A First Postural Tracking Using a Kinect v2 Sensor During an Immersive Wheelchair Driving Simulation

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Abstract*—Wheelchair simulators using virtual reality have been conceived for a better understanding of the mobility problem, and also to train people in wheelchair driving. Virtual Fauteuil is an immersive simulator equipped with a compact motion platform that reproduces physical effects like collisions, or being on slopes along the roll and pitch axis. Like most of the existing simulators, Virtual Fauteuil offers a training program, based on the performances of the user. However, a parameter is neglected for the performance evaluation, which is the posture of the user, although it affects his stability. This study focus on a light, basic and non-invasive solution for body tracking, the Kinect v2 sensor, and its implementation in the simulator Virtual Fauteuil. The experiment conducted in this paper consists in analyzing the movement of the torso when the user lives a perturbation in the simulator. This first postural evaluation has been done with 12 participants (9 males and 3 females). They were not asked to drive the wheelchair. The simulator was indeed programmed in such a manner that the avatar follows by itself a straight route composed of bumps which cause physical perturbations through the simulator. The experiment was in two sessions. During the first session, the travel was not displayed on the screen, so it means that the users lived perturbations without expecting it. During the second session, the participant lived the same travel but this time, with a visual immersion on a front screen. Perturbations are measured by investigating the rotation of the trunk compared to the rotation of the platform. Results shows that participants were more impacted by perturbation when the simulation was displayed on the screen. We also found that for the expermiment, participants were immune to trunk flexions, which means that the trunk of participants were mostly straight during disturbances. In-depth study will soon be done around the postural response of the user and on different exercises.

Keywords*–*virtual reality; simulation; wheelchair training; rehab; postural tracking.

I. INTRODUCTION

Wheelchair users are facing mobility problems that have different causes. Wheelchairs are a very practical solution for disabled people to recover a significant part of their mobility but it still have imperfections, that discourages people with reduced mobility. For example, wheelchairs are not adapted to all kind of terrain. In fact, public spaces have accessibility deficiencies like stairs, type of terrains, slopes etc. that make a wheelchair travel arduous. A poorly accessible route can expose the person to a loss of balance and in the worst situation to a fall from his wheelchair. In order to improve the mobility of people with reduced mobility in the broad sense, immersive simulators using Virtual Reality have been developed [1]–[6]. Indeed, wheelchair simulators can have different functions: First, it can raise able people awareness about mobility issues faced by persons with disabilities. Secondly, simulators can be an interesting tool to evaluate the accessibility and the arduousness of a route and help person to plan their trip. It also can help architects who conceive public infrastructures for the conception of their urban planning which are destined to wheelchairs accessibility. And finally, wheelchair simulators are a really valuable way to train people in wheelchair driving. Using an immersive simulator to train people to drive a wheelchair have a lot of advantages. The whole environment is configurable, which means that, for example, in the situation of a training program for a beginner, we control the type of exercises we want to train the user in. We also can regulate the difficulty, (by adding obstacles, or making the travel harder to achieve) so the simulator is always adapted to the person. Another aspect make the use of wheelchair simulators interesting. In fact, some people already experienced a traumatic experience and it repels them to use their wheelchair again. Simulators are secured. It is a comforting and attractive experience. Finally, using a simulator enable a monitoring of the performances of the user. Simulators can evaluate the performance from measured values provided by the simulator like: duration of a fixed travel, distance needed for the travel, number of collisions, etc. These functional index of performances focus on the wheelchair and its movement and neglect the user's posture. This study proposes a first method for postural tracking during a simulation. The postural tracking system has been implemented to the simulator Virtual Fauteuil [7], which has been developed in the LISV (Laboratoire d'ingénierie des systèmes de Versailles) - University of Versailles Saint-Quentin.

