8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

TRAJECTORY MODELING OF A PARALLEL STRUCTURE IN THE PRESENCE OF OBSTACLES

***Sezimaria F P Saramago[1], Aline R Assis[2] and Marco Ceccarelli[3]**

[1]Federal University of Uberlândia
Av. Joao Naves de Avila, 2160
Uberlandia (MG), Brazil
saramago@ufu.br

[2]Federal University of Uberlândia
Av. Joao Naves de Avila, 2160
Uberlandia (MG), Brazil
aline_eletrica@yahoo.com.br

[3] University of Cassino,
DiMSAT, Via G. Di Biasio,43,
Cassino (FR), Italy
ceccarelli@unicas.it

Key Words: *parallel manipulators, trajectory planning, obstacle avoidance.*

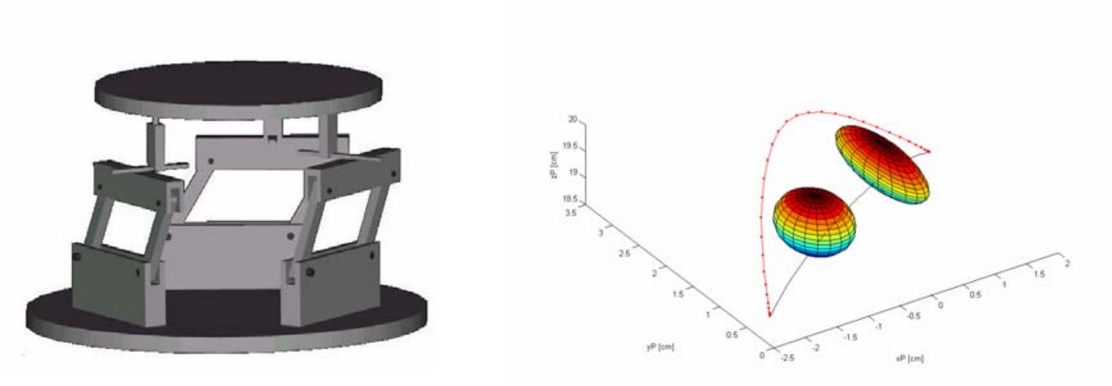
ABSTRACT

The goal of robot systems is to produce goods at as low cost as possible. The minimum-cost trajectory planning in the two-staged realization of manipulators control (i.e., planning first and tracking next) is, thus, an important effort to accomplish that goal. A large number of robotic applications involve repetitive processes. This technological characteristic justifies offline trajectory planning. Parallel manipulators are of great interest mainly because they present advantages in several applications, show load capacity (larger than serial manipulators) and they can be operated at high speeds and high accelerations. In the Laboratory of Robotics and Mechatronics in Casino, Italy, a parallel mechanism was created with three degrees of freedom (d.o.f), called CaPaMan (Cassino Parallel Manipulator).

This paper presents a design methodology to obtain the optimal offline trajectory planning for the CaPaMan parallel structure when moving obstacles have to be avoided by the end-effector. In the trajectory modeling, the uniform cubic B-splines that allow control of the degree of continuity at the joints between adjacent segments were used. This fact is important because smooth transition is required in most robotic applications. The optimization problem considers the minimization of the mechanical energy, the minimization of the traveling time and the jerk. To optimize a manipulator operation, the mechanical energy can be considered as one of the most significant aspect, since the energy formulation considers both the dynamics and kinematics characteristics of the manipulator. To maximize the operation speed it is necessary to minimize the traveling time. But, a minimal time represents an increment on jerk values. Thus, these three characteristics, and the minimum distance functions between colliding parts are considered together to build a multiobjective function and the results depend on the associated weighting factors. These objectives are in conflict with each other, mainly in the applications where the manipulator should work at high velocities.

The optimization problem is subject to physical constraints, namely, input torque constraints and obstacle avoidance. The distances between potentially colliding parts are understood as obstacle avoidance. The obstacles are protected by spherical or hiper-spherical security zones which are never penetrated by the end-effector. When obstacles are found in the tridimensional workspace, it is necessary to add penalty functions to the multiobjective problem to guarantee free-collision motion.

The CaPaMan is a three d.o.f. parallel manipulator, composed by a fixed base and a mobile platform which are connected by three mechanism legs. Each mechanism leg consists of an articulated parallelogram, a passive prismatic joint installed in the coupler link, and a vertical rod that connects to the mobile platform through a spherical joint. Figure 1a shows the CaPaMan scheme. The analytical model for the inverse dynamics of CaPaMan uses the equations of Newton-Euler. The resulting equations describe the motion in terms of the joint variables and the structural parameters of the manipulator.



a) b)

Figure 1. a) - A prototype of CaPaMan at LARM in Cassino;
b) A 3D plot of the position of the center of the movable plate for CaPaMan in the presence of obstacles (__ initial curve, -.-. optimal curve).

In multicriteria optimization, one deals with a design variable vector, which satisfies all the constraints and makes the scalar performance index as small as possible. It is calculated by taking into account the components of an objective function vector. Solutions to multicriteria optimization problems can be found in different ways by defining the so-called substitute problems. Substitute problems represent different forms of obtaining the corresponding scalar objective function.

The optimization problem is investigated by using genetic algorithms. It is an iterative technique based on random search with adaptations to search a minimum in coordinate directions. It can be useful to overpass small variations in the objective function by using a probabilistic criterion in order to avoid stopping the procedure at a local minimum. Figure 1b presents a comparison between initial and optimal positions of the center of the movable plate for CaPaMan prototype in the presence of obstacles.

The initial and optimal values are reported in Table 1. The results show that there is a significant improvement of the performances index by using genetic algorithms.

Table 1 – Initial and Optimal results for the CaPaMan prototype

	Energy [Nm/s^2]	Total traveling time [s]	Jerk [rad/s^3]
Initial value	309.46	0.30	826.04
Optimal value	201.37	0.45	410.64
Performance Index	65.1 %	-	49.7 %

REFERENCES

[1] G. Carbone, M. Ceccarelli, P. J. Oliveira, S. F. P. Saramago and J. C. M. Carvalho, “An optimum path planning for Cassino Parallel Manipulator by using inverse dynamics”, *International Journal Robotica*, Forthcoming article, Published online, (2007).