Approaches to Road Traffic Network Division

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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 of my papers)
- “road traffic network partitioning”
  - 162 results
  - 144 results dismissed based on title, abstract
  - 18 results chosen (including 1 of my papers)
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 - SParTTSim

• 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