Musculoskeletal, real-time and predictive simulation of pathological gaits

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Keywords: computer graphics, physics based animation, motion controller, real-time simulation

Context of the thesis:
The thesis falls within the ANR PRCI project named OMEGA (optimization-based forward musculoskeletal simulation of pathological gait). This project is conducted in collaboration with the Laboratory of Biomechanics and Biomaterials of the Medical School of Hanover (Germany). It aims to study and design a computer simulator for pathological gaits. This simulator will help to improve treatment and to provide new and effective methods for predicting the outcome of treatments in many cases related to musculoskeletal disorders.

Description of the thesis project:
Knowledge of the motion and loading of the human body and its parts is essential in many fields of human medicine and in particular in orthopedic and trauma surgery. Modern numerical methods have advanced to the point that they are useful for estimating forces in the relevant structures based on a priori knowledge motion and external loading. However, their general usefulness is limited by their inability to predict motion and loading in response to changes in the body caused by a pathology or as a result of applying a given therapy to treat a pathology.

The aim of this thesis project is to study and design numerical models of the body making it possible to represent musculoskeletal disorders in humans. We also aim to propose and develop algorithmic methods to predict locomotion. This work will eventually lead to the development of a new generation of predictive simulator, based on the estimation of optimal motions, with the objective of being able to predict and therefore improve patient-specific therapeutic strategies. The simulator will propose numerical means for guiding and predicting therapies, and can complement existing empirical approaches that currently rely on the evolution of therapies over time, based on measured data. The work will get inspirations from forward simulation methods that have so far been developed mainly for the representation of human motion in the entertainment and gaming industry [CPPD2016]. An innovative, predictive and musculoskeletal simulator will be developed and implemented for this purpose.

The validation of the developed approaches will be carried out in collaboration with the project partner, the Laboratory of Biomechanics and Biomaterials (Medical School of Hanover), an expert in the acquisition and modeling of musculoskeletal disorders. This partner will provide the data necessary for modeling the pathologies and evaluate the simulations. The simulator will be tested in three selected clinical situations: knee and ankle bracing, drop-foot pathology, and above knee amputees fitted with a microprocessor-controlled knee-prosthesis. These three clinical situations were chosen because they are well characterized, treatments modalities can be altered non-invasively without undue risk to the patients, and a sufficient number of patients are available. Each of these pathologies represents a serious reduction in quality of life for the affected patients.

The objectives of the thesis are therefore (i) to design a musculoskeletal motion controller for human locomotion, (ii) to model the selected pathologies and (iii) to experiment and validate the forward simulator in a clinical context.

About the research team:
The PhD student will join the SAARA research team of LIRIS Lab. This team is specialized in simulation, analysis and animation of complex scenes involving virtual humans. Numerous works have been done within this team on the modeling of virtual humans, kinematics and physical simulation. The work to be done in this thesis project will benefit from past and ongoing works undertaken in the research team on motion control, physics based animation and forward musculoskeletal simulation.

Funding:
The PhD position is funded by the ANR, under the PRCI project OMEGA. A budget for equipment and travels accompanies the position.

Collaboration:
The research project heavily relies on the collaboration with the Laboratory of Biomechanics and Biomaterials of the Medical School of Hanover (Germany). A dedicated research project will be done in parallel in this laboratory for which a researcher will be hired. The PhD student will have a continuous collaboration with this researcher within the OMEGA project. The researcher will work in particular on the biomechanical characterization of the selected pathologies, the clinical environment, the validation and the interpretation of the resulting simulations. Several visits to Hanover will be held during the duration of the project.

Start date and duration: the PhD position shall begin between 09/01/2017 and 10/31/2017, for a 3 year period.

Doctoral school: InfoMaths (ED 512) - University Claude Bernard Lyon 1

Workplace:
The job will take place in the Nautibus building on the Doua campus in Villeurbanne (University Claude Bernard Lyon 1).

Candidate profile:
The applicant must hold a Master's degree in Computer Science with a working knowledge of computer graphics, or a Master's degree in Mechanics with serious experiences in computer science and programming. Knowledge in control systems, optimization, robotics or biomechanics will be appreciated. The applicant must have good interpersonal skills, rigor and autonomy, writing and speaking skills in English (French will be appreciated). The applicant must have very good C++ programming skills.

Application procedure:
Application is open until the position is fulfilled, within the limit of 15/10/2017. Application should be sent to Nicolas Pronost (nicolas.pronost@univ-lyon1.fr) by submitting a detailed resume, grade transcripts of the Master degree (both years), a cover letter and a recommendation letter from the supervisor of the master internship.

Reference:
[CPPD2016] Cruz Ruiz, A.L., Pontonnier, C., Pronost, N. and Dumont, G. (2016), Muscle-based control for character animation. Computer Graphics Forum. doi:10.1111/cgf.12863