PhD/post-doc positions

- **Title**: Using IA and cable-driven parallel robots for the assistance to frail people and medical monitoring

- **Reasearch axis**: health and cable-driven parallel robots

- **Supervisor**: Jean-Pierre Merlet

- **Potential Co-Supervisor**: possibly C. Gosselin (Laval University), T. Bruckmann (U. Duisburg)

- **Team**: HEPAHISTOS team at INRIA

1   Introduction

The positions are proposed by the INRIA HEPHAISTOS team located at Sophia-Antipolis, near Nice, which offer a nice work environment together with enjoyable climate and surrounding. All documents and application have to be sent to Jean-Pierre Merlet (Jean-Pierre.Merlet@inria.fr) with as subject the position you are looking for and possibly the subject number you are interested in. Candidates will be screened by the team during one or several oral interview(s).

Funding is ensured for at least one year for the post-doctorate and is tentative for the PhD (or second post-doc) as it depends upon a grant of the local 3IA Institute.

Both position involve performing medical experimentation. They will be performed with the world-class hardware of the HEPHAISTOS team and with the strong support of a large network of medical partners either locally (Nice CHU, rehabilitation centers) or internationally. Sophia-Antipolis and its region also benefit from a large number of companies that are working in the medical field.

The proposed subjects have medical applications, that may be showcased in a special dissemination center located at Nice, but also involve a very original use of IA for robot control and data management in a context of low power consumption, together with its application to a non-usual type of robot, called cable-driven parallel robot, a topic on which the HEPHAISTOS team is recognized among the world leaders. Such a robot may be used not only for medical operations and the team is also involved in projects dealing with industrial use (maintenance, logistics), rescue operation, agriculture, education and art to name a few.

Context

The HEPHAISTOS team is dealing with assistance devices whose objectives are both to provide assistance to frail people but also to allow for medical monitoring. Mobility is an essential problem for the autonomy of frail people but it is also an important part of the medical monitoring as it allows one to assess the state of health of the subject. Motion assistance requires a powerful system as it may have to sustain the whole weight of the subject (or part of it) and have to fulfill several constraints:

1. being minimally intrusive

2. ensure the safety of the subject

3. provide reliable medical indicators on the subject motion

Regarding the lifting power and for dealing with the intrusivity we rely on *cable-driven parallel robot (CDPR)*. Such a robot consists in a mobile platform which is connected to the ground by several independent cables that can be coiled/uncoiled by winches disposed on the ceiling. The pose of this platform may be controlled at will by adjusting the length of the cables. Distributing the load on several cables allows to obtain a large lifting

capacity while cables have a low intrusivity. Winches are usually small and the whole system is quite discrete. We have currently two such robots with a lifting capacity of about 250 kg. The subject is loosely connected to the CDPR through a platform that support a medical harness or handles. The platform is instrumented to measure its own motion, which is reflective of the subject motion, and medical indicators may be deduced from the platform measurements. In spite of their mechanical simplicity CDPRs lead to complicated models, especially because the complexity of the cable behavior that combines elasticity, flexibility and sagging.

Such device is inherently submitted to uncertainties (in the design, in the measurements, . . .) that may affect their safety and performances. To manage these uncertainties the team is heavily relying on mathematical tools such as statistics, game theory and interval analysis. These tools are used at the design stage for developing devices whose performances will be guaranteed in spite of the uncertainties but also during the control and exploitation of the data (especially to establish the medical indicators that must take into account the uncertainties in the measurements). But these approaches require a representative model of the system and a compromise has to be find between the model complexity and the computation time of the algorithms used for control and data processing. Furthermore some of the model parameters may evolve with time (eg. because of wear) and have to be reevaluated over time. Additional constraints is that some of the processing should be fast (possibly real-time) and has to be performed on the embarked computer(s) of the CDPR platform which stores only a limited amount of energy.

The team is interested in exploring IA approaches for

- possibly get rid of the model approach

- improving the determination of the model parameters and to update their values over time

- possibly improving the calculation of medical indicators, both in terms of reliability and of computation time

- speeding up algorithms based on interval analysis that are inherently parallelisable and may therefore may benefit from the multi-core structure of IA devoted processors

For these purposes and to take into account the power consumption constraint, the team is considering to implement IA algorithms on low power consumption processors specialized for IA use, such as the NVIDIA JETSON family.

Subject 1

These methods will be tested on a particular CDPR called `MARIONET-ASSIST`[1] that is designed both for providing lifting assistance during walking in a room and to assess the quality of the walking process by providing indicators such as number of steps, required lifting assistance, subject velocity, stance data, ...

During walking the subject uses either handles located on the mobile platform or wear a medical harness that is connected to the platform. The CDPR should passively follow the subject during the walking, while provide a lifting assistance and perform measurements on the walking process. Our plan is to use IA methods for both the control of the CDPR and for the treatment of the measurements for determining walking indicators.

