The Computer Simulation of Social Dynamics and Historical Evolution.

The case of "Prehistoric" Patagonia.

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ABSTRACT. We introduce here our research project on the simulation of the historical trajectory of Patagonian societies since 13000 BP until the present. It pretends to be an explanatory simulation model whose aim is to identify yet unknown relationships and interactions that could have been present in the history of those societies, but we do not have any documentary source about them. In that sense, we start with a theory about hunter-gatherer societies and we try to show the plausibility of this theory using agent-based simulation methods and techniques. It is also a predictive simulation because it is built on historical, ethnological and archaeological knowledge available at the necessary level of detail. We pretend to build a simulation model that enables to predict how historical societies behave in the past under certain conditions. The general framework of agent-based simulation in the study of prehistoric societies is also presented.

KEY WORDS. Agent-based, Simulation, Patagonia, Prehistory, Hunter-Gatherers.

1. Simulating the Past in the Present

For 99% of human history we do not have any description of social activity, or explanations of motivations, intentions or goals of people who lived in the past. The only we have are some material evidences for some (not all) outcomes of a reduced subset of social activities performed in the past (archaeological evidences). Although in some cases we have evidence of human beings having been ritually buried or accidentally dead, and their corpses have been preserved until a certain degree, we do not have traces of the *agents* of past activities. Therefore, it should not shock anyone that a substantial proportion of research effort in archaeology isn't expended directly in explanation tasks; it is expended in the business of unearthing the traces of social action performed in the past, without arguing *why* those actions took place there and then.

Instead, archaeologists are social scientists who should explain social dynamics in the past by showing how the traces of the past observable in the present fit into a causal structure with an intrinsically historical nature. That is to say, we have to discover interacting *activities* and *entities* having produced in the past the recognized evidence in the present (the archaeological site). The trouble with such a view of archaeological-historical explanation is that we would need to travel to the past to be able to understand why it happened.

We cannot travel to the past in an effective way but we can do it in a virtual way. In the computer, we can explore (by altering the variables) the entire *possible* range of outcomes for different past behaviors. Such an implementation of historical and social knowledge within a computer can be seen as the action of embedding a model of behaviour (social mechanism) within another model (computational mechanism). In this way, although History only runs once, inside a computer a virtual model of the historical past may runs infinite times. Executing a model written in a specific computer program—spinning it forward in time—is all that is necessary in order to simulate social activity in the past. Since the model is "simulated" merely by executing it, there results an entire dynamical history of the process under study.

This approach can be characterized as "understanding by building". It is based upon the general assumption that theory building would be better served by synthesis (simulation) than analysis (logics). The approach exposed here challenges the received picture of historical explanation as an invariant structure. It allows us to modify the way we understand explanatory concepts like tribe, chiefdom, social elite, etc. They are not verbal labels we attach to some percepts by means of a previously existing rule but a cognitive action, or a requisite to a next action. Explanations should be based on purposeful, goal-directed mechanisms emerging from a dynamical system that has been calibrated by simulation to make the probably correct choices in the most diverse circumstances.

Writing a computer program to simulate social activity in prehistory has long seemed an impossible task. There are still many social scientists thinking that we cannot reproduce what humans did and believed inside a computer, because machines are a bad surrogate for the complexity of human beings. These scholars seem to believe that we do not have access to the knowledge necessary to accurately reflect all of the interweaving and evolving components of social activity through history. Machines are limited to the calculation of input-output pairs, and no social activity would be so simple. This criticism is mostly wrong, especially in modern times when artificial intelligence has shown how the appropriate interconnection of very simple computational mechanisms is able to show extraordinary complex patterns.

2 Simulating Social Activity

Our propose is to describe social systems from the perspective of their constituent units. Seen in the framework of agent-based modeling, artificial societies are sets of simulated social agents having a (virtual) body, and living in and interacting with a (virtual) environment. Agents are pieces of software with individual goals and rules of behavior and capable of self-controlled goal directed activity. They are represented as members of an evolving (virtual) population of social procedures (mechanisms), which determine important aspects of the population's structure and development and therefore of the individual's behavior.

