Master Research Internship

Water channels networks as cellular systems

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Abstract

Recently, the issue of climate change become concern of our societies. The climate change impacts water channel systems in delta with several effects coming from the sea level rise and various perturbations of flow along the river. Thus, designing a system for monitoring and predicting phenomenon about water flow is necessary. Building water flow simulation systems interfaces geographic databases to produce cellular systems, plus distributed sensing architectures. In this report, we present concept of cellular automata, wireless sensor network and their applications. The NetGen tool developed at Lab-STICC laboratory is introduced as a tool for cyber-physical system modeling and simulation based on cellular automata. We will have a further research based on these information.

Key-words: Physical Simulation, Wireless Sensor Network, Cellular Automata (CA), Water Flow.

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1. Introduction

The value of water resource play an important role in development of countries so the issue of water resource become concern of our societies. However, flat geography such as Mekong Deltas River can be very complex with numerous water channel systems. The climate change impact these systems with several effects coming from the sea level rise and various perturbations of flow along the river.

Mekong River with 4800km is the greatest river in the Southeast Asia. It flows through six countries China, Myanmar, Laos, Thailand, Cambodia, and Vietnam. In Vietnam, Mekong River divides into nine branches (nine dragons) before draining into the Sea. Vietnam Mekong Delta (Fig. 1) is located in downstream. The climate is tropical monsoon and is influenced by both the southwest and northeast monsoons. It consist of the wet season from May to October and the dry season from November to April.

Vietnam Mekong Delta (VMD) makes up 39,000 km^2 in which agriculture and aquaculture occupy 24.000 km^2 [6]. Cultivation in the Delta is primarily floating rice and produce 50% of the nation's rice. Vietnam ranks the second largest rice exporter in the world. In addition, seafood production accounted for more 50% of the country. Although VMD plays a vital role in contributor the Vietnamese economy and its major problems is facing like flooding in the wet season, seawater intrusion and drought in the dry season.

In Mekong River Delta, floods usually occur from July to November and covers almost 50% of the Delta. Floods cause great impacts to economic development and to people's livelihoods. Three heavy floods in 2000, 2001 and 2002 [19] demonstrated that. Farmers harvest poor yields or crop losses; Moreover, floods also cause damage to crops and livestock can be drowned or washed away. Human life and property are affected such as house and infrastructure are under water, epidemic diseases such as marsh fever, dengue fever, and diarrhea also appeared when floods occurred. Casualties happened among the several hundreds of thousand people living for several weeks on water and a large number of the victims were children [17]. Public infrastructures like roads, houses, school, embankments, canals, bridge, and church can be under water and damage.

On the other hand, water shortages arise in the dry season, it leads to seawater intrusion and drought that occurred in Vietnam Mekong Delta. Seawater intrusion leads economic constraints and limit rice production. In VMD, there are approximately 1,000 km^2 of triple rice cropping, 10,000 km2 of double cropping [29]. However, the second, triple rice crop is affected in saline intrusion areas because they cannot be cultivated. Besides limiting rice production, seawater intrusion also impacts on fisheries.

