Master research Internship

Bibliographic report

Modeling and simulation from marine information

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Abstract

Collecting marine information is currently investigated using floats that are set up in some oceanic position and will be carried by ocean currents. These floats can sink and collect several kinds of information that have physical interest, biological interest, or represent information on ecosystem. Floats can connect to satellite and send that information to orbiters to be stored in databases. This study will report on the project E-AIMS and Argo on various angles: float capabilities, sensors, float behavior in the ocean, accuracy, failures and live time. It will also report on parameter relation between different float options, and inference of knowledge attempted on such systems. We propose to represent, then connect float and cellular simulation together in view of checking cellular interpretation for simple problem such as agreement on tide direction.

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1 Introduction

As global warming continuously happens, extreme weather events occur more often and cause loss of damages. Each year, sea level is rising at a rate of 3mm; area of ice cover in artic sea is shrinking. It is also causing the ocean to create more floods, take over part of the land and beaches. To make those predictions or reduce loss of live and property, environment surveillances become necessary, especial ocean monitoring system.

For ocean monitoring, a European project has been operational which was named E-AIMS [1]. With 16 years of operation, E-AIMS has contributed to global project Argo and both provided a lot of ocean data for worldwide users. Argo has been successful in its mission providing useful information for predicting and reducing the damage of climate change, marine environment monitoring, weather forecasting, maritime safety and pollution forecasting, fisheries management and coastal and shelf-sea forecasting, and ecosystem research.

1.1 Motivations

As progressing, new challenges has arrived since the number floats are increasing to thousands with different location and function ability. Recently, there is a great deal of the unobserved ocean (see in [2] and figure 1), particularly in Southern Ocean (the ocean south of 30° S). Since the mean depth of the ocean is about 4267 m, but most of floats can only work at immersion of 2000m. The deep floats are being researched and tested. Due to higher technology, cost of deep floats are much higher than original floats. The Euro-Argo data centers, satellites and data transmission need also to be upgraded to handle deep floats. New type of satellite or even an orbit information of new satellite should be considered when launching new satellite is necessary. The challenges of deep float's position are similar to satellite issue where many of active original floats are out there.

1.2 Objectives

This study will report on the project E-AIMS and Argo on various angles: float capabilities, sensors, float behavior in the ocean, accuracy, failures and live time. It will also report on parameter relation between different float options, and inference of knowledge attempted on such systems.

LabSTICC has developed tools to manage physical modelling, sensor networks and mobiles. The physical simulation orientation is to break geography into cells of arbitrary size, to produce parallel simulators binding cells together according to the cellular automata paradigm. Sensor networks are separate but compatible systems that can communicate with the cellular systems using a federation mechanism.

If a GPU is used, both the organizations are produced automatically, and mobiles can be implemented in these systems by changing dynamically connectivity in shared memory.

We propose to represent, then connect float and cellular simulation together in view of checking cellular interpretation for simple problem such as agreement on tide direction.

The Bibliographic report is divided into six chapters:

Chapter 1: Introduction to the motivations and objective of the study is illustrated.

Chapter 2: Project E-AIMS and Argo are introduced. Detail information of floats, sensors, satellite communication, Argo data system and Argo data processing are also presented.

Chapter 3: State of the art modeling

Chapter 4: Illustration of LabSTICC's tool

Chapter 5: References

2 Project E-AIMS and Argo

E-AIMS: Euro-Argo Improvements for the Global Monitoring for Environment and Security (GMES) Marine Service. The overall objective of the project is contribution of European to the international Argo observing system.

