PHD OFFER CNRS – HONDA

A PhD position is opened at the CNRS (www.cnrs.fr) - University of Montpellier (www.umontpellier.fr) , LIRMM (www.lirmm.fr) on fundamental research in human-humanoid physical interaction with perspectives of assistive daily motions for persons in need (frail, aging).

The main topic of the research is toward humanoid multi-contact planning and control in close physical interaction with a human person (predefined assistive tasks), considering human perception, dynamic balance, safety and high uncertainties that should be considered at the level of both planning and task-space control. The uncertainties that shall be accounted for are for example, human positionning w.r.t the robot, lack of knowledge on actual human strength, uncertainties on human contacts (with its environment) and on robot-human interaction contacts. The work also comprises important efforts toward care-givers skill transfer and trials on real patients in EHPAD centers in South of France.

Eligible candidates must hold (or are to hold shortly) a master degree in applied mathematics, computational geometry, machine learning or closely related field.

Starting date: Sept. / Oct. 2021 Duration: 3 years
Location: mainly in Montpellier (south of France, mediteranean coast city) with potential short or relativeley long stays in Japan (Tsukuba/Tokyo).
Requirements: Master degree in applied mathematics or computational geoemtry or optimization or IA and machine learning with good skills in C/C++, Python.
Development environment: https://github.com/jrl-umi3218/mc_rtc

Applicants must submit a cover letter, curriculum vitae to:
Abderrahmane Kheddar, CNRS, kheddar@lirmm.fr
and Takahide Yoshiike, Honda Research Institute, takahide_yoshiike@jp.honda

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PROVISIONAL JOINT RESEARCH SCHEDULE

In the first year, the research will focus on modeling the problem of 3D dynamic balance in multi-contact settings from the perspective of fundamental computational aspects. The idea is to explore approaches based on the relation between the center of mass and its acceleration and contact forces considering multi-modal fixed/moving contacts (the moving contacts are those used for supporting the motion of the person, the fixed ones are the other between the robot and its environment). Comparison to other approaches, e.g. to what extent 3D capture point, extended 3D ZMP can be used in this context, will also be conducted. The start point is the existing current work in the new implementation of the 3D robust stability and its integration to the **mc_rtc** control framework. The first milestone is to optimize the computation time considering a moving contact point. Real experiments will assess the algorithms through a use-case where the humanoid is required to push a rigid box having different weights put on a tilted plan so as to emulate a robot assisting a person to stand-up or to sit. By the end of the year, if possible, we will consider replacing this box with a real healthy person. In order to achieve the experiment with a person, compliant contacts and manipulation control in multi-contact compliant contacts shall be investigated. In parallel to the dynamic equilibrium, the controller shall be extended to handle compliant contacts. As a canonical experience, we will consider the manipulation of a compliant box having a stiffness close to that of a human and various weights.

Expected outcome of the first year

- Demonstration of stable multi-contact pushing of a moving rigid object in simplified use-cases inspired from human-robot physical assistance.

- Task-space QP controller extended to compliant contacts and objects.
- Technical report including details of the achievements and eventually published and/or submitted research papers.

The second year shall extend dynamic equilibrium studies considering the pair human-robot. That is to say: how the robot can build the human dynamic equilibrium constraint and use it to plan and on-line control of the human-motion assistance. The estimation of the human center of mass has been investigated in several recent studies and could be assessed in various postures. Moreover, the estimation of the contact forces from vision is also investigated at CNRS[1],[2]. We can build on these technologies and improve them to be adapted to human-humanoid physical interaction with multi-contact settings so as to compute the dynamic equilibrium constraint set of the human while manipulated by the humanoid. This set will be coupled to that of the robot and reconsider the control under the conditions of sudden loose of contact (e.g. when a person stands from a chair, the contact between her/his body and the chair will vanish and hence the dynamic equilibrium constraints will abruptly change the shape. This means that if not accounted for by the robot controller, the human center of mass can suddenly be outside the balance space resulting of a person losing balance and fall). Research shall also consider robustness issues, that are related to safety, such as uncertainties in contact locations, uncertainties in contact model, uncertainties in the human center of mass location, etc. During this year, the controller handling compliant multi-contact manipulation is tried on some use-cases defined by HONDA of human manipulation by a humanoid robot.
This year, experiment on real use-cases will be defined from our current investigations with aging centers (EHPAD) in the South of France. They can be tested with this project developed technologies using HONDA robot on healthy subjects in Japan.

Expected outcome of the second year

- Demonstration of more reliable human-humanoid physical assistance in use-cases defined from specialists in geriatric centers gathering both robustness and handling compliant contact models;
- Technical report including details of the achievements and eventually published and/or submitted research papers.

For the last year, depending on previous year achievements, research will be continued but directed toward whole-body control integration for trials with real patients. On the fundamental level, and to increase the safety level of the humanoid assistance, the eventuality for the robot to plan additional contacts on the fly can be considered. That is to say, we consider that the controller is able to generate contacts on demand to increase safety margins. This problem could be approached by the following question: given a subscribed CoM path and an initial region with contact, how and where to generate a contact (eventually on the fly) which is conform to the needed expansion of the CoM dynamic equilibrium region. In other words, what contact to take to enforce a desired CoM path?

Exprected outcome for the last year

- Final demonstrator according to HONDA chosen scenarios and requirements (including the location of the demonstrator)
- PhD thesis
- Technology recommendations, TRL and future plans
- Dissemination and presentation in front of HONDA panel and officials

[1] T-H. Pham, S. Caron, A. Kheddar, *Multi-contact interaction force sensing from whole-body motion capture*, IEEE Transactions on Industrial Informatics, Vol. 14, Issue 6, pp. 2343-2352, June 2018. Doi: 10.1109/TII.2017.2760912

[2] T-H. Pham, N. Kyriazis, A. Argyros, A. Kheddar, *Hand-object contact force estimation from markerless visual tracking*, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 40, Issue 12, pp. 2883–2896, December 2018. Doi: 10.1109/TPAMI.2017.2759736.