

# Travelling Salesman Problem

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# Agenda

What is TSP ?

Quick Refresher - Branch & Bound

Research Paper-1

Research Paper-2

Research Paper-3

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# What is TSP?

- ➔ Given a complete weighted directed / undirected graph  $G = (V \{1, \dots, n\}, E)$  and a cost matrix  $C$ , a tour is a circle in  $G$  which visits each vertex exactly once.



Image retrieved from: <http://makeagif.com/i/4-ew7H>

## Image References:

<http://makeagif.com/i/4-ew7H>

# Branch & Bound Algorithm

# Branch and Bound Algorithm

❑ **Select:** A node is selected based on a search criteria

**Branch:** The selected node from above is subdivided into its child nodes

❑ **Bound:** Some of the nodes that are created are then pruned

**Repeat the first 3 steps**

# Research Papers

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# Research Paper -1

<b>Title:</b>	Parallel Branch-and-Bound Algorithms
<b>Author:</b>	Teodor Gabriel Crainic,Bertrand Le Cun and Catherine Roucairol
<b>Published in:</b>	C. (2006) Parallel Branch-and-Bound Algorithms, in Parallel Combinatorial Optimization
<b>Year:</b>	2006
<b>Pages:</b>	1-28
<b>URL:</b>	<a href="http://onlinelibrary.wiley.com/doi/10.1002/9780470053928.ch1/summary">http://onlinelibrary.wiley.com/doi/10.1002/9780470053928.ch1/summary</a>
<b>Publisher:</b>	John Wiley & Sons, Inc.

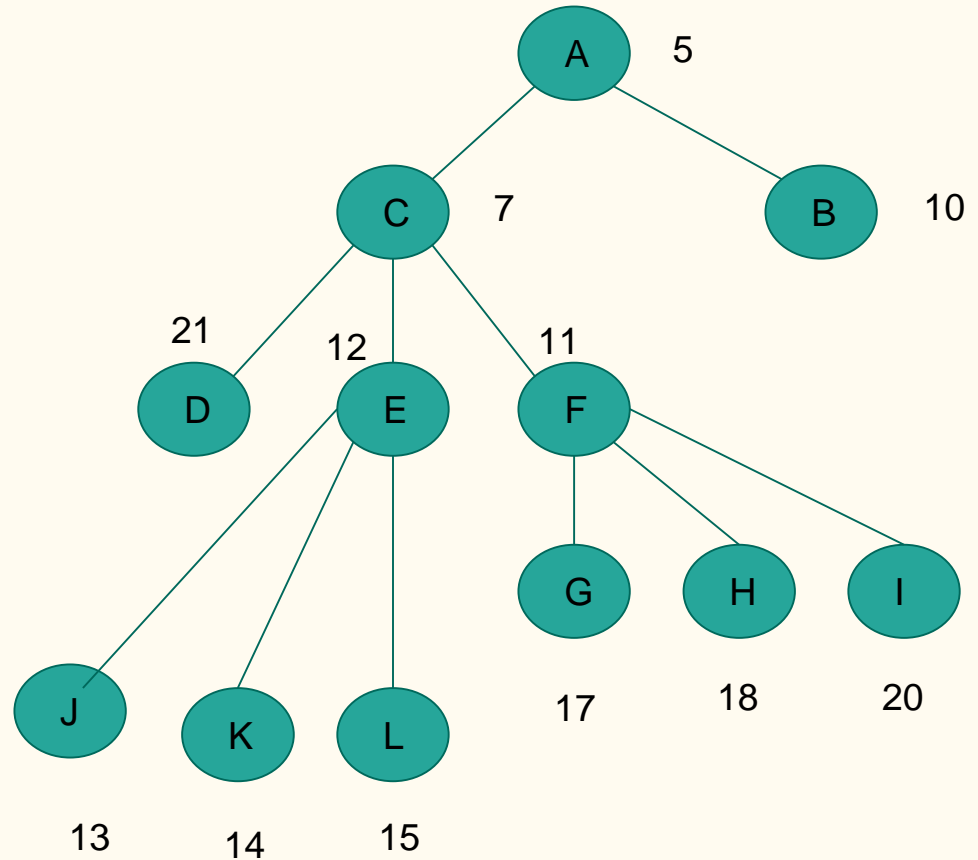
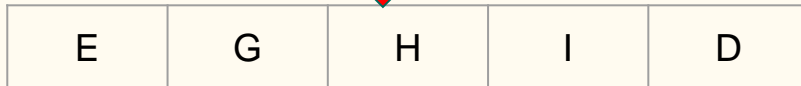
# Novel contributions towards solving problems

- ❑ Introduction to best first search for TSP.
- ❑ Parallel architecture for this problem.