Virtual social agents "live" in an environment populated by many other agents, so the successful completion of their tasks is subject to the decision and actions of others. Agents interact, influence others, reinforce some actions, interfere with others, and even sometimes prevent the action of other people due to a mere side effect of their activities. Agents may interact as well with non-agent entities in this environment. As the real world constrains the structure and behavior of the real agents, the simulated environment plays that role for the simulated agent system. The perceptions of the simulated agents have origin in the physical and social environment that constrains and sometimes even determines their action and interaction. These environmental dynamics can be very complex, so we should assign some form of behavior with the simulated environment, programmed as global state variables. Every environmental dynamic that is model-specific can be counted to it. An important consequence of this view is that the agent and the environment constitute a single system, i.e., the two aspects are so intimately connected that a description of each of them in isolation does not make much sense.

Social activity in the past can then be simulated as composed of subjects, objects, needs, motivations, goals, actions and operations (or behavior), together with mediating artifacts (signs, tools, rules, community, and division of labor). *Activities* are oriented to motivations, that is, the reasons that are impelling by themselves. Each *motivation* is an object, material or ideal, that satisfies a need. *Actions* are the processes functionally subordinated to activities; they are directed at specific conscious goals and they are realized through operations that are the result of knowledge or skill, and depend on the conditions under which the action is being carried out. In this framework, a subject is a person or group engaged in an activity. An object (material or non material, i.e., knowledge, information) is the consequence of this activity. An *intention or motivation* is held by the subject and it explains activity. Activities are realized as individual or cooperative *actions*. Chains and networks of such actions are related to each other by the same overall object and motivation. For their part, actions are programmed as chains of operations, which are well defined behaviors used as answers to conditions faced during the performing of an action. Goals, beliefs, and intentions are then arbitrary interpretations of events that took place within the simulation. They do not exist as explicit sentences. Rather, the programmer should be aware of those things that are playing a prominent role in constraining the global constraint satisfaction settling process within the simulation.

Running this computer model of an artificial society simply amounts to instantiate the simulated populations of people, letting the agents interact, and monitoring what emerges. Although simulated social agents tend to be computationally simple and they live in computationally simplified environments, if one places many agents together in the same environment interesting collective behaviors tend to emerge from their interactions. What *emerges* from the collective execution of rules packaged in form of agents is a gradual updating of agent's beliefs and the concomitant modification of their plans, arriving at some form of *social order* [1] [2]. This should be conceived as any form of systemic structuring which is sufficiently stable, to be considered the consequence of social self-organization and self-reproduction through the actions of the agents, or consciously orchestrated by (some of) them.

Because of this focus on social actions as *practiced* by human actors in reference to other human actors, simulated social activity appears as a goal-directed process that must be undertaken by some agents to fulfill some need or motivation [3] [4] [5]. The goal-directed nature of simulated social activity involves varying behavior of agents to carry out the same action in relation to a situation. Agents seem conscious (because the agent holds a goal in its software core), although they do not need to behave rationally because different actions may be undertaken to meet the same goal, and because heuristic criteria can be implemented as a decision-making mechanism. Agent motivations or intentions should not be implemented as mere conditions for developing cognitive activity, but they act in the simulation as real factors influencing agent behavior and productivity and defining the social matrix of agent interaction. Inside the computer model, social activity is characterized by essential variability in the behaviors with which they are executed. The frontier between intentional activity and operational behavior is blurred, and movements are possible in all directions. Agent rational intentions can be transformed in the course of an activity. An activity can lose its motivation and become an action, and an action can become an operation when the goal changes. The motivation of some activity may become the goal of an activity, as a consequence of which the later is transformed into some integral activity. The definition depends on what the subject or object in a particular real situation is.

This new paradigm tends to stress the *situatedness* of social activity, i.e., the study of agents that are situated in and interact with an environment; its *embodiment*, i.e., the assumption that agents (social or virtual) have bodies, receive input from their environment (physical or virtual), and produce social actions as output; and the *emergence* of social organization, i.e., the view of behavior and intelligence as the emergent result of the fine-grained interactions between the control system of the agent, its body structure, and the external environment [6] [7]. The key word is here "situated" action. *Situated* means any social agent should be seen as an integral part of the world in which it behaves. Although it has been implemented as a piece of software, the agent has its own goals and intentions. When it acts, it changes the world, and receives immediate feedback about the world through a simulation of "sensing" and "perceiving". What the situated agent senses affects its goals and how it attempts to meet them, generating a new cycle of actions.

An specific presentation of simulation issues as applicable to archaeology and historical sciences appear in a recent book by one of the authors of this paper [8].

