Title : Safe Learning for fast planning and re-planning for heterogeneous multi-robot systems for manipulation tasks in Factories of the Future.

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Brief Summary :
Nowadays, multi-robot systems are an important research area in robotics. Among multi-robot systems, multi-arm platforms are of particular interest due to the complexity of tracking, controlling and optimizing the articulated mechanisms. From a practical point of view, it is known that a multi-robot system can perform tasks that are difficult for one single robot like manipulating, moving or working on large set of objects (small, large, light, heavy,...). One of the research topics in this area, we propose to investigate in this PhD, is the problem of safe learning for planning and fast re-planning of heterogeneous multi-robot systems. Our final goal is to perform industrial tasks (manipulating, moving or working of general objects), using as best as possible the available robots inhibiting any damage for the robots and their environment. Obviously, the robots must be able to adapt themselves to changes of the tasks and/or of the environment still ensuring their integrity. As theoretical contributions, we expect to design motion planning methods and new motion re-planning (adaptation) methods suitable for multi-robot cooperating to perform the same task. Further, we will investigate the use of learning techniques which can be applied in the context of motion planning and re-planning. We will also consider new contributions in the constraint descriptions of robotics systems that will be easier to take into account during planning and re-planning processes.

Keywords :
Multi-robot systems, future factories, object manipulation, motion planning, motion adaptation, mobile manipulators.

Details :
In the context of the Factories of the Future, the robots are used to perform task within changing environments. Off-line optimization techniques proved to be efficient to generate complex dynamic motions for humanoid robots, ensuring the integrity of the robot and of its environment and the accomplishment of desired tasks [1]. Those techniques are also able to compute sequences of static postures for multi-robot locomotion and manipulation [2,3]. However, the computation time, from a few minutes to several hours, inhibits to use this techniques in on-line situations. Usually the motions are computed off-line and performed on-line using task-dedicated controllers such as the stabilizer for walking motions [4], or the Stack of Task for multi-task motions [5]. The main issues of those controllers are : 1) they consider only kinematic constraints (joint limits, collision avoidance, trajectory of the Center Of Mass, …), and do not evaluate dynamic constraints (torque limits, dynamic balance, …), 2) they converge to local solutions and cannot handle huge variations of the environment or of the tasks comparing to the supposed ones.

It is highly desirable that multi-robot systems can perform complex tasks in complex environment, such as factories, ensuring the safety of the people around, the integrity of the robots and the accomplishment of the task in the most efficient way. Obviously, real environments induces slight or large differences between the supposed situation and the actual one. Thus, the multi-robot systems must be able to quickly adapt their behavior while ensuring integrity and task accomplishment reliability.

In this PhD proposal, we will take advantages of previous work on motion optimization for humanoid and manipulator robots [1,4] and for mobile robots [9,10], in order to plan the most efficient way to perform a task for a heterogeneous multi-robot systems. We will investigate new methods in order to plan or re-plan the robots' motions when a slight or a large change occurs (in the task or in the environment). Interval analysis [6] proved to be efficient to ensure constraint satisfaction when solving optimization (hence integrity of the robots and accomplishment of the tasks) [7], but has too long computation time. Some machine learning techniques, such as Neural Networks [8], are able to quickly solve complex problems, but without any guarantee of on-line convergence, feasibility or system's integrity. In this PhD, we propose to investigate on-line and reliable methods based on learning, in order to quickly solve complex problems by producing safe motions that inhibits any damage of the overall multi-robot system in its environment.

[1] *S. Lengagne, J.Vaillant, A. Kheddar, E. Yoshida*
Generation of Whole-body Optimal Dynamic Multi-Contact Motions
International Journal of Robotics Research,vol. 32 no. 9-10 1104-1119 (2013)

[2] A. *Escande, A. Kheddar, S. Miossec*
Planning support contact-points for humanoid robots and experiments on HRP-2
Intelligent Robots and Systems, 2006 IEEE/RSJ International Conference on

[3] *K. Bouyarmane*
On Autonomous Humanoid Robots: Contact Planning for Locomotion and Manipulation
PhD Thesis : University of Montpellier (2011)

[4] S. Kajita, F. Kanehiro, K. Kaneko, K. Fujiwara, K. Harada, K. Yokoi, H. Hirukawa
Biped walking pattern generation by using preview control of zero-moment point
Robotics and Automation, 2003. Proceedings. ICRA'03. IEEE International Conference on

[5] *N. Mansard, O. Khatib and A. Kheddar.*
A Unified Approach to Integrate Unilateral Constraints in the Stack of Tasks.
IEEE Transaction on Robotics, 25(3):670-685, June 2009

[6] *L. Jaulin, M. Kieffer, O. Didrit, E. Walter*
Applied Interval Analysis.
(2001) Berlin: Springer

[7] *S. Lengagne, N. Ramdani, P. Fraisse*
Planning and Fast Re-Planning Safe Motions for Humanoid Robots
IEEE Transactions on robotics vol. 27 pages 1095-1106

[8] *D. Pomerleau*
Knowledge-Based Training of Artificial Neural Networks for Autonomous Robot Driving
In Robot learning, pp. 19-43. Springer US, 1993.

[9] *Adouane, Lounis*
Reactive versus Cognitive Vehicle Navigation based on Optimal Local and Global PELC
(2017) Robotics and Autonomous Systems (RAS), 88: 51 – 70.

[10] *P. Avanzini*
Modélisation et commande d'un convoi de véhicules urbains par vision,
Thèse de doctorat, Université Blaise Pascal, Clermont-Ferrand, 6 décembre, 2010.