Project 1: Pursuit Evasion Problems in Polygonal Environments (SA104X, 15hp, VT11)

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History

In 2006 the Swedish government initiated a project with acronym TAIS (Technologies for Autonomous Intelligent Systems), in which the Swedish Defence Research Agency (FOI) was one of the players. In the TAIS sub-project at FOI, Petter Ögren a former Ph.D. student at Opt & Syst was the project leader. The sub-project was called AURES (Autonomous UGV-system for Reconnaissance and Surveillance). In the AURES project except for FOI, academia was also represented by two institutions at KTH, Opt & Syst and Electrical Engineering. Industry was also represented by SAAB together with the subcontractor Rotundus.

The goal of the AURES project was to develop a system of autonomous ground robots to be used for patrolling the Swedish military Camp in Afghanistan. The project was successful in the sense that it resulted in a formidable list of publications, a successful software demo and (an almost) successful hardware demo.

The AURES project was divided into three (theoretical) work packages, where one was called “Search -and-secure algorithms for surveillance UGVs”. In this project the pursuit evasion problem in polygonal environments (in the plane) was addressed. At this time it was the Electrical engineering department who was responsible for this work package.

At 2009 it was decided if there was going to be a phase 2 of the AURES project. Even though it first was decided that the AURES project was going to be continued, suddenly the entire TAIS project was dropped.

At 2007 after finishing his Master’s thesis at Opt & Syst, Johan Thunberg started to work at FOI at the same department as Petter. After FOI, Johan worked at Ericsson for almost a year before returning to the safety of academia and a non linear control project in cooperation with the Swedish Space Corporation with professor Xiaoming Hu as his supervisor. When returning to academia, it was decided that Petter should be his co-advisor.

Petter together with Johan and Xiaoming wanted to take a final look at the pursuit evasion problem within the frame of the AURES project and they started to work with the Pursuit evasion problem, and formulated it as a Mixed Integer Linear Programming (MILP) problem for the first time.

Johan and Petter developed a model for the Pursuit evasion problem in which the environment is partitioned into a set of convex regions. At each time instant each region has one of four states: (1) it contains a pursuer, (2) it does not contain a pursuer but is seen by a pursuer, (3) it is not seen by a pursuer but is guaranteed not to contain the evader and (4) the complement to the former three. The framework is described in any of the appended documents paper1.pdf-paper3.pdf. In these papers the visibility pursuit evasion problem is also formally defined.

Now

In the framework Johan and Petter solved the visibility pursuit evasion problem in two different ways. The first way was to formulate the problem as a Mixed integer Linear Programming (MILP) problem. After formulating it as such a problem it can be solved with any MILP solver on the market such as CPLEX. The problem is that the underlying problem is NP-hard so the computational time grows exponentially with the problem size. Thus the authors came up with the idea that the problem can be solve iteratively for short time horizons, resulting in shorter computational times at the expense of longer paths for the pursuers.

The second way the problem was solved, was to model it as a boolean control network instead of a MILP. In this framework the computational times were significantly shorter and the problem could be solved in one iteration. However the searcher paths in the environment are unnecessary long.

One natural extension of this work is to extend the model. Now we basically assume that the pursuers can see infinitely long and have 360 deg field of view. We also assume that we have homogeneous group of pursuers, i.e. they have all the same sensors. It would be interesting to extend the problem in this way and see what new variables are needed in the MILP formulation and how the Boolean control network change.

Another extension to the work could be investigate how heuristic methods can be used to improve the boolean control network approach with the current model. There is a vast amount of publications in the literature regarding how to solve NP-hard combinatorial optimization problems with heuristic methods. These methods are also referred to as Voodoo approaches by Martin Grötschel who is a professor at TU Berlin, and some examples are simulated annealing, ant colony optimization and Tabu Search. One of the most well known such combinatorial optimization problems is the Travelling Salesman Problem (TSP). The idea is to implement such methods at this problem.

I will refer to the two sub-projects as the *Model Enhancement* project (1) and the *Voodo approaches* project (2).

A simulation environment has to be constructed for group 2. This is not necessary for group 1, even though it might be useful if this group wants to try their new model. It would be suitable if one could construct random scenarios for Monte Carlo simulations. This environment can be constructed in C, C++, Matlab or any other suitable framework. Try to use ready made packages to limit the work.

Suggested plan for reading

Common reading for both groups

Step 1: Read paper1.pdf-paper3.pdf, where you can start with paper3.pdf. These papers are similar. You don't have to read everything, the important thing is that the modelling is clear (the portioning of the environment into regions with states). paper1.pdf and paper2.pdf are not finally submitted and contains some smaller notational errors, which should not affect the understanding.

Step 2: Read the appended survey paper by Magnus Lindhé, survey1.pdf.

Step 3: Read suitable papers either cited either in the survey of Lindhé or in paper1-paper3 or found at google scholar.

Reading for group 1 (Model Enhancement)

Reading for group 2 (Voodoo approaches)