MINISTERIO DE CIENCIA E INNOVACIÓN

INSTITUTO DE AUTOMÁTICA INDUSTRIAL

Grupo de Bioingeniería

www.iai.csic.es/gb/

gbi

CSIC
Consejo Superior de Investigaciones Científicas

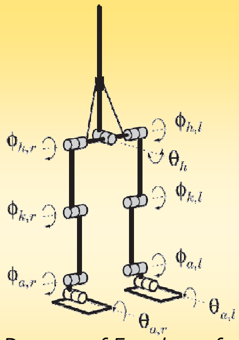
Bio-inspired prediction control of bipedal walking robots.

Edyta Anna Turowska, Arturo Forner-Cordero Juan Álvaro Gallego, Juan Camilo Moreno, José L. Pons

{turowska, aforner, gallego, moreno, jlpons}@iai.csic.es

Introduction and goals

It appears that humans use an internal model, that is a representations of the motor apparatus and the interacting environment in the Nervous System, [3]. Here we test if this idea can be applied to control a biped walker, the ESBiRRo 3D biped walker. A simplified Predictive Model is used to evaluate the adequacy of the recovery strategy [1] in order to recover from perturbations [2]. The major drawback of the internal model is the need to perform a lot of calculations depending on the model complexity. Here we test how simple the model can be while predicting the next double stance (DS). The model consists of a simple 3-link biomimetic model in the sagittal plane.



Degrees of Freedom of the biped ESBiRRo

The Predictive Model predicts body configuration in the next double stance (DS) and aims at forecasting if the configuration of the robot is stable or may lead to a fall.

Methods

A possible solution for the bipedal stability after a perturbation can be bioinspired: it has been proposed that biological motion is controlled by means of internal models to plan and predict the consequences of the actions.

A predictive model is defined as a simple 3-link model in the sagittal plane (see Fig.1). The mechanical parameters of the biped are the inputs for this model along with the current state of the robot. Dynamical equations were obtained through the Lagrangian method and solved with numerical methods.

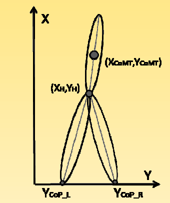


Fig. 1 Simple 3 link model.

Results

Results were obtained for different gait phases – early and late swing. We defined the different states of the robot as stable, stabilizable, and unstable that are dependent on step length, trunk inclination angle, speed of the CoM of each segment, and the dependence between Centre of Mass (CoM), Centre of Pressure (CoP).

In Fig.2 the next DS is ***stable*** because the because it does not lead to fall. This means that the recovery method was correct.

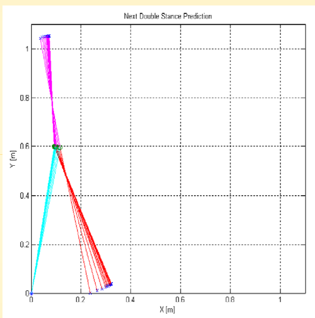


Fig2. Prediction of the next DS – stable, late swing.

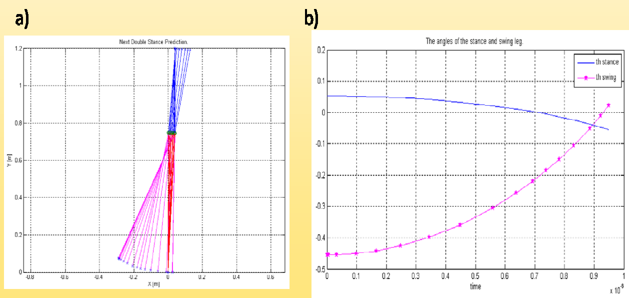


Fig. 3 Prediction of the next DS– stabilizable: a) 3 link model b) angles of the swing and stance leg

The ***stabilizable*** configuration of the next DS is presented in Fig.3. The step length is not long enough to maintain the trunk in upright position but there is still margin to bring the robot to a stable configuration. In this case there is still a possibility to avoid to fall without changing the recovery strategy.

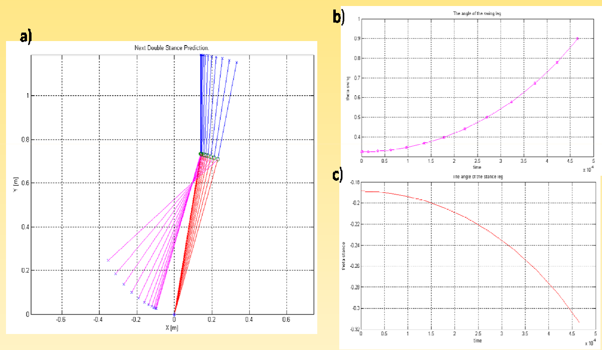


Fig. 4 Prediction of the next DS – unstable: a) 3 link model b),c) angles of the swing and stance leg, respectively .

In Fig. 3 the next DS is ***unstable*** (see Fig.4 b,c). In this case, the configuration of the robot leads to fall. The trunk starts falling down. This means that the method was taken incorrectly.

The similarity between the outputs of the simple 3-links biomimetic model and the 11 links complex model is presented in Fig.5. The trajectories of the hip and the trunk angle for both, simple and complex models are very similar.

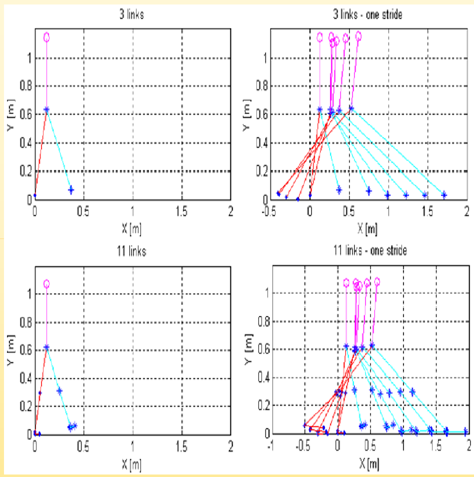


Fig5. A simple and complex model of the biped.

Conclusions

The simplified model captures the essential features of the complex one. This finding supports the plausibility of a simplified internal model and paves the way to implement computationally inexpensive models to control the stability of a bipedal robot.

Using proposed Predictive Model it is possible to evaluate if the recovery strategy was correctly chosen.

[1] Forner-Cordero A., Koopman H.F.J.M. and van der Helm F.C.T. Mechanical Model of Recovery from Stumbling Biological Cybernetics, 91(4): 212-222,2004.
[2] Forner-Cordero A., Koopman H.F.J.M and van der Helm F.C.T. Multiple-step strategies to recover from stumbling perturbations. Gait & Posture. 18(1):47-59 , 2003.
[3] Wolpert D.M., Miall R.C and Kawato M. Internal models in the cerebellum. Trends in Cognitive Sciences. 2 (10): 338-347, 1998.

Thanks to the Commission of the European Union that gave financial support to this research under contract ESBiRRo - IST-61-045301-STP.

INSTITUTO DE AUTOMÁTICA INDUSTRIAL - CSIC
Ctra. Campo Real, km 0,200 - LA POVEDA
28500 ARGANDA DEL REY (Madrid)
Tel: 34 91 871 19 00 - Fax.: 34 91 871 70 50

F.D. / J.A.G. 8-08

www.iai.csic.es

MOTOR CONTROL 2008
From Theory to Clinical Applications
Zakopane , Poland 19-21, September 2008