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ROUTING COOPERATING VEHICLES TO PERFORM PRECEDENCE-LINKED TASKS

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NOTICE

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THIS TECHNICAL REPORT IS APPROVED FOR PUBLICATION.

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14. ABSTRACT
The problem of scheduling cooperating vehicles is a generalization of the classical vehicle routing problem where certain tasks are linked by precedence constraints and vehicles have varying constrained resources. We describe a type of roll-out algorithm that finds an approximate solution to the problem in real-time and demonstrate the results of the computational experiments.

15. SUBJECT TERMS
Vehicle Routing Problem, cooperating vehicle orienteering

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Routing Co-operating Vehicles to Perform Precedence-linked Tasks

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Problem description

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- **Multiple Vehicle Orienteering Problem:**

  Given a set of vehicles and sites with rewards, maximize the total number of rewards collected subject to hard time constraint

  – Closely related to Vehicle Routing Problem (VRP)

- **Co-operating vehicle orienteering problem:**

  Certain sites must be visited multiple times to perform various tasks in given order.

Applications

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- **Synchronized vehicle dispatch [Rousseau, Gendreau, Pesant, 2002]**
  - Transportation of disabled persons
  - Hardware/software installation
- **Military applications:**
  - Shoot – look – shoot sequence
  - Standoff jamming
- **Problems of real-time nature**

Solution Methods

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- **Local search techniques**
  - Tabu search
- **Constrained programming**

Problem Formulation

- **Given:**
  - **Heterogeneous vehicle fleet.**

    For each vehicle:
    - Initial and terminal positions
    - Time constraint
    - Vehicle type
  - **Site set.**

    For each site:
    - Task sequence and vehicle type per task
    - Travel times to all other sites and initial/terminal vehicle positions per vehicle type
    - Precedence constraint per task pair: (min, max) times between tasks
    - Reward collected by performing each task

Problem Formulation (cont'd)

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Maximize:

Total collected reward

Subject to:

- Initial/terminal positions of the vehicles
- Travel time constraints
- Task precedence

Example

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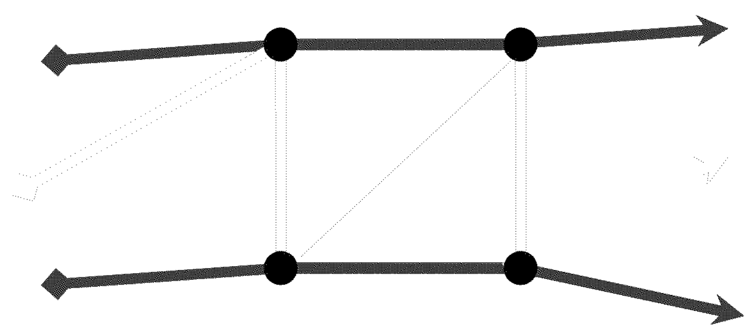
- Three vehicles to visit four sites, two ordered tasks per site
- Two type I vehicles; one type II vehicle



Roll-out Algorithm

- **Heuristic tree search using so-called "base heuristic"**
- **Start with an empty partial solution**
- **At each iteration:**
  - Given a partial solution
  - Construct *M* candidate extensions of a partial solution
  - Roll-out move:

    Evaluate each candidate extension by applying the base heuristic
  - Select the best candidate and re-iterate
- **Stop when a complete solution is obtained**
- **Variation: At each iteration use *W* partial solutions to extend**