Best First Search...

- Node with the most optimum cost is chosen.
- This search type uses a priority queue.
- The node with the least cost is put on the front of the queue



➤ Two ways to parallelize:

- Node Based Strategy

- Tree Based Strategy ➡ Our Approach

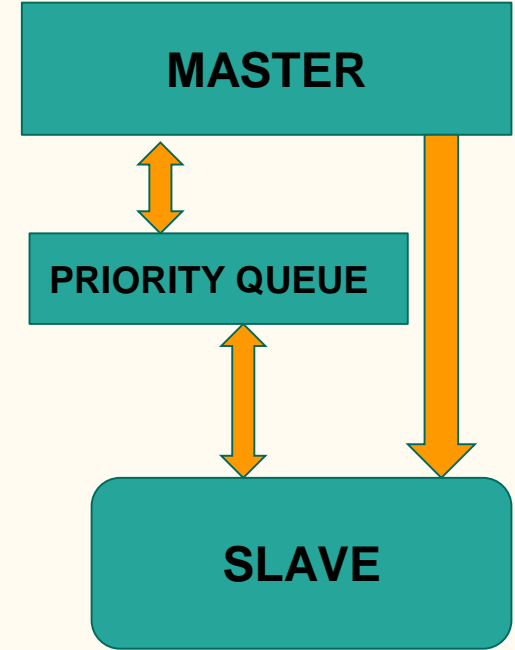
➤ Master Slave Architecture

- Slave will explore the tree

- Also, Compute the cost of the node

- Master allocates nodes to be processed to the slave.

- Priority queue is updated by the slave.



# How we plan to use these results ?

- ❑ Use Best First Search on cluster parallel computer.

# Research Paper - 2

<b>Title:</b>	Comparing a hybrid branch and bound algorithm with evolutionary computation methods, local search and their hybrids on the TSP
<b>Author:</b>	Yan Jiang, Thomas Weise, Jörg Lässig, Raymond Chiong, Rukshan Athauda
<b>Published in:</b>	Computational Intelligence in Production and Logistics Systems (CIPLS), 2014 IEEE Symposium
<b>Year:</b>	2014
<b>Pages:</b>	148 - 155
<b>URL:</b>	<a href="http://ieeexplore.ieee.org/document/7007174/">http://ieeexplore.ieee.org/document/7007174/</a>
<b>Publisher:</b>	IEEE Conference Publications

# Problems this paper addresses -

- ❑ Average Runtime of the traditional Branch and Bound Algorithm
- ❑ Requirement for Efficient Pruning techniques

# Novel contributions towards solving problems

- ❑ Introduction and Detailed Comparison of different hybridization schemes on BB algorithm
- ❑ An in-depth performance analysis of the BB algorithm, according to different time measures such as function evaluations (FEs) and normalized CPU times

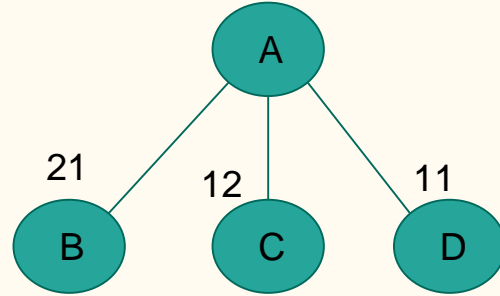
# How we plan to use these results ?

