Virtual and Augmented Reality for Neurofunctional Recovery and Human Movement Analysis

Alexandre F. Brandão
Brazilian Institute of Neuroscience and Neurotechonology/"Gleb Wataghin" Institute of Physics
University of Campinas
Campinas, SP, Brazil
abrandao@ifi.unicamp.br

Marcelo P. Guimarães
Brazilian Institute of Neuroscience and Neurotechonology/Multidisciplinary Department
Federal University of São Paulo
Osasco, SP, Brazil
marcelo.paiva@unifesp.br

Diego R. C. Dias
Brazilian Institute of Neuroscience and Neurotechonology/Computer Science Department
Federal University of São João del-Rei
São João del-Rei, MG, Brazil
diegodias@ufsj.edu.br

José R. F. Brega
Brazilian Institute of Neuroscience and Neurotechonology/Computer Science Department
São Paulo State University
Bauru, SP, Brazil
remo.brega@unesp.br

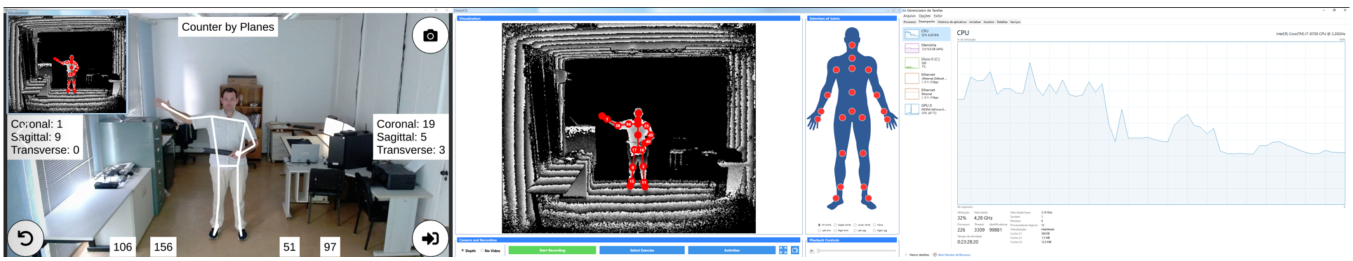

Figure 1: Interacting with BRAINN_VR applications and kinematic data recording by KinesiOS software; BioxLab – Health Informatics and Innovation Laboratory (https://pnipe.mctic.gov.br/laboratory/11752).

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

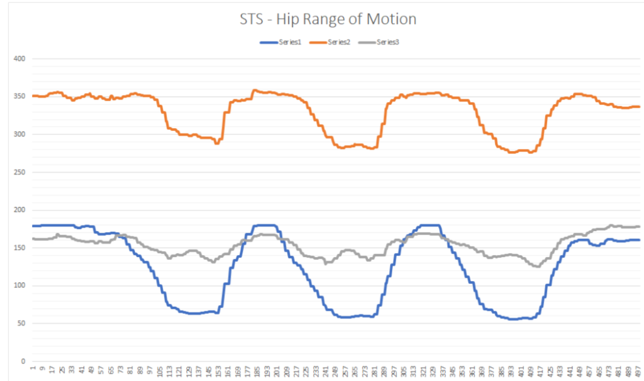

Figure 4: Hip joint range of motion data (angular variation 90º, blue line), calculated from the accelerometer information on the X axis, between a BSN positioned on the waist and another BSN set on the right leg.

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.

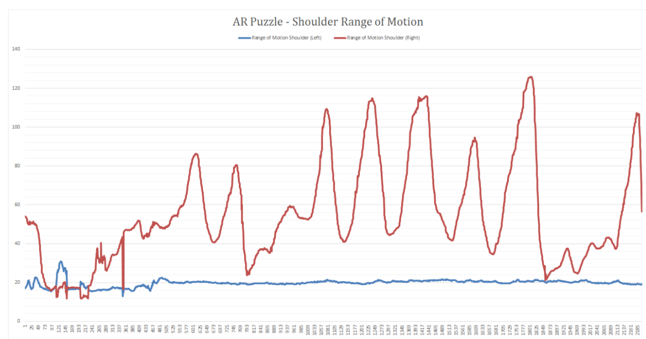

Figure 5: Right shoulder joint (red line) range of motion data (while solving the virtual puzzle), calculated from the spatial coordinates of the elbow, shoulder and hip joints.