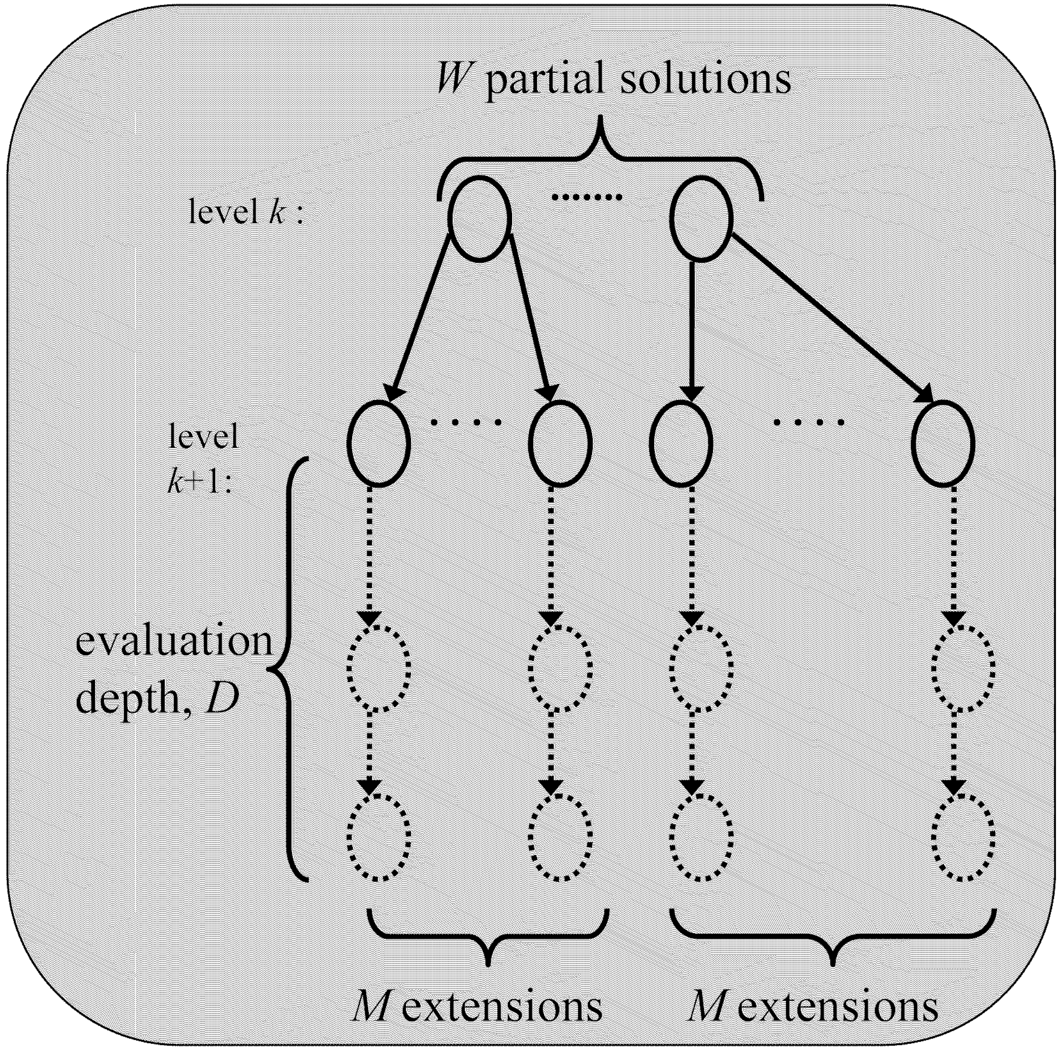
Roll-out approach: a single iteration

- **Base heuristic: generate *D* sequential greedy solution extensions**

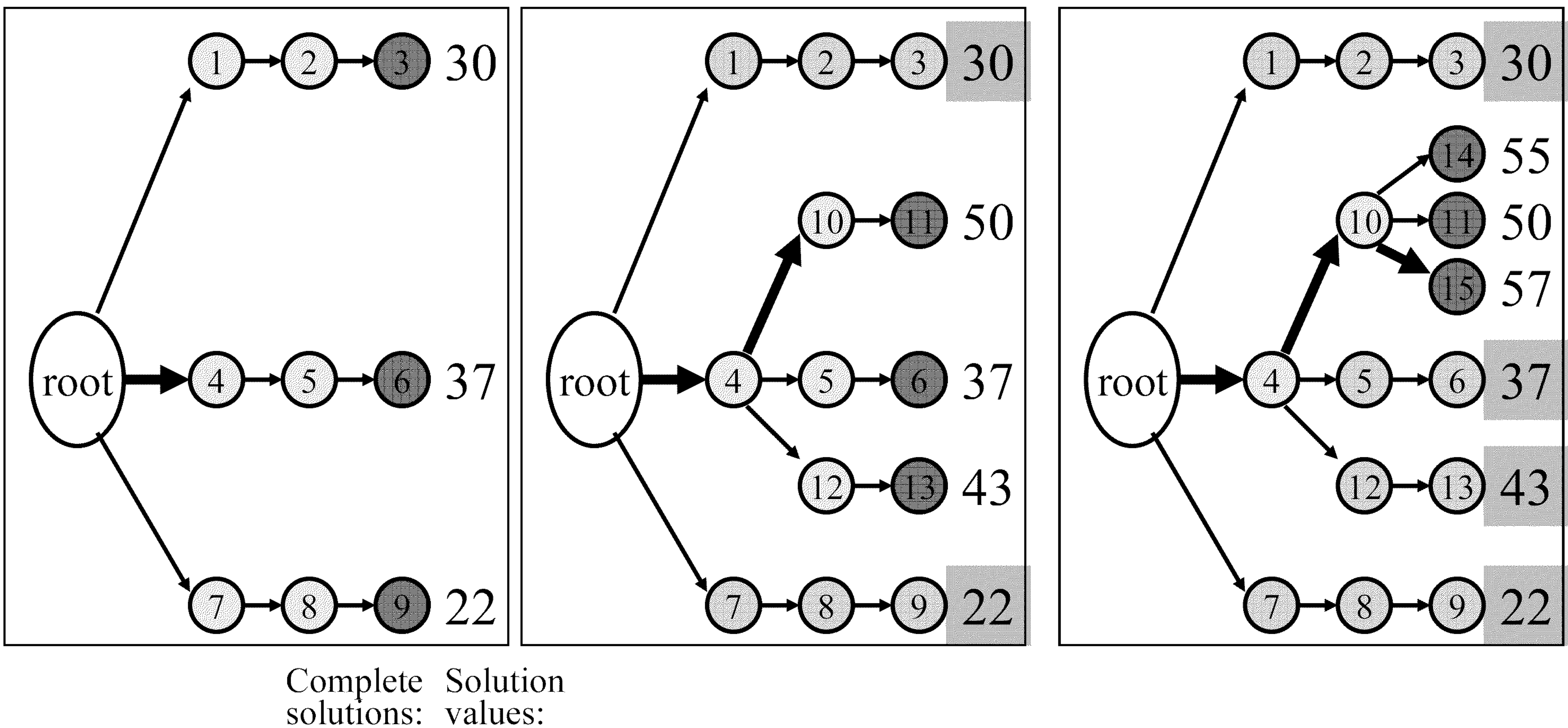
- **Algorithm running time:**

  ***O*(*WMDT*(GH))**

  where *T*(GH) is the time spent on a single greedy extension



Roll-out approach: Limited Tree Search



Numbers inside the circles indicate the order, in which the corresponding nodes are generated

Roll-out algorithm application to routing co-operating vehicles

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- **Partial solution:**
  - Sequence of site visits per vehicle subject to precedence and time constraints and terminal position reachability
  - At least one task can be added to at least one vehicle
- **Task availability:**
  - Given a partial solution, task is available if adding it does not violate precedence/time constraints
- **Solution extension:**
  - One available task is added to one vehicle
- **Base heuristic:**
  - Select an available task to maximize reward per travel time

