# CS 6310 Project 2: Heated Earth

**Design Study**

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## Context

In this design study, multiple configurations of the Heated Earth Simulation software are compared in order to find the optimal simulation configuration. Test were conducted for each configuration and results were captured in order to compare and analyse the results. The purpose of the study was to find the best configuration settings for buffer size, multi threading and component initiative.

## Research Questions

1. What is the impact of choice of initiative on system performance?
2. What are the pros and cons of using multi-threading for concurrent computation?
3. What is the effect of buffer length on:
    3.1. idle time?
    3.2. calculation and update times?
4. Under what conditions does the buffer fill up?
5. What is the optimal simulation configuration, and what circumstances may that configuration depend on?
6. How long does it take for the simulation to stabilize in relation to the initial conditions?
7. What effect does grid cell size have on:
    7.1. idle time?

7.2. simulation and presentation throughput?

7.3. memory usage?

## Subjects

The subject of this study is the HeatedEarth simulation program under 12 different conditions.

1. *HeatedEarth Demo with parameters "-s -p"*
2. *HeatedEarth Demo with parameters "-s -p -r"*
3. *HeatedEarth Demo with parameters "-s -p -t"*
4. *HeatedEarth Demo with parameters "-s "*
5. *HeatedEarth Demo with parameters "-s -r"*
6. *HeatedEarth Demo with parameters "-s -t"*
7. *HeatedEarth Demo with parameters "-p "*
8. *HeatedEarth Demo with parameters "-p -r"*
9. *HeatedEarth Demo with parameters "-p -t"*
10. *HeatedEarth Demo with parameters " "*
11. *HeatedEarth Demo with parameters " -r"*
12. *HeatedEarth Demo with parameters " -t"*

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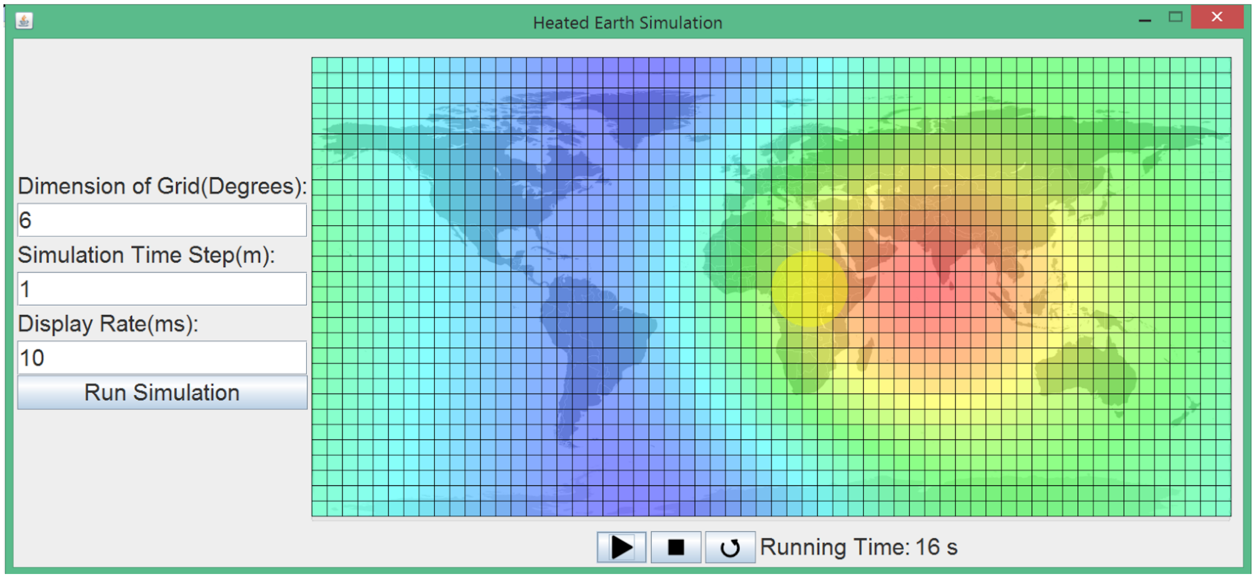
## Design Study




## Experimental Conditions

All experiments were run on the same machine with the following specifications:

| | |
|---|---|
| Computer model | Microsoft Surface |
| Operating system | Windows 8.1 Pro |
| CPU | 2.3 GHz Intel Core i5 |
| Memory | 8 GB 1333 MHz DDR3 |
| Java | JRE 7 |

The tests were run under the same conditions: no other software running, computer plugged in and no internet connections. The tests were executed on the windows command prompt using the following command:

"java EarthSim.Demo -cp .\bin **[-s] [-p] [-r|-t] [-b #]**"

This was repeated for every test, setting each parameter with test values.

