Virtual and Augmented Reality for Neurofunctional Recovery and Human Movement Analysis

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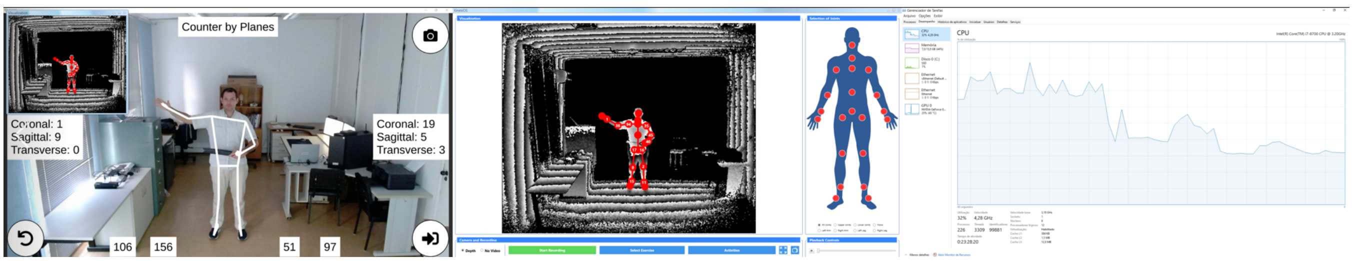

Figure 1: Interacting with BRAINN_VR applications and kinematic data recording by KinesiOS software; BioxLab – Health Informatics and Innovation Laboratory (https://pnipe.mctic.gov.br/laboratory/11752).

ABSTRACT

We present the research results on virtual reality and neurofunctional recovery, part of a multidisciplinary and inter-institutional project. The BRAINN_VR Initiative is a line of research and technological development in virtual rehabilitation solutions running on the Brazilian Institute for Neuroscience and Neurotechnology – BRAINN.

CCS CONCEPTS

• **Human-centered computing** → *Visualization*; *Visualization application domains*;

KEYWORDS

Mixed Reality, Gestural Interaction, Neurorehabilitation, Human Movement Analisys

BACKGROUND

Among the projects aimed at the creation and testing of new technologies for neurorehabilitation, the BRAINN_VR research line is responsible for the areas of development in a) virtual and augmented reality interfaces [1, 2, 6, 8, 16, 19, 20] (immersive and non-immersive virtual environments) associated with adapted physical activity and context physical and neurofunctional rehabilitation; b) wearable devices for sensing and body recognition associated with the control of virtual environments [3, 7, 9, 12, 14, 15] (from gestural interaction) and; c) movement analysis solution to quantify the functional evolution and describe the motor behaviour associated with gestural interaction [4, 5, 17] (KinesiOS software). Figure 2 presents the environment’s set-up for carrying out the tests.

Such initiatives include developing gesture recognition technologies from computer vision (body scanner) and sensing technologies (ultrasound and inertial units) (Figure 3). They aim to control (by gestural interaction) augmented and virtual reality interfaces with

Figure 2: Gestural interaction experimentation and human movement recording by KinesiOS.

gerontology [13] (mental health) applications and neurofunctional recovery therapies [2, 8, 10, 11, 18] not limited to those specialities or pathologies. Also, contributing to training kinesiology specialists with assistive technologies related to virtual reality, especially in physiotherapy, occupational therapy, physical education and medicine (orthopaedics and physiatrics) courses.

Figure 3: BRAINN_VR wearables with ultrasound and inertial sensors for controlling virtual environments.

The solutions developed following concepts related to the Natural User Interface – NUI, allow human-computer interaction unconventionally, that is, from the motor and cognitive stimuli (when associated with dual-task situations). Thus, it is possible to track the patients' movements and convert them into commands for interaction with the virtual environment, as well as record and measure the motor behaviour performed during the intervention in real-time, evidencing the functional evolution with the course of the treatment.

Using up to three Biomechanics Sensor Node – BSN wearable devices [4, 15, 20] makes it possible to reconstruct movements related to functional tests such as sit-to-stand (STS), evidencing the range of motion of hip and knee flexion/extension during the STS task (Figure 4). The movement occurs in the sagittal plane, and the BSN wearable devices' location is on the body's anterior face.

