On the Relevance of Common Humanoid Gait Generation Strategies in Human Locomotion - An Inverse Optimal Control Approach

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Abstract: One essential capability for humanoid robots to be able to operate in a world made for humans is to walk in a robust and versatile way. Even though walking is the most natural thing for humans, it is a complicated task to be taught to a robot. This is due to several reasons, e.g. the difficulty to define stability, the handling of under-actuation and redundancies, and the derivation of on-line pattern generators and control strategies. During the last decades several common strategies for gait generation have been established. Among them, several popular ones are based on the zero moment point (ZMP) on the one hand and the capture point (CP) or capture regions (CR) on the other hand.

The aim of this work is to use real motion capture data and the approach of inverse optimal control to identify the relevance of those criteria in human gait. The focus is on constrained walking situations, like walking on stairs, slopes and step stones. To this end some of the criteria have to be adapted to additional requirements that differ from the assumptions made for even ground walking.

For our studies we consider a simple three dimensional template model with actuated mass-less legs and formulate ZMP- and CP/CR-based optimization criteria. We set up a bi-level optimization problem, where in the upper level we minimize the difference between measured trajectory and model trajectory with respect to the optimal control model of the lower level. The objective of this lower-level optimal control problem is a linear combination of the ZMP- and CP/CR-based optimization criteria, which is minimized with respect to the simple walking model and additional constraints. The aim is to find a suitable weighting of this objective, such that the resulting optimal solution minimizes the fitting error in the upper level. To solve this inverse optimal control problem, we rely on a direct all-at-once approach, presented by Hatz et al., 2012.

The results of these studies can be used to formulate decision rules in which situation which control strategy - in terms of the criterion or combination of criteria optimized - is the most suitable to reproduce a human-like gait in different terrains.

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