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iFeel Walking: Real Time Walking Transfer from Human to Humanoid Robot Avatar

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***Abstract*— This paper presents iFeel Walking, a novel system for transferring human walking to a humanoid robot. The system enables a high level of embodiment for the operator, allowing them to control the robot's movement through their own footsteps. iFeel Walking is implemented using non-intrusive sensors that are worn by the operator, including a set of Vive trackers on the feet and waist, and iFeel shoes equipped with force/torque sensors. The system provides real-time feedback to the operator through the Vive headset, including directional arrows and safety warnings. The non-intrusive nature of the sensors makes iFeel Walking easy to use and suitable for a range of applications, such as telepresence and virtual reality.**

I. Introduction

Over the past years, there has been a growing interest within the robotics community in the development of avatar systems, aiming at the so-called *telexistance* [1]. These platforms are designed to enable human presence in remote locations or immersive virtual environments, as the *metaverse* [2]. The COVID-19 pandemic has highlighted the potential applications and positive impacts of avatar systems [3], and this trend is exemplified by the ANA Avatar XPRIZE, a 10M$ competition[1] aimed at creating real-time avatar systems that transport human presence to remote locations. In this paper, we present a portion of the iCub team's framework for the ANA Avatar XPRIZE competition, specifically the iFeel walking architecture, which enables the operator to transfer their walking capabilities to the iCub humanoid robot [4] (Figure 1). This system is characterized by its non-intrusive sensor requirements and high level of embodiment.

II. iFeel Walking Sensors

iFeel Walking utilizes various sensors to enable human motion to be translated into robot locomotion commands. These sensors include the iFeel Shoes[2] (Figure 2), equipped with F/T-45 sensors on the soles to estimate ground interaction forces, VIVE Trackers [5] to determine feet and waist orientation, and the HTC VIVE PRO eye [6] headset which provides the operator with feedback on the motion transfer process. The use of these non-intrusive sensors enhances the embodiment of the operator, while minimizing the need for cumbersome external equipment.

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[1]https://www.xprize.org/prizes/avatar

[2]https://ifeeltech.eu/

Fig. 1: The iCub humanoid robot walking during the ANA Avatar X Prize Competition

III. Method

The iFeel Walking system consists of two main logical components: *intention-detection* and *triggering* Figure 3a . The intention-detection component is responsible for detecting the operator's intended direction of movement, while the triggering component initiates the robot's corresponding movement. The operator movements are computed via the use of sensor outputs and estimation algorithms. In the intention detection phase, the system translates specific movements of the operator, into commands for the robot. These commands are mapped to corresponding references of a trajectory optimization layer that exploits the simplified unicycle model [7], [8] to generate control input to a whole body controller in real-time. The iFeel Walking system defines several types of locomotion, including forward and backward walking by moving one foot forward or backward, respectively. Lateral walking is achieved by moving one foot aside in the desired movement direction (e.g. right sidestepping). Clockwise in-place rotation is initiated by rotating the right

Fig. 2: The iFeel shoes with the VIVE Trackers.

(a) (b)

Fig. 3: In (a) an example of intention-detection together with the headset visual feedback. In (b) the ”chaperon”, in yellow the first safety zone is depicted meanwhile the red circle shows the zone outside which the robot movements are stopped.

foot clockwise, while counterclockwise in-place rotation is initiated by rotating the left foot counterclockwise. To trigger the robot's motion in the specified direction, the operator simply needs to step in place. When the operator walks in place, the robot moves, resulting in a high level of embodiment for the user. The desired walking speed of the robot can be modulated by adjusting the stepping frequency. To ensure that the operator is always aware of the iFeel Walking system's status, various types of feedback are provided through the VIVE headset. A white arrow is displayed to indicate the intention given to the robot, while a yellow arrow indicates that the robot is currently moving in the direction depicted by the arrow. Additionally, for forward movement, the arrow moves with the direction of the robot's gaze, further helping the operator predict the robot's direction of movement. To detect the operator's intentions, the relative position of each foot with respect to the waist must be estimated. This is achieved by using trackers on both the waist and feet. Furthermore, the iFeel shoes are used to determine which foot is in contact with the ground, allowing the system to compute the step frequency and detect the operator's intentions. To reduce the likelihood of novice operators becoming disoriented while performing movements wearing the headset, we have implemented a safety feature called the ”chaperon.” This feature alerts the operator via messages in the VIVE headset when they are moving outside of a designated safe zone, which is depicted in yellow in Figure 3b. In addition, if the operator exits the red zone (Figure 3b), the human movements are not mapped into the robot and the operator is directed by visual feedback given in the headset to re-enter a safe position before continuing to operate the robot. This safety feature is designed to minimize the risk of the operator colliding with objects in their surroundings.

IV. Results and Conclusions

The iFeel Walking system was successfully used to teleoperate the iCub humanoid robot during the ANA Avatar XPrize Finals in November 2022 at the Long Beach Convention Center, Los Angeles (Figure 4). The system allowed the operator to control the robot's locomotion and perform various tasks, including long-distance walks and precise movements. The judge had no prior knowledge about the system, and each team had 45 minutes to explain the teleoperation infrastructure

Fig. 4: The robot walking and the judge wearing the sensors and controlling the robot via the iFeel Walking.

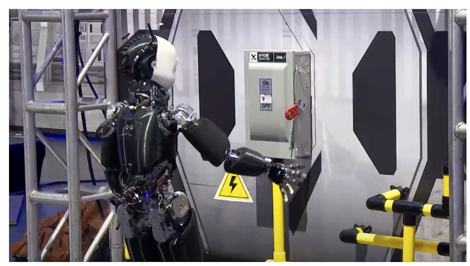

Fig. 5: The teleoperated iCub robot approaching the switch.

to the judge, thus demonstrating the intuitiveness of the proposed architecture. The competition consisted of multiple tasks, including approaching a table to receive information, activating a switch, performing a long-distance walk to activate a drill, and differentiating between different surfaces using haptic feedback The iCub robot was able to reach the table, walk towards the switch, and activate it (Figure 5). However, while passing through the gate, the robot hit one of the door's pillars causing it to fall and preventing it from completing the remaining tasks. The robot behavior was coherent with the operator inputs but the hit was caused by issues in perceiving the depth via the visual feedback provided in the headset. Nevertheless, the judge was able to successfully transfer her locomotion intention to the iCub Avatar using the iFeel Walking system. This included both precise and long-distance movements, demonstrating the system's effectiveness in enabling intuitive robot teleoperation. In addition, the judge was able to predict the robot's locomotion movements by utilizing the visual feedback provided in the HTC VIVE PRO eye headset. Overall, the iFeel walking system proved to be a promising infrastructure for enhancing telexistence.

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