II. PRESENTATION OF THE SIMULATOR VIRTUAL FAUTEUIL

Virtual Fauteuil (Figure 1) is a simulator composed of a compact and easily transportable platform whose dimensions are 1.20 meter by 1 meter which can host any type of wheelchair. This platform is equipped with haptic feedback systems which enhance the immersion and the realism of the simulation (Figure 2):

- 4 Jack actuators, located at the 4 corners of the

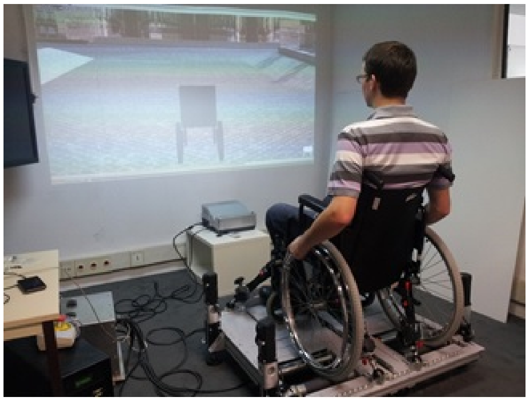

Figure 1. The simulator Virtual Fauteuil

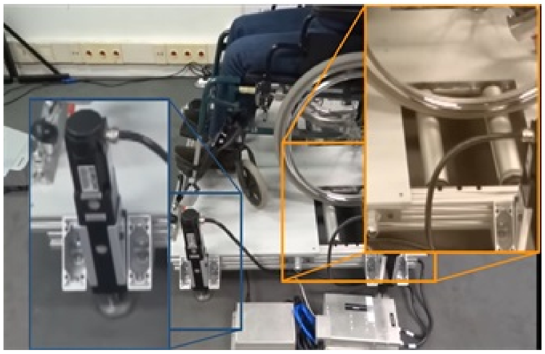

Figure 2. The two haptic feedback system of the platform. The Jack actuators in blue, and the force-feedback rolls in orange.

platform, which are used to rotate the platform in order to reproduce the sensations of going thought a slopes, or having perturbations like collisions or going down a sidewalk.

- 4 rolls on which are placed the two rear wheels of the wheelchair. Each wheel of the wheelchair is thus based on a roll in gear with an electric motorcycle-encoder and a passive roller which ensures the stability of the user. This configuration allows firstly to recover shift of the wheelchair data and thus to render the movements of the user in the virtual environment, and secondly, to send to the user's force feedback for example by simulating change of declination of the ground and/or inertial effect

The principle of the management of the haptic devices and the virtual environment is condensed in the figure 3.

A. *Projection of the simulation*

Simulations are conducted in a 3D virtual reality environment modeled on the Unity software. Thus, simulation can take place in any environment previously implemented in Unity or other modeling software such as Sketchup software. The projection, however, is done on one or more white front screen using a projector, or with a virtual reality helmet.
The projection of the simulation can be done in 3 different configurations, a single front view, a mixed-views display, and finally with a virtual reality headset. The mixed-views configuration offers a front view but also a top view for the visualisation near the ground in the front of the wheelchair. The mixed view also contains two lateral views.

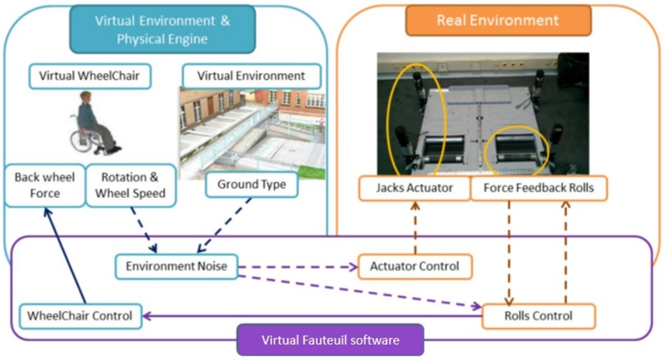

Figure 3. Communication diagram between simulator devices and the virtual environment