3 Simulating the Historical Trajectory of Patagonian Societies from 13000 BP until the Present. A Research Project.

For thousands of years, hunter-gatherer societies inhabited the southernmost area of South America: Patagonia. Traditionally studied as an example of marginality, Patagonia's history has been described in terms of the absence of marked social stratification and the development of conservative traditions with low rates of culture change, the absence of expansionist warfare, the lack of large aggregations of people the unimportance of food storage and the dependence on a few resources. It has been argued that this economic framework resulted in generally low regional population density, and a lack of permanent settlements. It has been also assumed the lack of ''capability'' for developing complex technology for long-range resource acquisition rendered many possible subsistence sources ''inaccessible''.

This is a false picture of Patagonian "prehistoric" trajectory. At the time when Europeans first contacted with them, complex polities began to emerge, showing the misguided nature of traditional hypotheses that only considered the "adaptation" to local resources and a simple-sided "optimal" rationality. Patagonian historic trajectory, like the trajectory of any other social formation cannot be really understood without taking into account the complex factors that determined, constrained and mediated social action across a very complex and heterogeneous territory.

We are interested in analyzing the formation of social contradictions through time. The term *contradiction* is used to indicate a misfit within the components of social action; in this case, among simulated agents, their needs, motivations, goals, actions and operations, and even among themselves and their mediating artifacts (division of labor, rules, institutions, etc.). As a result, the computer model should allow us to explain the emergence of internal tensions in apparently irregular qualitative changes, due to the changing predominance of one over other. We assume that social activities are fast always in the process of working through contradictions, which manifest themselves as problems, ruptures, breakdowns, clashes, etc. They are accentuated by continuous transitions and transformations between agents, needs, motivations, goals, behavior, signs, tools, rules, community, division of labor, and between the embedded hierarchical levels of collective motivation-driven activity, individual goal-driven action, and mechanical behavior driven by the tools and conditions of action. Here lies the true nature of the computer simulation of social causality mechanisms and the motivation force of change and development. A simulation of a society having existed in the past should show the global tendency to resolve underlying tension and contradictions by means of change and transformation. In this way we will learn that what we call today "institutions" were in fact the consequence of patterned and/or recurrent series of social interactions between different social agents in small-scale societies, and should be understood as preconditions for social life, unintended outcomes, and human devised constraints.

Running a simulation of the historical trajectory of Patagonian societies from 13000 BP until the present consists of creating a landscape and introducing initial populations of resources and hunter-gatherers. Ecological data to reproduce changing landscape conditions through time is available. The simulation of human populations is based on general assumptions derived from ethnographic studies of Patagonia historical groups (*mapuche, günuna-künne, tehuelche, selknam, hausch, chono, kawesqar, yamana, etc.*) and from different theories of hunter-gatherer socio-economic formations. Agents from different hypothetical ethnic groups are programmed as normal individual agents, with the same procedures and general goals, but with different plans and schedules: they have adopted historically different forms of division-of –labor, different activities and they have access to different resources. The past of the system will be introduced by the programmer, and changed when necessary to experiment with different hypothesis.

In a preliminary approximation, the system will be built around

- A two-dimensional simulated environment or "landscape" with a population of mobile agents and changing resources providing "energy" for the agents.
- Different kinds of agents are envisioned. Not only social agents simulating human beings, but also all their instruments and produced goods, as well as resources, and even social mechanisms are software objects with their own behavioral rules. In this way, a community of 50 members –as documented in ethnographic sources- can be simulated using 50 software objects for the people, and additional agents for households acting as an attractor of social life, the food they eat and once it was an animal moving across the step or a vegetable at a distinct location, the knife or the "bolases" they used to hunt animals, etc.
- Social agents are structured not only with behavioral, but also with cognitive rules that "reactively" connect environmental resources with social actions (hunting, gathering, consumption). If a social agent does not sufficiently regularly acquire energy by "hunting-gathering" and "consuming" resources, its energy level falls below its target satisfaction level and if the level falls to zero then the agent "dies", i.e., disappears from the simulation. Agents have offspring during a simulation trial.
- In addition, there are other rules implementing inter-agent communication, generating, maintaining, and updating simple plans for execution. In any case, not all social agents should behave identically. Men and women will be programmed with different roles.

Figure 1 shows the general dependency network between social agents, instrumental agents, and produced goods [9]. It is a multi-step procedure where to obtain food many previous procedures are needed, from the location of the resource, the acquisition (hunting, gathering), its processing, etc.

