PARCSIM: a Learning Support Tool for Parallel Programming Students[2]

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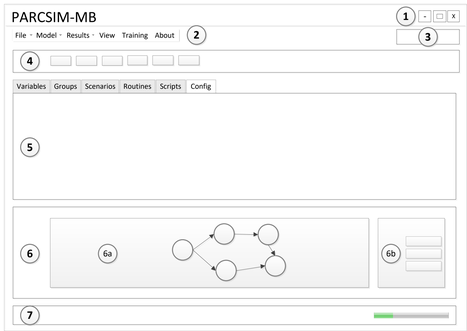
PARCSIM (PAR-allel C-omputations SIM-ulator)

A software simulation tool that shows, in an interactive way, the advantages of applying parallelism techniques as well as the selection of the appropriate library according to the type of computation to be performed on a given hardware platform. PARCSIM allows the user to capture algorithms that solve scientific problems using matrix algebra techniques. This task is performed thanks to the graphical user interface that collects the algorithm computations and their dependencies, making up a graphical parallel algorithm model. After that, this tool experiments with computations using different parallelism parameters and numerical libraries, analysing the execution times obtained in each case. On the other hand, this tool offers a self-optimizing execution mode that can help non-expert users in the selection of the best values for the parameters, proposing the temporal order of the computations to allow better exploitation of parallelism in a particular compute node, knowing the number of CPU cores and the number of available GPUs.

PARCSIM Interface



1. Window buttons.
2. A menu bar with access to the software's functionalities with submenus.
3. A text box displaying the name of the parallel algorithm model.
4. A toolbar containing a selection of shortcuts to the main utilities.
5. The main work area, where the information of the algorithm model is captured, with its execution scenarios (size and type of its data, basically) and its set of adjustable parameters (for each function: library to be used, number of threads, number of GPUs...), and where the general configuration of the simulator is established.
6. A window to display the graph corresponding to the edited algorithm model. In this part of the interface, two areas can be distinguished:
   (a) The graph itself, which is automatically updated when the user creates new algorithm elements or updates dependencies in the algorithm model.
   (b) A toolbar containing shortcuts to utilities that allow to modify the display of the graph, such as rotating or resizing it.
7. A status bar showing information about the hardware and operating system on which PARCSIM is running.

An example of routine: the Strassen multiplication

$A, B \in 2^n \times 2^n$, $C = AB$.

$$A = \left[\begin{array}{c|c} A_{1,1} & A_{1,2} \\ \hline A_{2,1} & A_{2,2} \end{array}\right],\ B = \left[\begin{array}{c|c} B_{1,1} & B_{1,2} \\ \hline B_{2,1} & B_{2,2} \end{array}\right],$$
$$C = \left[\begin{array}{c|c} C_{1,1} & C_{1,2} \\ \hline C_{2,1} & C_{2,2} \end{array}\right]$$

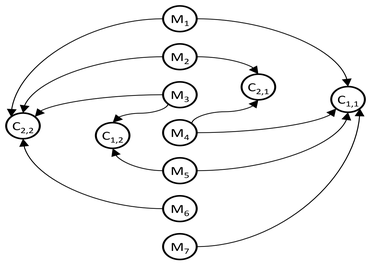
Considering:

$$\begin{aligned} M_1 &= (A_{1,1} + A_{2,2})(B_{1,1} + B_{2,2}) \\ M_2 &= (A_{2,1} + A_{2,2})B_{1,1} \\ M_3 &= A_{1,1}(B_{1,2} - B_{2,2}) \\ M_4 &= A_{2,2}(B_{2,1} + B_{1,1}) \\ M_5 &= (A_{1,1} + A_{1,2})B_{2,2} \\ M_6 &= (A_{2,1} - A_{1,1})(B_{1,1} + B_{1,2}) \\ M_7 &= (A_{1,2} + A_{1,1})(B_{1,1} + B_{1,2}) \end{aligned}$$

Then:

$$\begin{aligned} C_{1,1} &= M_1 + M_4 - M_5 + M_7 \\ C_{1,2} &= M_3 + M_5 \\ C_{2,1} &= M_2 + M_4 \\ C_{2,2} &= M_1 - M_2 + M_3 + M_6 \end{aligned}$$

Therefore, the calculation dependency graph is:



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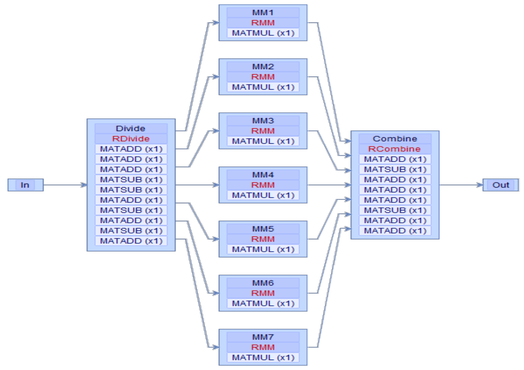
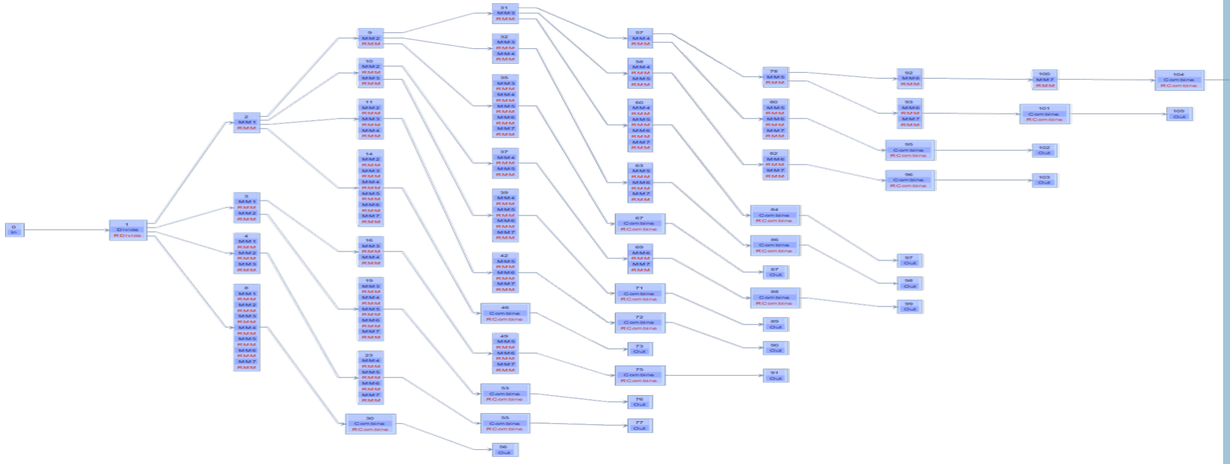
Modeling the Strassen multiplication in PARCSIM

The algorithm model:



The tree of possible temporal ordering of the calculations:



The simulated execution time for each combination of adjustable parameter values.