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Review of Ph.D. Thesis

Control Algorithms for Autonomous Embodied Agents

Author: **Mgr. Stanislav Slušný**

The thesis presented by Mgr. Stanislav Slušný deals with algorithms for embodied control of autonomous agents (robots). The text spans across 73 full pages. It covers a broad range of topics within the field of evolutionary robotics; namely evolutionary algorithms, artificial neural networks, reinforcement learning, self-localization, path planning etc. The thesis goal is to investigate four objectives: 1) comparison of reactive and deliberative agents, 2) study of reinforcement learning methods, 3) design of a hybrid agent controller that combines the studied methods and, 4) its evaluation. The main text is organized into 3 chapters that cover: 1) reactive agents, 2) path planning and, 3) deliberative agents.

The main issues of the thesis are:

- It eventually becomes obvious that the thesis is based on papers published by the author during his Ph.D. studies. I would welcome that to be clearly stated in the beginning. The thesis leaves slightly dis-organized impression. The text is incrementally built up and during the reading it is not clear what comes next. The *Structure of the Work* section, which itself lacks a structure, is not much helpful.
- There is not a clear distinction between chapters 2 and 3. Hybrid agents described in section 2 contain a deliberative planning layer, whereas the problem of deliberative planning is approached in section 3.
- Description of the related work done by others and author's own contributions are blurred inside the chapters (especially chapter 1, i.e. page 36, where first 5 paragraphs describe the related work and the following paragraph jumps directly to the own experiments with Khepera robots).

- The *bigger picture* to which the thesis contributes is under-explained. I would welcome a figure that plugs the contributions into e.g. reinforcement learning framework and explains them together with references to related work.
- There are missing references to literature at many places especially in the introduction. Although the thesis is targeted to an expert reader, paradigms like neural networks, Markov property, infomax algorithm, information gain, etc. require at least a citation.
- Author's own numerous publications are cited only in the special section but they do not appear later in the text when they are needed.
- Figure captions are not informative. They need to contain description of what can be seen in the figure.

Minor issues that should be considered for eventual re-publishing of the thesis or its parts are:

- Neural networks should be abbreviated as NN (p. 4).
- It seems that the author considers neuroevolution with direct encoding only, but further reading points the indirect methods as well (p. 12).
- Tables are hard to read a emphasizing the best results would help (e.g. table 1.4).
- MDP abbreviation occurs before it is explained (section 1.2 heading).
- Explanation of POMDPs occurs at two places, it should be merged and referenced (p. 43).

I recommend the author to clearly answer these questions during the defense:

- What is the relation between active learning and artificial curiosity?[1]
- It is obvious that a small MLP will be better than a small Elman network when no recurrent connections are needed (in the case of a reactive agent) but in principle, an Elman network can learn the same behavior as an MLP (by setting recurrent connection weights to zero), which probably explains their inferior performance (the conclusion on p. 73. is too general). How many weights (parameters) do the small NN have (p. 35)?
- What are the differences between tasks 2.6 and 3.1?
- What quantitative models were developed and in what form (p. 43)?
- How would the CP-based planner compare to traditional approaches like potential fields etc. (section 3.2)?
- The automata-based planner is compared to the CP-based planer (section 3.4), is the CP-based planner considered to be the traditional approach?

The thesis describes interesting results in not-so-easy to grasp field of robotics, motion planning in particular. I confirm that all of the stated goal objectives were addressed. The presented CP-based and finite automata-based planners are interesting and valuable contributions to the field. Despite my numerous comments, that are, in most of the cases, consequences of the chosen thesis structure,

I do recommend the thesis to be defended before the committee.

In Lugano, 7. 9. 2014

Jan Koutník, Ph.D.

1 J. Schmidhuber. Developmental Robotics, Optimal Artificial Curiosity, Creativity, Music, and the Fine Arts. *Connection Science*, 18(2): 173-187, June 2006.