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## Independent Variables

| Variable | Units of Measurement | Description |
| --- | --- | --- |
| gridSize | Degrees | The grid size is specified in degrees as an input text box in GUI and it represents the number of degrees a cell in the gr should cover in the simulation. |
| bufferSize | Number | The buffersize is specified by the command line parameter "-b" followed by a number specifying the size of the buffe |
| simulatorTimeStep | Minutes | The simulator time step is specified in minutes as an input box on the GUI and represents the amount of simulated tim passed in between calculations. |
| presentationDisplayRate | Milliseconds | The presentation display rate is specified in milliseconds as input text box on the GUI and it represents the amount of ti in between the GUI displaying the next values off the buffe |
| presentationThread | boolean | The presentationThread is specified by the command line parameter "-p". If parameter is present presentationThread set to true and the presentation runs in its own thread. |
| simulatorThread | boolean | The simulatorThread is specified by the command line parameter "-s". If parameter is present simulatorThread is s to true and the and the simulator runs in its own thread. |
| initiative | String | The initiative is specified by the command line parameter " or "-t". If "-r" then the presentation has the initiative and if then the simulation has the initiative and if neither is presen then the GUI has the initiative. |

## Dependent Variables

| Variable | Units of Measurement | Description |
| --- | --- | --- |
| MemoryUsage | Bytes | is expected to be affected by gridSize |
| SimulationUpdateTime | Milliseconds | is expected to be affected by gridSize |
| SimulationIdleTime | Milliseconds | is expected to be affected by bufferSize and Simulation Thread |
| PresentationUpdateTime | Milliseconds | is expected to be affected by gridSize |

| | | |
|---|---|---|
| PresentationIdleTime | Milliseconds | is expected to be affected by bufferSize, presentationThread and presentationDisplayRate |
| GUIResponsive | boolean | is expected to be affected by initiative, simulatorThread and presentationThread |
| stabilizationTime | Miliseconds | is expected to be affected by gridSize |

## Metrics

These are the units of measurements used in the experiment.

| Metric | Description |
|---|---|
| MilliSeconds | One thousandths of a second, which is a standard unit of measurement fo time. This will be measured using the internal java Date object |
| Bytes | A unit of memory size, containing 256 bits of data. This will be measure using the Runtime object |
| Degrees | Standard unit of measurement for longitude and latitude |
| Minutes | a standard unit of measurement for time. |

***Variable* Summary**

*Table 1. Independent and Dependent Variables per Question*

| Question # | Independent Variables | Dependent Variables |
|---|---|---|
| *1* | initiative | SimulationUpdateTime, SimulationIdleTime, PresentationUpdateTime, PresentationIdleTime, GUIResponsiveness |
| *2* | presentationThread, simulatorThread | MemoryUsage, stabilizationTime, SimulationUpdateTime, SimulationIdleTime, PresentationUpdateTime, PresentationIdleTime, GUIResponsiveness |
| *3* | bufferSize | SimulationIdleTime, PresentationIdleTime, SimulationUpdateTime, PresentationUpdateTime |
| *4* | initiative, bufferSize | SimulationIdleTime |

| | | |
|---|---|---|
| *5* | presentationThread,<br>simulatorThread,<br>initiative | stabilizationTime |
| *6* | gridSize, simulatorTimeStep | stabilizationTime |
| *7* | gridSize | SimulationIdleTime, PresentationIdleTime,<br>MemoryUsage |

## Methods

Experiments were conducted one at a time by printing the simulation output for a given set of variables. Every experiment was run on the same machine under the same conditions and the results were saved. Out of the 12 combinations of threading and initiative there was only 5 combinations that ran the initiative in its own thread freeing up the GUI to run.

We focused our experiment on those 5 combinations. For each of these five combinations we varied the inputs with one high and one low value. The buffers size 1 and 100, grid size 3 and 15, simulation time step of 1 and 60 and a display rate of 1, 10 and 100 were used in our experiments.