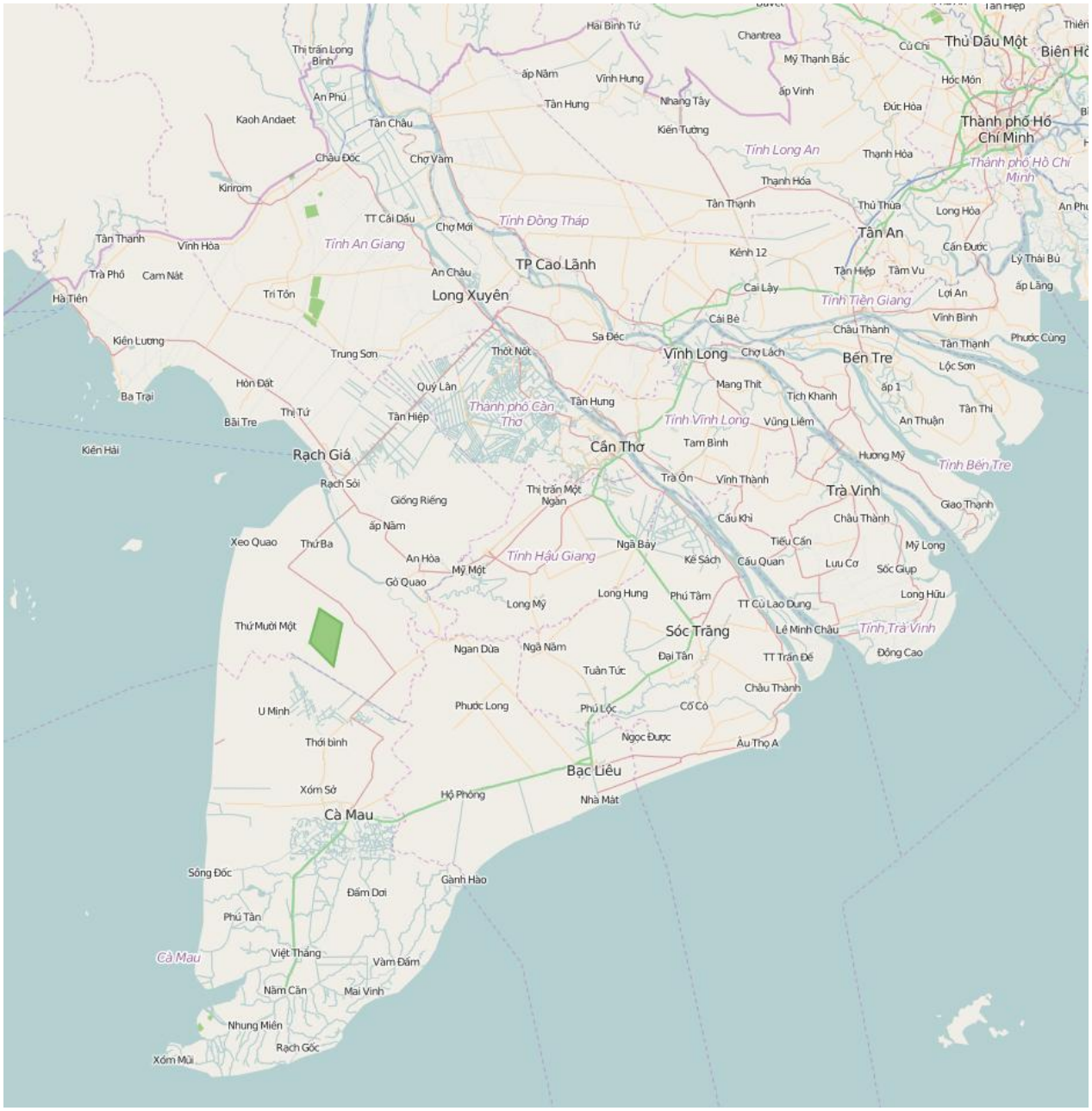

Figure 1. Vietnam Mekong Delta

Through a model is developed by the Quan Lo Phung Hiep Project [6], they installed 12 sluice gates on the major rivers and canals (Camau) connected to the East and West Seas to prevent seawater intrusion in Vietnam Mekong Delta. These gates open automatically on the ebb and close on the spring tide [6]. Achievement of this project, famers can cultivate two rice crops per year in saline intrusion areas behind the gates and the flow of freshwater from the Bassac River is increased in the dry season. However, this project caused a decrease in abundance-of natural fishery products in rivers and canals.

Drought is also a complex phenomenon like flood and seawater intrusion. It usually occurs in the dry season its impacts on agriculture are enormous so that it has become a concern

for farmers in Vietnam Mekong Delta. In agriculture, drought causes water shortages for rice crop production consequent in crop failure. Furthermore, water shortages also affected to human life. Drought in the period 2003–2005, Vietnamese Mekong Delta lost $60 million because more 10.000 ha of winter - spring rice is affected [15]. Drought in the Mekong Delta early 2016, according to estimates by the Ministry of Agriculture and Rural Development of Vietnam, around 160,000 hectares of rice were damaged and 800,000 tons of rice were lost [12].

