BRSU

Advanced Scientific Working
-Reading Report-
Evolving Look Ahead Controllers for Energy Optimal Driving and Path Planning

Bastian Lang

October 27, 2015

1 Reference

Gaier, A., & Asteroth, A. (2014, June). Evolving look ahead controllers for energy optimal driving and path planning. In Innovations in Intelligent Systems and Applications (INISTA) Proceedings, 2014 IEEE International Symposium on (pp. 138-145). IEEE.

2 Reading Report

2.1 Problem Formulation

- Developing techniques for near energy-optimal control of vehicles using controllers that base their decisions on characteristics of the road.
- Developing control strategies that make the best use of the terrain.

2.2 Why is this still a problem?

- Engineering of transport systems resulted in efficient designs, but further optimizations are diminishing.
- Driver-training programs have yielded impressive results.
- Instead of being reduced, emissions caused by transportation drastically increased in 2005 and 2007.

2.3 State of the art

- Energy-optimal control of commercial trucks and trains
- Energy-optimal control of experimental vehicles
- Energy-optimal control of hybrid gas-electric vehicles
- Finding fuel-optimal behavior of an experimental fuel-cell vehicle using optimal control theory and a simplified model of environment and vehicle
- It was found that only three commands are needed to produce an optimal strategy:
  - full power
  - maintain velocity
  - coast
- Reformulating the problem as a graph-search problem using A* and a special heuristic the number of nodes needed could be drastically decreased with still achieving near-optimal solutions
- Using dynamic programming to reduce complexity and rounding errors from state space discretisation

- Using inverted system equations real valued controls could be used. But not all equations can be inverted and it is often non-trivial
- Avoiding numerical issues by first defining the boundary line between feasible and infeasible states. This reduced computation costs by an order of magnitude.
- Neuroevolution techniques have shown to be more effective on some benchmark tests than reinforcement learning techniques
- NEAT is the current most successful algorithm within neuroevolutionary algorithms

2.4 What is the author's contribution?

- Use of evolutionary algorithms instead of graph search algorithms
- Application of a state-of-the-art evolutionary algorithm to the energy-optimal control problem

2.5 How did the solution solve the addressed problem?

- By using the method of NEAT (NeuroEvolution of Augmented Topologies) the authors evolve a controller for an e-bike
- Use of simplified vehicle model
- Use of three motor commands
- Evolutionary algorithms do not need to work in a discretized state space, so rounding errors are no problem
- Evolutionary algorithms do not use state space models. Therefore increasing the complexity of the model does not have a huge effect on the space complexity.
- Using a local solution that calculates new commands at every meter, a deggree of precision can be achieved that is not possible for graph search in most scenarios.

2.6 Evaluation

- Comparison of performance on 35 routes with a Graph Search algorithm
- Training of net using cross-validation
- Training on 5 maps, testing on remaining 30
- 50 training runs, each containing of evolving a population of size 150 for 1000 generations.
- Comparison to graph search in three different resolution levels
- Performance is only slightly worse than the highest depth graph.

- Analysed in detail most solutions performed better
- Computation time was nearly instantaneous versus about 1 minute for an 8km route
- Space complexity was about 1KB versus 11GB

2.7 Scientific Deficit

- The approach taken uses a very popular algorithm from evolutionary algorithms, but it does not use any techniques to ensure that the evolved controller will be able to run on a real device. Where the authors can give a prove of concept that an evolutionary algorithm may be better suited than a graph search approach, like this it probably is not usable in practise. Although giving prove of concept was the author's goal and this is not a scientific deficit but a shortcoming of this approach so far.
  - Miglino, O., Lund, H. H., & Nolfi, S. (1995). Evolving mobile robots in simulated and real environments. Artificial life, 2(4), 417-434.
  - Jakobi, N., Husbands, P., & Harvey, I. (1995). Noise and the reality gap: The use of simulation in evolutionary robotics. In Advances in artificial life (pp. 704-720). Springer Berlin Heidelberg.
  - Koos, S., Mouret, J. B., & Doncieux, S. (2013). The transferability approach: Crossing the reality gap in evolutionary robotics. Evolutionary Computation, IEEE Transactions on, 17(1), 122-145.

2.8 Scientific Contribution

- The authors were able to show that using evolutionary algorithms for optimizing energy-efficient driving outperforms graph search algorithms in terms of computation time and space needed and produces solutions that are nearly as optimal as solutions from very detailed graph search algorithms.
- As for this paper is very recent (2014) I am not able to quote any other work that supports my statement. Citeseer does not know this paper yet and google just gives one quote from a paper of the same authors.