Simulation of marine activities by coupling Geographical Information System and Agent Based Model: improvements and technical achievements

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Abstract

This short paper presents an example of integration between open source Geographical Information System (GIS) and Agent Based Model (ABM) in order to better simulate fishing activities on Iroise Sea (Brittany, France). This work makes part of the SIMARIS project: a simulation prototype that integrate multi-source and multi-scale spatiotemporal constraints as forcing variable in order to assess the intensity and the variability of marine activities. A pre-processing step, executed in batch in GRASS GIS, aims to calculate data for initialization and simulation step, then the Agent Based simulation is launched (in batch) on GAMA platform. All these operations are scheduled in a Python script to perform pre-processing and simulation. The work presents an example of integration from a geographical point of view. The technical improvements are detailed and the potentials of such integrated solution are discussed.

Introduction

Running a simulation requires to describe the behavior of elements involved in the model. ABM are born with the aim to interpret and execute a list of command able to model at best this behavior (Ferber, 1999). At technical level, if the model requires to interact with geographical object and handling maps, few of available Agent Based platforms can perform the simulation. While some tools exist, integrating GIS data for ABM is still a difficult process (Crooks, 2012). In fact, handling geographical data is a matter of Geographical Information Systems and even if recent development in Agent Based modelling have begun to implement some GIS functionalities some spatial analysis operations remain purely geographical and, in our opinion, should be better performed by a Geographical Information System without involving the Agent Based platform.

To take full advantage of GIS and ABM we believe that close coupling is a good way to perform the integration of multi-scale geographical data in ABM.

In the past, the integration between GIS and ABM represented an opportunity for GIS to integrate temporal variables into a plain geographical analysis (Batty & Jiang, 1999; Gonçalves et al. 2004). But since spatio-temporal representation is no more a limitation in spatial analysis (Gebbert & Pebesma, 2014), the improvements coming from GIS and ABM coupling is mainly tied to the execution of actions involving agents (intelligent entities) and a spatio-temporal process at the same time.

If different levels of interaction between GIS and ABM are possible, ideally, the best situation is to have a library which allows to call single functionalities of GIS into a simulation and/or *vice versa*. In this paper an example of "indirect cooperative coupling" (as defined by Karadimas et al., 2006) is presented, where both GIS functionalities and simulation are called by another (external) programming environment, written in Python.

Materials and methods

The SIMARIS model

The simulation model we are going to integrate with GIS is SIMARIS model (Tissot & Le Tixerant, 2008).

SIMARIS is a framework designed to describe human activities and their spatio-temporal distribution, modelled as responsive agents constrained by exogenous variables (biophysical, socioeconomic and regulatory constraints). The model is multiscale and multilevel. It allows different levels and types of analysis according to the chosen spatio-temporal extent. In particular, the model automatically sets the spatio-temporal granularity, the analysis and the outputs starting from a specific spatio-temporal scale defined by the user. This requires preliminary geographical operations to execute on input data in order to provide the right simulation environment. Until now, only fishing activities are considered, but the final aim is to integrate different activities in order to assess pressure and possible conflict zones on a marine protected area.

GAMA platform and GRASS GIS

The SIMARIS model is implemented on GAMA (GIS Agent-Based modeling Architecture, Grignard, 2013) which is a "modeling and simulation development environment for building spatially explicit agent-based simulations" (https://github.com/gama-platform/gama/wiki). GAMA is particularly interesting for our case study because in its architecture different operations can be performed at different spatio-temporal scales. For example, the simulation king-scallop fishing activity on a specific fishing zone over a period of a week will be considered as one computing process level. If the issue is to assess the fishing balance for all type of fishing activities over an entire fishing period, the spatio-temporal resolution would change as well. GAMA platform provides an infrastructure based on “agents” and “superagents” which allows the heritage of basic characteristics from a generic species (fishing boat) to a more specific one (king-scallop fishing boat) but also allows independency on specific agent’s actions. Moreover it allows the aggregation of output data between different analysis levels and it is able to manage georeferenced data.

In this work, the chosen GIS environment is GRASS (Neteler & Mitasova, 2013). GRASS is the leading open source software for geographical information analysis and research. Since it is open source a lot of different tools operating in different topics are implemented and made available for all the users. For SIMARIS the main advantage is the ability to call each single GRASS command/tool by bash. This means that an entire geoprocessing operations can be done without initializing the GIS graphical environment. Moreover the process can be easily automatized and coupled with the ABM by using a third code, written in Python.

