Unbalanced tree-search at scale using the Chapel's `DistributedBag` module

G. Helbecque[1,2], T. Carneiro[3], J. Gmys[2], N. Melab[2], P. Bouvry[1]

[1]University of Luxembourg, DCS-FSTM/SnT, Luxembourg
[2]Université de Lille, CNRS/CRIStAL UMR 9189, Centre Inria de l'Université de Lille, France
[3]Interuniversity Microelectronics Centre, Belgium

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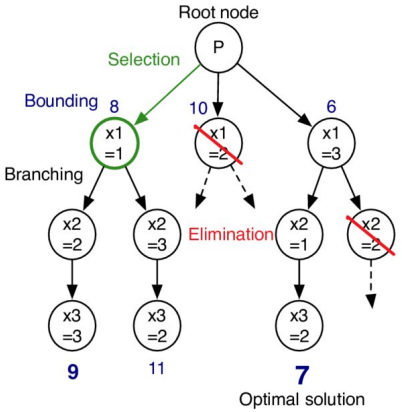
Virtual event

Need for a specialized data structure

Combinatorial optimization

e.g. the Branch-and-Bound (B&B) method:

- Exact method
  → Large trees
  → **Memory efficiency**
- Node elimination (pruning)
  → Irregular trees
  → **Load balancing**

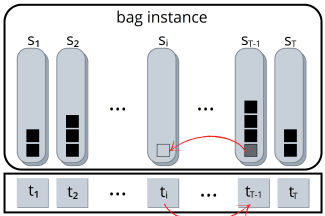


Source: M. Mehdi, Parallel hybrid optimization methods for permutation based problems, Université du Luxembourg, Université de Lille, PhD Thesis, 2011.

The Chapel's `DistributedBag` package module

The `distBag` data structure:

- Extensively reworked in Chapel 2.0
- Parallel-safe distributed multi-pool specialized for Depth-First Search (DFS)
- Dynamic load balancing mechanism, based on work stealing



`distBag`-based scalable B&B: Code demo

CODE DEMO:

`distBag`-based distributed multi-core B&B applied to the Permutation Flowshop Scheduling Problem (PFSP)

[Click here to access the video]

distBag-based scalable B&B: Experimental results

(higher is better)

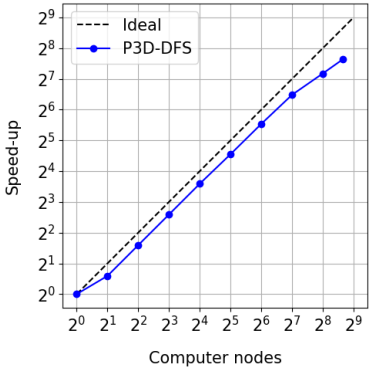


Fig. 1: Strong scaling efficiency.

- TOP500-ranked MeluXina supercomputer:
  2 × 64-cores AMD EPYC Rome 7H12 @ 2.6 GHz CPUs and 512 GB of RAM per node. Interconnection using the InfiniBand HDR high-speed fabric.
- 50% of strong scaling efficiency using 400 compute nodes (51,200 CPU cores)

Conclusions & Future perspectives

- `distBag` is a powerful tool to implement tree-based algorithms at scale
- We demonstrated its efficiency at scale on the B&B method applied to PFSP

Future perspectives:

- Look for ways that programmers might not need to pass the task ID
- Collect users feedbacks and improve/add features
- Performance optimization and tuning

Main references

[1] G. Helbecque, J. Gmys, N. Melab, T. Carneiro, P. Bouvry. Parallel distributed productivity-aware tree-search using Chapel. *Concurrency Computat Pract Exper.* 35(27):e7874; 2023. DOI: 10.1002/cpe.7874

[2] [Accepted for publication] G. Helbecque, T. Carneiro, N. Melab, J. Gmys, P. Bouvry. PGAS Data Structure for Unbalanced Tree-Based Algorithms at Scale. *24th International Conference on Computational Science*, 2-4 July 2024, Malaga, Spain

Thank you for your attention.

Contact:
Guillaume HELBECQUE
guillaume.helbecque@uni.lu

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