The international project Argo is a part of the Global Climate Observing System/Global Ocean Observing System (GCOS /GOOS), which aim to collect data of marine for observing and researching. The initial target of the ARGO program was a data coverage of 1 float per 3x3° grid cell and month over the global ocean. This data coverage is deemed to be sufficient to resolve many of the important global climate signals and support the enhanced real-time requirements of operational modeling applications in oceanography and meteorology. From 1999 to 2017, there are approximately 3739 active floats in many areas of ice-free global ocean under intermediate depths. These floats are maintained every year; float enduring and float reliability has also been improved. Thanks to these floats, temperature, salinity, and velocity of the upper ocean could be monitored continuously; Data from sensor on float could be available to be published a within short time after recording.

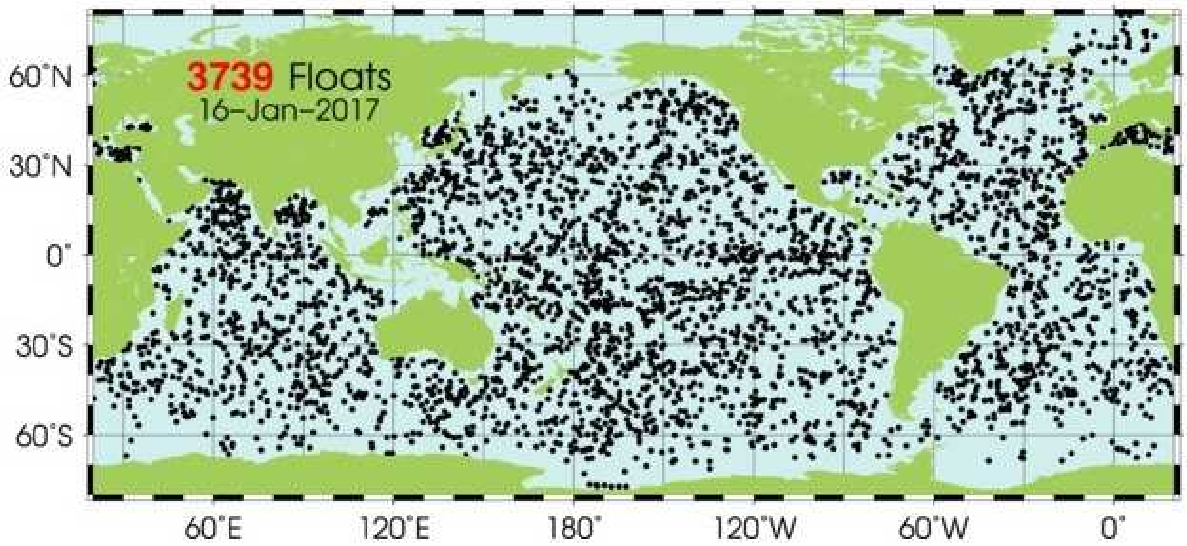

Figure 1: Argo float network

The Argo float distribution reveals that the network density nearly meets the initial target through the conscientious efforts of all involved partners. However, at present time some parts of the global array are already over-sampled while others are still under-sampled. There exists a marked northern hemisphere bias in data coverage while the Southern Ocean is still lacking data.

2.1 Floats

Argo float is an aluminum float attached some sensors and an antenna. Float weight varies from 20 kg to 34 kg, depending on number of attached sensors and float type. Argo floats have a lifetime of about 5 - 7 years and can be programmed before deploying from a research ship or even from a plane. A ten days' cycle of float, can be divided into two phases:

- At first, float is deployed on the ocean surface. After sinking down to 1000m – 1500m, it drifts along with the ocean currents for 8 – 10 days. On the last day, float changes its buoyancy to go deeper.
- When reaching immersion of 2000m, float rises to the ocean surface with data recorded. A communication with satellite will be established for data transmission.