- ❑ Introduction of Local Searches in BB algorithm
- ❑ Using a simple constructive heuristic such as a Double Minimum Spanning Tree



# Local Searches

- ❑ Variable Neighbor Search
- ❑ Random Neighbor Search
- ❑ Multi-Neighbor Search



# Research Paper - 3

<b>Title:</b>	A New Parallel Schema for Branch-and-Bound Algorithms Using GPGPU
<b>Author:</b>	Tiago Carneiro, Albert Einstein Muritiba, Marcos Negreiros, Gustavo Augusto Lima de Campos
<b>Published in:</b>	Computer Architecture and High Performance Computing (SBAC-PAD), 2011 23rd International Symposium on Computer Architecture and High Performance Computing
<b>Year:</b>	2011
<b>Pages:</b>	41 - 47
<b>URL:</b>	<a href="http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6105662">http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6105662</a>
<b>Publisher:</b>	IEEE Conference Publications

# Problems this paper addresses -

- ❑ Handles computationally intensive routines
- ❑ High cost and power consumption
- ❑ Performance gains making it suitable for scalable systems

# Novel contributions towards solving problems

- ❑ Massively Parallel Environment - GPU's provide a high throughput
- ❑ Manycore architecture mitigates economic and physical limitations making it scalable even for applications with large number of threads

# Approach:

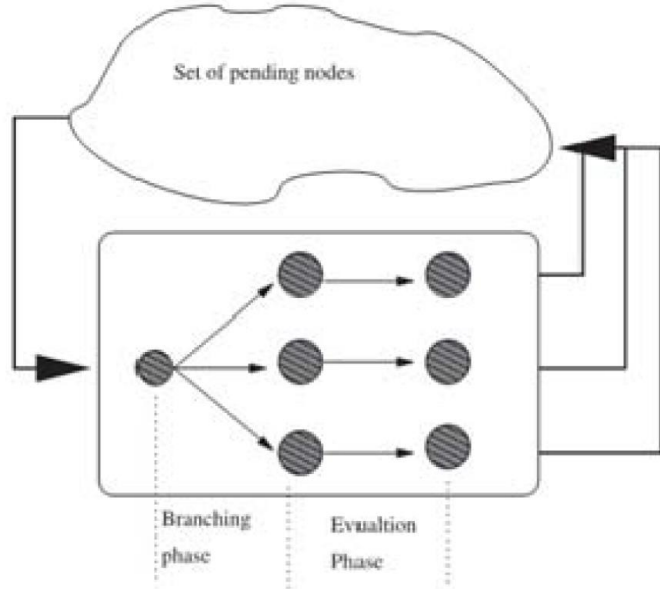
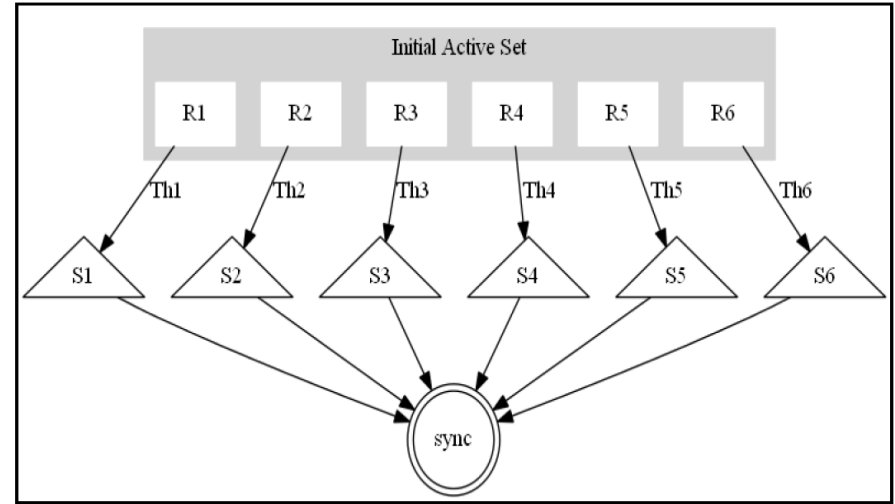


