Norms in H-F-G societies. Grounds for agent-based social simulation.

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Abstract
The use of agent-directed simulation in archaeology has a relatively long tradition. However, these simulations have been always oriented mainly to study spatial processes and resource management and systematically ignore an essential aspect of any society: the use of social and institutional norms as a mechanism to regulate the behaviour of the individuals. In this paper we propose a norm-centric simulation (in contrast to the traditional resource-centric simulation) where the normative system is both the core of the simulation and the subject of study. Our final goal is to set the foundations of a rather general model of social behaviour in a hunter-fisher-gatherer (HFG) society without political institutions but with strict social norms.

Keywords: Agent Directed Simulation, Normative systems, Hunter-Fisher-Gatherer societies.

1. Introduction

The relationships that people adopt to achieve what they need/want for subsistence and to reproduce their society are the essential feature that characterizes and distinguishes different human societies.

These relationships (like sexual division of labor and social asymmetry) are present in all recent hunter-fisher-gatherer societies (H-F-G from now on) and may have biological foundations but are certainly modulated by social norms; as attested by the large variability in the morphology and in the intensity of the different cases (see Brightman 1996).

The analysis of resource exploitation has been the major subject of study in archaeology. However, the organization for reproduction (biological and social) has been left aside because of its supposed archaeological invisibility. We claim that this organization for reproduction is the main structuring framework of a society, hence a necessary goal of the archaeological research on prehistoric societies. We have focussed on this question with a different methodological paradigm using ethnoarchaeology. In particular we have studied Tierra del Fuego H-F-G societies for 20 years (see Estévez and Vila 1996 and 2007).

As a first step of our roadmap, we have compiled and critically analyzed the extensive ethnographic sources of the area to synthesize the set of social norms that organized the Yamana/Yahgan people living along the southern-most coasts of the Tierra del Fuego Archipelago (see Gusinde 1937, Orquera and Piana 1999 Hyades and Deniker, 187#) having in this way grounds for computer simulations.

These people are H-F-G living along the southern-most coasts of the Tierra del Fuego Archipelago displaying mainly strategies of littoral resource exploitation and with sea faring devices. The existence of a ruled division of labor among H-F-G of Tierra del Fuego has been well documented ethnographically and reported, although subjectively qualified and not evaluated, by the ethnographers. These people did not organize themselves as tribes. The basic production unit moved around permanently (alone or with a few other units). Larger gatherings of people (50 -70 people) in villages were never long lasting.

There was no centralized power or government, but the supremacy of men was sustained by the authority of the father (a male figure) in each social unit. These social order based on discrimination of women was enhanced from time to time with the well described spectacle of the Kina ceremony for men only.

This ceremony was designed only for men and was a meant to reinforce the general authority of males. The organization of resource exploitation was strictly organized along a sexual division of labor. These of course are closely tied with the relationships for the production of subsistence because of the sexual division of labor. But the social norms specifically related to the working processes (who does what and how) are not so clearly established. They are part of the daily life and are learned from childhood. All these social norms and patterns of social daily life and production behavior are explicitly remembered and reinforced just once in their life, for adolescents of both sexes during the *Ciexaus* ceremony, which is also exhaustively described ethnographically.

So the power of decision belongs to men. This creates an asymmetric image justified by the social division of labor, the inequality of values, and the control of reproduction exercised by men on women (Vila and Ruiz 2001). Having addressed the inequality and exploitation recorded, we wanted to analyze these sources in a more objective way to quantify the inequality between sexes.

Our first attempt, KIPA, was based on a localized neuronal network shell (Barceló, Vila and Argelés 1994). Although we obtained some promising results, we did not succeed in modeling the dynamics of the system and social relationships.

This paper reports on our current efforts: an approach using multiagent systems to model the behavior of individuals and the norms that govern that society regulating their interactions.

We are building a realistic simulation, named YamanaSim, of a HFG society using the known Yamana rules. The model would allow us to explore the functioning of such a society in an experimental fashion and, hence, advance some hypothesis or explanations of its distinguishing features.