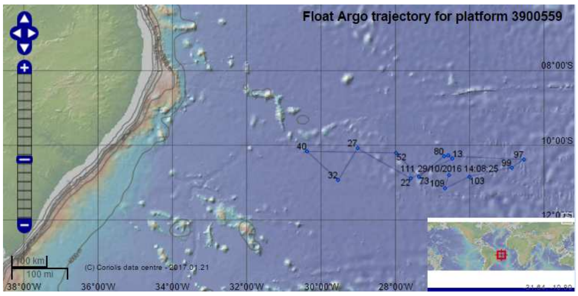

Figure 2: Float Argo trajectory

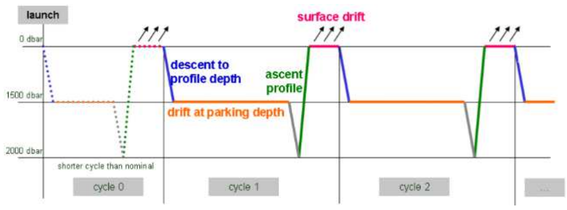

Figure 3: Float cycles

The Argo program is currently comprised of several float models:

- **The PROVOR** (2005) and the **ARVOR** (2008) (the new generation of PROVOR) are built by the two French companíe, NKE-INSTRUMENTATION and IFREMER. ARVOR is lighter and easier to deploy; it has **wireless connectivity** using **Bluetooth** for configuration and testing before start a mission.
- **The APEX** built by Teledyne Webb Research, 65% of the global ARGO floats are APEX floats (as of February 2008).
- **The SOLO** and the **SOLO-II** are designed and produced by Scripps Institution of Oceanography.
- **The NEMO-Float,** developed by the Navigating European Marine Observer (NEMO), can be deployed under ice and integrated new nitrate and oxygen sensors**.**
- **The S2A** is a rebranded name of SOLO-II, which was bought by American company MRV Systems.
- **The NAVIS** created by American company Sea-Bird.
- **The DEEP-ARVOR** float prototype, designed by IFREMER in May 2013, is used for collecting data at 4000 meters' depth or more.

2.2 Sensors

2.2.1 Conductivity, Temperature, and Depth (CTD) sensors

CTD is a measurement of temperature, salinity, and density of seawater. Base on this physical parameters, scientist can understand the distribution and abundance of species in specific region in the ocean. In addition, scientist can infer knowledge of particular biological process or alert abnormal occurrence from data of CTD sensors. Argo use Sea-bird SBE41CP sensors for PROVOR floats and SBE41 CTD sensor for APEX floats. The **brief specifications for both sensors** are:

	Pressure	Salinity	Temperature
range	0-2500 dBar	2 to 42 PSU	-2°C to +35°C
initial accuracy	2,4 dBar	3 mPSU	2 m°C
resolution	0.1 dBar	1mPSU	1 m°C
drift	< 5 dBar / 5 year	10 mPSU / 5 year	2 m°C / 5 year
transmitted range	0-2500 dbar	10 to 42 psu	-2 to 30°C
transmitted resolution	1 dbar	0.001 psu 15 bits	0.001 °C

Table 1: Argo CTD sensor specification

Because Argo floats drift in different trends, different direction and different depth (0-2000m), a comparison of nearby floats data and ship-base data should be considered to reduce inaccuracy value.

2.2.2 Dissolved Oxygen sensors

Dissolved Oxygen measurement can provide knowledge of both **physical** and **biogeochemical process**. There are two different sensor types using on Argo floats, **Seabird electrochemical sensor** and **Aanderaa Optode 3830**. The response times and initial accuracy of the Seabird sensors are evaluated better than Aanderaa Optode. However, the long-term stability, the ability to measure in low O2 concentrations, and the robustness of Seabird sensors cannot surpass Aanderaa Optode. The brief specifications of **Aanderaa optode 3830** are:

- The sensor accuracy is ±5 % or ±8 µM
- 90 % response time is around 40 seconds.
- The optode is switched on during 2 seconds, and off 8 seconds.
- Measurement is done every CTD sample (10 seconds).

2.3 Satellite Communication

2.3.1 Argos satellite system

The majority of the Argo float data are transmitted via the Argos System. The Argo System is a satellite-based system which collects, processes and disseminates environmental data to worldwide. Floats' transmitting-positions are accurate to ~100m depending on the number of satellites within range and the geometry of their distribution.

