Approaches to Road Traffic Network Division

Author: Tomas Potuzak
(tpotuzak@kiv.zcu.cz)

Introduction and Motivation

- Traffic simulation – an important tool for analysis and control of traffic networks
- Very detailed simulation problematic even for today's computers
- Utilization of a distributed computing environment for the speedup of the simulation
  - Necessary to divide the road traffic network into sub-networks
- Review of currently existing approaches to road traffic network division

Distributed Traffic Simulation

- Performed on a distributed computer
  - Multiple interconnected computers (nodes)
- Usually spatial (domain) decomposition
  - Road traffic network division
  - Alternatives (functional or temporal) decomposition rarely used
  - Road traffic network divided into sub-networks
  - Each sub-network simulation performed as process on a node of the distributed computer

D/P Traffic Simulation

- Distributed/parallel environment
  - Multi-core processors in each node → multi-threaded processes
  - Further division of sub-networks not necessary
  - Each thread processing its part of vehicles, crossroads, roads, … → no additional communication, only synchronization

Traffic Network Division

- Significant influence on the distributed simulation performance
- Important features
  - Load-balancing of the sub-networks → similar speed of processes
  - Inter-process communication minimization (message passing very slow)
  - Computation time (not so important)
- Current state of the art?

Search phrases

- IEEE Xplore database
- “road traffic network division”
  - 335 results
  - 321 results dismissed based on title, abstract
  - 14 results chosen (including 11 my papers)
- “road traffic network partitioning”
  - 162 results
  - 144 results dismissed based on tile, abstract
  - 18 results chosen (including 1 my paper)

Overall Statistics

- 18 papers chosen out of 497 results (3 papers in both sets, 11 my papers)
  - 9 papers containing automatic division algorithms (utilizable for distributed simulation)
  - 4 papers containing automatic division algorithms designed for distributed simulation
  - 6 papers dealing with distributed road traffic simulation

Repeating Traits I

- Load balancing
  - Mentioned nearly in all papers
  - Measured by cumulative length of lanes/roads
  - Measured by vehicle density (real measured values, calculated values based from the network)
  - Not always considered

Repeating Traits II

- Inter-process communication minimization
  - Mentioned nearly in all papers
  - Reduction of divided lanes/roads numbers (usual)
  - Considering the vehicle density in lanes (rare)
  - Considering number of neighbors (rare)
  - Not always considered
- Computation time
  - Usually not considered

Repeating Traits III

- Algorithm evaluation
  - Comparison to other algorithm implemented (and often developed) by the same party
  - Observed parameters – load balancing, inter-process communication, computation time, simulation time
  - Comparing the division only x testing on distributed simulation
- Not general graph division
  - Usually at least modified

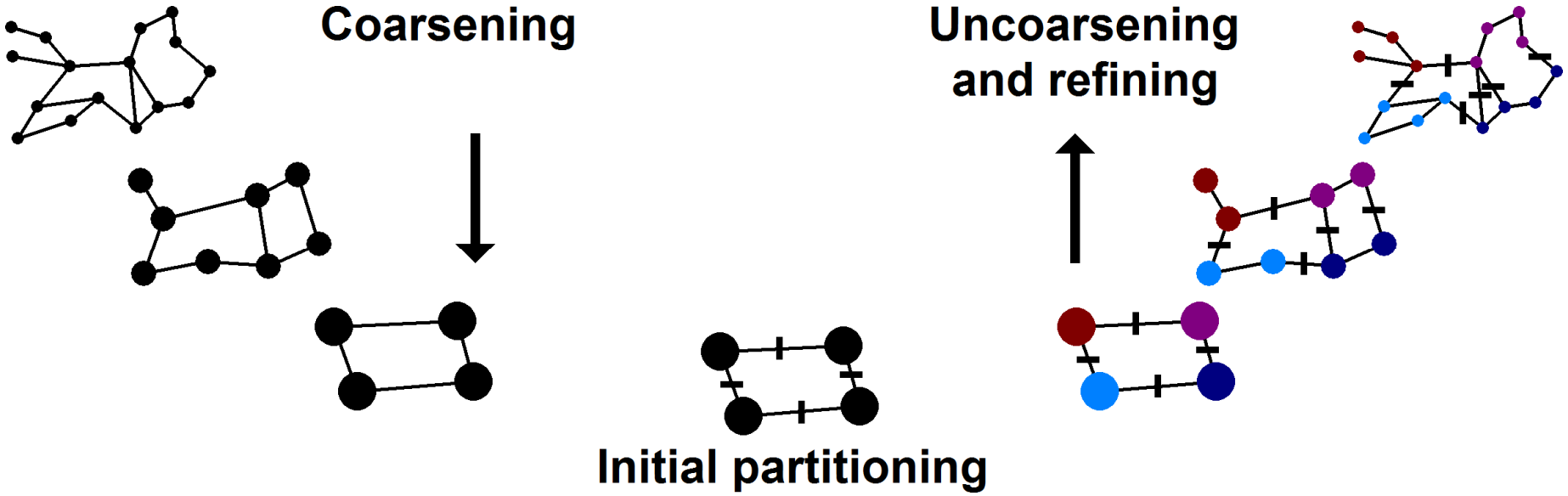
Usual Division Algorithms

- Cited in state-of-the-art sections of the paper and/or used as the basis for the algorithms described in the papers
  - Recursive bisection
  - Multi-level graph partitioning
  - Graph growing
  - Local heuristics for nodes exchanges

Recursive Bisection

- Division of a graph into two partitions based on the weights of the nodes and edges or even geographic positions
- Recursively repeated on the partitions until a required number of partitions is reached

Multilevel Graph Partitioning



- Coarsening – nodes merged into groups (iterative)
  - Lower number of nodes and edges
- Initial partitioning – division of coarsest graph using a division method
- Uncoarsening and refining – projection of the division to the finest graph (iterative)

Graph Growing

- Starting from a seed (a single node)
- Add a (most convenient) neighboring node
- Repeat until all nodes are consumed
- In parallel from multiple seeds (number corresponding to required number of partitions)

Complex Example - SParTSim

- Based on hierarchy of roads – high level roads most important
- Graph growing using high level roads in parallel from number of seeds
- Load-balancing of partitions
  - Exchanging sets of crossroads between the partitions with lowest and highest load – repeating until the difference in loads is small enough
  - Based on length of the lanes

Surprising Observations I

- Not uniform terminology
  - Links, roads, lanes
  - Nodes, crossroads, crosses
  - Partitions, zones, sub-networks
- Graph/road traffic network relationship
  - Not always node = crossroad, edge = road
- Very different sizes of networks for testing
  - From a few crossroads to USA network

Surprising Observations II

- Wasting of resources
  - Too much synchronization messages
  - Centralized transfer of all communication

Conclusion and Future Work

- Road traffic network division still researched
  - Newest paper from 2016, most paper 2010 and newer
  - Usually for different purposes than distributed road traffic network simulation
- Future work
  - More databases, more phrases
  - Get better picture of the research