These effects motivate scientists for researching and developing models to monitor and predict of phenomenon in water channel systems. Based on these models, simulation is a good solution to help people make better decisions so that they can prevent the impacts' climate change.

Around the middle of 1970s, SHE (Systeme Hydrologique Europeen) developed a physically-based distributed model for research about many hydrological problems [1]. Modeling water flow in such channels is a physical problem with a number of parameters [1] [3], as example shape and volume of the channels, shape of the grounds and elevations, rain, shore tides… In recent years, several researches about the hydrological process have built by using automata cellular and GIS knowledge. These research results can simulate the water flow on the Earth's surface. For example, [10] [14] Juraj Cirbus and Michal Podhoranyi used a CA (Moore neighborhood) and DEM input for simulating the spreading of liquid. In addition, coupling simple physical and semi-empirical rules of surface water motion and the cellular automata representation of spatial process, Jay A. Parsons and Mark A. Fonstad built a system to simulate unsteady flow in a cellular model of surface water flow [16].

Fortunately, data for simulations are presently coming from geographic representations (GIS), where rivers and channels are represented by their geometric side lines. Moreover, raw information is more and more precise, thanks to satellite, LIDAR, and ground sensor observations. The knowledge about rivers and related physical phenomena is also more and more precise. Efforts are developed to build more accurate measure and simulation systems, but recent events, such as Mandelieu and Paris, France, have shown the gap between technologies and risk management systems [2]: available predicting resources are not sufficient to manage future risks.

Lidar [11] (light detection and ranging) is an optical remote-sensing technique that uses laser light to densely sample the surface of the earth, producing highly accurate x,y,z measurements. The main advantage of LIDAR include collected data quickly with very high

accuracy both day and night. Moreover, topographic LIDAR can be used to derive surface models that is used in many applications such as forestry, hydrology, geomorphology, urban planning, landscape ecology, coastal engineering. With these advantages, LIDAR play an important role in collecting data for simulating water flow system in Vietnam Mekong Delta.

The internship investigates and studies water flow simulation systems interfacing geographic databases to produce cellular systems, plus distributed sensing architectures. The first part of the work will be to represent water flow using small geo-localized surfaces that can communicate by exchanging quantity of waters. The behavior of such systems should enable simulation of water circulation. In a second stage, we are interested to simulate control of channels with the perspective to temperate sea rise as well as river flow.

The rest of this report is organized as follows. In section 2 and section 3, we will present a brief background of the internship which includes, wireless sensor network and cellular automata. In section 4, the NetGen tools is given. We continue in section 5 by presenting Physical simulations based on cell system.

2. Wireless sensor network:

A wireless sensor network (WSN) is used in many projects to monitor physical or environmental conditions by using sensors [13]. The WSN is built by a set of nodes where each node is connected to one or several sensors. These sensors play roles to collect information of physical systems and cooperatively send it through the network to computer systems for analyzing and processing. Moreover, sensor activities can be control through networks.

Figure 2 is considered as an example wireless sensor network for motoring water flow system in the river. Sensors are used to monitor physical or environmental conditions. Then sensors pass data to computer systems for perform computations and simulation. Next, its results will be analyzed and help users make decision like send emergency announce to users.

