Evaluation of the biomechanical reliability of a physics-based digital human simulator

Context and Objectives

Work-related musculoskeletal disorders are a major health issue, caused by biomechanical constrains at work, such as awkward postures, force exertion, and repetitiveness of gestures [1]. These constraints therefore need to be taken into account when designing and optimizing workstations. Virtual prototyping based on digital human simulation is increasingly used to consider ergonomics guidelines early in the design process. Numerous digital human simulation software for workstations are available today, however the biomechanical realism of the avatar is often limited, with stereotyped motions and no consideration of dynamics [2]. On the other hand, musculoskeletal simulation software (e.g. OpenSim) provide a detailed modeling of the human body [3], but their simulation is computationally expensive, making them hardly suitable when a large number of simulations must be run (e.g. for optimization purposes). To bridge this gap, **physics-based digital human simulation using motion generation approaches inspired from robotics** has been proposed [4, 5]. Such simulation allows to dynamically replay motions from motion capture data, or synthesize motions from high-level task description, with a limited computational budget. However, the reliability of the human biomechanical quantities (motion, internal forces) thereby estimated remains to be assessed.

The aim of this internship is to **benchmark the realism of the motion and force quantities computed with the digital human simulation approach developed in the LARSEN team against standard approaches in biomechanics**.

Work plan

The reliability of the human biomechanical quantities estimated with the simulation will be assessed by collecting human motion capture data, and then estimating the corresponding angular motions and forces by two different methods : i) dynamic replay with the simulator, and ii) inverse kinematics and inverse dynamics with standard biomechanical tools. The values obtained by the different methods will be compared, on a set of diverse movements. The sensitivity of the simulator tuning will also be assessed, by varying the values of key parameters of the simulator, and evaluating the impact on the resulting motion and forces.

The intern will be expected to perform the following tasks :

- Conduct a literature review on digital human simulation and approaches to estimate human biomechanical quantities.
- Conduct a motion capture data collection campaign of humans performing a variety of whole-body movements. Defining the protocol will be part of the work.
- Perform inverse kinematics and inverse dynamics analyses of the collected data with standard biomechanical tools (e.g. OpenSim).
- Perform motion replay within the LARSEN digital human simulator, with different tunings of the simulator for the sensitivity analysis. The replay function is already implemented, but this step will require understanding how the simulation works, and may involve some coding.
- Compare the results of both approches with a statistical analysis.

Advising and Organization

The internship is for a duration of 6 months, starting between January and April 2025 (exact start date to be decided with the candidate). It will take place in the LARSEN team (https://team.inria.fr/larsen/) of the Loria – Inria Nancy laboratory (http://www.loria.fr), in Nancy. The intern will be supervised by Pauline Maurice (Chargée de Recherche CNRS / CNRS research scientist). Email address : pauline.maurice@loria.fr.

The intern will be paid ∼600€/month. S/he will have access to the Loria canteen for a low price. Nancy bus pass is also reimbursed up to 50 %. A laptop will be provided for the duration of the internship.

Requirements

M2 or final year Engineering school student in biomechanics with a keen interest in computer science and simulation, or in robotics with a strong interest for biomechanics.

Technical skills :

- Human biomechanics and/or modeling of poly-articulated systems (kinematics, dynamics).
- Human subject experiment, specifically motion capture.
- Programming : Python/C++ ; experience with Linux is a plus (OS used for the simulator).
- Experience with musculo-skeletal simulation tools (e.g. OpenSim) is a plus.

General skills : Team player, autonomous, proactive, creative, enthusiastic, organized, serious and rigorous (this list is not exhaustive).

Language : English or French (understanding English is necessary for the scientific literature review).

Application

Applicants should send their CV, motivation letter describing their specific interest for the topic, and their Master's grades to Pauline Maurice (email address above). Please use the following title for the email "Digital Human Simulation internship – Application".

Références

[1] J. De Kok, P. Vroonhof, J. Snijders, G. Roullis, M. Clarke, K. Peereboom, P. van Dorst, and I. Isusi, "Work-related musculoskeletal disorders : prevalence, costs and demographics in the eu," *European agency for safety and health at work*, vol. 1, 2019.

[2] S. Scataglini and G. Paul, *DHM and Posturography*. Academic Press, 2019.

[3] S. L. Delp, F. C. Anderson, A. S. Arnold, P. Loan, A. Habib, C. T. John, E. Guendelman, and D. G. Thelen, "Opensim : open-source software to create and analyze dynamic simulations of movement," *IEEE transactions on biomedical engineering*, vol. 54, no. 11, pp. 1940–1950, 2007.

[4] P. Maurice, V. Padois, Y. Measson, and P. Bidaud, "Assessing and improving human movements using sensitivity analysis and digital human simulation," *International Journal of Computer Integrated Manufacturing*, vol. 32, no. 6, pp. 546–558, 2019.

[5] J. Zhong, V. Weistroffer, J.-B. Mouret, F. Colas, and P. Maurice, "Workstation suitability maps : Generating ergonomic behaviors on a population of virtual humans with multi-task optimization," *IEEE Robotics and Automation Letters*, 2023.