Experimental results: evaluation depth, *D*

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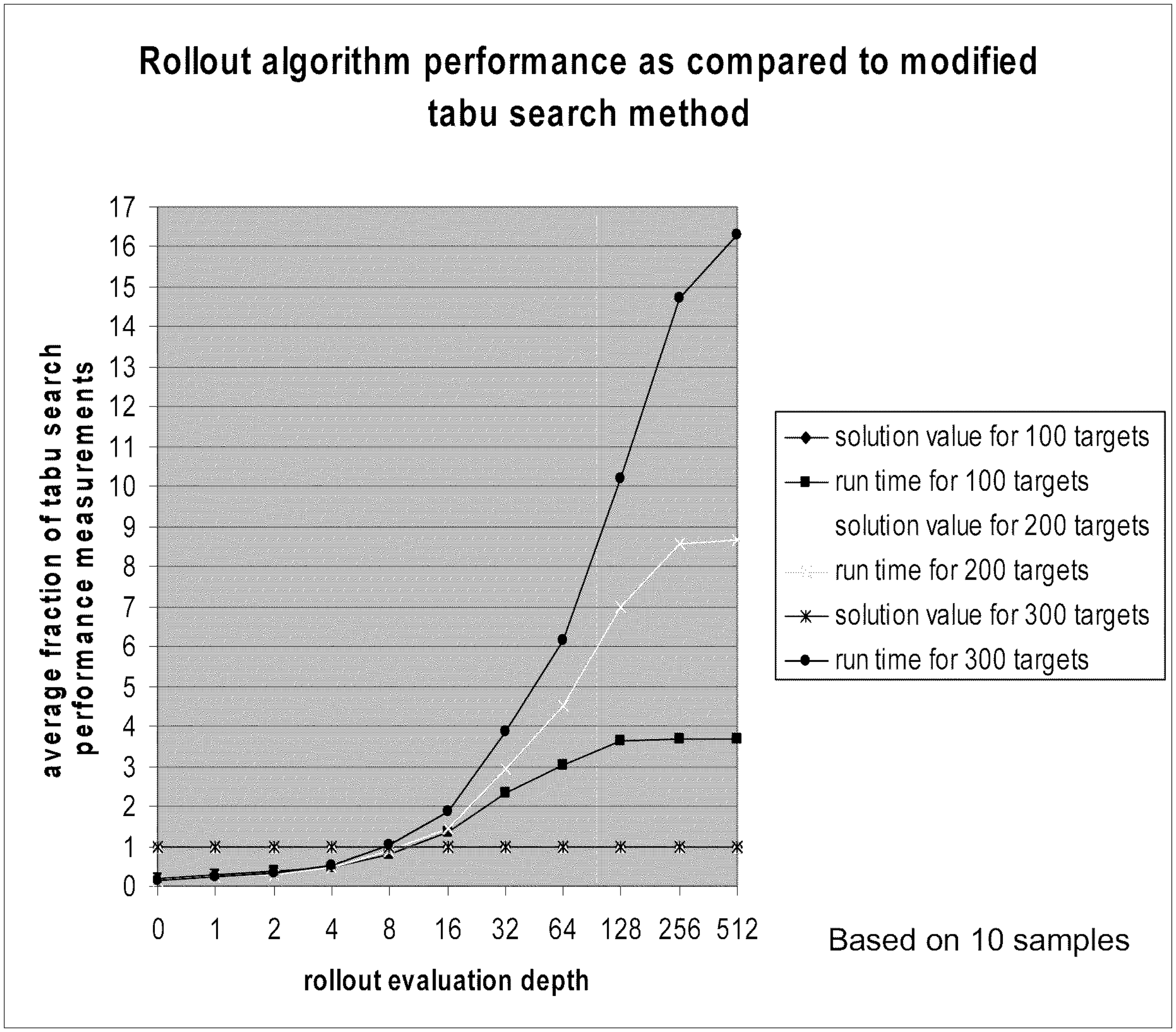

