# Guaranteed Computation of Constraints for Safe path Planning

Sebastien Lengagne, Nacim Ramdani, Philippe Fraisse

# Guaranteed computation of constraints for safe path planning

Sébastien Lengagne, Nacim Ramdani[1] and Philippe Fraisse
DEMAR : LIRMM - UMR CNRS 5506 / Université Montpellier II / INRIA
161 rue Ada 34392 Montpellier Cedex 5 - France
{Sebastien.Lengagne,Nacim.Ramdani,Philippe.Fraisse}@lirmm.fr

*Abstract*— **Path planning issues are often solved via constrained optimization methods but with constraints which must be satisfied over a whole interval of time or space. The use of fast numerical toolboxes implementing state-of-the-art constrained needs to discretize the continous constraints over a time grid. Thus, the obtained solution, in this way, will satisfy the constraints only for time values corresponding to the time grid. Obviously, some constraints could be violated with catastrophic consequences when dealing with, for instance, the balance of humanoid robots. In this paper we introduce a guaranteed discretization method which uses interval analysis to ensure that the constraints are satisfied over the whole time interval. We analyze numerically this method by performing a trajectory generation under constraints dedicated to the motion of the HOAP-3 humanoid robot.**

## INTRODUCTION

Path planning is an important topic in the humanoid robotics research field. Robot motion generation is usually achieved by solving a path planning problem which boils down to a constrained optimization one. This problem is solved by [1] for the planning of digital actors' locomotion ; by [2] for the optimization of motions such as a kick motion on HRP-2 robot or by [3] for the planning of a manipulator robot's trajectory.

The validity of the constraints during the whole motion is of prime importance. However, the optimization algorithms used need only the assessment of the constraints over a time or space grid. The *continuous* constraints must then be discretized to be taken into account in the optimization process. [2] and [4] use such a time-grid discretization, so they consider only discrete values of the continuous constraints. Therefore, these constraints are satisfied over the time-grid but can be violated elsewhere. This is the reason why we introduce a *time-intervals* dicretization method which guarantees the validity of the constraints for the whole motion.

This paper is structured as follows. First, we recall the path planning problem under constraints for generating optimal motions. Then, we present two simplified dynamic models considered to assess the proposed method : a double pendulum and the legs of the HOAP-3 humanoid robot expressed in the sagital plane. The next section will address the time discretization issue : we remind the classical discretization method usually used in robotics and then introduce our developments. In the last part, we compare the two discretization methods for the generation of a double pendulum motion. Finally, we apply the time-intervals method to the generation of a one-step motion with the HOAP-3 humanoid robot.

[1] Author Nacim Ramdani is on leave from CERTES EA 3481 Université Paris 12 Val de Marne

## CONCLUSION

In this paper we have presented a new method that ensures the validity of continous constraints for trajectories optimization. We have shown that the commonly used time-point discretization method is fast but do not ensure the validity of the constraints. Therefore the constrained optimization algorithm will accept some solutions which violate the contraints.

However, the time-interval method proprosed ensures constraints validity over the whole motion. We have compared the two methods for the contrained optimization of a double pendulum motion, and applied the time interval discretization to motion optimization of the humanoid robot HOAP-3.

We have planned to implement our method to address the contrained optimization of a whole step motion and to merge the two methods to decrease computation time.

## REFERENCES

[1] J. Pettré, J.-P. Laumond, and T. Siméon, "A 2-stages locomotion planner for digital actors," in *SCA '03: Proceedings of the 2003 ACM SIGGRAPH/Eurographics symposium on Computer animation*. Aire-la-Ville, Switzerland, Switzerland: Eurographics Association, 2003, pp. 258–264.

[2] S. Miossec, K. Yokoi, and A. Kheddar, "Development of a software for motion optimization of robots - application to the kick motion of the hrp-2 robot," in *Proceedings of the 2006 IEEE International Conference on Robotics and Biomimetics*, 2006, pp. 299–304.

[3] A. Piazzi and A. Visioli, "Global minimum-jerk trajectory planning of robot manipulators," in *IEEE Transactions on Industrial Electronics*, vol. 47, febru 2000, pp. 140–149.

[4] M. Hardt, K.Kreutz-Delgado, and J. Helton, "Optimal biped walking with a complete dynamical model," *Decision and Control, 1999. Proceedings of the 38th IEEE Conference on*, vol. 3, pp. 2999–3004, 1999.