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Locomotion by Natural Gestures for Immersive Virtual Environments

Andrea Ferracani, Daniele Pezzatini, Jacopo Bianchini, Gianmarco Biscini, Alberto Del Bimbo
MICC - University of Florence, Italy

Locomotion in IVEs

'Incompatible spaces' is a common issue that researchers in HCI have to face when providing natural interaction in IVEs. There are several solutions in the literature to allow infinite walking in IVEs, still maintaining in users a realistic sensation of walking. These solutions fall in **four categories** exploiting: 1) Additional Hardware; 2) Redirected Walking; 3) Software-based Navigation; 4) Gesture Recognition Using Cameras

Methods of locomotion proposed in our paper fall within solutions in 4). These are the most appropriate for **NUIs** mimicking real world interactions **without the need of specific controllers**.

Natural Interactions

Defining gestures in 3D IVEs exploiting natural interaction is easier than in 2D interfaces for the higher expressiveness that can be obtained by users simply acting like they do in the real world.

'Guessability' studies exploiting user-centered design show that in this scenario users' gestures are dominantly physical (e.g. walking moving knees) and metaphorical (e.g. selecting objects through pointing).

Building upon these studies, **we evaluate four gestures for locomotion in IVEs**. Among these gestures, two are derived from the literature whilst the two others are novel:

* **WIP (Walk-In-Place)** The user walks in a stationary position. It is the most used in the literature, validated through qualitative and quantitative studies;

* **Swing (Arms Swing)** The idea is to replicate the natural oscillations of the arms during locomotion. It is a gesture demonstrated being actually performed by users freely interacting with a IVE;

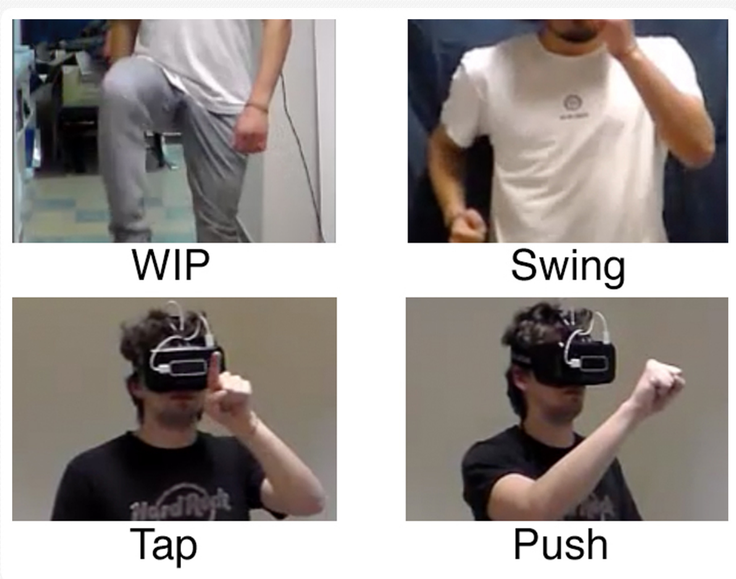
* **Tap** We propose a metaphorical gesture for locomotion consisting in a tap with the index finger in the direction the user wants to start walking. It is a gesture not so far from the real world: people commonly use the index finger to show a walking direction;

* **Push** We propose a metaphorical gesture consisting in closing and opening the hand while translating the hand itself forward with respect to the user elbow. In the real world it is the typical gesture to control locomotion machines moving a lever.

The Framework

The framework consists in a library we developed that enables a first person controller to navigate and interact in IVEs exploiting the **Unity3D engine**. Locomotion is provided through the described natural gestures.

Basic interaction with virtual objects is also made available. The library allows to easily connect the interactive IVE with output and input devices, namely with an **Head Mounted Display** which visualises the 3D environment, and two **tracking devices** which provide the motion data gestures' detection relies on.



[Tracking Devices: Microsoft Kinect - Leap Motion]
For WIP and Swing gestures recognition we exploited the Microsoft Visual Gesture Builder NUI tool that generates gesture databases used to perform runtime detection through machine learning techniques applied to skeleton data. Leap Motion SDK instead provides Tap and Grab gestures recognition natively. For Push and Tap gestures we have trained ad hoc classifiers.