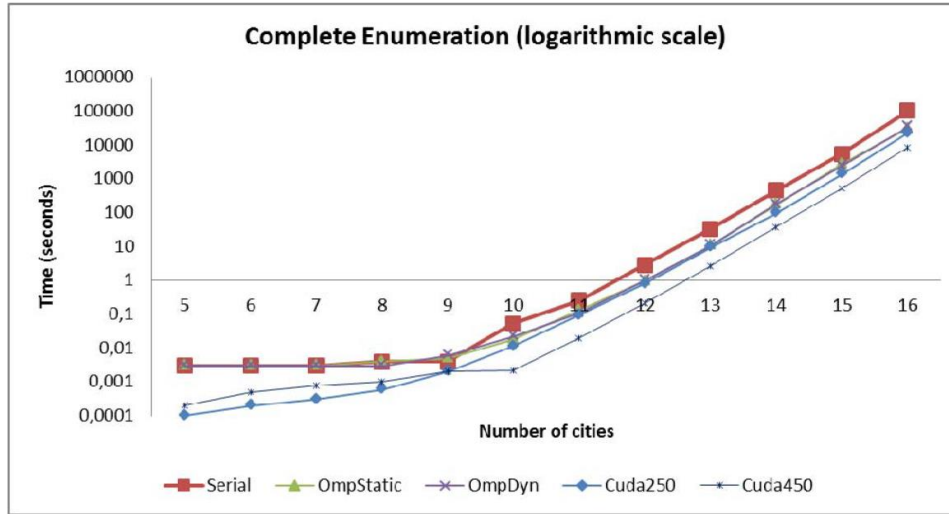
Image retrieved from: **T. Carneiro, A. E. Muritiba, M. Negreiros and G. A. Lima de Campos, "A New Parallel Schema for Branch-and-Bound Algorithms Using GPGPU"**



After the concurrent search, all threads will inform the amount of solutions found and the best one.

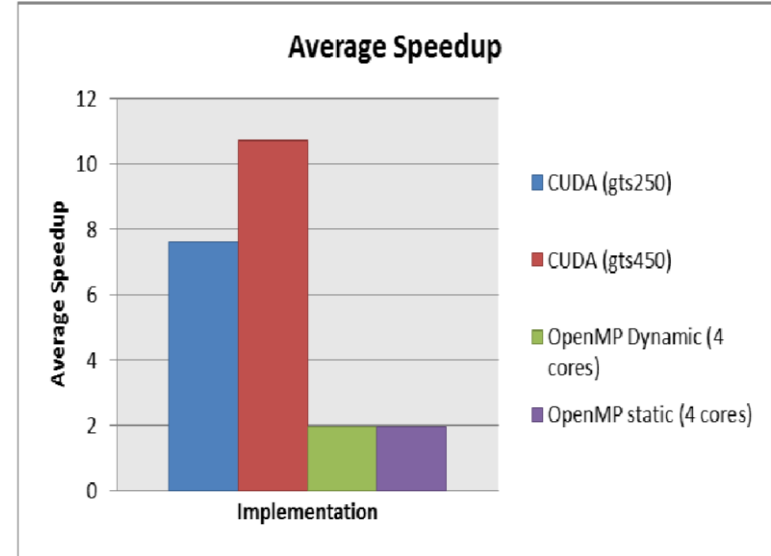
Image retrieved from: **T. Carneiro, A. E. Muritiba, M. Negreiros and G. A. Lima de Campos, "A New Parallel Schema for Branch-and-Bound Algorithms Using GPGPU"**

# How we plan to use these results ?



Graphic 1. Time required, in logarithm scale, to each implementation perform complete enumeration.

Image retrieved from: **T. Carneiro, A. E. Muritiba, M. Negreiros and G. A. Lima de Campos, "A New Parallel Schema for Branch-and-Bound Algorithms Using GPGPU"**



Graphic 2. Average speedup obtained by each implementation.

Image retrieved from: **T. Carneiro, A. E. Muritiba, M. Negreiros and G. A. Lima de Campos, "A New Parallel Schema for Branch-and-Bound Algorithms Using GPGPU"**

# References

- [1] Crainic, T. G., Le Cun, B. and Roucairol, C. (2006) Parallel Branch-and-Bound Algorithms, in Parallel Combinatorial Optimization (ed E.-G. Talbi), John Wiley & Sons, Inc., Hoboken, NJ, USA. doi: 10.1002/9780470053928.ch1
- [2] T. Carneiro, A. E. Muritiba, M. Negreiros and G. A. Lima de Campos, "A New Parallel Schema for Branch-and-Bound Algorithms Using GPGPU," Computer Architecture and High Performance Computing (SBAC-PAD), 2011 23rd International Symposium on, Vitoria, Espirito Santo, 2011, pp. 41-47.
- [3] Y. Jiang, T. Weise, J. Lässig, R. Chiong and R. Athauda, "Comparing a hybrid branch and bound algorithm with evolutionary computation methods, local search and their hybrids on the TSP," Computational Intelligence in Production and Logistics Systems (CIPLS), 2014 IEEE Symposium on, Orlando, FL, 2014, pp. 148-155.

# Questions?

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