Research on the acceleration of agent-based tsunami evacuation computing for complex urban environment simulation

Erick MAS* Shunichi KOSHIMURA‡
INTERNATIONAL RESEARCH INSTITUTE OF DISASTER SCIENCE (IRIDeS), TOHOKU UNIVERSITY, JAPAN

1. Introduction

Tsunami evacuation is a natural and social phenomenon involving hydrodynamic features and psychological and social behaviours of individuals and groups. It is a complex behaviour of individuals influenced by the perception of their risk, the condition of the environment surrounding them, and the interactions among them and their social structures. The task of modelling such complex urban environment can be done using the agent paradigm. Agent based modelling has become popular in the last two decades for its modelling style that has the capability of representing spatial and its physical components whom evolve and change on time due to the environment and their social interactions. However, agent based models can generate enormous amount of data as the number of agents included on the simulation increases. Therefore, a method for acceleration is needed when large-scale environments with large number of agents are simulated.

In previous research studies we developed a model of tsunami inundation and evacuation using the NetLogo platform (Wilensky, 1999) of agent based modelling (Mas et al., 2013). Our model can be applied for small communities, however in order to attempt a major scale simulation, in this research we explore alternatives for optimisation using a dynamic programming language to include CPU and GPU vectorization techniques.

In this paper we will present a preliminary test result for agent random movement behaviour to compare speedup outcomes between NetLogo and techniques of vectorization and parallel optimisation.

2. Background

Mas et al. (2013) developed an integrated tsunami inundation and evacuation agent based model using geospatial data and tsunami numerical simulation results as inputs on a NetLogo model (fig.1). However, there are certain limitations when complex urban environments and agent behaviour are treated in the model. In particular the computation time increases almost exponentially as the number of agents increases. Therefore it is necessary to rebuild the model on a suitable platform from massive computation or from scratch on a programming language which allows for high performance computing and handling of big data.

3. Objective

The final objective is to develop an agent based model of tsunami evacuation simulation with a high performance computation capability. It is required for the tsunami disaster mitigation to evaluate many possible scenarios of evacuation and the effect of new policies of mitigation. An agent based model can perform the analysis of hundreds of scenarios with thousands of agents; however extensive computation time is still a limitation on this technique. Therefore, on this paper we will describe a preliminary analysis of agent based simulation speedup using vectorization techniques on CPU and GPU. Results are compared across platforms and architectures.

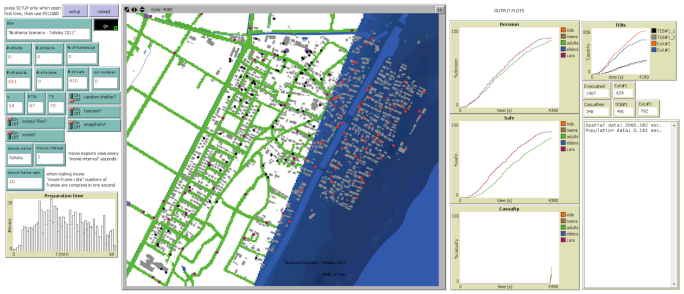

Figure 1: Interface of a previous developed tsunami evacuation model in NetLogo (Mas et al., 2013)

4. Methodology

We developed a simple model of N agents walking around an empty space without collision avoidance behaviour. It is our interest to compare the computation time of dynamic agents with the most simple behaviour possible. For this model an agent is described as an entity with position (x,y), speed (s), direction (d) and acceleration (a) (fig.2). The movement becomes random by adding a random nudge to the direction of the agent. We set a experiment to 3600 steps - ticks in NetLogo - of random walk on an empty space.

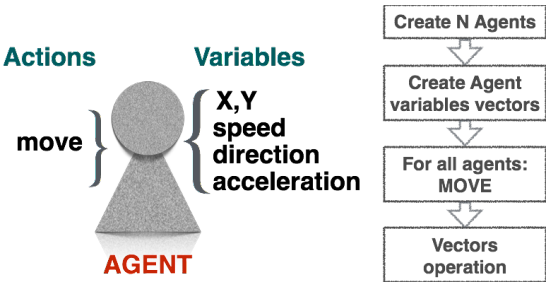

Figure 2: Agent variables and action. Flow of simple model.

The flow of the model described in figure 2 shows a second step where agent variables are created as vectors. In order to take advantage of multithreading techniques, agents with common variables are packed into vectors and then matrices which can be treated as textures easy to be loaded and used on GPUs and CPU processors. Using variable vectors a vectorize

*Assistant Professor, Laboratory of Remote Sensing and Geoinformatics for Disaster Management, IRIDeS, Tohoku University
†Professor, Laboratory of Remote Sensing and Geoinformatics for Disaster Management, IRIDeS, Tohoku University
‡Keywords: tsunami evacuation, high performance computing, agent based model

operation function is used as the code shown below:

```
from numbapro import vectorize
@vectorize([' float32 ( float32 , float32 , float32 ,
             float32 )' ], target ='cpu')
def VoperationCPUX(Tx,Td,Ts,Ta):
    # vectorization  for  X coordinate
    A = Tx + Ts * cos(Td) + 0.5 * Ta * cos(Td)
    return  A
```

The Python code showed before is an example of vector operation for the calculation of X coordinates of agents in move. Numbapro[1] is used to include universal functions which are compiled to machine code dynamically and loaded on the fly. This library offers the ability to target not only single-threaded CPU (`target='cpu'`), but also multicore CPU (`target='parallel'`), CUDA GPU architectures (`target='gpu'`).