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.

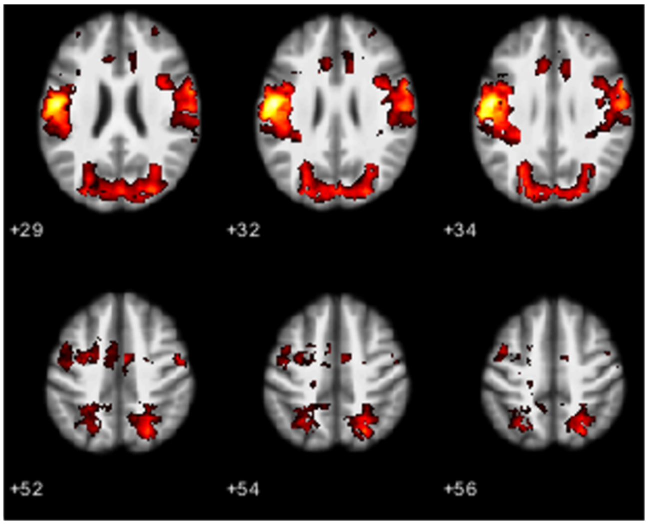

Figure 6: functional Magnetic Resonance Imaging (fMRI), for a single patient, presents mainly activation in the precentral gyrus (top view), associated with the primary motor area of the brain, after virtual rehabilitation with 12 intervention sessions (twice a week).

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.

ACKNOWLEDGMENTS

FAPESP (Sao Paulo Research Foundation, Brazil) grant number 2015/03695-5 | 2013/07559-3, FINEP (Funding Authority for Studies and Projects) XTReMe project grant number 10-0266/15 and the CPqD-EMBRAPII/SEBRAE grant number 0028/2017. The authors also acknowledge the contribution of Dr Raphael Fernandes Casseb, Medical Physicist, for processing and analysis of fMRI images.

REFERENCES

[1] Araújo, J. d. F. O., Ribeiro, E. H., de Paiva Guimarães, M., Brega, J. R. F., Brandão, A. F., and Dias, D. R. C. (2021). Immersive brain puzzle: a virtual reality application aimed at the rehabilitation of post-stroke patients. In *2021 16th Iberian Conference on Information Systems and Technologies (CISTI)*, pages 1–6. IEEE.

[2] Assis, G., Brandao, A., Corrêa, A. G. D., and Castellano, G. (2019). Evaluation of a protocol for fmri assessment associated with augmented reality rehabilitation of stroke subjects. *SBC Journal on Interactive Systems*, 10(1):35–42.

[3] Brandão, A., Dias, D., Alvarenga, I., Paiva, G., Trevelin, L., Gramany-Say, K., and Castellano, G. (2017). E-street for prevention of falls of the elderly an urban virtual environment for human–computer interaction from lower limb movements. In *Brazilian Technology Symposium*, pages 249–256. Springer.

[4] Brandão, A. F., Casseb, R., Almeida, S., Assis, G., Camargo, A., Min, L. L., and Castellano, G. (2019). Investigation of fmri protocol for evaluation of gestural interaction applied to upper-limb motor improvement. *Journal on Interactive Systems*, 10(1).

[5] Brandao, A. F., Dias, D. R., Castellano, G., Parizotto, N. A., and Trevelin, L. C. (2016). Rehabgesture: an alternative tool for measuring human movement. *Telemedicine and e-Health*, 22(7):584–589.

[6] Brandão, A. F., Dias, D. R. C., Guimarães, M. P., Trevelin, L. C., Parizotto, N. A., and Castellano, G. (2018). Gesturecollection for motor and cognitive stimuli: virtual reality and e-health prospects. *Journal of Health Informatics*, 10(1).

[7] Brandão, A. F., Dias, D. R. C., Reis, S. T. M., Cabreira, C. M., Frade, M. C. M., Beltrame, T., Paiva Guimarães, M. d., and Castellano, G. (2020). Biomechanics sensor node for virtual reality: A wearable device applied to gait recovery for neurofunctional rehabilitation. In *International Conference on Computational Science and Its Applications*, pages 757–770. Springer.

