ACT Stage Topic 4 - New Heuristics for Improving Trajectory Optimisation Algorithm Using Human Strategies in Computer Game

Background

Spacecraft trajectory optimisation problems [1] can be solved both analytically and numerically. Analytical techniques involve expensive approximations of system of equations and boundary conditions and can be easily obtained only in special cases. Numerical techniques [2] (e.g. gradient based approach) are most popular among researchers but can be very time consuming before converging to the best solution. More recent approaches are based on metaheuristics (e.g. Genetic Algorithms [3]) which do not always provide good solutions.

Computer games and simulators of space missions, besides being a stimulating and educational entertainment, can represent a powerful tool for formulating new heuristics for trajectory optimisation problems: the strategies and decision-making processes adopted by the player (or by multiple players) can be used to improve the intelligence of computer algorithms.

In occasion of the 'World Space Week' 2010, the ACT released the TheSpaceGame (http://thespacegame.org/), ESA's spacecraft trajectory optimisation web-based game. The TheSpaceGame represents ESA's first crowd-sourcing experiment aimed at finding new routes through the solar system. Up to date more than 5000 users registered to the web-game and 2453 solutions for 2 interplanetary space missions have been submitted to ESA.

Topic of the Stage

The topic of the stage is to develop a procedure of systematic data analysis able to identify specific TheSpaceGame patterns in the strategies adopted by the players. Data mining techniques [4] will be applied to the dataset stored in the TheSpaceGame database.

The analysis of human performances and strategies in the TheSpaceGame's missions will enable to:

- find new approaches to the design of spacecraft trajectories
- enrich mission design with insights from human decision-making in the problem of trajectory optimisation
- explore paths in the solutions space that spacecraft trajectory optimiser have not yet explored

Results obtained within this stage will tune the current tools and provide new guidelines and parameters for improving the data representation and the database structure of future releases of TheSpaceGame.

Candidate's tasks

The candidate is asked to

- Play with the TheSpaceGame in order to a) learn about the game, b) formulate a first set of hypothesis about possible strategies, c) provide new suggestions for improving the web-game interface
- Apply Data Mining techniques (using tools like Weka [4] or JDM [5]) and statistical methods on TheSpaceGame database in order to a) find correlations among users, b) verify previously formulated hypothesis and/or formulate new hypothesis on the strategies adopted by the users, c) identify patterns of decision-making processes and compare them with standard trajectory optimisation algorithms
- Define other parameters, relative to the actions performed by the player, that can be stored in the database in order to refine and improve the search for patterns in next releases of the TheSpaceGame.

The candidate will acquired knowledge on spacecraft trajectory optimisation problems and will work in a multidisciplinary environment.

The ideal candidate

- The candidate should be familiar with data handling (i.e. extracting data) in MySQL
- The candidate should have expertise in data analysis tools (statistical methods, data mining techniques)
- Possible candidate are Behavioural Psychologists, Computer Scientists, Applied Mathematicians
- Programming skills (e.g. Matlab, Python, C++) are preferred.

References

[1] Conway, B. (2010) Spacecraft trajectory optimisation, Cambridge Univ Press

[2] Betts, J. T. (1998) Survey of Numerical Methods for Trajectory Optimisation, Journal of Guidance, Control, and Dynamics, vol.21 no.2 (193-207)

[3] Hughes, E.J. (2004) Swarm Guidance Using a Multi-Objective Co-Evolutionary On-Line Evolutionary Algorithm, IEEE Congress on Evolutionary Computation, vol.2 (2357-2363)

[4] Witten, I. H., & Frank, E. (2005). Data Mining: Practical Machine Learning Tools and Techniques (Second Edition). Morgan Kaufmann

[5] Hornick, M.F. and Marcade', E. and Venkayala, S. (2007) Java data mining: strategy, standard, and practice: a practical guide for architecture, design, and implementation, Morgan Kaufmann Publishers