Parallel Solution Methods for the VRP

- Recent survey by Theo Crainic, chapter in “The Vehicle Routing Problem – Latest Advantages and New Challenges” by Golden, Raghavan, Wasil (2008)
- 80 references
- Main strategies, exact and approximative methods
- Promising directions

Some of Theo's observations/conclusions Motivation

- VRP research
  - larger instances
  - more difficult, richer formulations
  - more focus on real-time solving
  - need for ”robustness”
  - -> motivates utilization of parallel computing
- Shift in architecture of commodity computers

Some of Theo's observations/conclusions Research

- Relatively little parallel optimization work targeted at the VRP
- Most work done after year 2000

Some of Theo's observations/conclusions
Types of parallel computing

- Functional (task, control) parallelism
- Data parallelism
- Fine-grained
- Coarse-grained
- Multi-search

- Shared memory vs. separate memory
- Synchronous vs. asynchronous communication

Some of Theo's observations/conclusions Performance measures

- Speedup (wall-clock time)
  - exact methods
  - approximative methods
- Robustness

- Heterogeneous computing: utilization of special processor

Some of Theo's observations/conclusions Parallel metaheuristics - categorization

- Search Control Cardinality
  - 1-control (1C), e.g. master-slave
  - p-control (pC), e.g. multi-search
- Search Control and Communication
  - Rigid Synchronization (RS), e.g. independent multi-search
  - Knowledge Synchronization (KS), synchronized exchange of information
  - Collegial (C), e.g. asynchronous cooperative multi-thread search
  - Knowledge Collegial (KC), Collegial + procedures for information extraction and synthetization
- Search Differentiation
  - Same initial Point/population, Same search Strategy (SPSS)
  - Same initial Point/population, Different search Strategies (SPDS)
  - Multiple initial Point/population, Same search Strategy (MPSS)
  - Multiple initial Point/population, Different search Strategies (MPDS)

Parallel metaheuristics: Hierarchical levels (Talbi: Metaheuristics – from design to implementation, Chapter 6)

- Algorithmic level
  - independent or cooperating self-contained metaheuristics
  - problem independent
- Iteration level
  - each iteration of a metaheuristic is parallelized
  - speed-up by reducing search time
  - problem independent
- Solution level
  - parallel handling of a single solution
  - speed-up by reducing search time
  - problem dependent
  - flexible evaluation

Some of Theo's observations/conclusions - Parallel metaheuristics (1)

- fine-grained parallelization of neighborhoods (1C/RS/SPSS) has limited value
- may be interesting as low-level part of hierarchical parallel methods
- parallelization of classical multi-start methods may work well
- cooperative strategies seem to offer better performance than independent search
- asynchronous methods seem to be superior to synchronous methods
- information communication and exchange mechanisms are critical elements

Some of Theo's observations/conclusions - Parallel metaheuristics (2)

- Controlled, parsimonius, timely exchange of information is the clue
  - Direct (e.g. island model of Genetic Algorithms) vs.
  - Indirect, through memory (solution pool, warehouse, blackboard, ..)

  - Partial solutions (adaptive memory, vocabularies) vs.
  - Complete solutions (elite, diverse)
- Multi-level cooperative search is very interesting
  - works well on graph partitioning and network design etc.
  - VRP:

A survey of papers in parallel VRP a.r.t. - (meta)heuristics

- Olli Bräysy, Wout Dullaert, Pasi Porkka, Geir Hasle

- Parallel algorithms
  - 44 technical papers (1989-2007)
  - 3 surveys (2003, 2007, 2008)
- Cooperative (collaborative) search and multi-level search
  - 20 papers (1998-2007)
- Search reduction
  - 14 technical papers (2002-2008)
- Decomposition
  - 19 technical papers (1993-2008)

Ideas from the literature

- Rochat and Taillard (JoH 1, 1995)
  - Probabilistic Diversification and Intensification in Local Search for Vehicle Routing
  - Tabu Search threads
  - Adaptive Memory: tours of good solutions
  - TS threads pick tours randomly from AM
  - later developments: Set covering thread
- Gehring and Homberger (JoH 8, 2002)
  - Parallelization of a Two-Phase Metaheuristic for Routing Problems with Time Windows
  - concurrent searches
  - differently configured
  - two phase: (min # tours, min total distance)
  - exchange of solutions through blackboard
- Berger and Berkaoui (C&OR 31, 2004)
  - A parallel hybrid genetic algorithm for the VRPTW
  - GA with two populations
    - minimize total distance
    - minimize violation of TW-constraints

Ideas for our rich VRP solver
- General / Media product distribution

- Heterogeneous computing
- Better iteration level parallelization
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General Ideas

- Higher level parallelization with heterogeneous computing
- Cooperation exact methods and approximative methods
- Parallelization of LNS
- Multi-level search