Distributed and parallel computation to optimization and learning in the context of smart city

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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 models are developed by artificial intelligence and pattern recognition community to address such complex tasks related to human perception and cognition. Behind those problems, are complex optimization tasks to be solved efficiently in a parallel way. These problems are studied and modeled within the Vehicle Intelligent and Smart City projects at CIAD laboratory, where the PhD subject takes place.

Subject

An important challenge is the development of fast computation methods to deal with large volume of data and solve complex optimization problems modeling learning and cognitive tasks. Examples of powerful optimization methods are metaheuristics, such as neighborhood methods and evolutionary algorithms, that have good potential to be implemented in multi-processor systems to achieve great computation time acceleration.

The objectives of the thesis reside into the combination of techniques from learning and optimization, while following parallel computing. One of the goals is to develop and extend metaheuristics considering two levels of parallel execution: data level by data decomposition, and solution level by data duplication. New data structures for parallel execution and new style of programing are required and should be codified.

Another goal is optimization in relation to learning in this context of parallel programs. Learning and optimization can be envisaged in two different ways. In first way, goal should be optimization for learning, such as optimizing parameter model for data prediction, as in Deep Learning. In second way, goal should be learning to accelerate optimization process itself. This mechanism relates to hyperheuristic methods for optimization. The candidate will have to explore such domains of optimization and learning based on concrete and difficult problems from industry, related to intelligent vehicle and smart city, and studied in our laboratory projects.

Plan of work

The steps of the work are as follows:

- Perform bibliographical study of the domain.

- Study information processing tool chain provided in embedded systems in relation to smart city. Identify learning and cognition problems, explore their computational complexity.

- State combinatorial optimization problems to address in the context of learning and evaluate their solution methods. Propose and develop optimization framework, while integrating learning.

- Develop generic software tools to deal with the application 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.

Examples of some previously addressed problems, with parallel algorithms, are among the following list:

- Object detection and tracking
- Graph matching
- Optical flow 2D/3D
- Stereo-matching
- Mesh generation
- Super-pixel segmentation
- Minimum spanning forest segmentation
- Vehicle routing problems

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