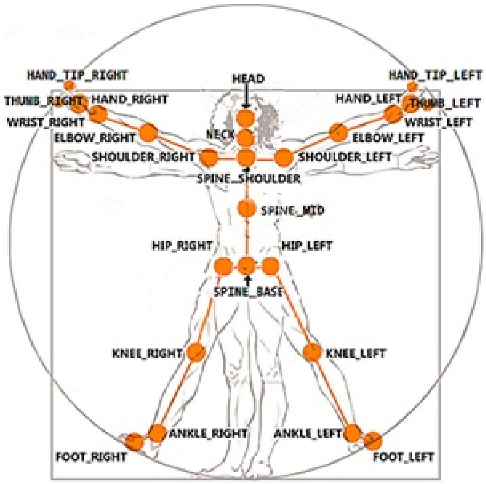

Figure 4. The 25 Joints tracked by the Kinect sensor

B. *Integration of the Kinect v2 sensor to the simulator*

In order to enable postural tracking during a simulation, a Kinect v2 sensor has been linked to Virtual Fauteuil. The Kinect sensor combines a RGB camera with depth sensor. Which enable to measure the spatial position of an object tracked, in this application: the body of the users. The SDK of the Kinect sensor eases the implementation to a software application such as Unity3D. As depicted on the figure 4, the Kinect sensor can track 25 joints in the user's body. This fits to a lot of cinematic models of the human body.
The framerate of acquisition of the Kinect sensor is up to 33.3 Hz. The reliability of the Kinect sensor has been the object of several studies. All these studies evaluates a great reliability [8], [9]. These experiments resulted in comparing the measures of the Kinect with the measures of another motion capture like for example the Nexus Vicon which is used as a reference.
The Kinect has two main uses in the simulator:

- Online mode: It enables to check online some criteria concerning the posture of the user. For the moment,

Figure 5. The virtual environment of the exercise used for the experiment

we focus on the lean of the trunk and the symmetric distribution of the posture in the frontal plane. Indicators are displayed during the simulation to instantly tell if the sufficiently well positioned on the sagittal and frontal planes.

- Offline mode: It is possible to record the joints position during a simulation. All the data are recorded in a .csv file. This enable postural analysis.

III. EXPERIMENTS

We have conducted a series of evaluations of the postural response of users during a simulation of a simple travel. This travel results in going forward until the finish which is symbolised by a blue diamond placed at the end of the way. The straight track is composed of bumps which causes perturbation with the motion platform during the simulation as we can see on figure 5.

The subjects have been chosen to represent a large amount of morphologies. There was also an additional condition for the selection of the subjects. They necessary need to be able person, which are novice in wheelchair driving.

During these tests, the users were asked to sit on a manual wheelchair, which were placed on the motion platform. The protocol is done on two phases:

1) In a first phase, the subjects were submitted to perturbations along the roll axis due to a chaotic road. In this phase, the user is facing perturbations but he does not control the avatar. The simulation is not displayed on this phase, which means that the users will experiments perturbations due to the motion platform but they will not be able to prepare themself to face these perturbations.
2) In a second phase, the subject still does not drive the avatar, but both feedbacks, haptic and visual, are activated. The user is placed on the same simulated situation but this time with a visual immersion.

12 participants have been selected for this experiment. 9 males and 3 females. They were students whose height vary between 1m62 and 1m90 with a mean of 1m75 and their weight vary between 45 kg and 100 kg with a mean of 70.3 kg

These first analyzes only focus on the rotation of the torso of the participant in order to see how it behaves during perturbations. We focus on the sagital plane because the perturbations also took place in the sagital plane.

At first, since the kinect allow us to assume the trunk as splitted in two parts because it can measure a point located at the top of the trunk (Spine Shoulder (P_{SS}) on the Figure 6), a point located at the middle of the trunk (Spine Mid (P_{SM}) on the Figure 6) and a point located around the hips (Spine Base (P_{SB}) on the Figure 6). The trunk can then be considered in three differents parts : the lower part: the segment D_{low} between the P_{SB} and P_{SM} points, the upper part : the segment D_{up} between the P_{SS} and P_{SM} points and finally the full trunk: the segment D_{full} between the P_{SS} and P_{SB} points. .We measured the rotations of these 3 parts from the position data collected during the simulation in order to see how these three variables varies in time.

