BIO Web of Conferences **1**, 00078 (2011)
DOI: 10.1051/bioconf/20110100078

Training Rowing with Virtual Environments

Emanuele Ruffaldi* Alessandro Filippeschi*
Benoît Bardy† Ludovic Marin† Manuel Varlet† Charles Hoffmann†
Maria Korman‡ Daniel Gopher‡ Massimo Bergamasco*
(*)PERCRO, Scuola Superiore S.Anna, Pisa, Italy
(†)University of Montpellier 1 (UM1), France
(‡)Technion, Israel
E-mail: e.ruffaldi@sssup.it

Abstract

This paper presents the results of the design, implementation and evaluation of a platform for rowing training in Virtual Reality called SPRINT. The paper discusses how various aspects of the rowing skill can be analyzed and trained over a single common methodology and system platform. The result is a vision for new directions in the domain of sport training with Virtual Reality.

1. Introduction

Rowing is an articulated skill that requires efforts at different scales, from the complex motor pattern required for efficiently performing each stroke to the strategy necessary to successfully win a race [1,4]. As in many sports multiple factors affect the final result of a single race, but among them training is a key aspect that influences all other components. The improvements in Virtual Reality technologies and their combination with training strategies, together with sophisticated data modeling is making possible the design of systems that allow new forms of training.

This paper presents how the SPRINT system [6], shown in Figure 1 has evolved from a prototype to a research platform allowing to test and design new training protocols. A diagram of system evolution is shown in Figure 2. In particular three main aspects of the rowing skill have been selected and evaluated on SPRINT following a taxonomy and a strategy for training in Virtual Environments [5]. The evaluation of technique optimization, energy management and team coordination has been supported by the definition of a workflow for the execution of the evaluation supported by data analysis. The real-time processing of acquired data is indeed a key element of the system that is common among the different evaluations performed.

The rest of the paper is organized as follows: the next section discusses the evolution and system design. Then follows a discussion about the results of the evaluation studies and the digital representation of the rowing skill.

Figure 1 SPRINT system overview with large projection screen

2. System Design and Evolution

The SPRINT system has been designed for training novice and intermediate rowers and for improving the understanding of the rowing skill. The first step of the design has been the application of a hierarchical task analysis that allowed to precisely identify the characteristics of the skill and to identify the critical elements for the design of the training system. From the task analysis, and from the research motivations behind this project, the first prototype was designed starting from the virtual reality experience and the mechanical platform. The SPRINT mechanical platform is the physical core of the system because it allows subjects to experience rowing with kinematics and dynamics similar to natural rowing, supporting both sweep and sculling styles. An alternative design for a rowing simulator is presented in [7]. The mechanics has been designed and tuned by using known force profiles from literature and then by integrating them with data acquisition on the Concept2 system. Then, after the system has been built, it has been validated by comparing rower behavior on a real instrumented boat and on the system itself.

Being the main purpose of SPRINT training, system architecture has been built around a loop that senses subject performance and provides feedback based on the currently selected training protocol. Performance is measured at the level of overall session, last stroke or just after the execution of an element of the stroke. Feedback is typically generated in real-time in the form of augmented feedback, by means of the selection of different modalities. Alternatively it can be delivered at the end of stroke or session. The overall strategy for training adopted in SPRINT is presented in [5].

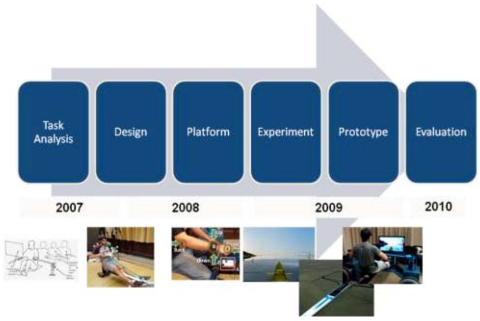

Figure 2 Evolution of the SPRINT system and major highlights

3. Evaluation Studies

The proposed system has been evaluated by addressing several aspects of the rowing skill combined with research questions in the domain of training in virtual environment. Looking at the evaluation in terms of skill elements this work has considered the following:

- Technique of the stroke that is based on motion patterns and timing of actions
- Energy management at the level of race
- Coordination among members of the crew in team rowing [2][3]

A common methodology and implementation has been employed: identification of performance measures and association of subject specific goals, selection of a training feedback, design of the training protocol and analysis of results as typical in experimental design.

Two types of augmented feedback have been identified and tested: the first is based on the combination of visual and vibrotactile stimuli for conveying timing or corrections of behavior inside the stroke or at the end of each stroke. This type of feedback combined the effect of multimodality with spatial and time localization of the feedback.

The second one is based on the use of virtual humans as mediator of feedback being able to provide a reference behavior to be followed or an indication of error.

The results of these evaluation studies [8][9][10][11] have highlighted the capacity of VR training to improve performance and retention compared to classical training, even with protocols of few days.

4. Digital Representation of Rowing

The evaluation of the SPRINT system has not been possible without the analysis of subject performance. The acquisition of data has been performed on several platforms: on the main SPRINT platform, on the Concept2 instrumented with motion capture and SPRINT software, and on instrumented boats. These different data capture sessions have allowed constructing models of subject performance and comparing them under different conditions. The combination of these models, and their application in different elements of rowing has allowed also the identification of a digital representation of the rowing skill.