The combination of these test makes 7 tests and we ran those 7 tests against the 5 combinations of the threading and initiative for a total of 35 tests. We captured the results of these tests by printing out the average display update time, average calculation time, average simulation idle time, presentation idle time, memory usage and the time it took for the temperatures in the simulation to stabilize. The Java Runtime was used to calculate the memory used and the average times were calculated using Javas Date class.

## Analysis Techniques

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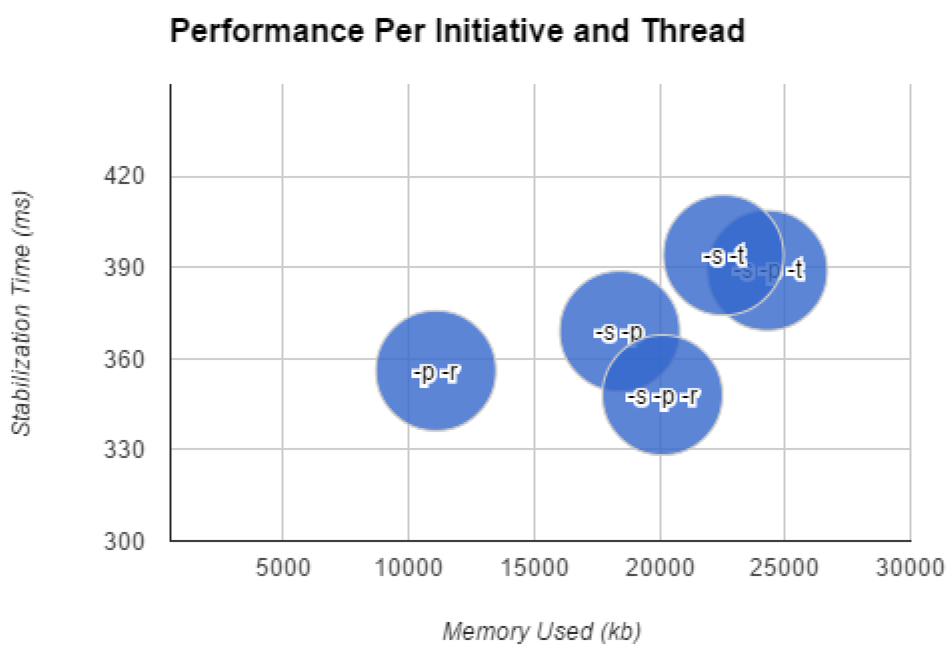
In order to better understand the results we prepared several graphs and used the Pearson Correlation Coefficient calculator to calculate the Correlation Coefficient. The results of this is shown in the graphs below.

**Results**

The following figure is the result of running the different combinations of initiative and threads that still allowed the GUI to respond. Correlation coefficient R = 0.6605 shows a moderate correlation.




The following figure is the results of running the simulator with parameters "-s -p -b 100" and shows a direct correlation between the display rate and the average time the simulation waits to put the next message on the queue because it is full. The simulator seems to wait the same amount of milliseconds that the display rate is set to. Correlation coefficient R = 1 shows a strong correlation.

