University of BRISTOL
Department of Mechanical Engineering

BIPED HUMANOID GAIT CONTROL FOR THE FIRA ROBOT GAMES

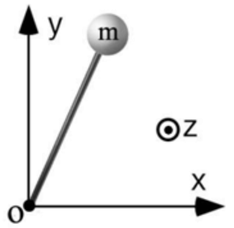
Motivation

There is an ever growing interest in the realm of human inspired robotics fuelled by the desire to fully understand human behavioural and structural characteristics. Humanoid robots are recurring by-products of the research in this field, usually favoured for their autonomous and biped features. The Federation of International Robot-soccer Association (FIRA) is an organisation that encourages advancements in autonomous robot technology through an annual robot world cup competition. The University of Bristol is set to host and participate in the FIRA 2012 games.

A humanoid built using a Bioloid kit

Objective

To devise a computationally inexpensive and dynamic free approach to biped gait generation based on a centre of mass (COM) trajectory by means of; adapting an Inverted Pendulum Mode (IPM) and carrying out feasibility tests on a developed two dimensional (2D) biped model with the aid of MATLAB and Working Model 2D (WM 2D).



Inverted Pendulum Mode

Modelling for COM computation

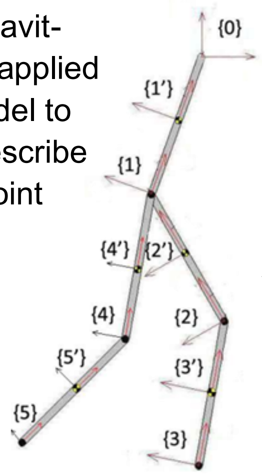
Forward kinematics and Denavit-Hartenberg conventions are applied to a developed 2D biped model to compute expressions that describe robot COM as a function of joint variables.

X-component of COM

$$\bar{x} = \frac{\sum_{i=1}^{n} m_{i'} x_{i'}^{0} T_{1,4}}{\sum_{i=1}^{n} m_{i'}}$$

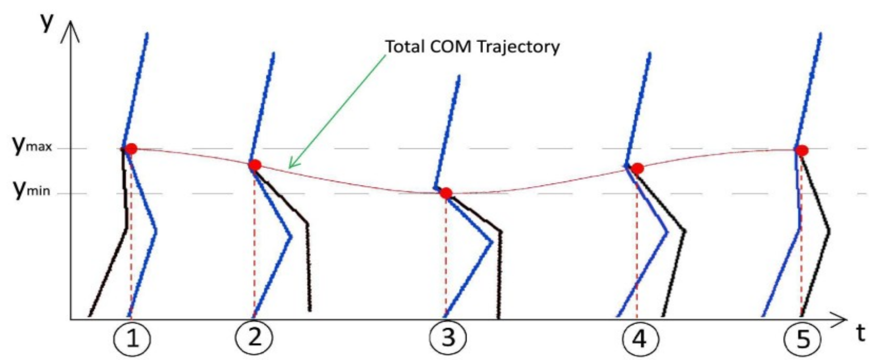
Y-component of COM

$$\bar{y} = \frac{\sum_{i=1}^{n} m_{i'} x_{i'}^{0} T_{2,4}}{\sum_{i=1}^{n} m_{i'}}$$



Schematic of 2D biped model in sagittal plane: { } = coordinate systems used to produce transformation matrices containing orientation and translation elements