Objectives:

- for the model-based control of the CDPR compare the efficiency of IA methods with methods already developed in the team (in terms of computation time, robustness of the result, exactitude)

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[1]see `http://www-sop.inria.fr/hephaistos/mediatheque/index.html`

- determine if IA methods may use the CDPRs instrumentation to update the model parameters (calibration)

- determine if pure IA methods may allow to avoid using models (partly or completely) both for the control of the CDPR and for the the calculation of the medical indicators. In the later case it is important to assess the reliability of the provided indicators (that are inherently uncertain) by providing a quality score

- examine, in collaboration with our medical partners, if medically pertinent indicators may be determined with the system, beside established walking indicators

- ensure the safety of the subjects by providing a risks analysis and possible remediation of these risks

- run validation experiments with subjects

Subject 2

Subject 2 is somewhat similar to subject 1 except for the robotics context and the application which is related to the current development of a rehabilitation station in a virtual reality environment.

The purpose of the use of a virtual environment is to increase the motivation of the subject by making the rehabilitation less tedious and more realistic but also to allow for safely immersing the subject in specific and reproducible contexts that will be difficult to obtain in reality and are appropriate for training specific musculoskeletal groups.

The rehabilitation station is intended to be modular by allowing a fast change of the training devices (e.g. treadmill, equilibrium platform, rowing machine, . . .). Furthermore these training devices are themselves actuated with the purpose of providing more realistic training conditions (which may improve the motivation of the subject) and allowing the medical community to adjust the exercise difficulties and to favor the use of specific musculoskeletal groups. For example the slope of the treadmill may be changed to reflect different walking condition in a mountainous virtual reality environment while its inclination may also be changed to increase the load on a specific leg. This rehabilitation station will allow to develop various training exercises such as: mountain walking on an actuated treadmill, testing human equilibrium by driving a boat in a rough sea, paragliding, realistic tennis lessons (the CDPR will be used to actuate the racket), ski jumping, ... In each case the environment (and possibly the subject whenever it is possible) will be instrumented for determining the motion of specific musculoskeletal groups in order to assess the progress of the rehabilitation process by providing a set of medical indicators. The whole environment (hardware and software) should be designed in a modular way in order to allow a fast switch between exercises. The virtual environment will use a 3D setup that has been recently bought by the INRIA center.

A major component of the rehabilitation station is an innovative cable-driven parallel robot (CDPR), called `MARIONET-VR`, that is able to lift about 250 kg. This 6 dof CDPR uses linear actuators and a pulley system to change the cable lengths. This CDPR will be used as a motion/measurement device whenever necessary (for example for measuring the motion of an arm, to lift the subject during a ski jumping exercise, . . .).

Regarding the objectives many of them are similar to the ones of subject 1 (especially regarding the constraint of a low energy consumption of the IA algorithms) but with an initial focus on the CDPR. Indeed although the CDPR hardware and the low-level software are available, the control part has to be developed.

Specific objectives:

- develop a full control framework for the CDPR, possibly including IA-based modules

- develop the virtual reality environment and its connection to the CDPR and to the training devices. This work will be done in collaboration with a team maintaining the virtual environment

- develop a set of sensing environments allowing to measure the posture of the subject in the different conditions of the exercises. We systematically use redundant measurements with different modalities in order to increase the measurement quality

- develop the software for exploiting the sensing data and compute pertinent medical indicators. A comparison in terms of result quality, robustness and computation time between IA-based methods and alternate approaches already available in the project will be performed

- interfacing the system in order to allow its use by the medical community

- run validation experiments for each exercise on a cohort

Experience required

Both subjects are extremely interdisciplinary as they involve the use of robot modeling, mathematical analysis, IA, data and uncertainties management, hardware development, programming, biomechanics, sensors and signal processing, health experimentation, virtual reality (subject 2), system interfacing (subject 2). We clearly don't expect candidates to master all these topics but candidates with a variety of experience will be favored compared to candidates with only a strong expertise in a specific topics, while the team and the environment will provide the necessary additional experience.

Many of the items are common to both subject 1 and 2. Items with an * are not compulsory but some knowledge on several of such items will be appreciated

- basic Linux knowledge

- proficiency in C/C++ programming

- basic knowledge in robotics especially on parallel robots and assistance robotics

- basic experience in IA methods (deep learning, neural networks). Experience in programming IA hardware (NVIDIA JETSON) will be appreciated

- interest in mathematical and numerical analysis

- interest in experimentation

* basic knowledge of interval analysis

* basic knowledge in signal processing

* basic knowledge in hardware development and sensors interfacing (Arduino, Phidgets)

* experience in biomechanics (especially walking analysis for subject 1)

* experience in virtual reality and in the use of Unity (subject 2)

Documents to provide

- full CV

- publication record,

- last available official academic transcript for the PhD position

- motivation letter,

- recommendation letters,

- contact information (mail, phone, skype alias),