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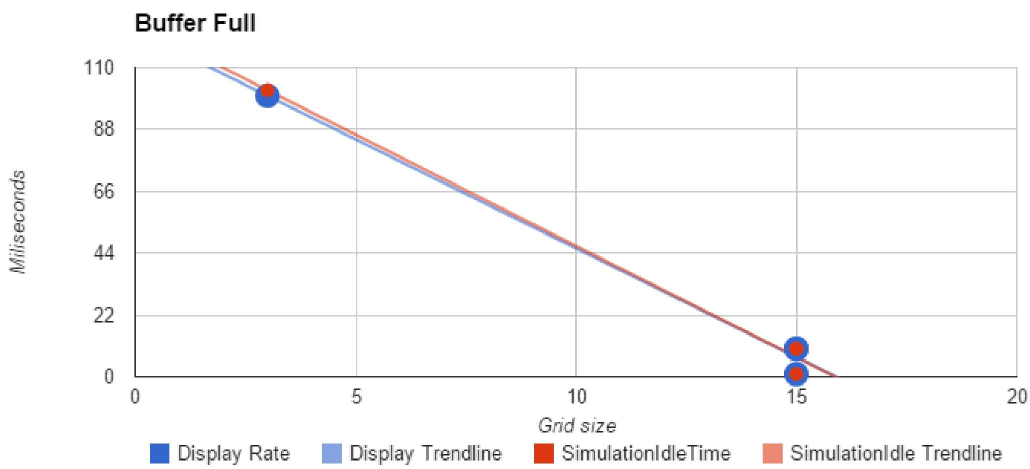
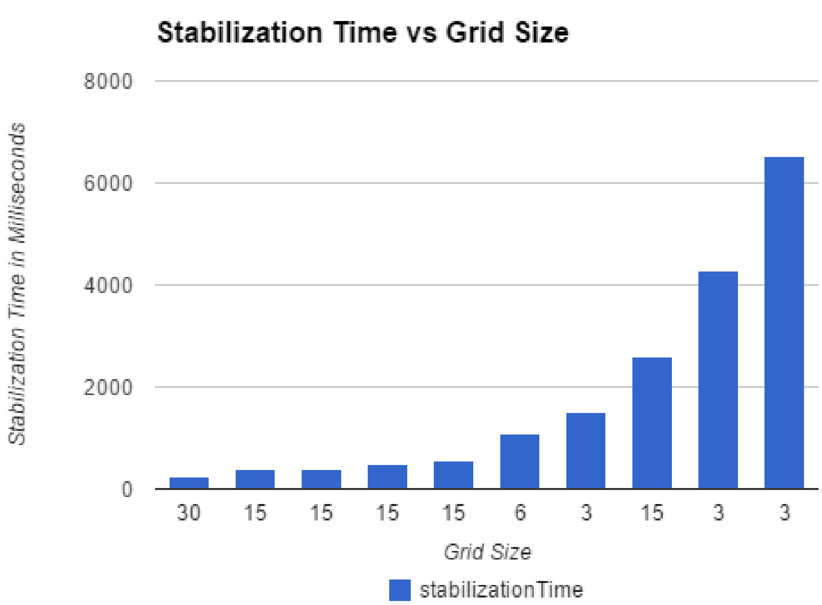



The following figure shows the highest correlation we found between the time it takes for the temperatures to stabilize and any input variable. Other variables also contribute but in a much smaller scale. This is what accounts for the grid size of 6 and 3 that seem out of place. Correlation coefficient R = -0.6241 shows a moderate negative correlation.



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**Discussion**

For the most part, our results matched our intuition. In each experiment, while absolute performance was quantified it was only relative performance that could be measured. To improve the study, we could go further with benchmark tests to compare against similar programs. We can also pick relationships and try to predict absolute performance and explore any inconsistencies.

## Conclusions

After conducting this study and analyzing its results we derived the following conclusions, which answers our research questions:

1. The impact on performance of choosing the initiative was large. If initiative was given to to the component that was running in the main thread then the GUI would lock up rendering the software useless. The impact on performance of choosing the initiative of a component running in its own thread was minor.
2. When we tried to run the simulation or presentation in the same thread as the GUI, when the GUI had the initiative, the GUI became unresponsive. When both modules had their own threads, or the one in a separate thread had the initiative the application would run well.
3. In changing the buffer length we found:
   3.1. There was no change in idle time of the Presentation or the Simulation.
   3.2. The effect of buffer length was noticeable when a lower value was set for the grid size. This meant that there was more data to pass through the buffer, and a larger buffer to fill.
4. In our experiments we found the buffer tended to fill up only when the GUI was given the initiative. This effect was exaggerated when the display rate was slowed down.

5. We found that the optimal configuration was to run the Presentation in its own thread, and give the initiative to the Presentation. Separating the Simulation into its own thread did not make much difference seemed to improve performance slightly over this configuration for larger grid spacing.
6. We defined stabilization to be the point at which the hottest recorded temperature and the lowest recorded temperature stayed constant for 5 steps. We found that the simulation took longest to stabilize when the grid cell size was smaller, and the time interval was smaller.
7. We found that the grid cell size had the following effects:
   - 7.1. There was no change in idle time based on grid cell size.
   - 7.2. Simulation throughput was marginally increased (still measuring less than 2 ms) but the rate of frame updates in the presentation was noticeably reduced.
   - 7.3. Memory usage was increased for smaller grid cell size, as the dimensions of the storage array and the display were increased.