The communication of Argo floats and satellite system can be described in 5 phases:

- The platforms send data to the satellite.
- The orbiting satellites receive data.
- The ground antennas relay data from satellites to processing centers.
- Processing centers collect, process and distribute data to Argo users.
- Global users retrieve data via many ways (Internet, email, fax, or CD-ROMs).

	levels of CTD sensors	surface-time requirement	Type of communication	Other Ability

Argos-2	100	6-12hr	one-way	
Argos-3	1000	5-11hr	two-way	- improve transmission efficiency - float re-programmation

Table 2: Comparison of Argos System 2 and Argos System 3

2.3.2 The Iridium System

A few of Argo floats are using the newer Iridium satellite constellation. The **Iridium satellite constellation** is a large group of satellites providing voice and data coverage to satellite phones, pagers and integrated transceivers over Earth's entire surface. The Iridium system have significant advantages in data transmission time. It is takes only 3 minutes at the sea surface for **an Iridium float** to send data. Due to short time tracking the movements of the floats, surface currents properties cannot be observed.

2.4 Argo Data System

2.4.1 Platform Transmitter Terminal (PTT)

Platform, an equipment which integrating Argos-certified transmitter, is in charge of uploading short time message to a satellite at altitude of 850km. Powered by batteries or solar energy, each platform has an identification number. Platform transmits periodic messages have transmission frequency of 401.650 MHz (± 30 kHz), computable measurements of Doppler effect. Message's interval between two consecutive message dispatches, varies from 90 to 200 seconds, depending on platform type, platform identification number, and size of data. Usually, it takes less than one second to transmit a message.

2.4.2 Receiving stations

There are roughly 70 stations for receiving real time data from the satellites and retransmitting them to processing centers. With those stations, the distribution network ensures worldwide coverage for data transmission. if the station locates within satellite's range, satellite will transmit received data to that stations in real time. The main receiving stations also receive data in real time.

Figure 4: Argo station

2.4.3 Argo Data System

The international Argo Data System is based on two Global Data Assembly Centers (GDAC), a series of 11 national Data Assembly Centers (DAC) and several Argo Regional Centers (ARC). Function of these centers are defined as follow:

- GDACs, located at Coriolis/France and FNMOC/USA, collect processed data from 11 DAC and provide to users as NETCDF format via FTP and WWW. The two GDACs synchronize their database every day.
- DACs, receive the data from the satellite operators, decode and real time test as standard of international Argo program. Errors data are flagged, corrected and sent to the two GDACs, to the World Meteorological Organization (WMO) and Global Telecommunication System (GTS).
- ARCs provide wide expertise on specific geographical ocean regions in order to provide the most comprehensive data sets (including non-Argo data) of the highest quality.

2.5 Data Processing

2.5.1 Accuracy of Argo data

- The temperatures in the Argo profiles are accurate to ± 0.002°C
- The pressures in Argo profiles are accurate to ± 2.4dbar.
- For salinity, the data delivered in real time are sometimes affected by sensor drift [8]. If the drift of floats is small, the uncorrected salinities are accurate to ± .01psu. Otherwise, salinities are corrected in delayed-mode by expert examination, comparing older floats with newly deployed instruments and with ship-based data. in most cases, the data become good enough to detect subtle ocean change.

The estimated accuracy of the delayed mode quality controlled salinity can be found in the PSAL_ADJUSTED_ERROR fields in the D profile files. If the salinity is found to be questionable even after delayed mode adjustment, the error and the qc flag are adjusted to higher than usual to make users aware of this. Therefore, users should use the *_ADJUSTED_ERROR and *_ADJUSTED_QC fields in the profile files to filter the data set to remove less accurate measurements. In general, data that are considered bad and un-adjustable are marked with a qc flag of '3' or '4'. These bad data should not be used in any scientific applications.

