Sensitivity analysis on MIMBOT biped robot through parallel computing

Alejandro Bustos*, **Giuseppe Carbone#**, **Higinio Rubio***, **Marco Ceccarelli#**, **Juan C. García Prada***

* Department of Mechanical Engineering
Universidad Carlos III de Madrid
Av. Universidad, 30, 28911, Leganés, Madrid
[albustos, hrubio, jcgprada]@ing.uc3m.es

LARM: Laboratory of Robotics and Mechatronics
DiCEM-University of Cassino and South Latium
Via G. Di Biasio 43, Cassino (FR), Italia
[carbone, ceccarelli]@unicas.it

Abstract

Several research teams have been investigating biped locomotion and several biped robots have been designed and built as reported for example in [1,2]. However, most of the existing solutions are very complex and expensive. Recently, there have been efforts to reduce the complexity and cost of a biped robot. A specific research line on this topic has been investigated at LARM, since early '90s. A similar topic has been addressed within a collaboration between LARM and MAQLAB that has been established since 2005. Within this collaboration frame a low-cost easy-operation biped walking robot has been built as shown in Fig.1. This robot has been further investigated as described in [3,4]. Results of simulations and tests have lead to a novel biped walking robot design that has been named MIMBOT. Still further investigations on MIMBOT kinematics and dynamics are needed to achieve a suitable design solution that can properly mimic human biped walking. For this purpose, optimal design procedures are needed for identifying an improved kinematic topology solution as well as for fulfilling a proper optimal size synthesis of MIMBOT.

In this paper, kinematic and dynamic models of MIMBOT are proposed as referring to different kinematic topologies. The proposed models have led to a mathematical model that is composed of 179 explicit equations. The solution of this set of equations for a proper topology search and size synthesis leads to huge computational costs, which can be estimated in the order of several months. Also the required data storage is extremely large and often leading to memory overflows. Considering the above aspects, in this work it is investigated the opportunity to apply the last trends in parallel computing for reducing the computational costs to a reasonable value. A specific flow-chart of the proposed procedures has been proposed as shown in Fig.2. In particular, the proposed explicit kinematic/dynamic equations can be solved within a dedicated algorithm in CUDA C++ environment. Working in this environment allows to take full advantage of the parallel computing on GPUs for general purposes applications (GPGPU) as reported for example in [5]. CUDA C++ environment also allows to take full advantage of the most recent features that have been developed as referring to the management of the UM (Unified Memory) as described for example in [6].

Each single step of an optimal design procedure will follow the steps in the flow-chart in Fig.2. In particular, the loop will start by assigning a topology and a guess values for the link lengths. Then, the algorithm will define the input variables and the time discretization. Then, the kinematic and dynamic model will be explicitly defined. At this stage the attributes of the available GPU are identified and the required Unified Memory is allocated. According to the available resources, the algorithm will launch a feasible number of parallel threads, which will share the required computations. Then, the obtained results are stored and the memories of GPU and CPU are synchronized and results are plotted.

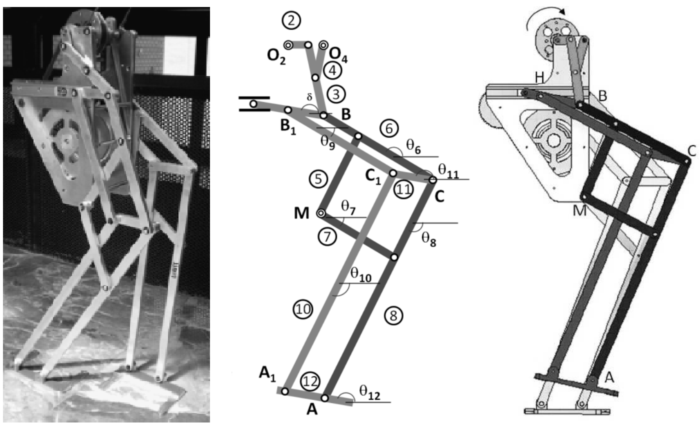

Figure 1. PASIBOT robot and its main kinematic chains.

Calculations will be made by referring to a subset of the proposed mathematical model in order to identify how the computational costs and memory usage are affected by the number of equations and their distribution to the parallel threads. Numerical simulations have been made in order to test the sensitivity to several design parameters such as shown in the plots of Fig.3 and 4. As example, Fig.3 illustrates the variation of a global index measuring the similarity between the real and the simulated gaits with the length modification of a specific link. Closer is this index to zero, more similar are both gaits analysed. Fig.4 plots both gaits for the minimum index value achieved. The obtained results are very promising with a reduction of overall computational costs in the order of 1/100.