The aim of our work so far, has been to set the foundations of a rather general model of social behaviour in a HFG society without political institutions but with strict social norms. We have started by modelling a fundamental social aspect: the reproductive social and biological rules.

2. State of the art

In archaeology, there have been efforts in the simulation of individuals' behavior for more than 30 years now. So far, the agent metaphor has been applied in the study of ancient societies mainly to study spatial processes and resource management (Lake 2000, Kohler 2000). From the extensive literature in the area, the most influential works that use the multiagent systems approach are the following:

The EOS Project (Doran and Palmer 1995) is one of the seminal works in the area. They developed a computational simulator that helped in the interpretation of some archaeological assumptions for the growth of social complexity in the Upper Paleolithic period in the Southwestern France. The main contribution of Doran's work is how a set of agents forms hierarchies in order to harvest the resources they might find spread in the environment where they can freely move. Doran's model is one of the first models where agents adopt some social organization in order to reach a common goal.

TongaSim (Small 1999) modeled Tonga society (Western Polynesia) to explain why growing stratification did not result in a devaluation of women's status. The main goal of the simulation was to prove whether the *fahu* relationships (based on the superior spiritual position of sister over brother and of sister's children over brother and his children) became problematic as warfare appeared, and hence, stratification occurred in the model.

Based on the Sugarscape model developed by Epstein and Axtell (1996), we find the work of Dean (Dean et altri 2000). In this work they present a model that describes the population dynamics of the Anasazi in the Long House Valley in Arizona between 800 and 1350.

Closer to our current work is that in (Villatoro and Sabater-Mir 2007) where the authors develop a genetic algorithm that selects the set of social norms that optimizes the average life expectancy of a population.

In all these models, however, agents are just simple cellular automata with a set of wired rules that fix their behavior in the *microlevel*, resulting in a *macroscopic behavior*. Another significant limitation all of these models share is that they ignore an essential aspect of any society: the use of social and institutional norms as a mechanism to regulate the behavior of the individuals. In these simulations, such norms usually are implicitly represented in the parameters of the simulation. Since the norms are not explicit and implemented agents are given limited rationality, individuals cannot decide whether to follow a norm or not.

3. Conceptual model

We propose an approach for designing multiagent simulations of human societies where the normative system is both the kernel and the main research subject of the simulation. In other words, the purpose of the simulations is to answer questions like: How the normative system determines the viability of a society? Which norms are essential for its sustainability in that specific environment? Could other normative systems have the same effect on that society in that environment? How much does the normative system contribute to the sustainability and prosperity of a society?

In contrast with more traditional archaeology simulators – focused on resources and their management -- our focus is on interactions among individuals and the regulation of those interactions through norms. In our approach the normative system establishes what an agent should and shouldn't do but, at the same time, an agent is free to follow or not the norms according to its personal goals.

3.1 Interaction spheres, norms and normative levels

The simulation environment in the YamanaSim is divided in what we call *interaction spheres*. An *interaction sphere* is a space where individuals interact around cohesive activities. Examples of *interaction spheres* are reproduction, social life, conflict resolution, and resource management. Each *interaction sphere* is regulated by its set of norms.

At any given time an individual is active in one or several *interaction spheres*. The behavior of an agent in each *interaction sphere* is determined by its current goals, its internal state and the set of norms that regulate that *interaction sphere*. While the goals and the internal state are specific of each agent, the norms that regulate the behavior are common and assumed to be known for all the agents in the simulation.

