Distributed computation models for optimization and learning tasks in vehicle system interacting in smart city

Director : Jean-Charles CRÉPUT

Key words : learning and pattern recognition, artificial vision, combinatorial optimization, topological maps, semantic maps, multi-processor, GPU, embedded systems.

Context

Advanced technologies simulating human cognitive abilities are more and more required in embedded systems, intelligent vehicles and autonomous robots. Mathematical tools and their related computational numerical models are developed by artificial intelligence and pattern recognition community in order to address such complex tasks related to human perception and cognition. These problems are studied and modeled within the Vehicle Intelligent and Smart City project of CIAD, where the PhD subject takes place.

Subject

An important challenge is the development of fast computation methods in order to deal with large volume of data and solve complex optimization problems modeling learning, and cognitive and identification tasks. Examples of such methods are neural networks and evolutionary computation that have a good potential to be implemented in multi-processor systems in the context of supervised and unsupervised learning.

Considering robot behaviors or vehicle driving assistance, the subject consists in identifying and modeling specific situations where some cognitive assistance or guidance should be a crucial point augmenting the human capacity in face of injuries or unexpected situations. Once such situations identified, during the course of the robot mission or driving sequence, and modeled, the work consists in the development of the computational parallel methods in order to solve learning optimization problems provided by the numerical representation of the cognitive tasks. Computational architectures considered are multiprocessor systems such as GPU, Clusters, or distributed objects as internet of things.

Plan of work

The work involves the use of combined techniques of artificial intelligence, neural network, and optimization. Supervised and unsupervised learning techniques in conjunction with optimization methods are the background methods that are to be implemented and executed in standard multi-processor platforms.

The steps of the work are as follows:

- Study the information processing tool chain provided in embedded systems in relation to smart city infrastructure.

- Identify and model learning and cognition task problems, explore statistical learning and inference solutions, as well as computational complexity.

- State combinatorial optimization problems to address in the context of learning in convolutional neural network (supervised learning) as well as in self-organizing neural network (unsupervised learning) and compare their potential.

- Develop generic software tools to deal with the problems in a generic way. Software engineering models should be based on meta-programming techniques.

- Implement the massive parallel solution methods on concrete multi-processor platforms.

Inference and optimization problems are to be addressed in the context of autonomous vehicle driving in the relation to smart city. It should of interest to extend and generalize previously developed parallel optimization techniques in this context. Examples of some previously addressed problems and algorithms are among the following list :

- Object detection and tracking
- 3D environment reconstruction
- Stereo-matching
- Optical flow 2D/3D
- Super-pixel segmentation
- Self-organizing maps
- Parallel local search
- Parallel genetic algorithm
- Contour detection
- Semantic map generation
- Graph matching

References

[1] Beibei Cui, Jean-Charles Créput, *A Systematic Algorithm for Moving Object Detection with Application in Real-Time Surveillance*, SN Computer Science, Springer, vol. 1(106), DOI: 10.1007/s42979-020-0118-5, 2020.

[2] Beibei Cui, Jean-Charles Créput, *Affinity-Preserving Integer Projected Fixed Point Under Spectral Technique for Graph Matching*, in Advances in Computer Communication and Computational Sciences, AISC volume 924, Springer, 2019. DOI: //doi.org/10.1007/978-981-13-6861-5.

[3] Beibei Cui, Jean-Charles Créput, *Using Entropy and Marr Wavelets to Automatic Feature Detection for Image Matching*, In Proc. of the 15th International Conference on Signal Image Technology and Internet-Based Systems, SITIS 2019, IEEE sponsorship, Italy, 2019.

[4] Wenbao Qiao, Jean-Charles Créput, *Massive 2-Opt and 3-Opt Moves with High Performance Gpu Local Search to Large-Scale Traveling Salesman Problems*, Annals of

Mathematics and Artificial Intelligence, to appear, DOI: 10.1007/s10472-019-09679-x. Springer, 2019.

[5] Wenbao Qiao, Jean-Charles Créput, *Gpu Implementation of Borůvka's Algorithm to Euclidean Minimum Spanning Tree Based on Elias Method*, Applied Soft Computing, Elsevier, vol. 76, pp. 105-120, 2019.

[6] Hongjian Wang, Abdelkhalek Mansouri, Jean-Charles Créput, *Cellular Matrix Model for Parallel Combinatorial Optimization Algorithms in Euclidean Plane,* Applied Soft Computing, Elsevier, vol. 61, pp. 642-660, 2017.

[7] Hongjian Wang, Naiyu Zhang, Jean-Charles Créput, *A Massively Parallel Neural Network Approach to Large-Scale Euclidean Traveling Salesman Problems,* Neurocomputing, vol. 240, pp. 137-151, DOI: 10.1016/j.neucom.2017.02.041, 2017.

[8] B. Zerbo, M. Sevaux, A. Rossi, J.C. Créput, *Optimizing the Cyclic K-Conflict-Free Shortest Path Problem in a Network-on-Chip*, International Journal of Computer & Software Engineering, vol. 1(2), pp. 115.1-115.12, Graphy Publications, DOI: 10.15344/2456-4451/2017/115, 2017.

[9] Hongjian Wang, Naiyu Zhang, Jean-Charles Créput, Yassine Ruichek, and Julien MOREAU, *Massively Parallel Gpu Computing for Fast Stereo Correspondence Algorithms*, Journal of Systems Architecture, vol. 65, pp. 46–58, 2016.

[10] Hongjian Wang, Naiyu Zhang, Jean-Charles Créput, Julien Moreau, Yassine Ruichek. *Parallel Structured Mesh Generation with Disparity Maps by GPU Implementation.* In IEEE Transactions on Visualization and Computer Graphics, (99), ISBN 1077-2626, 2015.