2.5.2 Oxygen sensors and other additional sensors data

All merged profile names, date, latitude, longitude, ocean, profiler type, institution, ocean state parameters such as TEMP, PRES, DOXY, etc., are available in the file argo_merge-profile_index.txt which available on the Argo GDAC ftp. However, ‘additional sensor’ data are not Argo’s mission, thus those data have undergone quality control [9] and may require the user to do.

2.5.3 Argo data file

The V3.1 profile files will be split into **trajectory** files, **Core-Argo** files, **B-Argo profile** files and **M-Argo profile** [10] files.

- The trajectory files have been modified to include more information about the events during a cycle and the times associated with these events. There are two-file system for trajectory files, **Real Time (R)** and **Delayed Mode (D)** trajectory files. R files, created by DACs, contain only real time data. D files, created by the scientist responsible for the float, contain both real time and delayed mode data. It is possible that a float may have both an R and a D trajectory file, so user must look at both files to get the entire trajectory information for that float.

- The parameters included in a **Core-Argo** file will be pressure, temperature, salinity, and perhaps, conductivity. Additional parameters from other sensors are stored in a B-Argo profile file.
- The **B-files** will include any Argo parameter except temperature, salinity and, if applicable, conductivity. They will also include any intermediate parameters that are necessary to calculating ocean state parameters. A float that performs only CTD measurements will not have B-Argo files
- The **M-files**, where "M" means merged, will contain all ocean state variables that a float measures. Examples of additional ocean state parameters that might be present in an M- file are DOXY, CHLA, etc. This file will be a combination of the core parameters and any other ocean state parameters found in the B-file.

2.5.4 Retrieve specific time and location data

Both Global Data Assembly Centers (GDACs) offer ways to search for data in a specific time and location and then download that data.

- The US GDAC has a GUI data browser that allows user to download trajectory files in NetCDF format. User can use date, location, DAC, real or delayed mode data and float ID as search criteria.
- The Coriolis GDAC also provide a data selection page for user to find Argo profile or trajectory data using date, location, real or delayed mode data, float ID and data type as search criteria. Request file can be in NetCDF or ASCII.

If user wants to keep data locally. There is an index file for profile files, trajectory files and meta files. Each index file has one line for each Argo file that exists along with metadata about time, location, DAC, etc. The index files can be found on the FTP sites at both GDACs: **Coriolis** and **Global Ocean Data Assimilation Experiment (GODAE)**.

Argo Technical Coordinator (argo.kml) has developed a Google Earth layer which help user tracking latest position of active and inactive Argo floats. By using this way, float's trajectory and float locating are much more simple.

3 State of the art modelling

3.1 Cyber Physical System

Cyber-Physical Systems (CPS) are integration of physical processes, software and networking, providing abstractions and modeling, design, and analysis techniques physical phenomenon. Most of CPS application are sensor-based communication-enabled autonomous systems [4].

3.2 Wireless Sensor Networks (WSN)

A sensor network provides an infrastructure for sensing, computing, and communication, for observing and reacting to events and environment phenomena. Usually, these sensors are low-cost, small in size and short-distance untethered communication devices [5]. WSN are known to solve practical problems in emergency and environment monitoring.

