3iA Côte d'Azur
Interdisciplinary Institute for Artificial Intelligence

Ph.D. research topic

- Title of the proposed topic: Using AI for the design/exploitation of a walking assistance/walk monitoring device
- Research axis of the 3IA: integrative computational medicine, core elements
- **Supervisor (name, affiliation, email):** J-P. Merlet, INRIA,Jean-Pierre.Merlet@inria.fr
- Potential co-supervisor (name, affiliation): Y. Papegay, INRIA, Yves.Papegay@inria.fr
- The laboratory and/or research group:HEPHAISTOS

Apply by sending an email directly to the supervisor.
The application will include:

- Letter of recommendation of the supervisor indicated above
- Curriculum vitæ.
- Motivation Letter.
- Academic transcripts of a master's degree(s) or equivalent.
- At least, one letter of recommendation.
- Internship report, if possible.

⇨ **All the requested documents must be gathered and concatenated in a single PDF file named in the following format: LAST NAME of the candidate_Last Name of the supervisor_2023.pdf**

- Description of the topic:

The HEPHAISTOS team is leading extensive research on the full development of devices that combine assistance to frail people and health monitoring.
A major axis is the development of a non intrusive walking aid based on the concept of cable driven parallel robot (CDPR). Such a device is constituted of 4 winches located in the ceiling at the four corners of a room, each of them being able to coil/uncoil a cable. The end of the 4 cables are connected at the same point on a platform and controlling the lengths of the cables allows one to move the platform at any place in the room. Such a robot has a low intrusivity, may disappear in the ceiling when not in use and is able to lift large loads. On the platform we have handles that are grasped by the frail people and the robot provides a lifting support that just follows the motion of the subject (alternatively an harness may be connected to the platform). The purpose of the platform is also to use several sensors to monitor the walking pattern of the subject which allows to estimate walking indicators (e.g. number of steps, level of required lifting force,..) that are essential for the medical community. As the location of the platform is also known it allows one to get some information on the activities of the subject without resorting to intrusive sensors such as cameras.

A drawback of a CDPR is that it allows to cover a single room. We are currently developing a pulleys system that will allow to cover multiple rooms with a single CDPR but for its design we have to determine, for example, what will be the maximal tensions in the cables whatever is the position of the subject in the apartment. For a given platform position determining the cable tensions (or any other significative performance criterion) amounts to solve a square system of non-linear equations that admits usually several solutions and it is necessary to determine all of them. Although we have methods for that, they are computer intensive (typically the solving time is between several minutes and one hour). For determining the maximal cable tensions we may sample the apartment with thousands of positions and compute the cable tensions for each of them but this clearly cannot be done with the actual methods. We are looking at AI as possible candidate for a faster approach, with the constraint that errors on the maximal tension shall not exceed 5% but with the advantage that we are able to produce arbitrary large training sets.
We have already tested AI for the inverse problem (finding the possible positions being given the cable lengths) and it appears that it may work provided large changes in the core methodology of classical MLP (e.g. using hybridization and clustering of the training set in order to satisfy the accuracy constraint and to find several solutions for the same input). Note that the approach we are using are not specific to CDPR but may deal with any multiple-solutions system provided that it exists methods that are able to solve exactly the problem for a few cases. Note also that the training may have to be performed on an on-board computer with very limited access to energy and part of the research will have to deal with implementing the neural networks on such a processor, typically a Jetson nano.

The second part of the topic is to exploit the walking data obtained from the platform sensors (lidars, accelerometers, gyrometers,..). Preliminary tests have shown that we were able to determine accurately some basic medical indicators such as walking distance, number of steps... But we are interested in a more user-specific approach that will be able to learn the walking pattern(s) of the subject based not only on the platform sensors but also on the location of the subject in its apartment (as obstacles and/or the place specificity may lead to changes in the walking pattern) , determine medically pertinent indicators (possibly discovering new ones that may be specific for a subject and/or a pathology), monitor their variations over time, possibly detect "rare events", i.e. events that are outside the usual walking pattern but last a short time, as these events may be the premises of an emerging pathology. We are also interested in determining trends on the daily activities of the subject.

The topic therefore covers a full spectrum of AI problems: helping to design the assistance/monitoring device, provide algorithms that will process the sensory data for providing medically pertinent indicators and validate them through clinical tests. The HEPHAISTOS team is familiar with such type of development with numerous contacts in the medical community for the clinical trials.