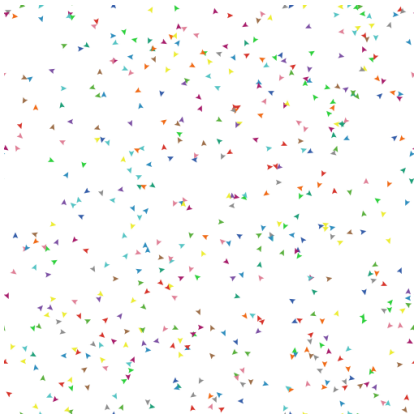

Figure 3: Snapshot of 500 agents random movement on NetLogo

Next, we measured the total computation time of one experiment for N equal to 5, 50, 500, 5000, 50000 and 500000 agents (fig.3).

5. Simulation Results

All scenarios were ran using a MacBook Pro with Intel Core i7, 2.7GHz of processor speed. For multicore computation a total of 4 cores were used, and for CUDA GPU computation a NVIDIA GeForce GT 650M card was used. Computation times were measured in seconds and plotted as shown in figure 4. NetLogo shows better performance than a simple Python programming using NumPy linear arrays and a `for` loop. However the optimisation of the original Python code using single-threaded CPU, multicore CPU and CUDA GPU options show speedups from 2x to slightly over 1000x when handling big data. It is observed that NetLogo has good performance when handling small amount of agents and high performance approach is convenient when using big data. A future effort to translate the available NetLogo model of tsunami evacuation (Mas et al., 2014) to a high performance version in Python is part of our agenda.

6. Conclusions

We have conducted a comparative analysis of a simple agent based model speed up for a future development of a tsunami inundation and evacuation simulator following our previous efforts on the field. The use of our previous model developed in NetLogo has been limited by the number of agents and behaviours possible to include with a trade off on computation time. Therefore, a test between NetLogo and Python programming with optimisation techniques has been presented. It was observed that NetLogo yields good performance for small amount of agents in comparison to a common looping architecture on Python, however NetLogo has also a limitation when the number of agents is increased. The use of multicore CPU shows better results than the use of GPU under the present amount of agents and data throughput. For the case of single-threaded CPU computing, computation times increase drastically when the number of agents are significantly big. As an expected finding GPU and parallel optimisation of CPU show the best results almost constant for small data and slightly increased for big data. It is then our next step to put together the GPU and parallel optimisation into a new version of tsunami inundation and evacuation agent based model using Python.

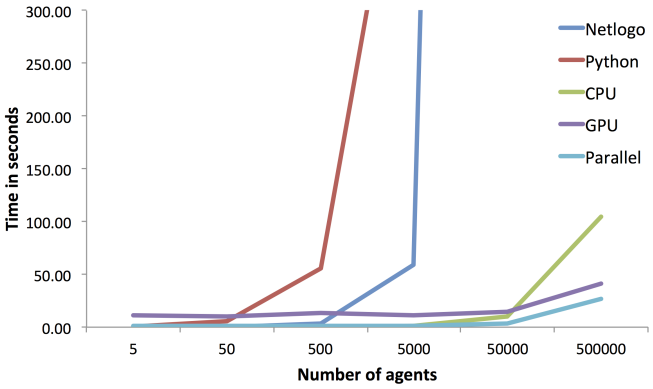

Figure 4: Computation time of each platform and technique

Table 1: Speedup test results

No	NetLogo	Python	CPU	GPU	Parallel
5	1.00	0.17	2.63	0.01	0.14
50	1.00	0.06	6.87	0.03	0.34
500	1.00	0.06	24.96	0.27	3.51
5000	1.00	0.11	54.16	5.16	44.99
50000	1.00	0.61	319.10	217.12	1017.65
500000	1.00	0.15	77.98	200.62	311.36

Acknowledgments

This research is supported by the International Research Institute of Disaster Science (IRIDeS) at Tohoku University.

References

Mas, E., Adriano, B., and Koshimura, S. (2013). An Integrated Simulation of Tsunami Hazard and Human Evacuation in La Punta , Peru. *Journal of Disaster Research*, 8(2):285–295.

Mas, E., Adriano, B., Koshimura, S., Imamura, F., Kuroiwa Horiuchi, J., Yamazaki, F., Zavala, C., and Estrada, M. (2014). Identifying Evacuees Demand of Tsunami Shelters Using Agent Based Simulation. In Kontar, Y., Santiago-Fandino, V., and Takahashi, T., editors, *Tsunami Events and Lessons Learned*, chapter 19, pages 347–358. Springer Netherlands.

Wilensky, U. (1999). NetLogo.

[1] http://docs.continuum.io/numbapro/index.html