Design of a Virtual Reality-based Framework for Supporting the Work Reintegration of Wheelchair Users

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Abstract
Accidents at work often lead the involved people to severe impairments, which can seriously compromise their life and their work activities. Various studies have proven that, for disabled people, being employed contributes to a better quality of life, thus it is important to give them the opportunity to continue their professional career. This paper presents a framework aimed at supporting the training and the work-reintegration of people that, after an accident, are forced to use a wheelchair. In the proposed work, the Virtual Reality is the leading technology for allowing the wheelchair users to be trained in simulated environments thus, in safe conditions. Moreover, the behaviour of the users is tracked during the whole training session for monitoring, processing and assessing, through semantic models, their functional level and the jobs that are still suitable for them.

1. Introduction

An accident at work is a discrete occurrence during the course of work that may lead to physical and/or mental harm. Even non-fatal job-related accidents often involve considerable harm for the workers and burden for their families. Consequences related to these events can force people to live with a permanent disability, to change their job or to leave the labour market. Since different studies have proven that long term unemployment has a negative impact on quality of life [HW03], particularly for disabled people, it is important to establish new and more effective vocational rehabilitation programs [VKAV06].
This paper presents the design of a framework based on Virtual Reality (VR) and semantic models to support the return to work and, more in general, to daily life of people forced to use a wheelchair because of a traumatic injury [LL02].

2. Research objectives and approach

The main objective of the presented framework is to allow novice wheelchair users (WUs) to get familiar with their changed physical condition and to activities, also related to work, that have to be necessarily performed in a different way. To achieve this goal, the training in virtual environments (VEs) is structured according to three different phases (see §3).
The designed system allows both an auto-evaluation that the WU can accomplish trying to perform tasks of increasing difficulty, and an objective estimation of the user's performance, based on biomedical and motion signals acquired from specific sensors and systems. The acquired data, properly elaborated, constitute the input to the ontological model [Gru92], which produces, from one side, the ICF-based evaluation of the subject [WHO16], and, from the other, the most proper difficulty level of the tasks to be proposed in the VE. The results of the ICF evaluation are also used to discriminate which jobs are still suitable for the WU.

3. The VR-based framework

A process based on interactive digital simulation has been designed in three main areas of intervention have been identified to support the WU from the acute phase to the return to work.

1. The driving simulator

The VE for the simulation of the wheelchair driving presents various scenarios, both outdoor and indoor. In the latter case, the proposed scenarios represents living environments, as the house and the workplace, with particular focus on places where maneuvreing a wheelchair can be potentially more difficult. The user is encouraged to perfom specific maneuvers included in the Wheelchair Skills Training Program [WSP16]. The functionalities of the driving simulator, especially the synchronization between the wheelchair propulsion velocity and the visual flow in the VE and with the mechatronic platform on which the wheelchair is mounted, constitute the fundamental layer on which the other VEs are implemented.

2. Upper limbs preservation training

To prevent the development of secondary pathologies leading to musculoskeletal pain in the upper body, the VR system assists the WU while performing: (1) specific physical exercises and (2) daily wheelchair user's actions. In the former case, exercises are aimed at stretching and strengthening specific groups of muscles [MTK*11]. In the latter case, the tasks are presented by the system with precise indications on how to optimize them, in order to reduce the exerted forces and improve the muscles' performance [WSP16].

3. Work-related training

The work-related VE is a digital scenario aimed at reproducing real life's situations and the interactions that normally occur in workplaces. The acting of the WU, in this case, is contextualized in a specific working scenario, where the WU is likely to return to, as for example an office or a shopfloor. In these scenarios, the WU has to perform a set of specific exercises aimed at training not merely physical capabilities, but also job-related tasks, that necessarily have to be performed in different manner for a user forced to remain in a sit position.

Starting from the data coming both from sensors and from in the VEs, the evaluation of residual capabilities and of functional capacity of the patient are performed by a sematic module (§4).

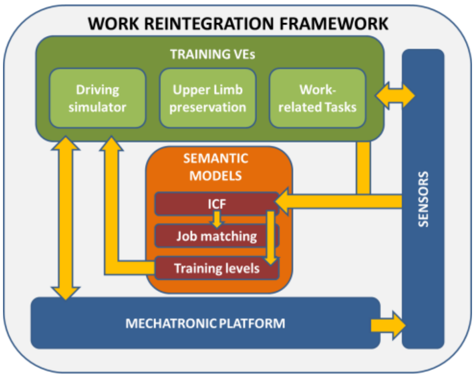

Fig. 1 *The elements composing the framework and their mutual relationships.*

4. Health and Functional evaluation

The main goal of the semantic web technologies in this framework is to assess the WUs' residual functional capacity and their general health condition, according to the ICF standard. In this way, it is possible to evaluate the functions and the presence of impairments influencing the patients' health condition. Basing on this assessment, a second goal is to provide a list of jobs eligible for the patients' health condition, according to their residual capabilities. Finally, thanks to specific data set collected from the sensors and properly elaborated, in conjunction with the health condition assessed by medical personnel, it is possible to set the difficulty of the training exercise in the VEs.

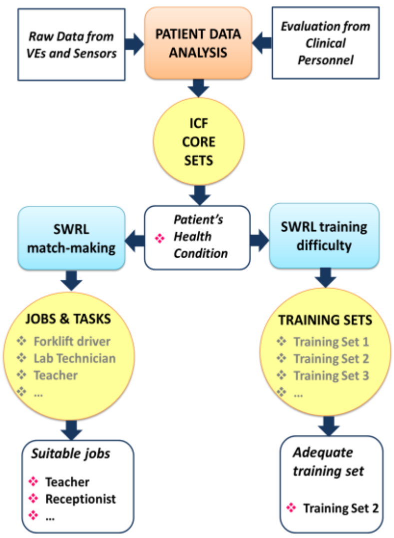

Fig 2. *The flow along the three semantic models.*

5. Technologies involved

The wheelchair is mounted on a mechatronic platform actuated in order to provide the proper vestibular feedback according to the simulated environment. The visualization relies on a semi-cylindrical powerwall and head mounted displays. The motion capture system is used for tracking the movements and the postures of the patient during the simulated experience, while dynamometers are used for measuring the force exerted by the WU. Different devices will be taken in consideration to permit the interaction of the WU with the user interface of the VE, according to the tasks that the WU has to perform in a certain scenario. The software engine of the VE is developed and programmed with Unity3D [UN16]. The semantic models can be developed in RDF/OWL [OWL16], supported by inference rules written in SWRL [SWR16]. An RDF-store and SPARQL endpoint allow a high level of expressivity to represent inference rules and a large amount of semantic data. The most likely editor yet for the development of the ontologies is Protégé, that also allows reasoning with Pellet [SPG*07], using SWRL.

6. Conclusions

This work presents the design of a VR-based framework aimed at supporting people who lost their legs' functionality in regaining autonomy during daily life and at work. This framework will be implemented within a project financed by the Italian National Institute for Occupational Safety and Prevention. This will assure that in all project development phases, users' requirements and indications provided by experts will be always taken into account.

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