Real-time Humanoid Gait Pattern Generation Optimizing Footstep Placement and Timing

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I. Motivation

For the humanoid robot to be useful for the society it has to be able to navigate in an existing or post-disaster human-made environment, which on one hand comprises a variety of surfaces that are difficult to model, while on the other hand is very dynamic and full of moving objects. To be able to handle this kind of environments the robot has to be equipped with the real-time control algorithms that are able to very quickly respond to the dynamic changes in the environment or to the changes in the motion that result from inaccuracies in the models or external disturbances

II. Background

The research on humanoid robots significantly intensified in recent years producing numerous methods for disturbance rejection and quick gait pattern regeneration. Diedam et al. developed a Linear Model Predictive Controller which includes the foot step planning in the optimization task, thus enabling generation of reactive steps in case of disturbance [1], [2]. Nishiwaki et al. proposed a series of methods of quick gait pattern regeneration [3] and motion replanning strategies for walking on rough terrain [4]. Morisawa et al. developed a method of simultaneous planning of center of mass (COM) and zero moment point (ZMP) with use of numerical optimization method. The controller enabled disturbance rejection by changing the step position and ZMP shaping [5]. Urata et al. derived an explicit solution of modified version of preview controller and used it in real-time optimization of gait pattern for disturbance rejection [6].

Most of the existing disturbance rejection methods assume a constant step time or allow only its minimal change when replanning the motion. The major corrective actions are realized by modifying the step placement. This however limits the kind of disturbances the robots are able to handle. Especially when the disturbance acts in the direction of the present stance foot, which can be only realized by changing the step time or by crossing the legs. The latter action is however mechanically risky or impossible due to self-collision between the legs for most of the existing humanoid platforms. Humans when subjected to external disturbance or unexpected change in the ground conditions manipulate not only the step position, but also a step time.

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III. Talk contribution

In this talk I will describe a novel method which enables optimized simultaneous selection of all the three fundamental parameters defining the gait, namely step position in sagittal and coronal plane as well as the step time, thus extending the kind of disturbances the robot is resistant to. Given the estimated COM position and velocity we use a nonlinear optimization method to find optimized step positions and step timing for the present and proceeding two steps. For calculation of the remaining steps we use previously developed method [7]. The gait pattern regeneration time which includes solving optimization problem and generation of gait pattern with Multi Body System (MBS) in the loop takes less than 40 ms.

I will present the experiments that we performed on our research platform COMAN [8] which show that the method is able to cope with disturbances and that the algorithm controls both step position and step time. I will also present our latest works on the implementation of the method on our adult size humanoid robot WALK-MAN [9].

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