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 is linked with the SIMARIS project: a simulation prototype that integrates multi-source and multi-scale spatio-temporal 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.

Keywords: marine simulation, GIS, ABM, Python

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 objects 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 and Castle, 2012). In fact, handling geographical data is a matter of Geographical Information Systems and even if recent development in Agent Based modeling 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 and Jiang, 1999; Gonçalves et al., 2004). But since spatio-temporal representation is no more a limitation in spatial analysis (Gebbert and 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 and Le Tixerant, 2008).

SIMARIS is a framework designed to model interactions between human activities and their environment. The methodology is based on a cross-cutting approach focused on combining multi-agents model with multi-scale spatio-temporal databases with the aim to simulate simultaneously several activities. Each element is implemented as an agent that interact with its environment and other agents according to internal and external constraints and factors (weather conditions, regulation, market price, etc.). These variables can be very heterogeneous and their combination can generate completely different output. In order to take into account this heterogeneity the model is multiscale and multilevel. It automatically sets the spatio-temporal granularity, the analysis and the outputs from a specific spatio-temporal scale defined at initialization step. This requires preliminary geographical operations to provide a relevant 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 et al., 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 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 consider 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 provide 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 independence 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 and 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 users.

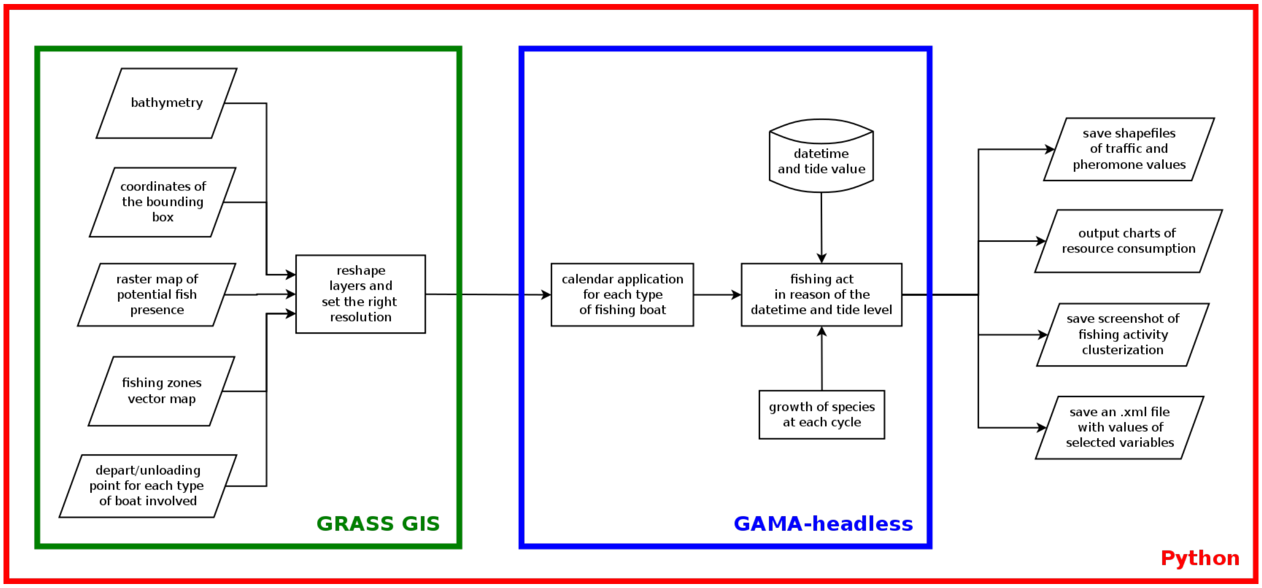


Figure 1. The Python procedure, which involves preliminary geographical operations (executed in GRASS GIS), the GAMA simulation and the restitution of outputs.

For SIMARIS the main advantage is the ability to call each single GRASS command/tool by bash. This means that an entire geoprocessing operation 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.

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 according to the spatial granularity, reshape potential fishing zones, reshape a possible 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 40 kmsq area, the software automatically resamples 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 with each type of fishing activity. This type of simulation can provide assessments (on a daily, monthly or annual basis) on the number of vessels that operated in a specific zone over a given period, and thereby contribute to estimating an activity's impact on a resource. It can apply to several activities with distinct developments in space and time, and highlight positive (complementary activities) or negative (generating potential space use conflicts) interactions. Boats movements generate traffic on the map which is recorded into a spatial grid as frequentation value.

