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Stability Analysis of the Walking Robots Motion

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Abstract

The theme of walking robots stability is analyzed in the paper as a particular case of stability for dynamic systems that depend on parameters, deduced, in the mathematical model, by specifying the parameters, not specified numerically, that define the dynamic system. Another aspect of the walking robots' stability assurance is the necessity of sequentially using parameter time, in evolving a dynamic system that permits the local constant selection of the dynamic system's remaining parameters, assuring its stable evolution. In opposition is the stability of rocket flight, which presupposes asymptotic stability. The optimization of the walking robot's dynamic system evolution is possible by identifying the mathematical conditions of separation between the stable and unstable zone in the range of free parameters, inspired from the mathematical conditions already analysed by us for the general case of the dynamic systems, in some of our previous papers. The theoretical considerations are exemplified on walking robot's mathematical model. The possible chaotic evolution of the dynamic systems, with possible application on walking robots evolution is also analysed.

Keywords: dynamic systems, walking robot motion, robot stability, separation of stable zones, chaos.

1. Introduction

The problem of separation between stable and unstable zones, in the range of free parameters, for a linear or nonlinear dynamic system is important for assuring the possibility of the dynamic system stability control. We

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underline that any dynamic system can be looked at as a dynamic system that depends on parameters, without specifying the parameter values as geometrical parameters, physical parameters (as mechanical parameters), possible chemical, biological or economical parameters and so on, that can define the dynamic system.

A special problem is the dynamic gait control of walking robots. So, there is a known control strategy of dynamic walking humanoid robots, based on the walking pattern generation on the time path of stable zero point and stability by monitoring online [1-4, 10]. When analyzed from different viewpoints, in movements such as walking on rough terrain, running or fast walking, the dynamic of the centre of gravity can be defined by the simple mechanical action of springloading the leg during positioning known as SLIPs – Springloaded Inverted Pendulums. Using compliance for representing these movement systems not only has the advantage of allowing energy to be reused, but also ensures the effective reduction of the centre of gravity during ground impacts. Another advantage of compliant representation of a leg is to shape and potentially simplify the control of highly dynamic movements. Until now dynamic control of a stable movement on rough terrain for walking modular robots remains an unresolved problem. Starting from similar research applied to humanoid robots [2, 9, 11], in order to the increase mobility and stability of modular walking robots' movement, this paper approaches the new concepts of applied mathematics in modeling the autonomous walking robots in order to develop an open architecture real-time control system.

We remark that the definitely dynamic systems encountered in the specialized literature, as dynamic systems specified by the Mathieu equation, Hill equation, harmonic vibration equation and so on, have the property of separation, in the free parameters range, between stable and unstable zones. The free parameters range contains stable and unstable zones separated by the boundary. The separation property can be defined by the quality that one stable point, which is not on the boundary has a neighbourhood composed only from stable points and similar formulation for unstable points. This property of separation creates the possibility of stability control in the neighbourhood of the dynamic system's selected stable point. Some mathematical conditions of separation have been discovered by us, using the results from matrix theory, from linear or nonlinear stability theory of dynamic systems, from real analysis theory and so on.

Our study has not exhausted the stability control subject. New results in matrix theory, in linear or nonlinear dynamic system theory, in chaotic or non chaotic dynamic system evolution, in real analysis theory, will complete this study.

2. Stability analysis of autonomous walking robots

The locomotion activity of walking robots joins the category of high automation movements. The mechanical system needs to have a great number of mobility ranges, in order to form high complexity synergies, respectively the realization of coordinated motion of the legs. By using the walking robots as means of transportation, a portion of the parameters which characterize its dynamic features can be subjected to modifications to a greater extent [4, 10]. For example, the occurrence of an extra load on board will modify its weight, the positioning of the load centre and the rotating moment of the robot's platform. A series of environmental factors, such as the wind and other forces, can act on the walking robot, their influence being hard to anticipate. Some of these interferences could be the cause of considerable variations of real motions in comparison to those estimated, that could lead to robot control drift.

On the walking robots basis, these are considered as a group of articulated rigid solid bodies that represent the platform and the elements of the legs. The more the number of the legs of a walking robot increases, the more intricate the driving and command system becomes. On the other hand, due to the large number of supporting points, the static and quasi-static movement stabilizes itself even more [15,17]. The movement of the quadruped robot is stable only when certain, quite restrictive conditions are met. The issue of static stability is resolved by calculating the position of the end of each leg in relation to the axes system attached to the platform, originating in its centroid. As for the construction of the mathematical model, based on the quasi-dynamic analysis, each leg is considered by the authors as a function generator, with a limited precision in constructing the walking systems. If the number of mobility range is equal to n and if the internal constraints have the form of: then within the differential equations structure: exist random coefficients ui – used for identifying the walking algorithm.

To those differential equations apply, the constraints imposed by the general base (the platform), onto which the legs are fixed, and second, the constraints assessed by the load-bearing surface. Mathematical modelling of the gravity centre's position, which allows the walking robots to move over ground with difficult configuration, is presented in