A norm in our simulator has a set of antecedents and a set of consequents. There can be two types of antecedents in a norm: facts about the internal state of the agent or the relationships of the agent with other members of the society (for example, "*age<13*") and actions that have to be performed so the norm is activated (for example "go_hunting"). If all the antecedents are satisfied (in our example that the agent's age is below 13 and the agent decides "go hunting"), the consequents reflect: (i) how the internal state of the agent will change and (ii) if there are some actions that will be performed as a consequence. The norm can have also consequents that will become active if the norm is not observed. The actions in the consequents will induce new changes (on top of those associated directly to the norm) in the internal state of the agent once they are performed. An example of a norm is:

"If a man is married and his wife has a very low prestige level the man can divorce. In that case the woman will fall into disgrace. If the man does not divorce he will lose credit in front of the other members of the society"

This norm can be formalized as:

Antecedents:
- facts: man(X), woman(Y), married(X,Y), prestige(Y)<low
- actions: divorce(X,Y))

If observed:
delete(married(X,Y)), prestige(X)=, prestige(Y)--

If not observed:
prestige(X)—

Where prestige(X)--, prestige(X)= means that the prestige of the individual will decrease or remain equal respectively.

That is, if there is a man and a woman, they are married (as reflected by the social network), the prestige of the woman is very low and the man decides to divorce, then the "married" relation is removed from the social network, the prestige of the man remains untouched and the prestige of the woman decreases even more. If the norm is not observed (the man decides not to divorce) then the prestige of the man decreases.

The norms in each *interaction sphere* are organized in *normative levels*. We distinguish three different normative levels:

Basic level. Here we find all the norms dictated by the nature of the individual. Two types of norms are found at this level: biological norms like, for example, "A woman do not become fertile till she has the first menstruation" and basic social norms, that although are not biological we assume are also part of the nature of the individual. The norms at this level have only facts as antecedents and therefore the agent cannot influence on their activation. However, as we will see, the agent can decide to follow norms that belong to higher normative levels that can cancel the activation of the norms at this level.

Social level. The norms at this level are norms dictated by the society as a whole. There is no central authority or institution that imposes their observance but following or not one of these norms usually has implications in terms of how the individual will be considered among the other members of the society. The social position of an individual influences the kind, frequency and quality of interactions she can have.

Institutional level. Finally, at this level we find those norms dictated by central authorities and institutions. Apart from the social consequences in front of the rest of the society, not following one of these norms normally imply sanctions coming from the central authority.

Norms in the basic level define the *default behavior* of the agent. The social and institutional levels modulate this default behavior by reinforcing or restricting specific conducts. In our model an individual can decide to follow or not the norms in the social and institutional levels and by so doing, modify the default behavior.

3.2 Social networks

In addition to the three constructs just mentioned – the state of the internal variables of an agent, its personal goals and the normative system– there is a fourth element that determines the behavior of an individual in our model: the social relationships.

A social network is a graph that represents social relations between the members of a society (e.g. kinship). The nodes of the graph represent individuals and the edges, the existence of a relation between them. Edges can be weighted to represent the strength of the relationship. We assume that all the members of the society know about these social networks.

3.3 The agent model

An agent in the simulator is defined by a set of internal variables that describe the state of the agent at each simulation step (see Figure 1). Agents also have personal goals and satisfying those goals is their *raison d'être*. Each goal has an associated *strength* that represents the relevance of that goal for the agent.

Gender [male, female]
Age[0,120] int
Health [bad, so-so, good]
Morbidity [0,1] probability
Fertility [0,1] probability
Accident-rate [0,1] probability
Prestige [0,10] int
Libido [0,10] int
Norm_observation_level [low, medium, high]
States [pregnant, fertile, postpartum, infertile, child, couple, married, widow, divorced]
…

Figure 1: Some of the variables that define an agent in the YamanaSim simulator.

The agents can perform *actions*, and these *actions* lead them to follow (or not) a norm by satisfying its antecedents. The set of possible actions is a closed set defined in each specific simulation scenario. We use the symbol '¬' to denote the opposite conduct associated to that action. For example we can have the action "go_hunting" and also the action "¬go_hunting". In the second case, the action the agent is taking is "avoid go hunting" (whatever this means in that context)

Of course, the observance of norms has consequences for the agents. Every time the agent is in the dilemma of deciding if it is worth it or not to follow a norm analyzes (by looking at the consequents of the norm) how the observance of that norm favors its personal goals. According to that, it takes the actions associated to follow or avoid the norm. Notice that if, for example, following the norm requires (as stated by the antecedents) "go_hunting" and the agent decides not to observe the norm, this implies that the agent will perform the action "¬go_hunting".