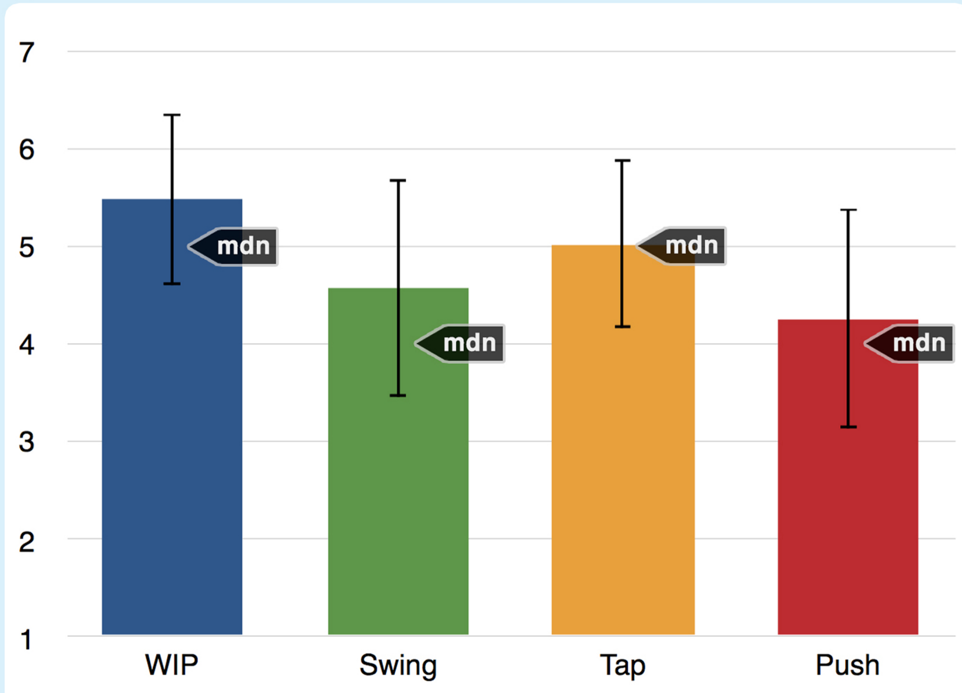
Evaluation

Evaluation was conducted with **19 participants** (11 males and 8 females) aged between 21 and 39 years old (average 26.4, σ = 5.8).

For the tests we created an IVE representing a forest. Two position in the virtual environment were defined by visual markers: a starting position A and a destination position B. Participants were asked to perform **six tasks** using all the four locomotion methods.

The following tasks were defined:
T1 Move from position A to position B.
T2 Move from position A to position B and back to A.
T3 Move from position A to position B, avoiding obstacles on the path.
T4 Move from position A to position B and then back to A, avoiding obstacles on the path.
T5 Move from position A to position B, grab an object and then bring it back to A.
T6 Move from position A to position B, grab an object and then bring it back to A, avoiding obstacles on the path.

Locomotion techniques in the framework were evaluated using both qualitative and quantitative methods. Naturalness and effectiveness of locomotion were assessed using the following measures: **perceived naturalness**, **overall preference**, **time completion**, **collision avoidance**.



Perceived Naturalness of locomotion methods. The higher the better. The black bars stand for the standard deviation.

	WIP		Swing		Tap		Push	
	Avg	σ	Avg	σ	Avg	σ	Avg	σ
T1	**15**	2	**15**	2	16	3	21	6
T2	40	7	39	6	**30**	2	35	5
T3	**17**	2	19	7	20	5	26	9
T4	43	10	42	10	**37**	6	52	16
T5	56	13	n.a.	n.a.	**51**	9	64	21
T6	**53**	21	n.a.	n.a.	57	23	75	34

Time Completion in seconds. The lower the better.

	WIP		Swing		Tap		Push	
	Avg	σ	Avg	σ	Avg	σ	Avg	σ
T4	0.46	0.78	0.54	0.77	**0.38**	0.61	0.84	0.98
T6	0.92	1.11	n.a	n.a	**0.61**	0.96	1.00	0.91

Collision avoidance results: number of collisions. The lower the better.

See the demo video of the framework on VIMEO