Evolving distributed vision algorithms on FPGAs

Stage topic Description

The field of computer vision has made tremendous progress in the last few decades, moving from applications in very controlled environments to applications in ever-changing real-world environments. The most recent successes have been obtained with Bayesian algorithms, often involving Markov or Conditional Random Fields (MRFs / CRFs) that acknowledge both the partial observability of most vision problems and the spatial structure of vision. The algorithms involve intricate networks of stochastic variables related to the information that should be extracted from the image. The values of the variables are typically determined by passing messages around in the large Bayesian network, which is equivalent to optimizing an energy function modelling the quality of solutions.

The above-described Bayesian approach has met with great success on tasks relevant to space robotics. For example, the top ranking algorithms with the best results on the stereo vision data set of the University of Middlebury (http://vision.middlebury.edu/stereo/) all adopt variants of this approach. Stereo vision is foreseen to provide the main depth information for navigation of the Mars explorer.

The disadvantage of the Bayesian approach is that it is computationally expensive on a Von Neumann type processor, limiting the frame rate with which new measurements can be taken. Since the network and message passing can be parallelized, a solution is to implement the algorithm in a Field Programmable Gate Array (FPGA). For instance, in [1], an implementation was made of a stereo vision algorithm in order to be able to perform stereo vision on large images in real time.

ESA's Advanced Concepts Team (ACT) is interested in novel vision algorithms implemented in FPGAs. The advantages of FPGAs are that they allow fast and accurate vision processing, while being reprogrammable at large distances. The long-term goal would be to use evolutionary algorithms to construct novel "message-passing" schemes that are more efficient and / or successful than the existing ones.

Candidate's tasks

The ACT therefore offers a three month stage with as main goals (1) to make the experimental setup that will allow evolutionary algorithms to change the structure of the FPGA implementation and (2) perform preliminary experiments in which the FPGA performs the task of stereo vision. The stagiaire will have access to a space-hard FPGA, and will have to interface it with a PC in order to receive stereo images and return a disparity map representing the distances. The stagiaire will then make a first simple setup of an evolutionary algorithm on the PC with the FPGA in the loop for testing different hardware realizations of a stereo vision algorithm. The work will be done in close cooperation with the ACT research fellow on artificial intelligence.

The ideal candidate

The candidate should have experience in programming FPGAs. Additional (but less necessary) qualities include experience with robotic (vision) projects and a background in artificial intelligence or computer science.

References

[1] Pérez, Sánchez, and Martínez, “High-definition belief-propagation based stereo matching FPGA architecture”, In Proceedings of Conference on Design of Circuits and Integrated System, Zaragoza, Spain, November, 2009.