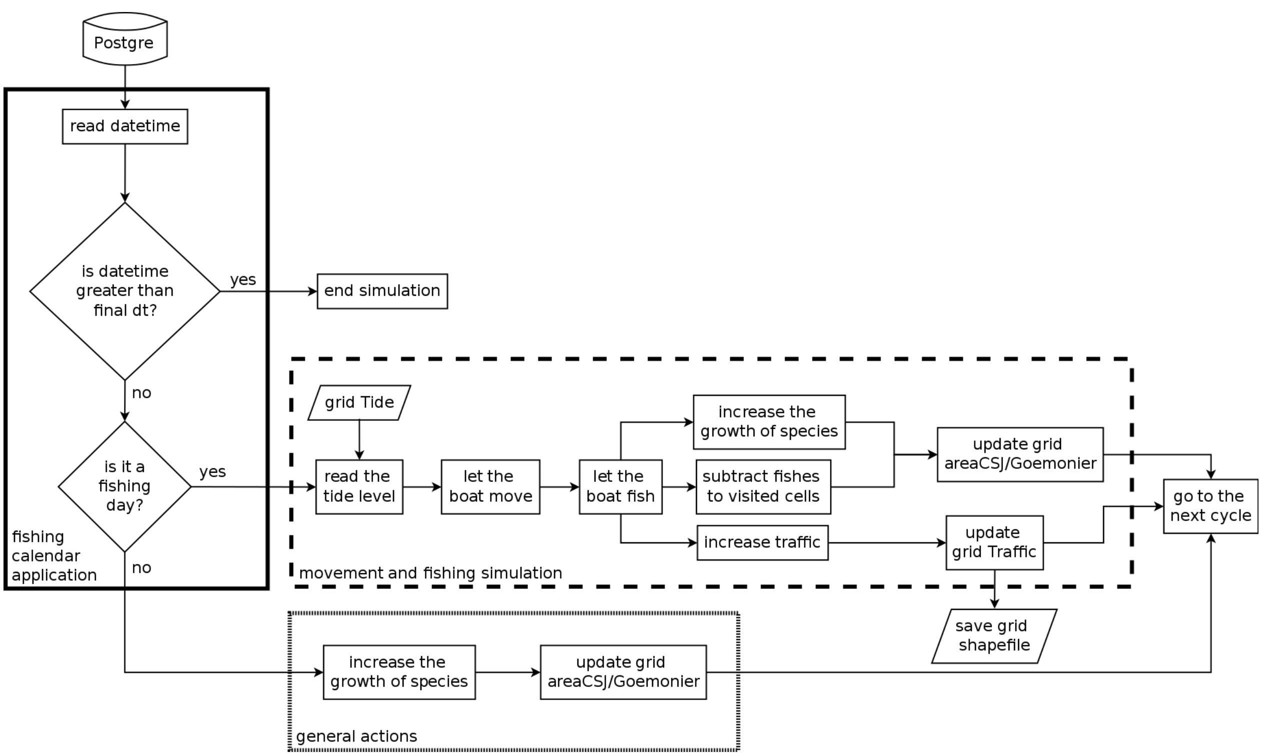


Figure 2. The detailed flowchart of the simulation running in gama-headless. Each block (solid black, dashed black and dotted grey) specifies one of the generic actions reported in the blue box of Figure 1. From Minelli et alii, 2016 (submitted).