It can happen that following a norm favors the achievement of a specific goal but at the same time is in detriment of achieving another one. The (normalized) strength of each goal becomes the probability that the agent decides to follow the norm or not (and therefore favor some goals and disfavor others). The same principle is applied if there is more than one goal affected by the norm.

Each step of the simulation follows the algorithm shown in ***¡Error!No se encuentra el origen de la referencia.***. In each step, the system evaluates for each agent what are the norms (in the three normative levels) that given the current internal state of the agent are candidates to be fired. For those candidate norms that have actions in their antecedents, the agent decides if it wants to perform the actions and, as a consequence follow the norm, or ignore those actions (so the norm is not observed). The result of the previous process is the set of norms that are candidate to be fired.

4. The YamanaSim architecture

The YamanaSim system, depicted in Figure-2, is composed of three major components: a Simulator Initializer, a Multiagent System (MAS) and a Rule engine.

The job of the Simulator Initializer is to load a simulation specification file and setup the MAS and the rule engine accordingly with their initial values. The simulation specification file allows the user to define: the population of agents that will participate in the simulation, parameters to simulate the population dynamics and the set of rules that will lead the agent's actions. The population of agents can be defined in two ways: (i) by declaring all the agents inline where all the agents and its relationships (networks) are defined one by one in the configuration file or (ii) by using demographic population information. By using demographic population information the user can define large sets of agents population easily, although at the cost of losing some detail.

The MAS is in charge of the agent population, the social networks and the control of the simulation. The MAS component is built using Repast Simphony (http://repast.sourceforge.net/) a well known agent-based modeling toolkit. The agents in the multiagent system are instantiated following the directives of the Simulator Initializer. An agent in the YamanaSim simulator has three major elements: a set of attributes, a set of goals to maximize or minimize and a decision making module. The agents' attributes, as we have seen before (see Figure 1) are used to store data like gender, age, health and prestige. The goals define the current objectives of the agent, and can change along time. Finally the decision-making module uses these goals to select the actions that will be performed by an agent.

Also part of the MAS component is the social networks. There can be multiple networks to define different relationships between agents e.g. family, kinship, dominance relationships and so on. These networks are also initialized by the simulator initializer and evolve along the simulation execution.

Finally, the Rule Engine is in charge of evaluating, every timestep and from an individual point of view, the set of rules that concern the agent (see *Algorithm-1*). As we said, for each candidate rule, the rule engine asks the agent about the actions to be performed and this determines if the rule is finally fired or not. The implementation of the Rule engine is based on Drools (http://www.jboss.org/drools/). The set of rules loaded into Drools is set and fixed in the Simulation Specification File.

Simulation workflow

When the system starts, the Simulator Initializer loads the specification file. With this data, the simulation is populated with the agents and relationship networks. Also the simulation duration, the length of a timestep plus other parameters regarding the simulation execution are set. The Rule engine component is also initialized with the rules from the specification file.

Once the system components are initialized, the MAS element takes the control of the simulation.

Each timestep, the MAS component iterates through all the agents. For each agent, the Rule engine is invoked to evaluate the rules that might affect that agent. The Rule engine has full access to the MAS context, agents and networks, so it can evaluate the rule antecedents. If any of the antecedents of the rule is an action, the rule engine asks the agent what to do. The agent evaluates the consequents of the rule and according to its internal state and its current goals decides to perform the actions associated to the antecedents of the rule (and therefore observe the norm) or not.

After that, the agent returns a list with the actions to perform associated to the current candidate rule. These actions are not yet executed but simply stored in a short-term memory of "to-be-performed" actions. This is done for each candidate rule starting from those less salient and following the order established in the Simulation specification file. Every time a new action is added, a comparison with all the previous actions in the "to-be-performed" list is done. If the new action contradicts a previous action (for example "go hunting" and "¬ go hunting"), the oldest action is removed (and therefore, the associated rule is no longer a candidate rule).