The second main study is about the comparison between the postural reaction, in and out of the visual environment to see if the visual immersion can have an impact on the behaviour of the user.

The Table I. depicts the means intercorrelations amongst the 12 participants between the three angles related to the trunk: α_{up}, α_{low} and α_{full}. Figure 7 is an example of these three angles. Rely on these results, we conclude that for these partipants, who are abled people, the perturbations had very little impact on the trunk flexion, which means that the trunk was praticly always straight.

TABLE I. THE MATRIX OF THE MEAN OF THE R COEFFICIENTS CORRELATION BETWEEN THE 3 ANGLES RELATED TO THE TRUNK. THE LOWER, THE UPPER AND THE FULL TRUNK.

r-coefficient between:	α_{up}	α_{low}	α_{full}
α_{up}	1	0.9708	0.9882
α_{low}	0.9708	1	0.9599
α_{full}	0.9882	0.9599	1

IV. RESULTS

In order to compare the difference between the postural behaviour of the participants with and without the visual immersion, we did, as a short analysis, a comparison of the standard deviation of the rotation of the trunk with and without the visual feedback. The Figure 9 depicts the oscillation of the trunk of the participant 7 which is a representive for the others participants. The signals compared almost have an alternative and periodic pattern, in this, we use the standard deviation as an indicator of the dispersion of the signal. We suggest this hypothesis : the bigger the standard deviation is, the more the participants was perturbated.

The results (in Table II) show that standard deviation values are always bigger with the visual immersion and the maximum variation is with the participant 3 who has almost doubled his perturbation located on the trunk. We suppose that one of the reason is that, in the first case, the participant does not know when the perturbations will occur, so he may unconsciously strengthen himself to get ready, whereas, with the visual feedback, the participant is more confident because he can expect the arrival of perturbations.

V. CONCLUSION

This first experiment strengthen us in the idea that enabling simulators dedicated to training to track the body of the user during his simulations can lead us to a better comprehension

TABLE II. STANDARD DEVIATION (SD) OF α_{trunk} FOR EACH PARTICIPANT DURING THE NON-VISUALLY AND THE VISUALLY IMMERSIVE SIMULATION

	Standard Deviation of α	*Standard Deviation of α*
Participants	*1st phase : No visual immersion*	*2nd Phase: with visual immersion*
1	0,0925	0,0987
2	0,0257	0,0279
3	0,0318	0,0607
4	0,0355	0,0505
5	0,0999.	0,1047
6	0,0201	0,0263
7	0,0493	0,0778
8	0,0272	0,0378
9	0,0375	0,0381
10	0,0442	0,0546
11	0,0253	0,0341
12	0,0857	0,0972

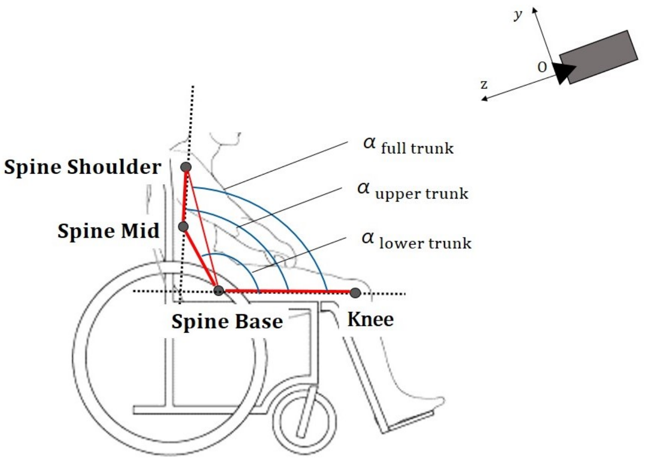

Figure 6. Joints of the body used to calculate the angle between the trunk and the thigh. From left to bottom right, Spine shoulder, Spine Mid, Spine Base , and knees

