Offer #2021-03665

PhD Position F/M Force-based criterion for in-situ analysis of physical activity at work: application to load carrying

Contract type : Fixed-term contract

Level of qualifications required : Graduate degree or equivalent

Fonction : PhD Position

Level of experience : Recently graduated

About the research centre or Inria department

The Inria Rennes - Bretagne Atlantique Centre is one of Inria's eight centres and has more than thirty research teams. The Inria Center is a major and recognized player in the field of digital sciences. It is at the heart of a rich R&D and innovation ecosystem: highly innovative PMEs, large industrial groups, competitiveness clusters, research and higher education players, laboratories of excellence, technological research institute, etc.

Context

Within the framework of a partnership

- collaboration (MimeTIC and the start-up Moovency

a model more specifically dedicated to the determination of robust joint torques based on noisy and incomplete motion capture data, and the design of a criterion to quantify the risk of musculoskeletal disorders based on these continuous joint torques.

The PhD will be co-supervised by 3 researchers (in biomechanics, computer sciences) and 1 representative of Moovency start-up.

In a context of globalization, new manufacturing processes impact the organization and working conditions. Industrial production contexts involve many factors defining the activity of operators: organizational, managerial, pace, tools and work environment.... This activity can be the cause of many physical disorders, in particular musculoskeletal disorders, which represent more than 80% of reported occupational diseases, and are the second cause of sick leave in France (AMELI statistics 2017).
Designing and adapting workstations to avoid the appearance of these musculoskeletal disorders therefore means taking many factors into account. Biomechanical constraints covering elements such as uncomfortable postures, heavy loads, repetitive movements...Thus, monitoring the physical activity of the operator in a work situation is a way to evaluate these biomechanical constraints and to include them in a broader approach of activity analysis to design or transform work situations.
In this approach of monitoring the physical activity of operators, Moovency develops a methodology of objective measurements of biomechanical constraints in work situation, from measurement systems usable on site and not very invasive. For the moment, Moovency proposes a monitoring of the operator's movement, and can extract levels of postural solicitations which are very useful to draw up an assessment of the operator's activity in real
work situations. This analysis is generally included in a more global approach of ergonomic analysis of work fatigue. Nevertheless, these postural reports bring a limited light on the biomechanical constraints related to the operator's activity. They do not make it possible to analyze the physical solicitations (forces) undergone or generated by the operator. This analysis is fundamental for the investigation of physical risk factors involving an effort, and requires more complex calculations, generally based on rather invasive measurements, even impossible to carry out on site. To be able to estimate these physical constraints without carrying out complementary measurements is thus an important issue for developing tools such as KIMEA, developed by Moovency.
This is why the objective of this thesis is the development of an force-based criterion for the analysis of the physical activity of the operator, exploitable in-situ, i.e. from data that can be acquired on site, without impact for the activity. To develop this effort criterion in a relevant application framework, we will focus on a very common task in an industrial environment: the bimanual load carrying. Indeed, the handling of heavy objects concerns many sectors of activity: the logistics sector for storage or order preparation, the construction sector for the
manual transport of raw materials on site or the carrying of hand tools. In the literature, several equations, such as NIOSH (Waters et al., 1994), are used to estimate whether the masses carried are acceptable, given task-related information such as grip height, vertical displacement, etc. This approach, which is very simple to implement on site, however, neglects the actual way in which the gesture is performed by the operator, and may therefore

underestimate, or overestimate, the actual biomechanical constraints. Therefore a criterion based on forces, taking into account the movement of the operator, is very promising to better restore the biomechanical constraints of the handling activity.

Assignment

The objective of this thesis is therefore to define a quantified effort criterion based on biomechanical variables that can be measured in-situ, for bimanual load carrying. This criterion will provide ergonomists with an objective element to quantify the level of effort solicitations, which they will be able to compare with other parameters such as the movement and the operator's feeling. The main questions addressed in this thesis are :

- How to estimate the joint physical solicitations from a limited set of data, such as the flow of a depth camera or a video stream, without additional effort measurement?
- How can we deduce from these joint physical solicitations an instantaneous effort criterion that is easy to interpret and exploit, as we have with postural scores?
- How to exploit this instantaneous criterion in a long-term projection of the operator's activity, i.e. how to integrate the notion of repetition and fatigue in this criterion to make it representative of the chronic activity of an operator.

We will try to integrate these works to the Moovency tools.