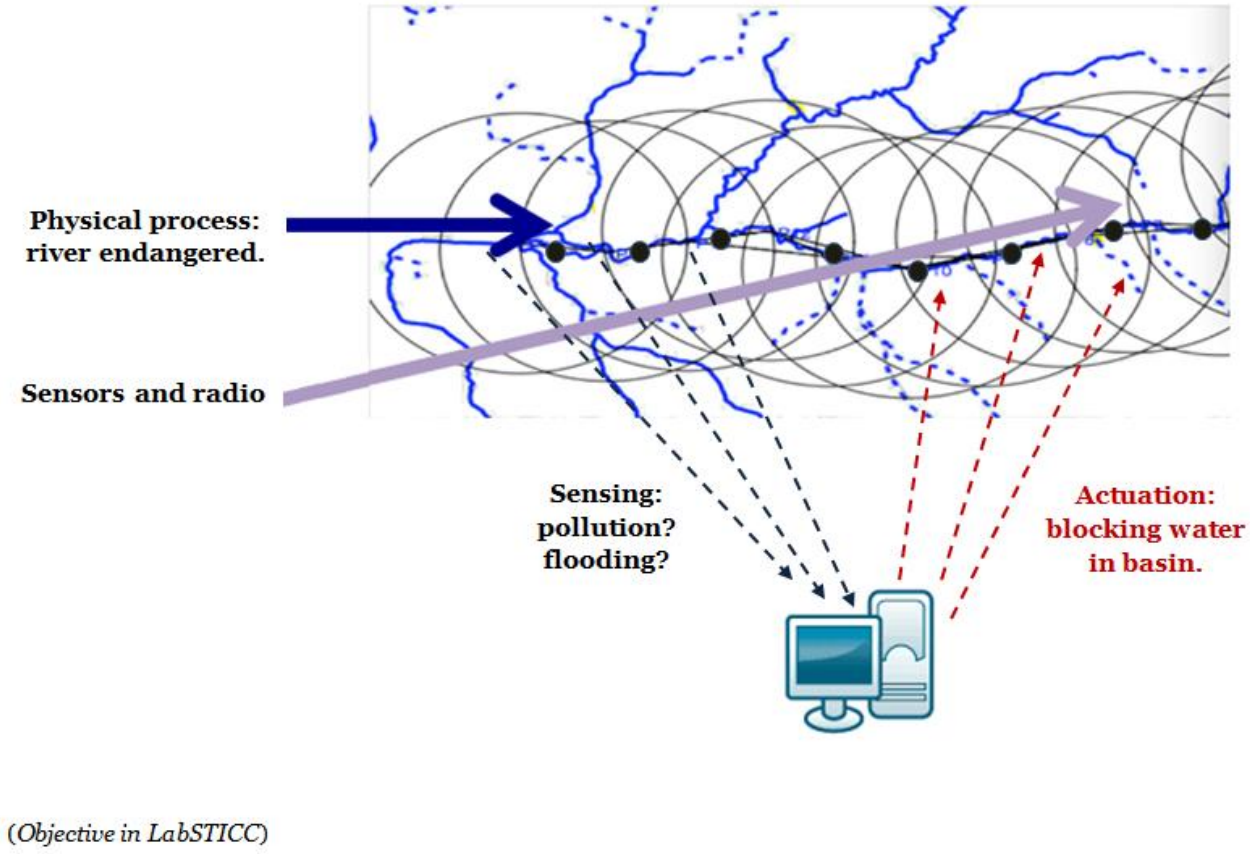

Figure 2: Wireless Sensor Network

3. Cellular Automata:

The concept of Cellular Automata (CA) was introduced in the 1940s by Stanislaw Ulam and John Von then CA becomes a popular technique that is used to simulation complex physical systems such as reaction diffusion, modeling of hydro dynamical systems, model different chemical processes, and self-reproduction in biology [8] [9] [10]. In addition, CA is used for Parallel Computing, VLSI Design, Pattern Recognition, and Games [20] like "Game of Life".

A Cellular Automata consists of four primary components. The first components is grid that is a set of cells. Secondly, a set of cell states, each cell belong to one of cell states. Thirdly, a cell has one or a set of neighborhoods around that is defined as an area of influence. Finally, state of cell at time t+1 is determined by a transition rule based on its current state and the states of its neighborhoods at time t.

There are three types of neighborhood that is commonly used in simulation systems like Von Neumann, Moore, and Hexagonal. The Von Neumann neighborhood (Fig 3-a) has four adjacent cells including the east, west, north and south directions. In Moore neighborhood (Fig 3-b) consists of a central cell and the eight cells are neighborhood. In a hexagonal

lattice (Fig 3-c) is composed of a central cell and six nearest neighbors. However, the Moore, Hexagonal neighborhood it is more appropriate to apply in the field of hydrology.