The analysis has been performed at multiple levels, depending also on the complexity of the involved datasets, moving from simple analysis when only oar angles are available to biomechanical analysis [1]. Figure 3 shows, for example, the analysis of forces exchanged by the subject with the virtual boat during rowing on the SPRINT. Data have been obtained by applying biomechanical modeling over the motion capture data [12].

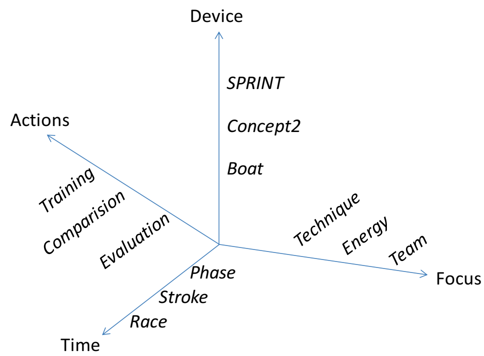

Figure 3 Organization of the digital representation of the rowing skill based on four key axes: device used, focus of analysis, time level and application.

In the case of technique training the trained model is based on a data set obtained by asking experts to perform on purpose well-known errors. A combination of PCA and Neural Networks allows to extract in real-time the error during execution at different stroke rates [13].

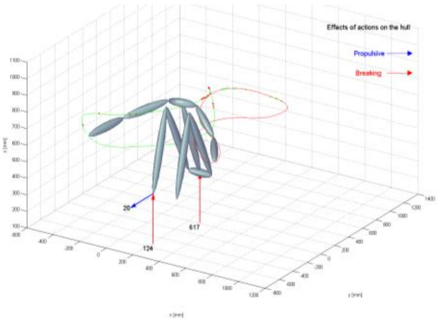

Figure 4 Analysis of rowing performance with estimation of the exchange of forces between the athlete and the boat.

5. Conclusions

Sport training by means of Virtual Reality is increasingly interesting and this work shows how it can be performed not simply by focusing on a specific aspect of a sport but by addressing the whole skill using a single platform. There are many opportunities for transferring these results to other sports, to better understand the digital representation of the skill and identify new protocols and feedback methodologies that could exploit this type of technologies. There is also a large opportunity for improving the adoption of robotic systems for providing a more realistic force feedback both for simulation and training.

Additional information can be found at: http://www.skils-ip.eu/row.

Acknowledgments

This work was supported by the SKILLS Integrated Project (IST-FP6 #035005, http://www.skills-ip.eu) funded by the European Commission.

References

[1] Baudouin, A., & Hawkins, D. (2002). A biomechanical review of factors affecting rowing performance. *British Journal of Sports Medicine, 36*, 396-402.

[2] Filippeschi, A., Ruffaldi, E., Frisoli, A., Avizzano, C.A., Varlet, M., Marin, L., Lagarde, J., Bardy, B.G., & Bergamasco, M. (2009). Dynamic models of team rowing for a virtual environment rowing training system. *The International Journal of Virtual Reality, 4*, 19-26.

[3] Hill, H. (2002). Dynamics of coordination within elite rowing crews: evidence from force pattern analysis. *Journal of Sports Sciences, 20*, 101-117.

[4] Nolte, V. (2005). *Rowing faster*. Human Kinetics Publishers.

[5] Ruffaldi, E., Filippeschi, A., Avizzano, C. A., Bardy, B., Gopher, D., & Bergamasco, M. (2011). Feedback, Affordances and Accelerators for Training sports in Virtual Environments. *MIT Presence*, *20*(1).

[6] Ruffaldi, E.; Filippeschi, A.; Frisoli, A.; Avizzano, C. A.; Bardy, B.; Gopher, D. & Bergamasco, SPRINT: a training system for skills transfer in rowing, SKILLS09 International Conference on Multimodal Interfaces for Skills Transfer, CEIT- Centro de Estudios e Investigaciones Técnicas de Gipuzkoa, 2009

[7] Zitzewitz, J. von, Wolf, P., Novakovic, V., Wellner, M., Rauter, G., Brunschweiler, A., et al. (2008). Real-time rowing simulator with multimodal feedback. *Sports Technology*, *1*. John Wiley and Sons Asia Pte Ltd BP, Asia (Melbourne).

[8] Charles P. Hoffmann, Alessandro Filippeschi, Emanuele Ruffaldi, Sébastien Blanc, Luc Verbrugge, Benoît G. Bardy. (2011) Mastering Energy Management During Rowing Using Virtual Reality. *SKILLS 2011, Montpellier, France.*

[9] Yifat Shorr, Alessandro Filippeschi, Danny Gopher, Emanuele Ruffaldi, Maria Korman. (2011) Evaluation of Multimodal Feedback Effects on Improving Rowing Competencies. *SKILLS 2011, Montpellier, France*

[10] Alessandro Filippeschi, Emanuele Ruffaldi, Maria Korman (2011). Preliminary Evaluation of Timing Training Accelerator for the Sprint Rowing System. *SKILLS 2011, Montpellier, France*

[11] Varlet, M., Filippeschi, A., Ben-sadoun, G., Ratto, M., Marin, L., Ruffaldi, E., & Bardy, B. G. (2011). Learning Team Rowing Coordination using Virtual Reality. Manuscript submitted for publication

[12] Alessandro Filippeschi, Emanuele Ruffaldi (2011). Expert Rower's Motion Analysis for Synthesis and Technique Digitalization. *SKILLS 2011, Montpellier, France.*

[13] Leonard Johard, Alessandro Filippeschi, Emanuele Ruffaldi (2011). Real-Time Error Detection for a Rowing Training System, *SKILLS 2011*, Montpellier, France