Main activities

Main activities (5 maximum) : develop machine learning approach, collect data for machine learning, integrate the method in Moovency software, adapt inverse dynamics method

Additional activities (3 maximum) : write papers in international conferences and journals, experiment in real use case (Moovency customers), write documentation report

Preliminary work has shown that it is feasible to develop joint torque estimation methods based on depth camera type data such as the Kinect (Plantard et al. 2017, Elthouky et al. 2017). Nevertheless, these works required limiting simplifying assumptions (degrees of freedom of the associated biomechanical model, ground detection for reaction force estimation). By focusing on a specific task (load carrying), we plan to overcome these limitations with a learning approach allowing to keep a richer model while exploiting less explicit data. This work base will then be used to develop an instantaneous effort criterion that we will try to validate through experimentation. The work will thus be divided into three main scientific tasks, to which we will add an application task:
T1: Estimation of the joint torques involved in the bimanual load bearing by learning.
The classical method for estimating joint torques from motion measurements is inverse dynamics (Muller et al. 2019). This method involves using the laws of dynamics to trace so-called internal forces (joint torques) from the accelerations of body segments inferred from the measurement, and external forces. Using this approach with data from Kinect or video measurements, as Moovency does, is very delicate, because the measurement noise and the sampling frequency have a strong impact on the accuracy of the calculation of the acceleration of body segments. Moreover, the estimation of external forces seems impossible from a simple camera. In the equations of dynamics, the external forces reflect the resultant of the motion of the masses involved. However, the exact relationship between these quantities is difficult to find faithfully if the motion measurements are not precise and of high frequency. In this thesis, we hypothesize that recent advances in machine learning should make it possible to train a network to learn this relationship, despite the measurement noise.
This task will therefore consist in the definition of a recurrent neural network learning method (Liu et al. 2009, Ardestani et al. 2014) allowing the estimation of joint torques during bimanual load bearing based on motion data such as depth camera or video, individual factors (subject anthropometry, expertise...) and/or environmental factors (load carried, lifting height...). For this, an experiment will be conducted in the laboratory where a cohort will carry out controlled loads and where synchronized measurements between a reference system (opto-electronic capture, force platforms, instrumented loads) and the in situ measurement systems will be carried out. The data collected will serve as the basis for learning the network. The subjects of the study will also have to quantify their level of effort during the controlled tasks, using self-evaluation tools such as CR10 (Category-Ratio scale, Borg, 1998) or BPD (Body Part Discomfort scale, Corlett & Bishop 1976).
T2: Instantaneous effort criterion for load carrying
Using the data from the learning method, we will try to construct a criterion representative of the level of articular solicitation in terms of effort, which will complete the postural analyses already largely carried out. For this, we will exploit the existing bibliography in terms of joint torque envelopes (Frey-Law et al. 2012, Haering et al. 2019) to allow the implementation of a dynamic estimation of the level of solicitation, in the manner of the static estimation implemented in tools like the JACK simulator (Chaffin & Erig 1991). This criterion and this level of solicitation will be compared and processed by comparison with the self-evaluations of the subjects reported during the experiment proposed in task 1.

T3: Definition of a long-term effort criterion for load bearing
Once the instantaneous method is functional, it will be envisaged to set up an experiment involving peripheral fatigue in order to project the impact of the latter on the effort and the feeling of the subject. For this, a protocol similar to the one proposed in task 1 will be set up. The experimental combinatorial will be reduced in order to favor the repetition of gestures. A measurement of the cardiac activity and of certain muscles involved in load carrying (deltoids, pectorals, dorsal erectors) will be added at this stage in order to complete the approach and monitor fatigue. Based on existing works, fatigue models allowing a longer term projection of the solicitations will be proposed (Frey-Law et al. 2012, Ma et al. 2009).

T4: Implementing tools in KIMEA
All of the previous scientific developments will be continuously integrated into the MOOVENCY analysis tools, through constant monitoring of the thesis work by an application development engineer. If necessary, MOOVENCY will propose use cases for the tools developed on the basis of requests from its customers.

Skills

Technical skills and level required :

The candidate should have a basic knowledge in machine learning, optimization, deep learning, and computer sciences. Development in Python and C++ is required. Additionnal expertise in biomechanics, physical simulation, and motion analysis would be positive.

The candidate should appreciate to carry-out experiments, work in teams of students, and should be interested in industrial applications.

Languages : English is important to read, write papers and communicate in an international team and in international conferences.

Relational skills : he or she should like working in a team, with other students

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs

Remuneration

Monthly gross salary amounting to 1982 euros for the first and second years and 2085 euros for the third year

General Information

- **Theme/Domain :** Interaction and visualization
  Statistics (Big data) (BAP E)
- **Town/city :** Rennes
- **Inria Center :** Centre Inria de l'Université de Rennes
- **Starting date :** 2021-10-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2021-08-31

Contacts

- **Inria Team :** MIMETIC
- **PhD Supervisor :**
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About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

The keys to success

The candidate should appreciate to work both on coding original machine learning and carry-out experimental protocols. He or she should appreciate working in an international team, should be curious. He or she should be open to multidisciplinary research, mixing biomechanics, computer sciences and ergonomics.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

Instruction to apply

Please submit online : your resume, cover letter and letters of recommendation eventually

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating

to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.