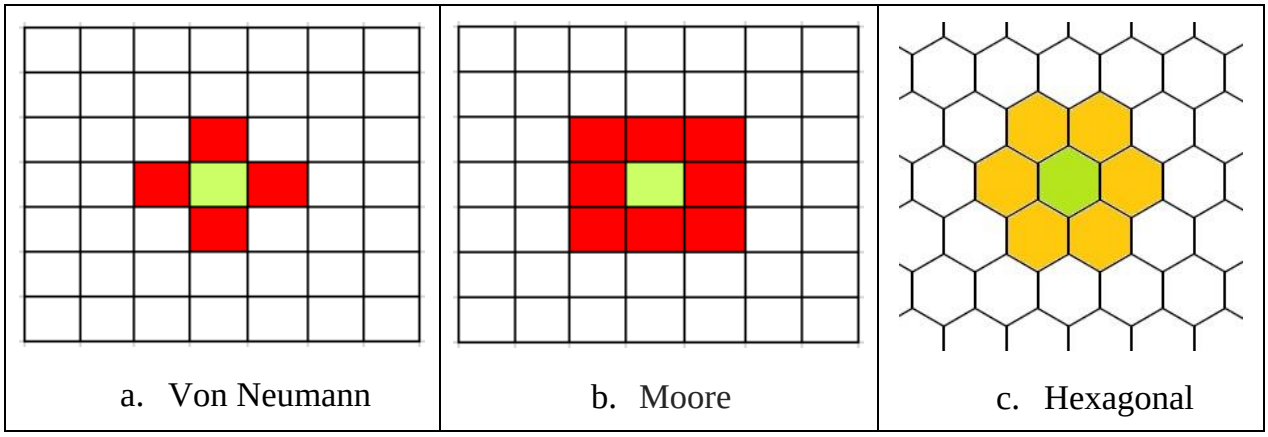

Figure 3: a. Von Neumann, b. Moore, c. Hexagonal neighborhood.

Cellular automata is considered as a tool for supporting to build simulation systems and predicting of behaviors in real systems and natural phenomena. The main advantage of cellular automata in simulating physical systems is based on transition rules that are simpler than mathematical equations.

In the next section, NetGen tools is developed in Lab-STICC laboratory to automatically generate the cellular system from geographic data for supporting to simulate physical system based on CA.

4. NetGen tools:

NetGen is a general tool for cyber-physical system modeling and simulation based on cellular automata [7]. It is a set tool flow (QuickMap, PickCell, NetGen) that are developed at Lab-STICC, UBO, France. The NetGen is used for building networks abstractions appearing as graphs, including nodes representing actual systems, edges representing communication links between nodes. This tools provides function which allow to access geographic data like GoogleMap and OpenStreetMap. It then allows to analyze, process of a geographical zone and generate automatically to the simulation code. Tool flow combine three main steps:

Firstly, QuickMap (Fig 4) plays a role as browser that enable to select tile systems, geographic position, and zooming factor. In addition, it also allows to place sensors in map.