Procedure description and sample run

The entire procedure is briefly summarized by the flowchart in Figure 1.

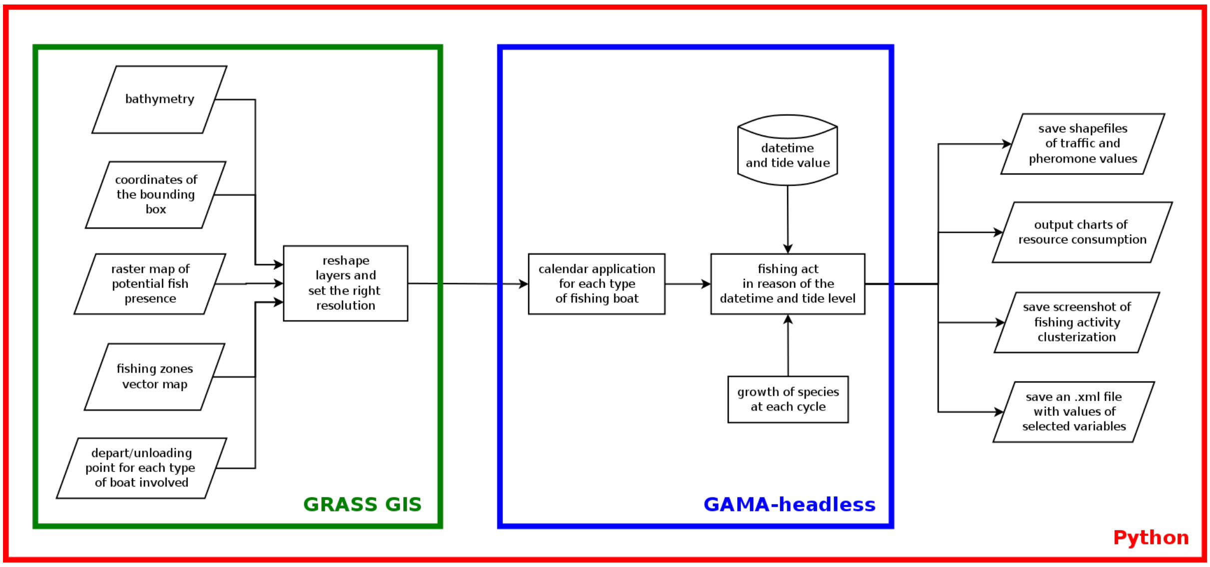


Figure 1. The Python procedure, which involves preliminary geographical operations (executed in GRASS GIS), the GAMA simulation and the restitution of outputs.

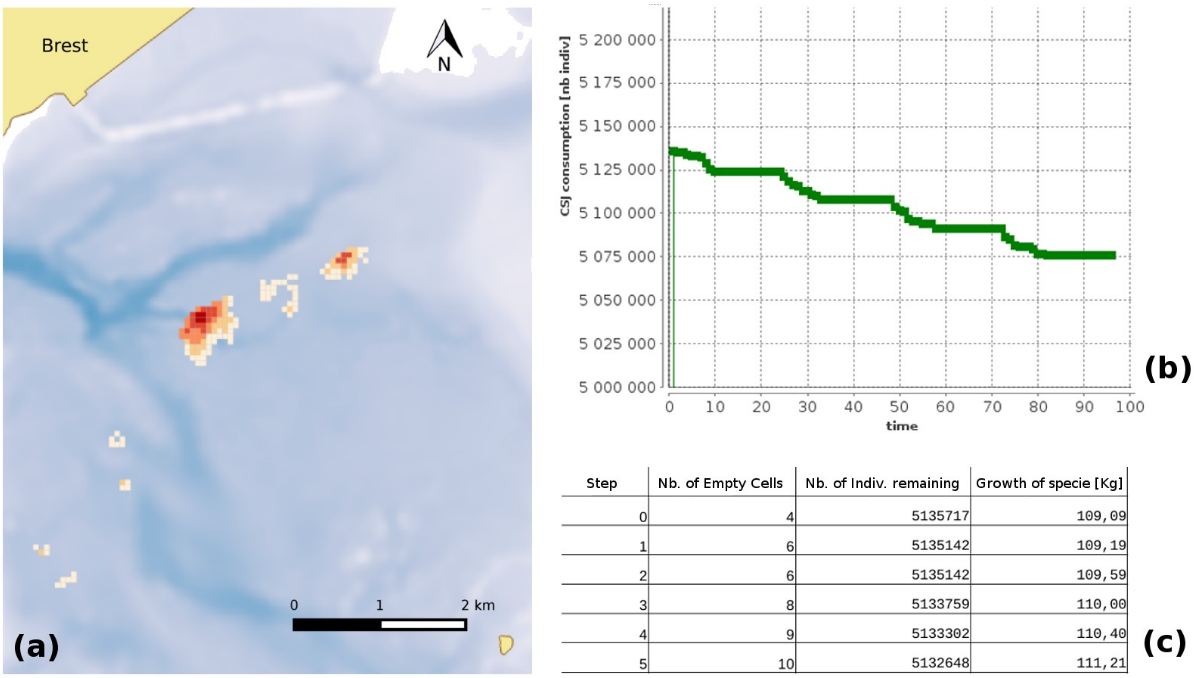
Firstly, since the system is multi-scale, we have to define a zone where to perform the simulation. By defining the extent of this zone, a spatial and temporal granularity is automatically defined. So, entering into the graphical interface the coordinates belonging to the bounding box (N, S, E, W) the appropriate GRASS commands are launched in order to reshape and calculate the resolution of the bathymetry in reason of the spatial granularity, reshape potential fishing zones, reshape an eventual fishing probability map and select the starting and unloading point for each type of fishing boat.

