reality system rather than typical virtual environments: the display screen becomes a window to the virtual world, resulting in a good overlapping between real and virtual oars, and having the tip of the boat in front of the athlete. For obtaining this type of view (Figure 4) we have adopted the same type of perspective corrections that is used in immersive stereographic display, that take into account screen size and position of the user with respect to the projection screen. This projection could take advantage of the tracked position of the user head, but it can be roughly derived from the seat position, and in the context of single channel display the error is not noticeable. We have not considered, for this setup, the adoption of stereo projection because the device has been designed for prolonged training and we wanted to remove elements that could visually fatigue the athlete. Finally it is worth mentioning the fact that the visual refresh rate is 60Hz with a mechanism for reducing the latency between the captured data at 120Hz and the video synchronization signal.

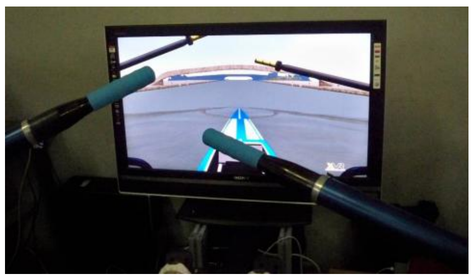

Figure 4 Particular of the point of view from the position of the athlete.

TRAINING FEEDBACK

The design of an immersive system, involving both cognitive and sensorimotor activities, poses challenges in the definition of the way training stimuli are directed to the user. In particular it is important to not overflow a given sensori channel and at the same time to not introduce dependency for a given feedback stimulus. Among the several channels available we have selected the visual and the haptic ones, and in particular for the haptic we have reduced the training feedback to the aspects of vibrotactile stimuli, because the haptic channel is already fully involved in the main task of rowing. The description of the design space for feedback can be performed by sensory channel or by task; in this case we will describe it by channel in parallel with the above description about simulation feedback.

Visual Feedback

The role of the visual feedbacks is multiple, and while their goal is in general to improve the performance of the user toward some specific goal, some act directly others indirectly to the action of the user. In addition in the specific case of rowing the behavior of the user can be modified only periodically at every stroke, or for energy related behaviors with slower rate, and for this reason it is important to select the correct type of feedback. The quantitative indication of power output is an example of direct information that cannot be easily estimated by the user, while velocity can be indirectly perceived from the motion in the virtual environment. The other important aspect for indicators is the way they are placed on the virtual environment. For example if it is necessary to keep the distance to the opponent that is behind the user a non-immersive solution is to present an horizontal gauge layered over the screen while an immersive solution, selected in one of the strategy training, is to display an arrow over the basin connecting athlete's boat and the one of the opponent behind. Virtual Environments allow anyway to adopt feedback mechanisms that act at the level of the environment and that are more subtle. In particular in the case of the study of inter personal coordination between athletes a direct feedback can be shown layered over the screen, while an indirect one acts on the speed of the boat, without being directly correlated with a precise simulation of the synchronization between the athletes. In general anyway visual feedback selection should follow the rules of visual encoding of information. For example expressing quantitative values with shades of gray makes comparison difficult, but when such shades are animated depending on error it can provide a good estimate of the amount of error. The result of this consideration can be applied to a feedback scheme that gives color to the avatar of the peer during interpersonal rowing.

Haptic Feedback

The haptic feedback that has been selected for training is provided by a set of vibrotactile bracelets that, with the use of two (or four) motor for each wrist provide directional or timing indications to the effort of the user. This type of feedback is currently being investigated in comparison with the visual one for assessing the capacity of training for specific aspects of the technique like the motion pattern. In this context the tactile gives indications of error in the trajectory of the arms (Ruffaldi 2009b).

TRAINING AND EVALUATION STUDIES

The system described above is currently in the phase of evaluation, with specific focus on multimodal contribution to technique optimization and energy management training. In these experiments intermediate and naïve rowers are being first assessed over the system in terms of their skill level and then there are being trained in one of the sub-skills discussed above. Specifically we are focusing on gestural procedure, motion coordination (between arms and legs) and timing for novel-intermediate rowers, addressing the typical errors found at this level. A series of visual and vibrotactile accelerators are used for indicating timing errors and corrections in the trajectory performed. A second study is related to the energy management in 2000 race, characterized by the training for adopting a given velocity profile that manages at best the energy of the athlete. In this case the feedback is based on the use of avatar's opponent for stimulate user's strategy. Finally a third study is focused on inter personal coordination in team rowing based on visual feedback and behavior of avatar's peer for stimulating synchronization.

During the development of the system, for obtaining a first understanding of the quality of the system with real rowers we performed a qualitative assessment of the system asking a group of intermediate rowers to practice with it and express judgments on its capacity of being adopted as a training device for technique and strategy. These comments allowed understanding the qualitative correspondence with boat rowing and the capacity of the system to keep the presence during the training experience. Each rower in the group has been first asked for a self-assessment of its level of expertise in terms of years of practice and types of competition in which participated. Then we asked 11 questions with answers expressed in a 7-point Likert scale. We asked information about the system in terms of stability, perceived capacity of rowing, water resistance in scull and sweep rowing, perceived realism of the virtual environment and effectiveness of displayed real-time information about the rowing performance. The group was of 8 intermediate-expert rowers, all male; with a mean age of 18 years, practicing rowing between 4 and 13 years, two of which competing at international level, 5 at national and one regional. The presence of the virtual environment, compared to commercial training systems in which is it absent, was making the experience more pleasant although at that time the quality of the landscape was not considered sufficient. From the questionnaire it emerged that perceived resistance was fine in scull rowing, while it was too strong for scull rowing, confirming, in this way, the mathematical modeling. This information provided a first insight for updating the strength of the system for the scull configuration. Another force related aspect discussed above that has been considered is the realism of the entrance in the water that at that time was not considered convincing.

CONCLUSIONS

The elements discussed above, although having some aspects specific to rowing, could be easily extended to other training activities in which there is a sensorimotor component, and for which the training feedback has to be accurately selected. There are several aspects that have not yet be addressed: investigate how to balance between different type of stimuli in a given protocol, investigate the role of audio, how the motivational component impacts on the training efficiency and finally the training of teams with multiple SPRINT systems. Additional information and material on the project are available on the website http://www.skills-ip.eu/row .

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