Experimental results: search width, *W*

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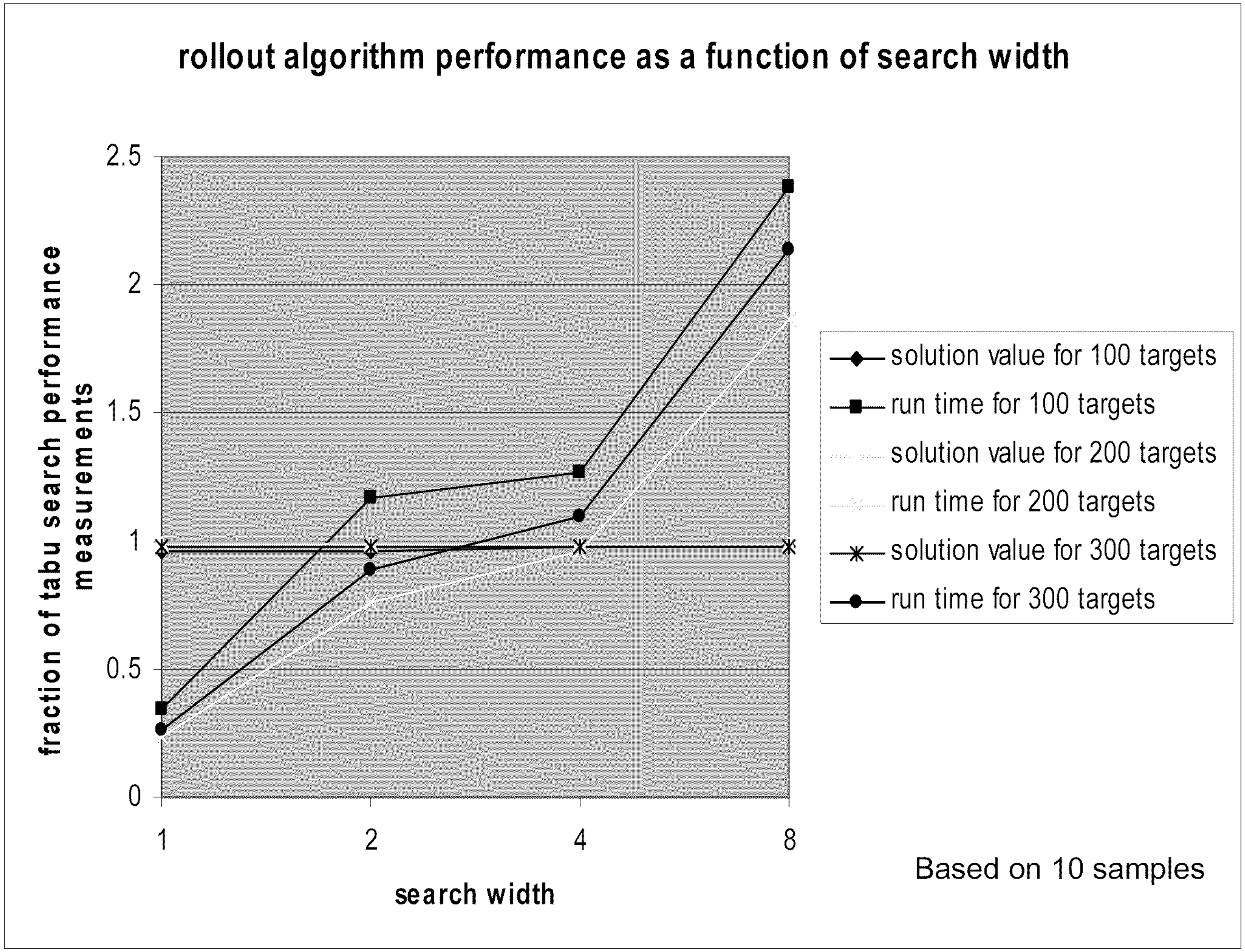