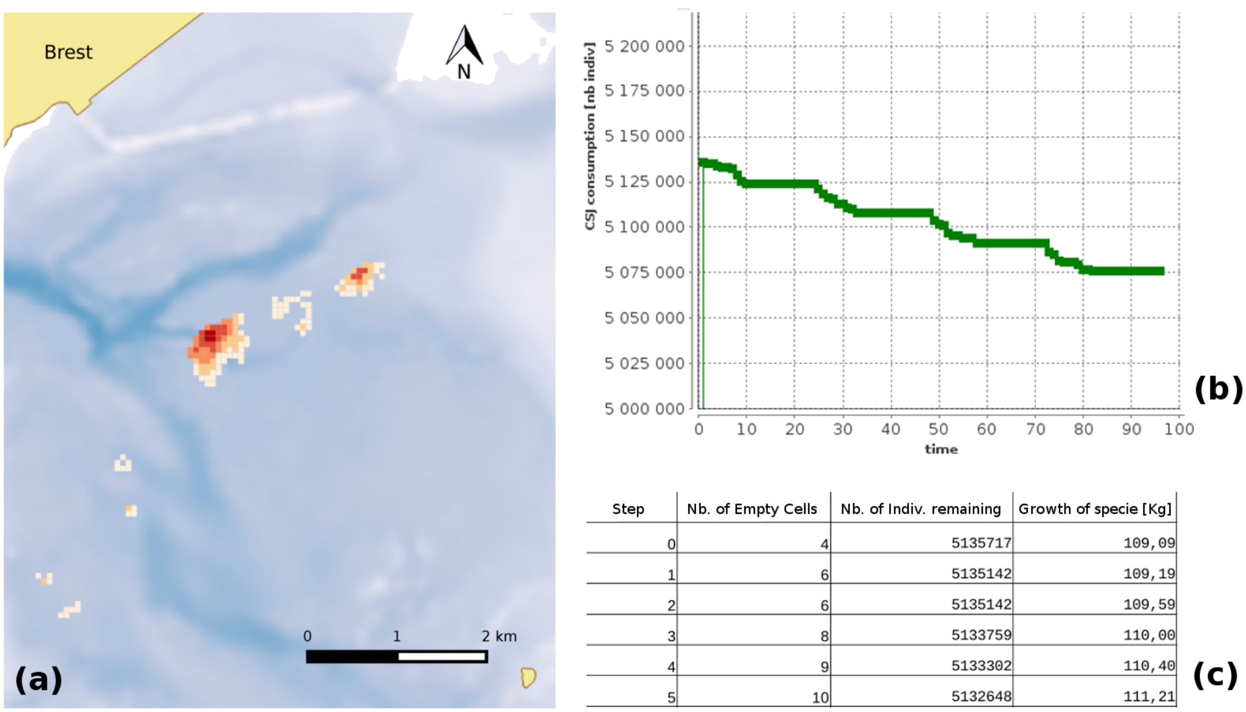
The code also implements a colony ant algorithm which allows the boats leaving a pheromone track on the map according to the quantity of the catchment. In the meanwhile each specie grows, following established growing rules. Since the focus of this paper is not to present the simulation itself but the integration between an ABM and GIS, we will not deepen into the simulation specifics in this phase, but a detailed flowchart of the code is reported in the following Figure 2.

RESULTS

The simulation script in this specific case provides the following outputs Figure 3:

- images which shows the variation of the frequentation in time;
- charts, providing an assessment of resource consumption and cell frequentation;
- shapefiles of the fishing zones with traffic and resource data;
- an .xml file, where all this data are stored at a fixed time step.

If the simulation has been launched in 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 al. (2016).



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 3. 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.

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, manages 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 more theoretical aspects of the integration process, the best solution would be a specific library which allows the coupling of the two software (the implementation of this library is not considered for the moment).

Finally, despite some geographical computations have been already implemented in GAMA, advanced geographical operations are still limited (e.g. map algebra, topology maintenance, etc.) in ABM. In our opinion, it would be right to let GIS doing geographical analysis and multi-agent platform perform agent based simulation.

REFERENCES

Batty, M. and Jiang, B. (1999). Multi-agent simulation: new approaches to exploring space-time dynamics in gis.

Crooks, A. T. and Castle, C. J. (2012). The integration of agent-based modelling and geographical information for geospatial simulation. In *Agent-based models of geographical systems*, pages 219–251. Springer.

Ferber, J. (1999). *Multi-agent systems: an introduction to distributed artificial intelligence*, volume 1. Addison-Wesley Reading.

Gebbert, S. and Pebesma, E. (2014). A temporal gis for field based environmental modeling. *Environmental Modelling & Software*, 53:1–12.

Gonçalves, A., Rodrigues, A., Correia, L., do Brasil, A., and Portugal, P. P. (2004). Multi-agent simulation within geographic information systems. In *Proceedings of the 5th International Workshop on Agent-Based Simulation (ABS-2004)*, pages 107–112.

Grignard, A., Taillandier, P., Gaudou, B., Vo, D. A., Huynh, N. Q., and Drogoul, A. (2013). Gama 1.6: Advancing the art of complex agent-based modeling and simulation. In *International Conference on Principles and Practice of Multi-Agent Systems*, pages 117–131. Springer.

Karadimas, N. V., Rigopoulos, G., and Bardis, N. (2006). Coupling multiagent simulation and gis- an application in waste management. *WSEAS Transactions on Systems*, 5(10):2367–2371.

Minelli, A., Tissot, C., Rouan, M., and Le Tixerant, M. (2016). Multi-scale modelling for simulating marine activities under heterogeneous environmental constraints. *Revue International de Géomatique*.

Neteler, M. and Mitasova, H. (2013). *Open source GIS: a GRASS GIS approach*, volume 689. Springer Science & Business Media.

Tissot, C. and Le Tixerant, M. (2008). Simaris: Simulation du déroulement d'activités marines, mappemonde. *Mappe Monde*, 92:4.