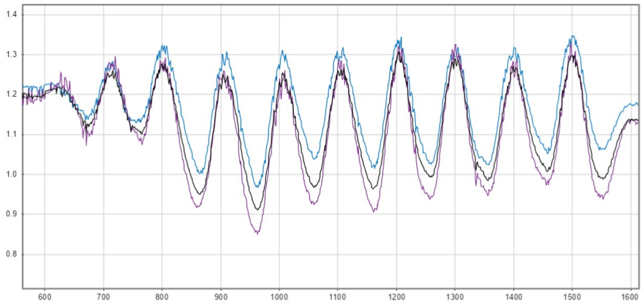

Figure 7. Oscilliation of α_{up}, α_{low} and α_{full}
In blue: α_{up}
In purple: α_{low}
In black: α_{full}
Legend : X-axis : Time (ms) Y axis(rad)

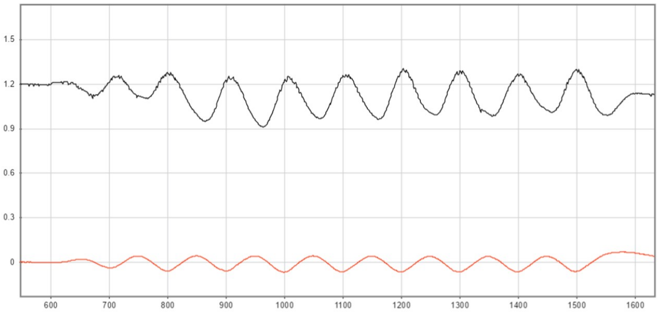

Figure 8. Oscilliation of α_{full} and $\alpha_{platform}$
In black: α_{full}
In orange: $\alpha_{platform}$
Legend : X-axis : Time (ms) Y-axis(rad)

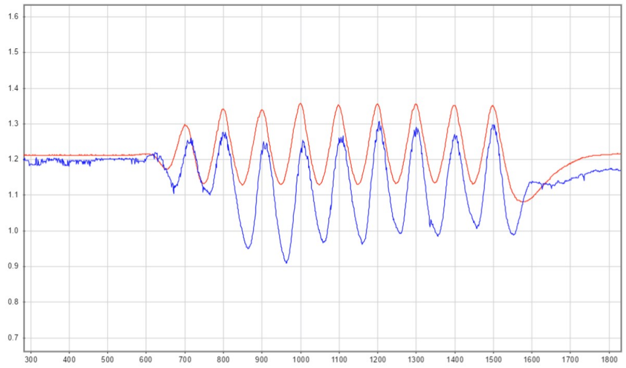

Figure 9. Oscilliation of α_{full} with and without the visual immersion
In blue: α with visual immersion

of the postural stability of wheelchair drivers. This is not the first study about the postural analysis for wheelchair users, others have been lead using different kind of sensor in contrast. Like cushion for the seat and the back rest that measure the pressure distribution and its variation [10], [11]. Some study [12], [13] has also been done with motion platforms and body tracking analysis. But to our knowledge, we are the first study that deal with postural analysis managed by a non-immersive sensor and with a simulation of an immersive driving scene. . Body tracking can highly improve the performances of most of wheelchair simulators on several points. This can also be, coupled to others sensors, a tool to analyse the stroke of wheelchairs driver in the simulator like a lot a biomechanical studies [14]–[18], but instead of ergometers, with the simulators we can make the user in a realistic situation, and the use of a simulator allow the monitoring of more variables due to the virtual environment, and the sensors.

VI. FUTURE WORK

This first preliminary study fosters us in our approach. This results is not statiscally significant yet, but next experiments will provide us better insights. In addition, new tests will be newly done in order to investigate differents leads. The first one is to determine if following a light but weekly training program on the simulator can improve the resistance of participants. In fact, we will train the same twelves participants in a period of

2 mounth and collect their performances in order to observe their evolution We also consider making tests with wheelchairs users, to see if their motor deficiency brings on new cases, and the simulator can help them as part of a training program.

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