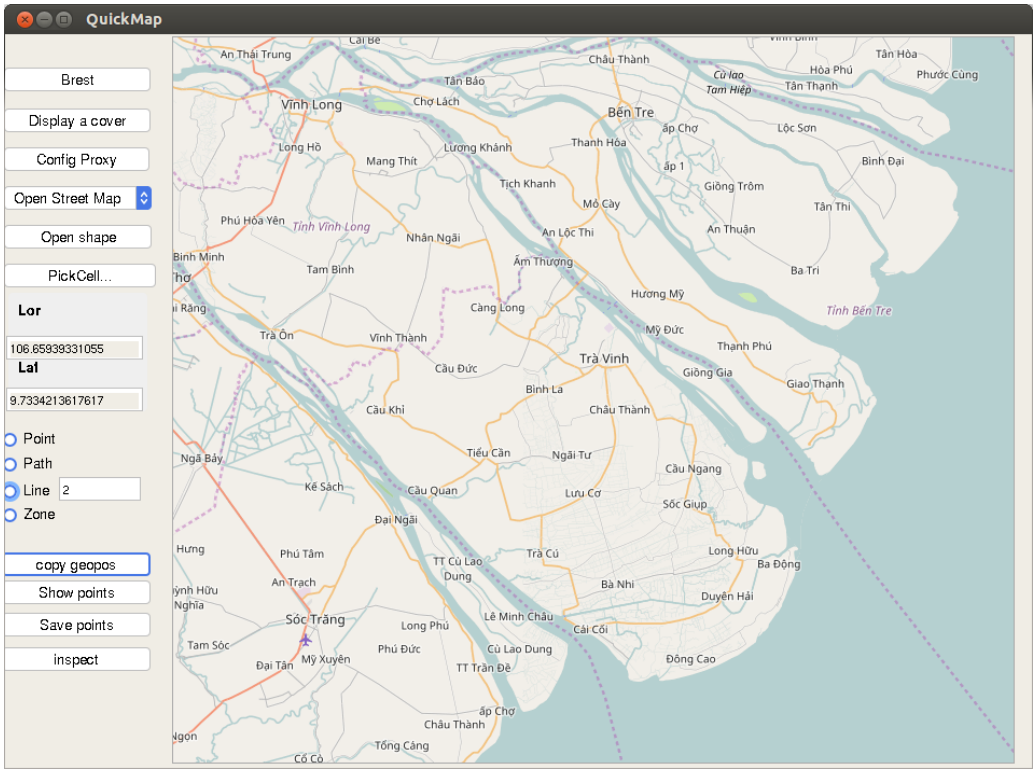

Figure 4. Quickmap displaying a map of Vietnam Mekong Delta

Secondly, Pickcell (Fig.5) could be used to divide an image into rectangle cells size(x, y). The value of parameter x and y (counted in pixels) show the width and the height of cells, respectively. Depend on the model objective, parameter x and y will be chosen high or low.

Thirdly, NetGen (Fig. 6) can produce automatically Occam or CUDA code for simulation a physical phenomenon based on cellular method.

