LINEACT cesi

PhD Dissertation Proposal

Titre: Cartographie sémantique en temps réel via la fusion de données issues des perceptions individuelles d'un essaim de robots mobiles dans un contexte industriel homme-robot

Title: Real-time semantic map using a data fusion algorithm and individual perceptions of a mobile robots swarm in a human-robot industrial environment

Scientific domains: industrial robotics, computer science, data processing
Keywords: data fusion, semantic map, real-time, human-robot cohabitation, digital twins

Supervising:

Thesis director:

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Context:

The objective of research at CESI, through its laboratory LINEACT CESI for "Digital Innovation Laboratory for Companies and Apprenticeships for the Competitiveness of Territories" is to produce knowledge and methods at the service of the scientific community. Its current organization is linked to the fields of training and helps a better identification of LINEACT CESI within the research ecosystem. Thus CESI, while being affiliated at the national level to the ComUE HESAM, promotes in its regions the links with the local ComUE. The LINEACT CESI teams are thus in fact in a dynamic of collaboration which facilitates their integration in collaborative research programs. Relations with higher education institutions and research laboratories have been strongly developed in recent years. Great attention has also been paid to competitiveness clusters and industrial sectors, with a permanent search for complementarity and coherence with other territorial actors. A detailed analysis of each territory and each campus was carried out before determining the themes developed.

To support its research and training activities, LINEACT CESI has Factory of the Future demonstrators including:

- a metallic additive manufacturing unit,
- a flexible production system,
- manual and cobots workstations,

- mobile robots and robotic arms,
- prototyping or machining equipment.

Digital twins associated with human machine interfaces based on virtual or augmented reality have been initiated and allow, for example, to perform simulations, in an immersive environment of assembly operations on manual workstations integrating a cobot station. These physical and digital twins will be exploited within the framework of the development of the proofs of concept of this thesis.

LINEACT CESI is organized around two interdisciplinary scientific themes and two application areas. The themes "Learning and Innovation" and "Engineering & Digital Tools" develop and cross their research in the application areas of the “Industry of the Future” and the “City of the Future”. The objective of the “Engineering & Digital Tools” team is to conduct research based on multidisciplinary and integrated approaches, particularly in Computer Sciences and Engineering Sciences, combining modelling, optimization, data and usage analysis in order to address the challenges of the city and the industry of the future. This research theme is structured along three main axes:

- Axis 1 – Cyber Physical Production System (CPPS)
- Axis 2 – Collaborative processes and digital tools
- Axis 3 – Sustainable urban systems

This PhD proposal integrates the Axis 1, and deals more specifically with the dynamic organization and planning of service activities in the 5.0 industry context. Within the framework of this research project, the PhD student will be able to rely on the laboratory's expertise in the architecture conception, modeling, development and evaluation of augmented environments or dynamic and collaborative virtual environments applied in the field of Industry 5.0. He will also be able to rely on the laboratory's skills and work on industrial cyber-physical systems and more specifically on digital twins, their architectures and Artificial Intelligence integrated decision system.

Research topic:

In the context of industry 5.0 with human and robots sharing the same working area, the need of an updated map with the exact position of static and dynamic elements is required [1]. Indeed, to avoid collision and make the human-robot collaboration possible, the information of the position of each element is needed. It is necessary that a robot have a map of its closest dynamic environment [2] to manage its trajectory. Today, in the literature [1, 2], there are lots of works for static scenes but only few works have addressed the problem of the map representation in dynamic scenes [3]. In recent years, there has been a growing interest in adding high-level information to many robotic applications to achieve more efficient robots with a diversity of planned tasks, even capable of reacting to unexpected events. To do so, the field of mobile robotics is starting to include semantic information in navigation tasks, leading to a new concept: semantic navigation [1]. This type of navigation brings the human way of understanding the environment closer to the way robots understand it [2,4]. Semantic navigation approaches follow some common principles, including a framework for topological mapping that includes geometric information, adding a topological abstraction.

In the case of displacement of humans and robots in the same area, the map of the environment should be updated at a high frequency level. One of the major challenges of creating dynamic map is the real-time constraint [5, 6, 7]. Indeed, in addition of the time required for the data

processing and data fusion, latency periods should be considered. In one part, the data processing time is considerable since there are different kinds of data: video stream (from static camera and robot's camera), position, velocity, distance measures (from ultrasound Lidar, odometers, cameras, INS, laser, ...) [8, 9, 10]. Digital twins will be used to perform the data processing and map computation. In another part, transmission times between sensors and digital twin should be taken in consideration in particular if augmented reality is used as one of the data providers. A tradeoff should be studied between the map execution time and the precision of the map (number of data, sensors precision and algorithm performance) [11, 12] with a considerable high reliability index to ensure the security of people.

This thesis aims at tackling the challenges specific to the industries 5.0 and Human-Robot collaboration. The work goal is to provide a real-time map of human-robot industrial environment. The number of use cases is very large. Obviously, these maps will be used for the planification of robot tasks providing safety to human and robots, sharing the same working space. We can imagine that this kind of map will be used to provide an inventory in case of a fire or accident.

Contributions on the following topics are expected:

- Develop a data fusion algorithm to be used in our context
- Build a semantic map using different kinds of information (provided by different static and dynamic sources).
- Respect real-time constraints in considering data processing time and latency periods.
- Provide a reliability index associated to the map

The PhD thesis major steps can be described as follows:

- State of the Art of a real-time data processing, data fusion, 2D/3D mapping methods and static/dynamic environment.
- Development of a data fusion algorithm
- Development/Usage of a static element mapping model.
- Contribution in a real time dynamic elements mapping model.
- Experimentation, simulation and validation of the model (reliability study, ...).

The expected deliverables are:

- At least, two communications in major conferences and one JCR journal paper.
- The deployment of the algorithms on LINEACT platforms.
- An evaluation of the algorithms performance on a real system.

Thesis organization:

Laboratory: LINEACT (Digital Innovation Laboratory for Companies and Apprenticeships for the Competitiveness of Territories) https://lineact.cesi.fr/en/
Workplace: CESI Toulouse Campus (Labège). Some periods of time can be spent on another CESI campus.
Start date: Autumn 2021.
Funding: CESI PhD scholarship.
Duration: 3 years.
Hiring procedure: Application files and interview.

Your application must be sent to Yohan DUPUIS (ydupuis@cesi.fr) and Madeleine EL ZAHER (melzaher@cesi.fr) with the object:

«Application PhD Thesis: Real-time semantic map»

Your application files must include:

- **A detailed resume**, please provide explanations in case of gap period in your resume
- **A cover letter,** a focus should be given on your experience related to the topic and your motivations to pursue a PhD thesis
- **Your master grades**, the candidate must hold a Master in Computer Science and Robotics
- Any related document that could help evaluating your application

Please send the document as a zip file entitled « LASTNAME_Firstname.zip »

Applicant skills:

Hard skills:

- Industrial robotics
- Good programming skills
- Knowledge in ROS and Gazebo
- Data processing
- Notion in real-time issues is a must-have
- Scientific writing
- Good English speaking and writing proficiency

Soft skills:

- Autonomy
- Adaptability
- Communication
- Creativity
- Problem solving
- Teamwork

Bibliography

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