The results of quantification of movement with the KinesiOS software [5, 17] allow the reconstruction of motor activity during interaction with augmented reality interfaces. Figure 5 shows the

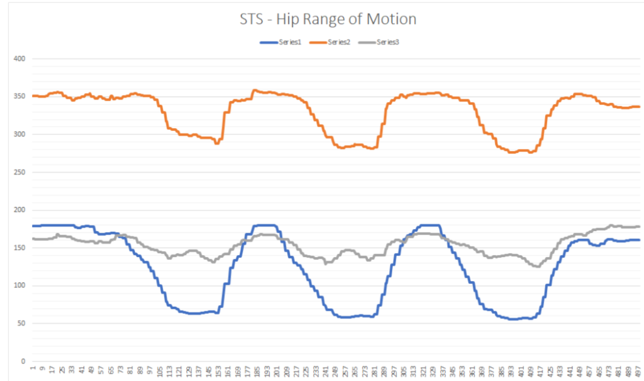

Figure 4: Hip joint range of motion data (angular variation 90º, blue line), calculated from the accelerometer information on the X axis, between a BSN positioned on the waist and another BSN set on the right leg.

abduction and adduction movements of the right shoulder joint during the assembly of a virtual puzzle. The left shoulder (blue line) remained at rest with minor balance and body compensation signs.

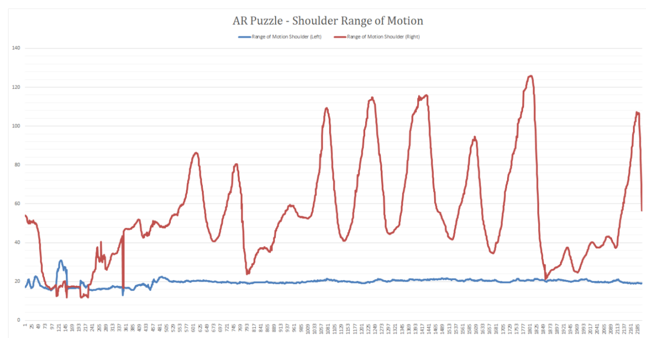

Figure 5: Right shoulder joint (red line) range of motion data (while solving the virtual puzzle), calculated from the spatial coordinates of the elbow, shoulder and hip joints.

Part of the investigations of the BRAINN_VR research initiative consists of measuring brain activity (through brain connectivity analysis, Figure 6) from the intervention associated with virtual rehabilitation solutions [8, 19], thus accelerating the neurorehabilitation process in patients with neurological pathologies with compromised functionality. Approval by the ethics committee for research with human beings at the State University of Campinas (CAAE: 35771314.4.0000.5404), all subjects signed an informed consent form before data collection.

The BRAINN_VR solutions are currently being tested in collaborative research projects in the areas: 1. motor behaviour (department of physical education); 2. non-institutionalized elderly (department of gerontology); 3. cerebral palsy (department of physiotherapy); 4. spinal cord injury (department of occupational therapy); 5. stroke (department of medicine) and 6. educational practices associated with teaching-learning methods in assistive technologies.

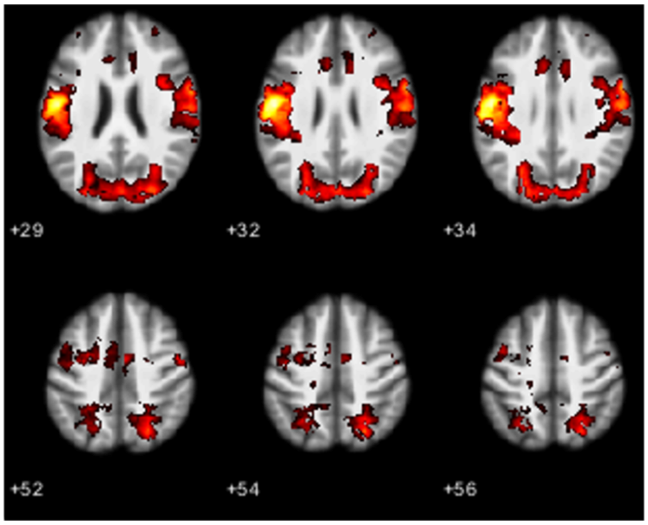

Figure 6: functional Magnetic Resonance Imaging (fMRI), for a single patient, presents mainly activation in the precentral gyrus (top view), associated with the primary motor area of the brain, after virtual rehabilitation with 12 intervention sessions (twice a week).

The development of solutions, which cover the complementary areas of virtual and augmented reality, wearable devices and motion quantification, is the result of collaborative work between the participants of the BRAINN_VR research initiative. This line of research has the participation of a multidisciplinary team involving researchers from the fields of health, sports psychology, computer scientists, physicists, and engineers.

CONCLUSIONS

The technological transition experienced by contemporary society evidences the importance of the constant improvement of virtual reality interfaces and increases their applications in health areas. In society 4.0 (especially in the post-pandemic scenario), artificial intelligence technologies and the mass digitisation of personal data must be oriented to quantify and empower the patient and the different health processes to which they are exposed.

FUTURE WORKS

The next steps include developing specific solutions for integrating assistive technologies, testing neurotechnologies associated with mixed reality interfaces and new gestural interaction solutions for adapted physical activity aimed at the elderly, people with disabilities and adapted sports.

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