For example, in a simulation at small scale, we want to evaluate the resource consumption and regeneration, and calculate potential fishing zones' clustering.
As input data we have the raster file of bathymetry (at 5x5m resolution) and the vector file of fishing zones. Once established the bounding box limits, delineating a ~40kmsq area, the software automatically resample raster bathymetry values in 10x10m resolution cells and cuts the fishing zones on the bounding box. A departure and unloading port fall into the zone, so the simulation can be launched by using gama-headless module.
During the simulation, boats are moving on the map, following fishing calendars according to regulation associated to each type of fishing activity.
Boats movements generates traffic on the map which is recorded into a spatial grid as frequentation value.
The code also implements a colony ant algorithm which allows the boats leaving a pheromone track on the map according to the quantity of catchment. In the meanwhile each specie grows, following established growing rules.

Results

The simulation script in this specific case provides the following outputs (Fig. 2):

- Images which shows the variation of frequentation in time;
- Graphs, providing an assessment of resource consumption and cells frequentation;
- Shapefiles of the fishing zones with traffic and resource data;
- An .xml file, where all this data are stored at a fixed timestep.



Step	Nb. of Empty Cells	Nb. of Indiv. remaining	Growth of specie [Kg]
0	4	5135717	109,09
1	6	5135142	109,19
2	6	5135142	109,59
3	8	5133759	110,00
4	9	5133302	110,40
5	10	5132648	111,21

Figure 2. An example of the results: (a) the vector map of the frequentation of a little zone in the Brest Bay - frequentation increase from white to red; (b) numbers of individuals (King Scallop Fish) remaining on the selected zone after each fishing act in time (cycles); (c) an extract of the xml table in output.

If the simulation has been launched on a wider area and for a longer period (lower spatial resolution and higher temporal granularity), aggregated results would have been produced. More details about agents actions and interactions, aggregation processes and multi-scale organization of SIMARIS model are given in Minelli et alii, 2016.

Conclusions

The above mentioned results belong to the simulation, and can be achieved even with a simple (non headless) simulation. Conversely, the real interesting result of this experiment is that the integration experiment seems to successfully evidence the geographical analysis capabilities of GRASS GIS and the simulation capabilities of GAMA platform.
In fact, using both the software by batch, it is possible to:

- Obtain better performances on duration of the analysis and in RAM consumption;
- Recall only the functionalities we need without initializing the graphic environments;
- Easiness to automatize a future WPS (Web Process Service).

Regarding the last point, the host model written in Python, organize the simulation to be launched remotely on a server, called from an external client. This is convenient because it allows the final user not to have all the software installed on his machine. Moreover, it will be easier to perform more runs of the same simulation in order to statistically assess the reliability of a future scenario. Results presented in this paper are interesting for an efficient cooperation between GIS and ABM environment. However, regarding the integration process, the best solution would be a library which allows the two software strictly working together, but the implementation of this library is not considered for the moment.
Finally, despite some geographical operations have been already implemented in GAMA, it is not possible to performed advanced calculation and, in our opinion, it would be right to let GIS doing geographical analysis and multi-agent platform perform agent based simulation.

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