[8] De Assis, G. A., Brandão, A. F., Araki, L. Y., and Corrêa, A. G. D. (2017). Electromyography and augmented reality for motor rehabilitation. In *2017 19th Symposium on Virtual and Augmented Reality (SVR)*, pages 43–49. IEEE.

[9] Dias, D. R., Alvarenga, I. C., Guimarães, M. P., Trevelin, L. C., Castellano, G., and Brandão, A. F. (2018). estreet: virtual reality and wearable devices applied to rehabilitation. In *International Conference on Computational Science and Its Applications*, pages 775–789. Springer.

[10] dos Santos Krutli, R., Calixto, G. S., Sime, M. M., Mendes, P. V. B., Brandão, A. F., Carrijo, D. C. D. M., and da Cruz, D. M. C. (2018). Applicability and evaluation of the gesturechair virtual game: comparison between people with and without spinal cord injury. *SBC Journal on Interactive Systems*, 9(1):64–71.

[11] Frade, M. C., Dos Reis, I. M., Basso-Vanelli, R. P., Brandão, A. F., and Jamami, M. (2019). Reproducibility and validity of the 6-minute stationary walk test associated with virtual reality in subjects with copd. *Respiratory Care*, 64(4):425–433.

[12] Jurioli, M. M., Brandao, A. F., Guedes Martins, B. C. S., Simões, E. d. V., and Motta Toledo, C. F. (2020). Wearable device for immersive virtual reality control and application in upper limbs motor rehabilitation. In *International Conference on Computational Science and Its Applications*, pages 741–756. Springer.

[13] Magna, T. S., Brandão, A. F., and Fernandes, P. T. (2020). Intervenção por realidade virtual e exercício físico em idosos. *Journal of Health Informatics*, 12(3).

[14] Paiva Guimarães, M. d., Dias, D. R. C., Rocha, L. C. D. d., Ribeiro, E. H., Iope, R. L., and Brega, J. R. (2021). Motion and interaction tracking tool for virtual reality environments. In *International Conference on Computational Science and Its Applications*, pages 621–630. Springer.

[15] Ribeiro, E. H., de Paiva Guimarães, M., Brega, J. R. F., Brandão, A. F., and Colombo Dias, D. R. (2021). Biomechanics sensor nodes for body tracking: a development solution for virtual reality interaction. In *Symposium on Virtual and Augmented Reality*, pages 120–126.

[16] Rodrigues, L. G. S., Dias, D., Guimaraes, M. d. P., Brandao, A. F., Rocha, L., Iope, R. L., and Brega, J. R. F. (2021). Classification of human movements with motion capture data in a motor rehabilitation context. In *Symposium on Virtual and Augmented Reality*, pages 56–63.

[17] Scudeletti, L. R., Brandão, A. F., Dias, D. R. C., and Brega, J. R. F. (2021). Kinesios: A telerehabilitation and functional analysis system for post-stroke physical rehabilitation therapies? In *International Conference on Computational Science and Its Applications*, pages 174–185. Springer.

[18] Tossini, N. B., Côrrea, G. R., Petrella, M., Soares, V. E. B., Brandao, A., da Silva Serrao, P. R. M., et al. (2017). Influência da realidade virtual sobre a dor, fadiga, capacidade funcional e qualidade de vida na fibromialgia: estudo de caso. *Acta Fisiátrica*, 24(4):212–215.

[19] Trotta Lara Barbosa, T., Guimarães, M. d. P., Brandão, A. F., Chaves Dutra da Rocha, L., Iope, R. L., Brega, J. R. F., and Colombo Dias, D. R. (2021). Rebase: data acquisition and management system for neuromotor rehabilitation supported by virtual and augmented reality. In *Symposium on Virtual and Augmented Reality*, pages 182–186.

[20] Valente, F. R., de Paiva Guimarães, M., Cirilo, E. J. R., and Dias, D. R. C. (2022). A multi-agent body tracking application framework applied to physical and neurofunctional rehabilitation. In *International Conference on Computational Science and Its Applications*, pages 459–472. Springer.