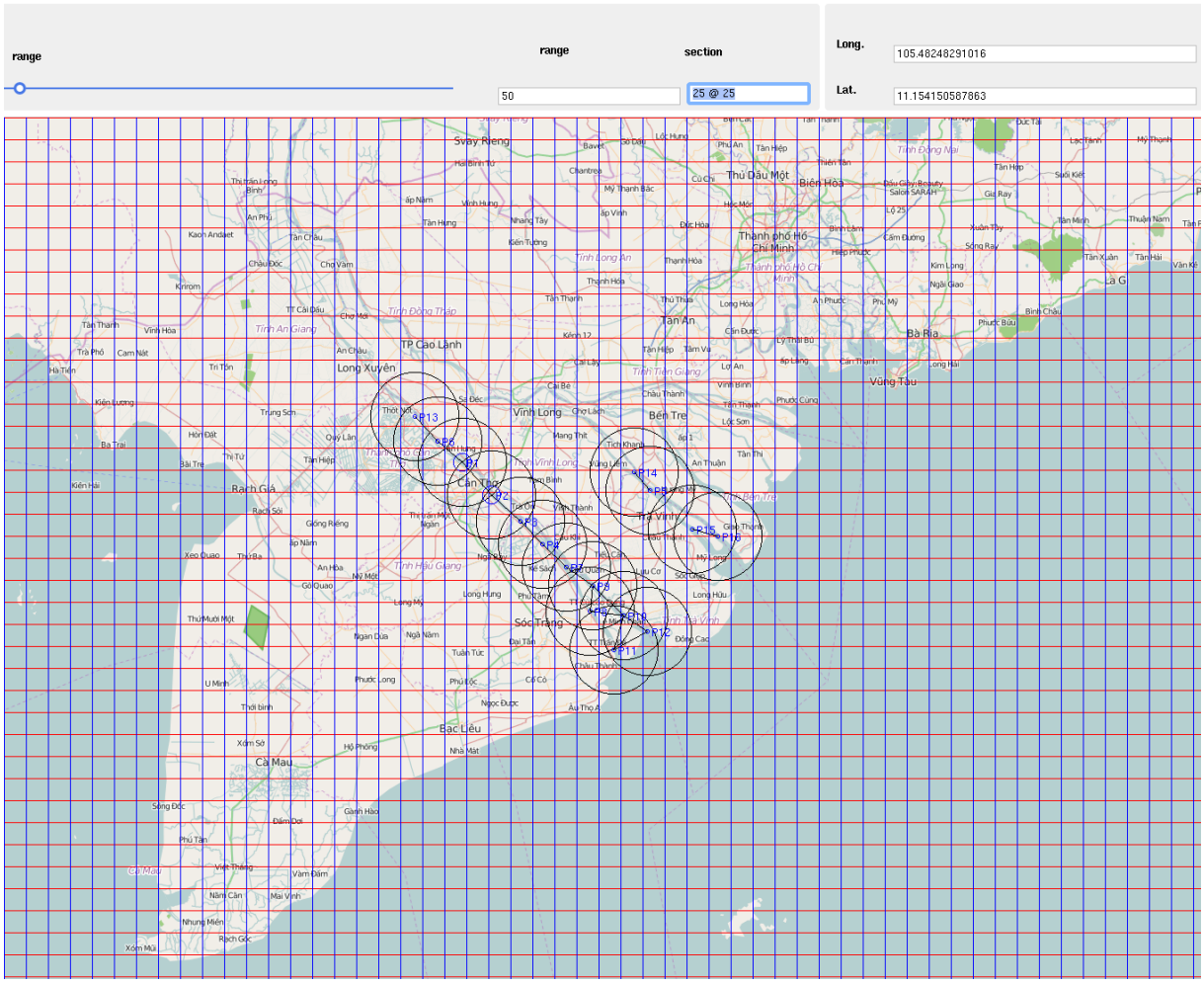

Figure 5. PickCell

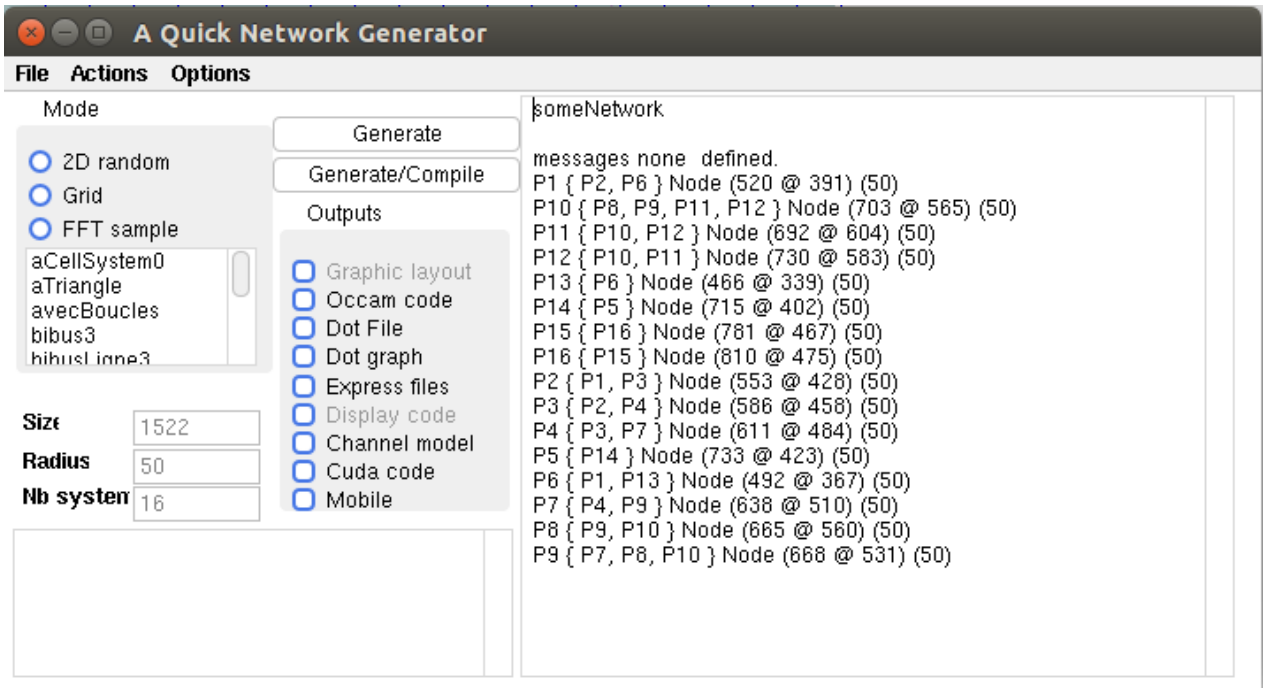

Figure 6. A Quick Network Generator

5. Physical simulations based on cell system:

Pickcell allows to generate cell systems for supporting to simulate physical phenomenon. A cell system is a set of cells. Each cell includes three properties: identity, state of cell and relationship to other cells considering as its neighbors. The neighbors of a cell can be define by cellular automata like the Von Neumann neighborhood and the Moore neighborhood.