When all the rules have been evaluated, each agent starts the execution stage of those candidate rules still active. The execution of the rules starts from the most relevant to the less salient rule. For each executed rule, the actions in the consequents (if any) are again compared with the list of "to-be-performed actions" and, like in the previous stage, those actions that are older and contradictory with respect the action in the consequent are removed (removing at the same time the rule from the candidates list). At this point the rule is finally fired and its consequences in the agent attributes, network relationships, etc. become effective.

This treatment of the actions and the evaluation of the rules in two stages allow simplifying the decision-making mechanism of the agents. The agents do not have to analyse the interaction among rules and their effect. However, this approach requires that the rules be carefully prioritized at design time.

After these phases, the simulation step finishes and

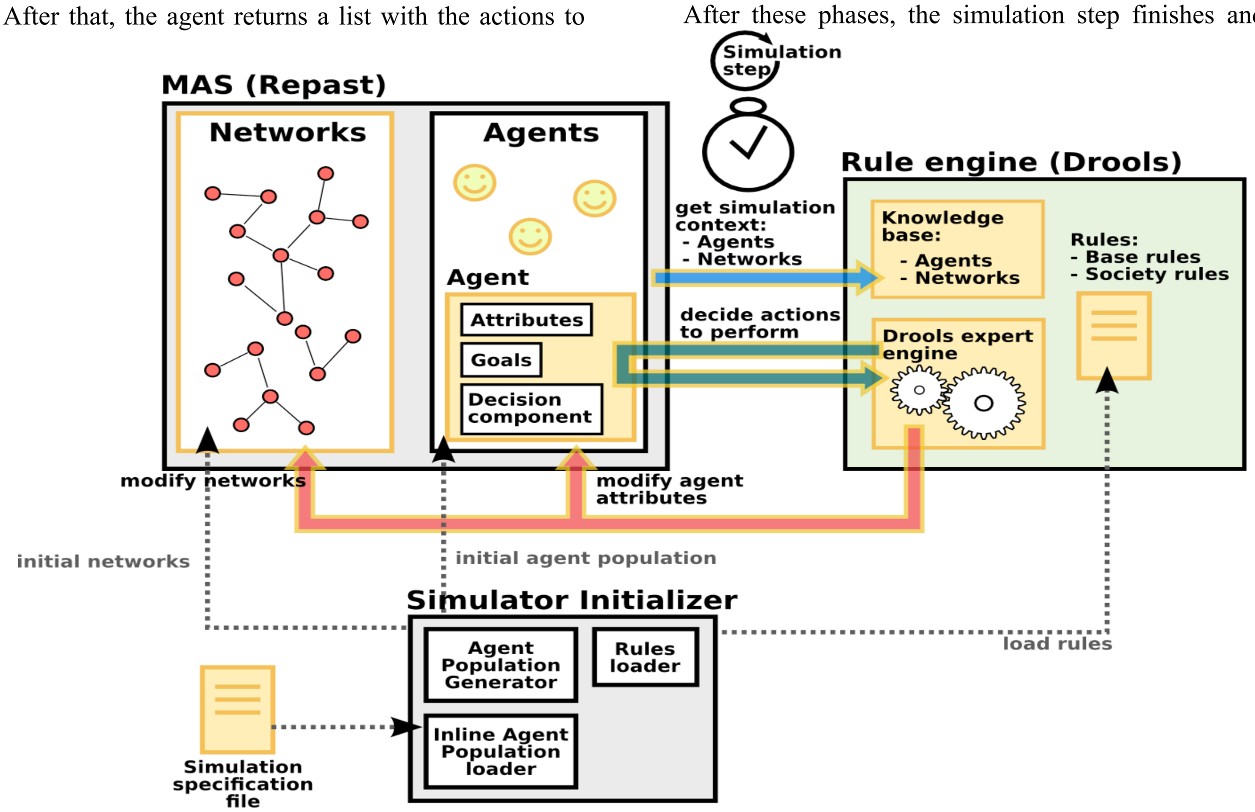

Figure 2: The *YamanaSim* architecture

the MAS element jumps to the next step.