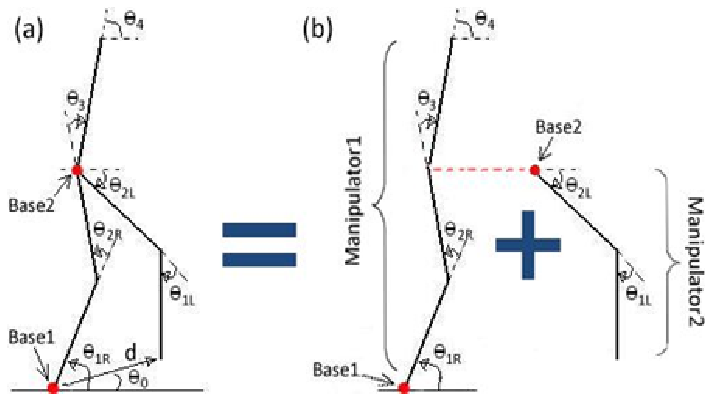
Trajectory Planning



Sinusoidal COM trajectory in sagittal plane

Mixed kinematics- joint variable solutions

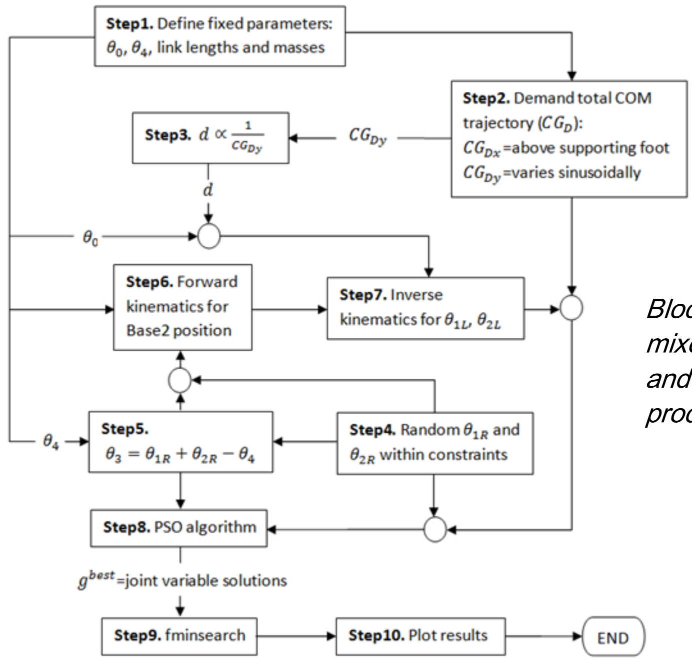
The under-determined nature of deriving joint variable solutions from a COM coordinate is overcome by treating biped model as two separate manipulators unified at robot hip position. For one of the manipulators a closed-form solution is obtainable using inverse kinematics. The second manipulator presents an under-determined problem with numerical solutions and fewer degrees of freedom than the original biped system. This demands the used of forward kinematics and optimisation tools; Particle Swarm Optimisation (primary) and fminsearch (secondary). All computation is done using MATLAB.



Joint variable convention: biped model (a) manipulator model (b)

System variables	Possible values
θ_0 (user defined)	$0 \le \theta_0 \le \pi$
$\theta_{1R}, \theta_{1L}, \theta_{2R}, \theta_{2L}$	$0 \le \theta \le \pi$
θ_3	$\theta_3 = \theta_{1R} + \theta_{2R} - \theta_4$
θ_4 (user defined)	Fixed arbitrary value: $\pi/4 \le \theta_4 \le \pi/2$
d (user defined)	Function of total COM trajectory and length of leg links
Base1 position	(x,y)=('user defined', 0)
Base2 position	Function of θ_{1R}, θ_{2R} and length of leg links

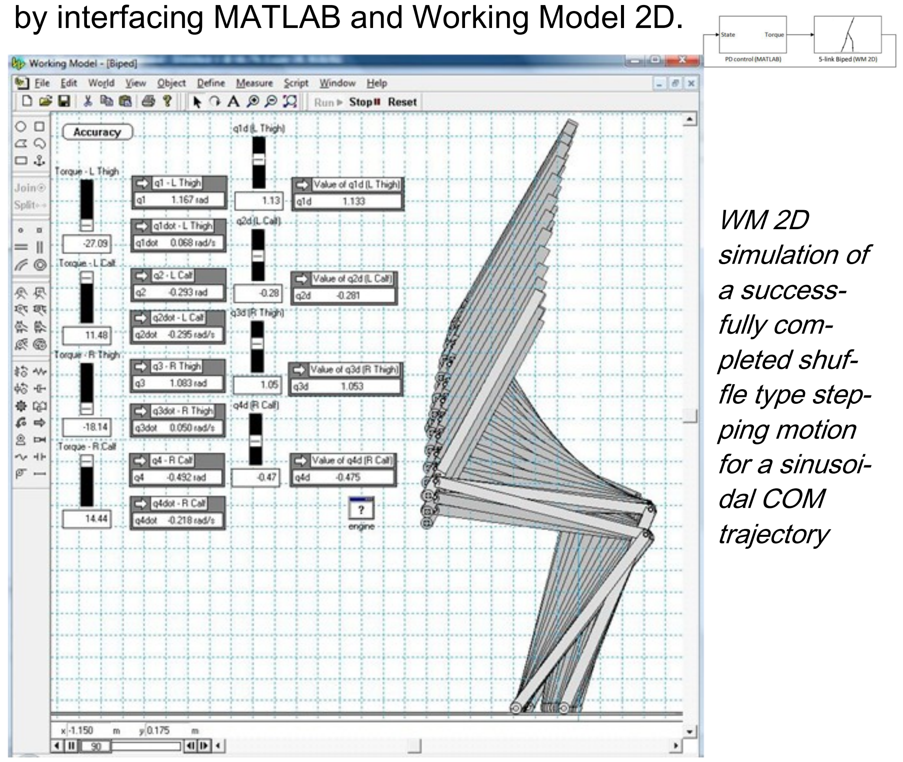
Variable constraints for biped model convention



Block Diagram: mixed kinematics and optimisation process

Dynamic Simulation

The joint variable solutions from mixed kinematics approach prove to be numerically and geometrically feasible. Dynamic viability is confirmed by subjecting a 5-link biped model to joint level PD controllers based on torque computation using feedback linearization methods. Simulations are conducted by interfacing MATLAB and Working Model 2D.



WM 2D simulation of a successfully completed shuffle type stepping motion for a sinusoidal COM trajectory

Brian Thomas. 3rd year individual project 2010-2011
Project supervisor: Dr. Guido Herrmann