# Improved Humanoid Robot Movement through Impact Perception and Walk Optimisation

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# Abstract

The proficiency of humanoid robot movement, which is currently quite elementary, needs to be improved if humanoid robots are to fulfil most of their intended applications. Two of the more essential motor skills of a humanoid robot are related to its ability to stand and walk. Enhancement of these abilities is the focus of the work presented in this thesis.

We first investigate the use of the proprioceptive sense, in particular the joint velocities, to perceive and quantify external perturbations to a standing humanoid robot. A system consisting of an optimised threshold detector, a Support Vector Machine and a pair of orthogonal Support Vector Regression models is developed to utilise this proprioceptive sense. We demonstrate, through the implementation on a physical robot, that the proposed system is able to detect, locate and estimate the magnitude and direction of any given impact.

Next we consider improvements to humanoid robot walking through the enhancement of walk optimisation techniques. To this end, in simulation, a meta–optimisation is performed to determine: an appropriate set of tuning parameters for three different optimisation algorithms, the most suitable optimisation algorithm, a relevant fitness function and a pertinent parameter space. The optimisation algorithms we consider include: Evolutionary Hill Climb with Line Search, Particle Swarm Optimisation and Policy Gradient Reinforcement Learning (PGRL). We evaluated fitness functions based on the walk speed, efficiency and Froude–number. The parameter space for the walk engine was assessed with and without additional joint stiffness parameters. We found that the best walk optimisation technique consisted of PGRL with an efficiency based fitness function utilising additional joint stiffness parameters.

We achieved further improvements on the walk optimisation by applying the safe redundancy concept to extend PGRL. PGRL is a local optimisation algorithm, whereby incorporating safe redundancy allows the algorithm to escape from local extrema. We also expanded the parameter space to include gait–phase dependent joint stiffnesses. Furthermore, to facilitate a trade–off between the optimisation and the stress placed on the physical hardware, a measure of the wear experienced by the robot during the optimisation was introduced.

To verify the generality of the systems developed for the walk optimisation, they are evaluated on several different humanoid robot platforms: a simulated NAO, a physical NAO and a DARWIN-OP. The effectiveness of the proposed systems are demonstrated through their implementation in physical humanoid robot hardware and application to the RoboCup soccer competitions.