Cognitive architectures for human-robot collaboration

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Description:
Collaborative robots in manufacturing scenarios have been proposed to be deployed alongside human operators to perform a series of tasks traditionally considered stressful, tiring or difficult. Recently, we have proposed a comprehensive humanrobot collaboration (HRC) framework called FlexHRC [1, 2], showing interesting results on the Baxter dual-arm robot and on cooperative mobile manipulators [3], while maintaining a uniform control architecture based on task priority [4].

The goal of this research proposal is to develop the new, cognitive-oriented version of FlexHRC, which will encompass the following directions.

1. Extending the capabilities of the task-priority control approach, with the aim of including force regulation, admittance schemes and integrating simulationin-the-loop motion planning techniques.
2. Designing new approaches based on Task-Motion Planning, and therefore integrating high-level, continuous-discrete, planning frameworks, e.g., based on PDDL+, with belief-space planning techniques.
3. Develop modules able to adapt the human-robot collaboration scheme on the basis of an assessment, done autonomously by the robot, of the activities carried out by human operators, for instance to easy their fatigue or to perform actions on their behalf should these be difficult to them [5].

The overall goal is to design a novel HRC framework capable of exhibiting rich cognitive capabilities as far as human-robot collaboration is concerned. As a consequence, the development aspects will involve state-of-the-art software engineering methodologies to attain a novel framework usable in different configurations, e.g., dual arm robots and/or mobile manipulators. The framework will use improved techniques at the action sequencing and execution levels, and will show integrated capabilities in executing high-level (i.e., discrete) actions via lowlevel (i.e., continuous) behaviours, adapting the overall execution of such low-level behaviours to better adapts to human behaviour.

The PhD student will work within an engaging, stimulating, and multi-cultural environment. He or she will be involved in the activities carried out by two involved research teams, namely GRAAL and TheEngineRoom. This will involve also helping the teams supervise MSc students in their thesis work, most notably students from the UniGe's Robotics Engineering program. To conduct the research activities, the PhD student will use state of the art dual arm manipulators (a Baxter robot from Rethink Robotics and Tiago++ from PAL Robotics), a

network of RGB-D devices, motion capture systems (two combined OptiTrack systems), wearable devices (both commercial and custom IMUs, custom data gloves), AR/VR equipment (an Oculus Rift, a Hololens2), as well as advanced computational machinery.

Requirements:
Sought applicants have good knowledge in rigid body kinematics and dynamics, as well as on robot control, artificial intelligence (including deep learning), excellent C/C++ skills, including also software engineering aspects, and a strong motivation for challenges.

References:

[1] K. Darvish, F. Wanderlingh, B. Bruno, E. Simetti, F. Mastrogiovanni, G. Casalino. Flexible human–robot cooperation models for assisted shop-floor tasks. Mechatronics, vol. 51, pages 97-114, 2018.
[2] K. Darvish, E. Simetti, F. Mastrogiovanni, G. Casalino. A hierarchical architecture for human-robot cooperation processes. IEEE Transactions on Robotics, vol. 37(2), pages 567-586, 2021.
[3] E. Simetti, G. Casalino, F. Wanderlingh, M. Aicardi. A task priority approach to cooperative mobile manipulation: theory and experiments. Robotics and Autonomous Systems, vol. 122, 103287, 2019.
[4] E. Simetti, G. Casalino. A novel practical technique to integrate inequality control objectives and task transitions in priority based control. Journal of Intelligent and Robotic Systems: Theory and Applications, vol. 84(1-4), pages 877-902, 2016.
[5] Careful with that! Observation of human movements to estimate object properties. Proc. of the 13th Int. Workshop on Human-friendly Robotics (HFR), Anywhere on Earth, October 2020.

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