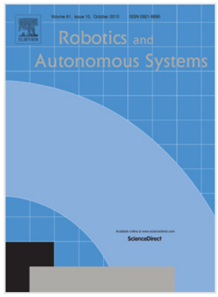

Biologically-inspired push recovery capable bipedal locomotion modeling through hybrid automata

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Biologically-Inspired Push Recovery Capable Bipedal Locomotion Modeling Through Hybrid Automata

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***Abstract*— The earlier developed two stage hybrid automata is not a perfect representation of human walk as it is a combination of discrete and continuous phases and the whole human GAIT has 8 stages. Our major contribution is eight stage hybrid automata for large push recovery and various dynamic parameter studies for stable walk model. We have developed a controller to verify different stage of human locomotion by using OpenSim data for model *3DGaitModel2354* and lower extremity data. We verified the hybrid automata model using the real human GAIT data for normal person. We identify the importance of the human lower extremity for locomotion and push recovery from large perturbation. The novelty of research work is to model the bipedal locomotion as a re-usable component based framework. Our original contribution lies in the fact that we have tried to view it from a software engineering perspective.**

Keywords—Humanoid Locomotion; Hybrid System; Hybrid automata, Dynamic System, Push Recovery, Component based modelling.

Tools:Webots, Matlab, Imitator,OpenSim.

I. Introduction

Human like machine development in various areas is the need of the hour, for instance, in an event of disaster anthropomorphic bipedal robots can come in handy. Studying human anatomy for walking can also be utilized to design prosthetics for the injured or handicapped [1]. The bottom line is giving the reality to the dream that robots perform tasks conducive for humans like climbing stairs, avoiding obstacles, traversing inaccessible rough terrains and space exploration are to name a few. Currently available humanoids, Honda's Advanced Step in Innovative Mobility (ASIMO), Humanoid Robotics Project (HRP)-2 and NAO walk with bent knees so that dynamic CoM is always above the feet so that it doesn't roll at the cost of the flat foot move. The most evident solution to bent-knee problem seems to be purely passive walking gait without actuation. But ballistic knee dynamic walkers, similar to that of Ted McGeer's [2], need actuation when plying on flat surfaces, uphill or rough terrains and more importantly considering 3D i.e. yaw effects is necessary.

To be compatible with human environment, bipeds are preferred albeit inherently unstable. Human walk is outcome of several thousands of years of evolution and thus worth this attention while most of the presently available robots walk with bent knee/flat foot [3]. We are habitual of walking on flat ground so we are not bothered to pay attention to it. Human-robot interaction will also help in rehabilitation of injured [5], prosthetics and assistance to elders. We develop robot capable of doing wide variety of works in place of humans. A human-inspired method for achieving bipedal robotic walking is proposed in which a hybrid model [6] of a human is used in conjunction with experimental walking data to obtain a multi-domain hybrid system.

Humanoid locomotion modeling and generation of rhythmic pattern is considered as a highly complex and non-linear problem. There is lot of research already done in the field of bipedal locomotion. There are several methodologies which have been used to attain the insight of biped locomotion. Kiyotoshi Matsouka [7] has described how simple neurons can be connected together to design a neural oscillator [8] to produce rhythmic patterns for given input parameters.

We seek to find a new way toward automatically generating stable flat ground biped robotic walking from human gait combined with human inspired control which displays a universal behavior. Human walking is realized the several DoF (Degrees of Freedom) coupled with highly non-linear dynamics and forces such that the (velocity of) leg comes to rest when it strikes the ground [9] [10]. So we try to obtain a low dimensional representation of human walking and modeling the continuous and discrete behavior through hybrid systems [11] [12].

The hybrid system [13] is a dynamic system which has both continuous and discrete components. To represent such type of system we apply hybrid automata representation [14] [15]. To manifest both components, flow is represented by a differential equation while jump can be described by a difference equation or control graph allowing for more flexibility in modeling dynamic phenomena. There are several systems which can be modeled using the Hybrid systems [16] [17], such as physical system with impact, logic-dynamic controllers, and even internet congestion to name a few [18] [19]. In general, the state of a hybrid system [20] [21] is defined by the values of the continuous variables and a discrete control mode [22] [23]. The state evolution is governed either, continuously according to a flow condition, or discretely according to a control graph. Continuous flow dictates, as long as so-called invariants hold true, while discrete transitions occur as soon as stated jump conditions are agreed