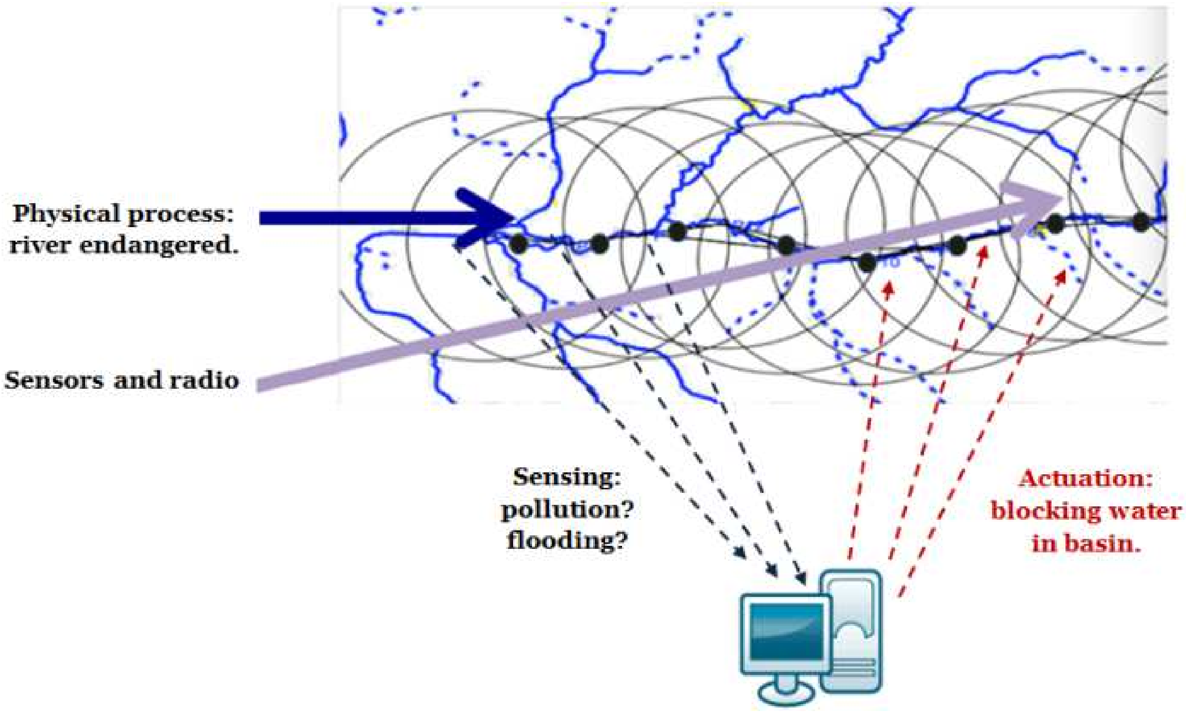

Figure 5: Sensor Network monitoring status of river

Sensor network can monitor status of river by observing water in the river and sending data to computer system. When receiving data, computer system analyze data, does computation and giving decision for blocking water in basin whenever dangerous event occurred.

3.3 Cellular Automata

Cellular Automata (CA) is a discrete, abstract model which mimic the self-reproduction ability in biology. This become one preferred technique for simulating physical system thank to its simplicity but effectiveness. CA consists of a grid of cells and a set of fixed transition rules. Each cell has a finite number of states and a set of neighbors. The number of neighbors depend on grid's dimension and model of adjacent cells. In two dimensional grid, there are two common pattern of neighbor, the Von Neumann neighborhood pattern and the Moore neighborhood pattern. For Von Neumann neighborhood pattern, each cell has 4 neighborhoods North (N), East (E), South (S), and West (W). And for the Moore neighborhood pattern, each cell has 8 neighborhoods, North (N), East (E), South (S), West (W), North-West (nw), North-East (ne), South-West (sw), and South-East (se). The transition rules, can be consider mathematic function, is the rule for updating the state of neighborhood. Usually, the interval is 1-time step and distance of each cell and its neighborhood is also 1. When time goes by, neighborhood states will be determined by state of cell (at time t) and appropriate transition rules for cell neighborhoods (at time +1).

