REDUCED WEAROUT BY AUTOMATIC FITNESS ESTIMATION FOR THE EVOLUTION OF GAIT PATTERNS

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Abstract

Genetic programming[1] is a promising solution to design fast and robust walking patterns for legged robots [2–5]. In fact, using this approach we have evolved very fast and stable patterns for SONY four legged robots in the past [6, 7]. The genetic programming approach is easy to implement since the fitness function here is given implicitly by the robots' speed using a specific gait pattern. The best performing individual can be found easily by executing footraces. Unfortunately, such tournaments suffer from heavy wearout during the different stages of evolution. Therefore, different techniques are used to reduce the number of tournaments. An efficient method is to use physical simulation as a fitness module [8]. In other cases, financial resources or time to market might be limited. Such constraints make the implementation of complex simulations impossible. Therefore, we suggested the use of a meta-model that can be generated automatically by an advanced artificial neural network [7].

For that, all M parameters that represent a single gait pattern are interpreted as point in an M-dimensional signal space. That signal space is partitioned by hyperplanes into different subspaces, whereas all "slower" individuals are located in other subspaces that the "faster" individuals. The reliability of each decision is calculated by the distance of a signal point to a bounding hyperplane and other constants [7] Predictions of high reliability are used directly for the Evolutionary Algorithm, those of low reliability must be validated on the robot. The tournaments' results are internally used to train the neural network. Afterwards, a new generation is build after the rules of the Genetic Programming approach.

Doing this, the fitness of each individual gait pattern can be estimated automatically. As presented in [7], up to 99.9% of the tournament results can be predicted correctly. To achieve this, the population size is reduced significantly as all unreliable classifications are not used for the evolutionary algorithm. Thus, it has to be investigated in general, if discriminating low reliable patterns against unreliable decisions prevents from finding optimal gaits. To do this, we have examined how neural networks and signal space parameters can automatically be adjusted to the actual robot control program.

Therefore, we analyzed the performance of the Signal Space Approach as already presented under varying environmental conditions: First, we vary the evolutionary algorithm. Exactly spoken, we compare the performance of an 1+1 evolution against Genetic Programming using two different selection schemes. Then, we use different predictors and estimates for reliability-calculation. Third, to proof the usability of the approach, we utilize three different walking engines.

To benchmark all results, we performed footraces and measured the fitness by hand. This is a long process with heavy wearout, but it takes to a result, that can be used to [...] all other results.

We observed, that the quality of the evolved gaits really depends on all varied parameters. As expected, different walking engines lead to reliability information of varying quality. On the other hand, the suggested approach was successfully adapted to all three different walking engines. Generally spoken: A small value of M takes to a difficult reliability estimation - a large M needs lots of reference tournaments to calculate the reliability precisely.
The complexity of the artificial neural network, namely the number of perceptrons inside the MLP, strongly influences the quality of the fitness estimation. Best results was observed with MLP's of two or three layers. And about M to $2M$ perceptrons.
The simplyfied fitness estimation does not impact the quality of gaits, significantly. Therefore, this methods can be applied to small embedded platforms as used in many modern robots.
This results show, that the suggested meta-model approach performs well under real-world constraints. The presented results should be a good guideline for other developers, how this approach works on different walking engines and which parameters should be used for a good estimation. Such that, it is a good starting point when adapting the given approach to other than SONY robots.

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