5. Future Work

The first task we are now facing is to find an objective foundation to boot-strap the model. The immediate objective is to identify reliable sources for parameters of "default behaviour", then make explicit any adaptation to the Yámana case of available demographical, environmental, biological and normative data starting with the *reproduction* sphere of interaction.

We expect to address the problem of model validation in a conventional manner running experiments to make sensitivity analysis, calibrate parameters and eliminate spurious and redundant input. We also anticipate the need to adapt –and design– pertinent social indicators to make longitudinal population analysis.

We expect to face methodological challenges that are particular to agent-based modelling. In particular, simulation runs involving variations in the features of individual agents and variations in the form and strength of interactions among agents. For example, we expect to study structures of agent cohorts and distributions of individual propensities within cohorts. That type of experimental setting would lend itself to try elusive questions like path-analysis through individual trajectories.

Because of a parallel research project on Experimental Economics (MacNorms) we are designing experimental settings to study social punishment and reward and others to study various possibilities and emergence of coordination mechanisms.

6. Final Remarks

Our immediate research goal has been to frame a classical question of ethno-archaeology in a different methodological paradigm. We have attempted to build a realistic simulation of an H-F-G society that may serve us to explore in an experimental fashion the functioning of such a society and, hence, advance some hypothesis or explanations of its distinguishing features.

The aim of our work so far, has been to set the foundations of a rather general model of cultural behaviour in a closed society. We have started by modelling one fundamental social aspect: reproductive behaviour and we intend to intertwine it with other core social behaviours like conflict resolution and gathering and transformation of resources. Our modeling, so far, intends to isolate "default" social behaviour —e.g., available death and fertility rates for contemporary HFG societies— and modulate that raw behaviour with parameters and control devices (suggested by ethnographical and archaeological sources) that reflect characteristic features of a particular society, the Yamana in our case.

We are still at an early stage in the development of a model that addresses our ultimate research question: the role of sexual differentiation and dominance in the survival of HFG societies. However, the experience so far is promising and we expect to continue in this direction in the future.

7. Acknowledgements

This work is supported by the CSIC [Proyecto Intramural de Frontera MacNorms, PIFCOO-08-00017]; the Spanish Education and Science Ministry [Engineering Self-*Virtually-Embedded Systems (EVE) project, TIN2009-14702-C02-01]; and the Generalitat de Catalunya [2005-SGR-00093]. Daniel Villatoro is supported by a CSIC predoctoral fellowship under JAE program.

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```
Data: Simulation.context contains all the agents and
      social networks.
Data: agent_list list of all agents.
Data: norm_list list of all norm ordered by
      Basic, Social, Institutional and relevance.
begin
  foreach agent in agent_list do
    /* Builds default actions for the step */
    agent.action_list ← buildDefaultStepActions();
    foreach norm in norm_list do
      norm_action_list ←
      norm.antecedents.actions;
      if norm_action_list ! = [ ] and
      fulfilledAntecedents(norm.antecedents,
      agent.attributes, Simulation.context) then
        decision_action_list ←
        agent.decideActions(norm_action_list,
        norm.consequence.goals);
        foreach decision_action in
        decision_action_list do
          agent_action ←
          agent.actions.find(decision_action);
          if agent_action ! = nil then
            /* Changes action's sign if
               it's different:
               action →¬action or
               ¬action → action */
            if agent_action.sign ! =
            decision_action.sign then
              agent_action.sign ←
              decision_action.sign;
            end
          else
            agent.action_list.add(decision_action);
          end
        end
      end
    end
    agent.triggered_norm_list ← [ ];
    foreach norm in norm_list do
      if fulfilledAntecedents(norm.antecedents,
      agent.attributes, simulation.context,
      agent.action_list) then
        agent.triggered_norm_list.add(norm);
      end
    end
  end
  /* Execute actions and triggered_norms for
     each agent */
  foreach agent in agent_list do
    foreach action in agent.action_list do
      execute(action);
    end
    foreach norm in agent.triggered_norm_list do
      execute(norm.consequences);
    end
  end
end
```

Algorithm 1: Main simulation step