H.F.R.I.
Hellenic Foundation for Research & Innovation

Description of the funded research project

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment

Title of the research project:

MOBILE ROBOTIC MANIPULATORS AS HUMAN OPERATOR COLLABORATORS

Principal Investigator:

K.J.KYRIAKOPOULOS, Prof. NTUA

Reader-friendly title:

COHORT

Scientific Area:

ENGINEERING SCIENCES & TECHNOLOGY

Institution and Country:

ELIDEK, GREECE

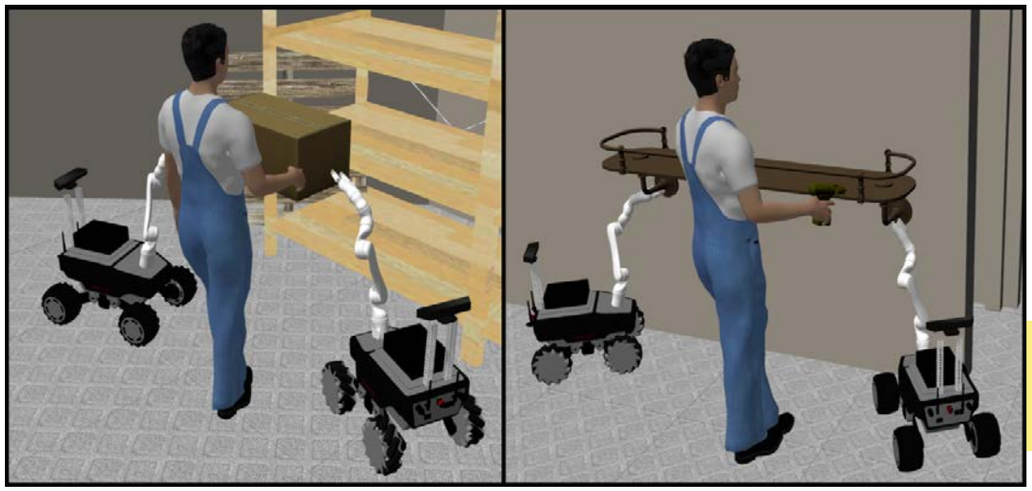
Host Institution:

NATIONAL TECHNICAL UNIVERSITY OF ATHENS (NTUA)

Collaborating Institution(s):

U. Of PENNSYLVANIA (UPEN)

Project webpage (if applicable):



Budget: 187,843.02 €

Duration: 36 MONTHS

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Research Project Synopsis

Complex applications that require multiple robots to execute a task in physical cooperation with humans call for further investigation to meet challenges and issues related to safety, robustness and complexity. Towards this direction, the purpose of COHORT is to extend the state of art on human-robot collaboration by developing a cooperative framework between mobile manipulators and a human operator for tasks pertinent to warehouse and logistics applications, manufacturing and servicing. In particular, we envisage two scenarios:

- load transportation, where a multi-robotic system transports a load following the instructions of a human- operator, expressed by a wrench vector applied on the load, while avoiding collisions and satisfying contact constraints and load transportation requirements, and
- object restrain, where a multi-robotic mobile manipulator system holds steadily a load against possible wrench perturbations that are derived by the human-operator.

The envisioned approach will yield a semi-autonomous operation mode, which will pave the way towards efficient human-robot cooperation in various application domains. Specifically, the targeted objectives compared to the existing work indicate that:

i. neither transportation nor restrain problems have ever been addressed under the implicit instruction (augmentable manipulation) of a human-operator,
ii. automatic collision avoidance and user-imposed reconfiguration within a clattered environment have never been integrated in transportation and restrain control, and
iii. the object restrain has only been tackled as a generic disturbance rejection objective, without considering at all the efficient reconfiguration of the robotic team to increase robustness.