To simulate physical phenomenon based on cell system, model is integrated three main components: cell system, input data, and transition rules. The two last components are defined based on the characteristics of physical systems. The process is depicted in figure 6. Firstly, from geographic data, PickCell tool generates cell system, NetGen generate simulation code with two version codes Occam and Cuda. Then, it combines with input data and transition rules to run physical simulation.

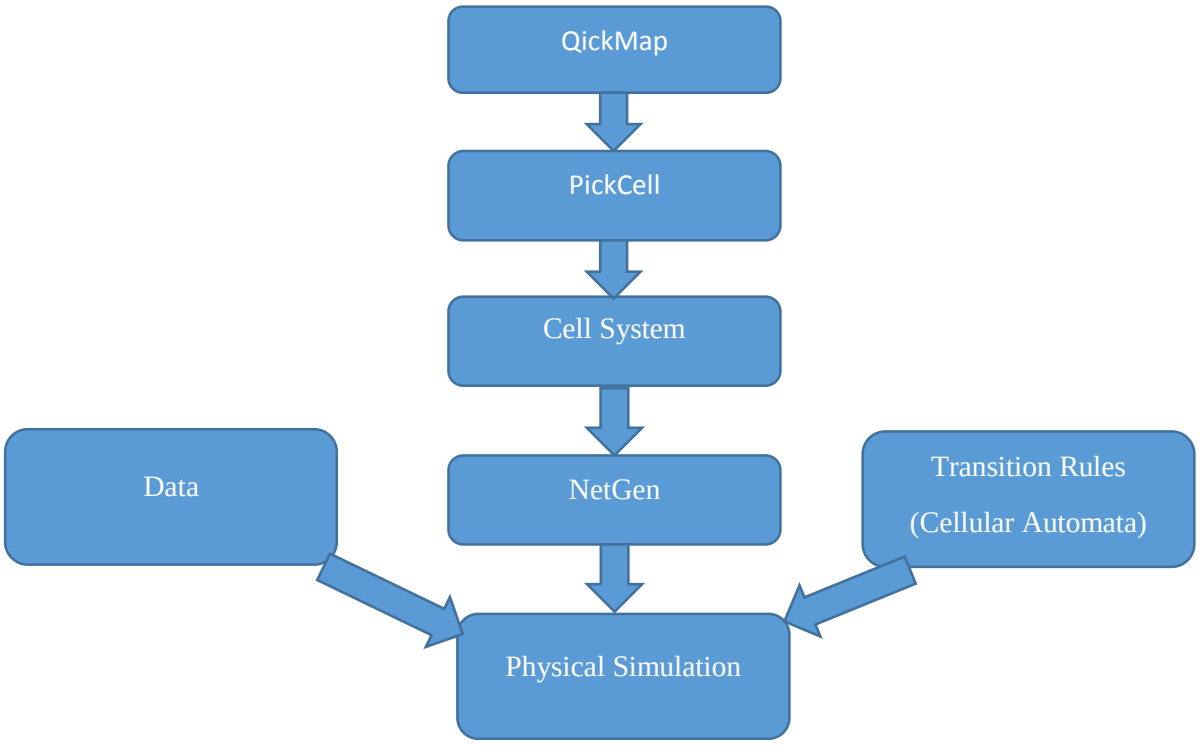

Figure 6: A process of physical simulations.

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