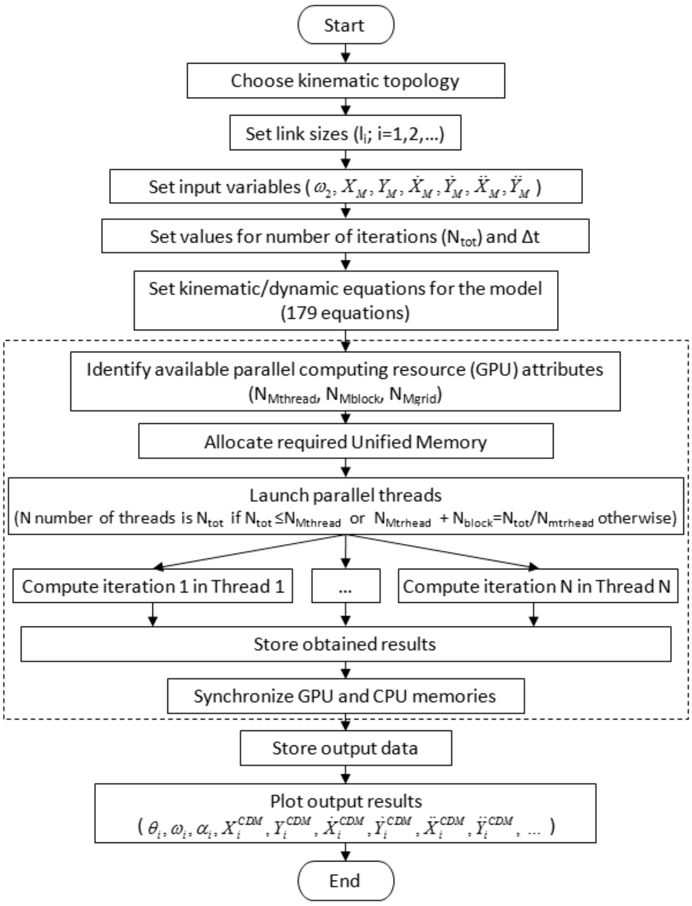

Figure 2: Flow chart of the core algorithm.

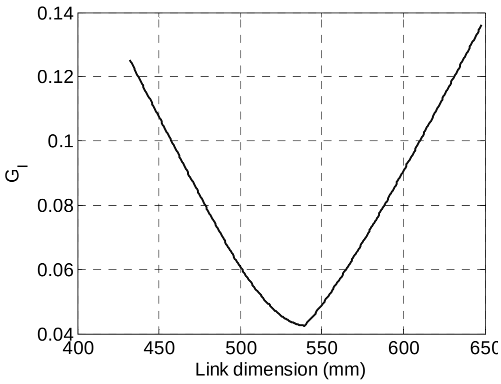

Figure 3: Global index vs. femur length. Better closer to zero.

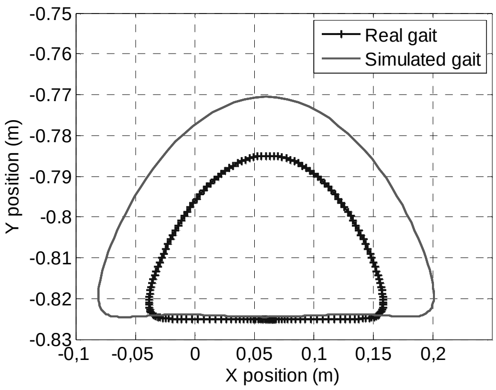

Figure 4: Real and simulated gaits for the best global index.

References

[1] G. Carbone, M. Ceccarelli. Legged robotic systems. Cutting Edge Robotics, 2005, 553–576

[2] C. Liang, M. Ceccarelli, G. Carbone. Design and Simulation of Legged Walking Robots in MATLAB® Environment, MATLAB for Engineers - Applications in Control, Electrical Engineering, IT and Robotics, Dr. Karel Perutka (Ed.), 2011. ISBN: 978-953-307-914-1.

[3] H. Rubio, A. Bustos, C. Castejón, J. Meneses, J.C. García Prada. Tool for the Analysis of New Skills Biped Pasibot. New Advances in Mechanisms, Transmissions and Applications. Mechanisms and Machine Science Volume 17, 2014, pp 173-181. Proceedings of the Second Conference MeTrApp 2013. Springer. ISBN 978-94-007-7485-8J.

[4] J. Meneses, C. Castejón, H. Rubio, J.C. García. Kinematics and dynamics of the quasi-passive biped PASIBOT. Journal of Mechanical Engineering. Vol. 57, No. 12, pp. 879-887, 2011.

[5] J. Ghorpade, J. Parande, M. Kulkarni, A. Bawaskar, GPGPU processing in CUDA architecture. Advanced Computing: An International Journal (ACIJ), Vol.3, No.1, January 2012.

[6] D. Negrut, R. Serban, A. Li, A. Seidl. Unified Memory in CUDA 6.0. A Brief Overview of Related Data Access and Transfer Issues. SBEL Technical Report. June 2014.