The aforementioned innovations as well as their implementation and testing on real robotic platforms call for new ways of thinking and analysis, which render COHORT a beyond the state of art and groundbreaking approach in the field of robotics. The goal of COHORT is to restate the collaborative motion control design so that it is integrated with communication as strongly interconnected components. Aiming at decentralized solutions and given the limited (computational and energy) resources of the on-board IT hardware, owing to the autonomous character, we address the design of an integrated scheme of implicit communication & control in a way that it is effective (the tasks are successfully fulfilled), computationally efficient (perception and control can be applied with the state of the art of real-time computing equipment) and cooperative (robots can coordinate with the human given the communication limitations).

Project originality

We consider scenarios involving multiple mobile manipulators (i.e., manipulators on top of wheeled holonomic or “nonholonomic” platforms) and a single human-user. We propose the investigation of the motion control problems associated with such a group of mobile manipulators when assisting the human in two types of tasks that are critical for the described operational framework:

Load Transportation: We envision a multi-robotic system transporting a load by following the instruction of a human operator expressed by his/her wrench vector applied at a user-selected point on the load, while the multi-mobile manipulator system avoids collisions with the surrounding environment and respects contact constraints (e.g., motion in contact to a wall) without violating the load transportation requirements set by the user. If this is not possible for a specific mobile manipulator, the user can intervene by reconfiguring the system in a fully compliant mode.

Object Restrain: We envision a multi-robotic mobile manipulator system holding steadily a load against possible wrench perturbations that are applied by a human as a part of operations (e.g., drilling a hole, assembly, etc.). For random wrench perturbations a disturbance rejection control mechanism will compensate for them. If the direction of a wrench perturbation is known beforehand (e.g., when drilling a hole) then this could be demonstrated at small magnitude and then the system could kinematically reconfigure itself to benefit from a better configuration. In terms of innovation, our objectives compared to the aforementioned related works indicate that:

- Both the cooperative transportation and restrain problems for multiple mobile manipulators have not been addressed under an implicit communication based control scheme (augmentable manipulation) with a human user, subject to physical contact constraints induced by surrounding objects.
- Capabilities, such automatic collision avoidance or user-imposed reconfiguration to tackle with a clattered local environment, have not been integrated into transportation and restrain control.
- The object restrain problem has not been addressed beyond the usual generic disturbance rejection approach, while the reconfiguration of the kinematic chain has not been addressed at all.

Expected results & Research Project Impact

The expected results are linked to the following set of objectives :

Objective 1: Coordination between human and multiple mobile manipulators via physical interaction.
Objective 2: Coordination under environmental physical interaction constraints.
Objective 3: Automated obstacle avoidance of the coordinating mobile manipulator system.
Objective 4: Human-user controlled reconfiguration.
Objective 5: Disturbance rejection for object restrain.
Objective 6: Object restrain by system reconfiguration.

COHORT results are projected to be useful for the development of general-purpose cooperative mobile robotic manipulator platforms in service robotics, where manipulation and information exchange minimization are key issues. Typical examples of related tasks include warehouse and indoor logistics operations, manufacturing and servicing. It is pointed out ["IFR Statistical Department, World Robotics Survey 2015," 2015. [Online]. Available: http://www.worldrobotics.org/index.php?id=home&news_id=285] that "…*service robots for professional use boom*", with logistics being a major market. Sales of professional service robots in the logistics segment registered a growth of 28% in 2014 with the value of sales increasing to USD2.2 billion. This shows the huge opportunity of COHORT within the market demands in this area.

The importance of this funding

We aim at disseminating the project widely to both the targeted communities and the general public at the Greek and international levels. We will utilize our broad academic and industrial networks, and extensive experience on EU projects for the dissemination of the envisioned results through web pages, publication of scientific papers and patents, active participation in conferences, workshops and press releases. It is noted, that the proposed dissemination activities will invigorate the exploitation of the project's outcome and assist the use and continuation of the results beyond the project.“WP-9: Dissemination” will incorporate all related activities and will run from the beginning of the project till its end and beyond.

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