Experimental results: number of candidate extensions, *M*

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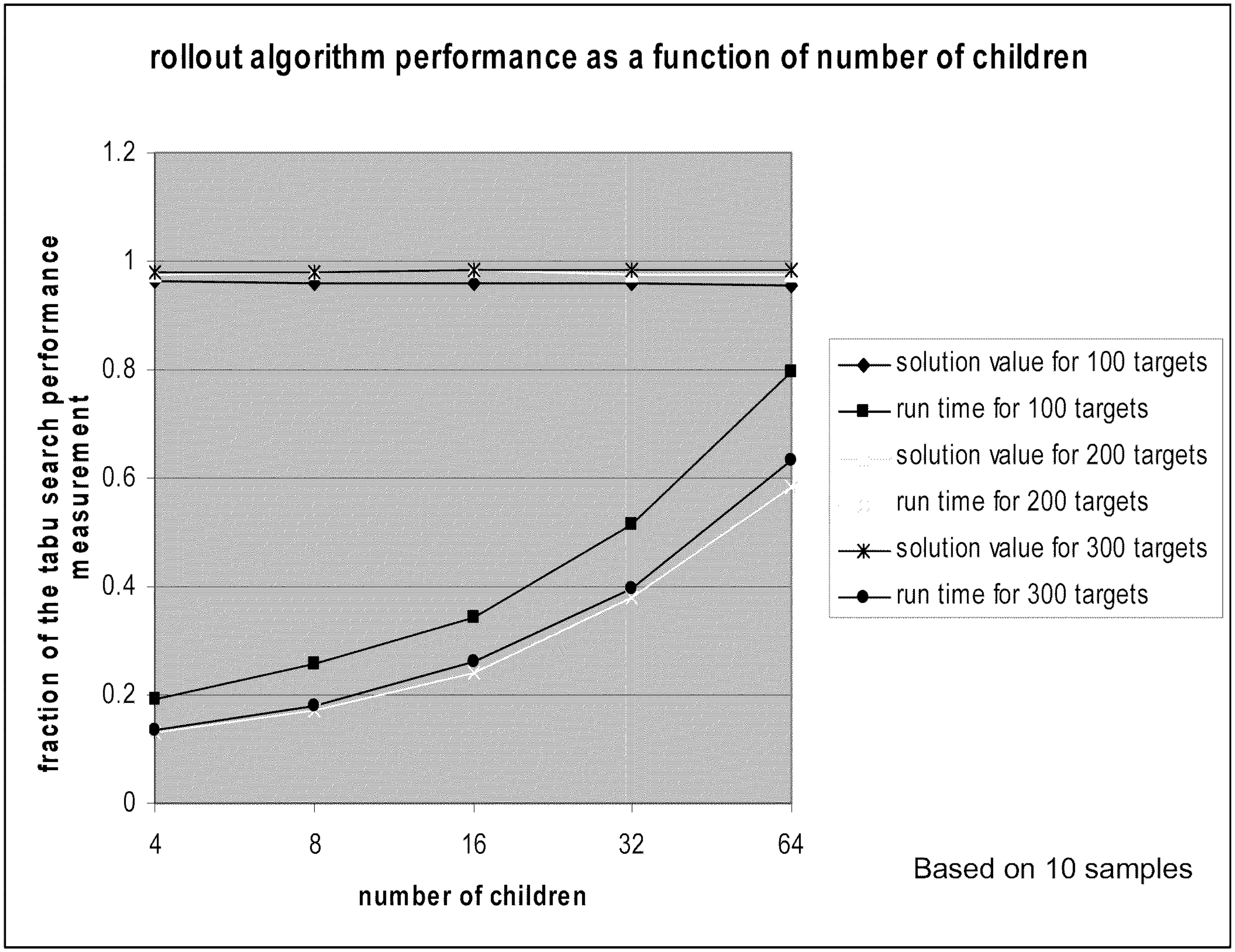

Conclusion

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- High-quality solution as compared with tabu search
- Scalable algorithm
- Applicable to real-time scheduling by adjusting parameters to speed-up computation
- Applicable to limited-horizon routing under uncertainty in fast changing environment