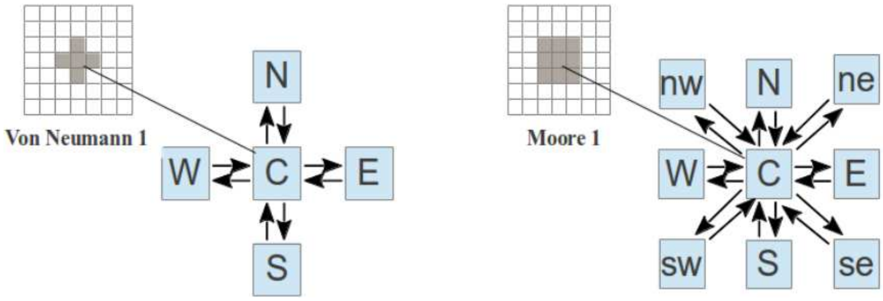

Figure 6: Von Neumann and Moore neighbourhood (distance = 1)

3.4 Numerical modeling

The CA model of UNDATA [11] bases on a numerical method for simulating electromagnetic fields, which is use Transmission Line Matrix or Transmission Line Modelling (TLM) [12]. The TLM is a numerical method which translate incident pulses into state of CA. SCIDDICA-SS2 [13] [14] is CA with support hexagonal cells. The tool is usually used for simulation landslides, surface erosion and changes of water transition.

4 LabSTICC Tool

4.1 PickCell tool

PickCell, developed in Lab-STICC, is a modeling tool which can access to public geographical data such as GoogleMap, OpenStreetMap or event picture files. These data will be used for analyzing, processing and generating cell network of physical phenomenon.

From input data, the tool could extract interesting geographic properties and separate physical systems as group of cell network. Data are divided into small cells depend on model size and data size. Each cell has two coordinal (x, y) which x and y are parameter of width and height of cells.

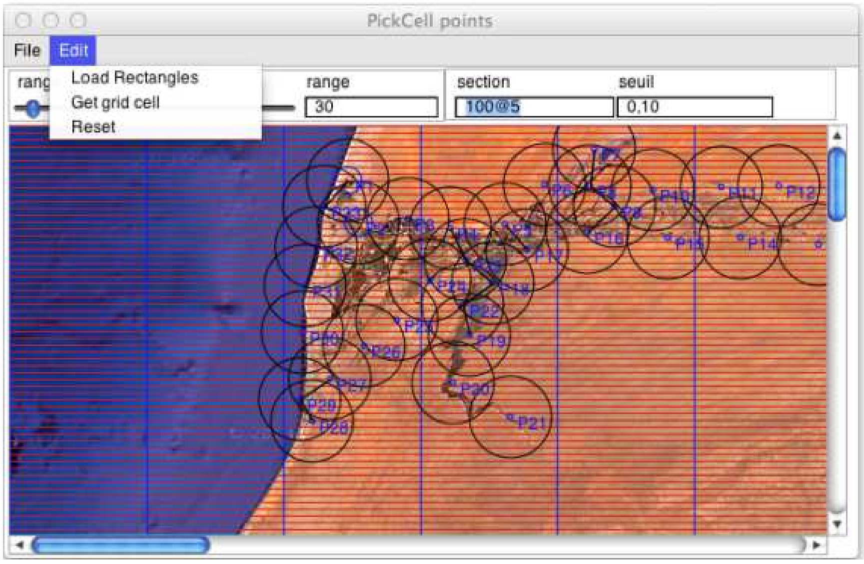

Figure 7: PickCell

Cell network produced by PickCell has four characteristic: identity, local state, cell links and relative positions to neighbors. The identity is for identifying cell, each cell will have different identify. Local state of each cell represent state of physical issue for example pollution density, insect population, bio-properties, or even ocean state. Cell links determine the relationship of each cell and its neighbor. Relative position is a mathematic function for selecting cell neighbor. There is option for choosing pattern of neighbor (Von Neumann and Moore).

4.2 Physical simulations based on cell networks

The cell network can be produced by PickCell. However, a full model is required three components: cell network, input data and transition rule. The second and third component are related to specific physical system which transition rules can be defined as CA rule. By applying these transition rules, input data will generate states for its neighbor and contribute to complete system.

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