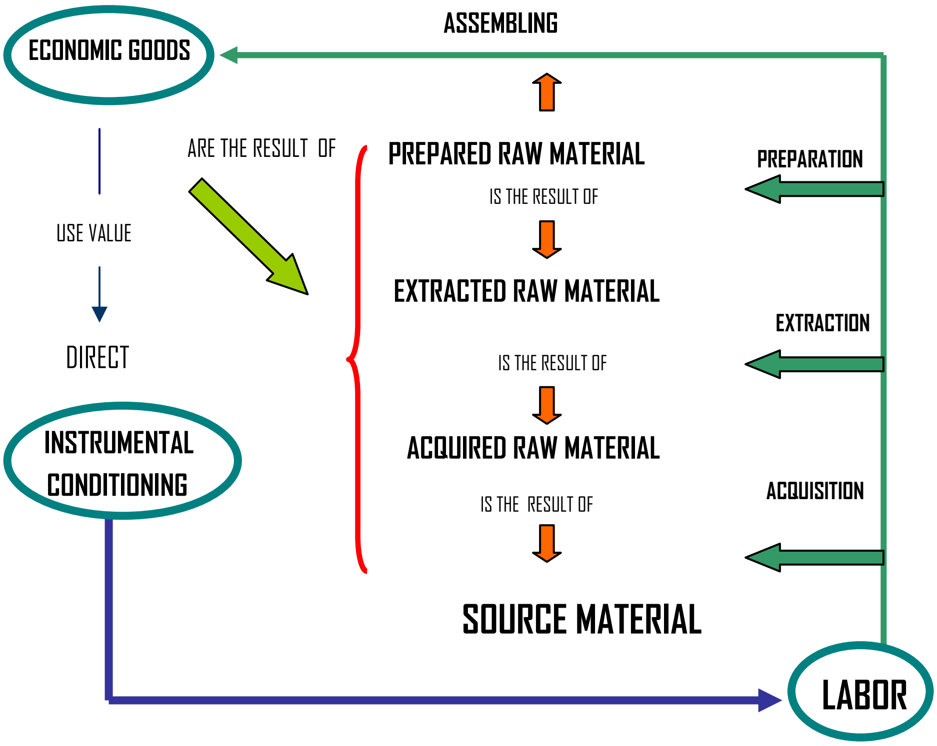

Fig.1 A dependency network between social agents, instrumental agents, and produced goods in the case of the economy of subsistence. Based on the theory argued in [9].

For instance, in the case the source material is an animal then acquisition primitive procedures will be: hunting, capturing or scavenging and also transporting. From the acquired animal, the social agent will "extract" many different secondary products (animal parts), but also some refuse material: the head, the skin, and the guts. Primitive procedures are now: skinning, draining guts and butchery. To prepare the consumable goods (meat, fat, leather), social agents need some other procedures like:

- SHAPING –Change of shape, without changing quantity or quality
- CHANGE OF QUANTITY –cutting, segmenting
- CHANGE OF QUALITY – change of physical properties (physico-chemical)
- CHANGE OF CONTEXT –insertion of components

An agent should make an instrument before some executing an acquisition/extraction/preparation goal. Additionally, the amount of work necessary to execute those social procedures is scaled according to different parameters. In the case of the preliminary acquisition of raw materials, the following parameters are of relevance:

- Time of access to the source material: scale from 1 to 3
- Temporal availability: constant, sporadic, seasonal
- Spatial availability: continuous, discontinuous, concentrated, rare
- Transported weight from the area of acquisition: 1) up to 10 kg, 2) 10-40 kg., 3) more than 40 kg.
- Technical complexity 1) simple (without instrument) 2) simple (with instruments) 3) complex with many different tasks and procedures
- Labor force: 1 person, 2 persons, more than two persons
- Time for obtaining the raw material: direct, 1 day, more than 1 day

Each agent will be initialized based on demographic characteristics and nutritional requirements based on ethnographic real cases and theoretical research on hunter-gatherer socio-economic formations. The spatial location of social agents, as well as the size of each community (the number of agents at each site), will be updated cyclically. Additionally, the amount of work or product needed to fulfill the goal of "survive" will produce some temporal dynamics given the need to reproduce the different procedures a number of times, and the need to collaborate with different "men" and "women", all with the same goal for surviving, but with different schedules to obtain their needs.

The purpose of the simulation is to reproduce the way Patagonia was populated by the first humans in South America. The beginning of human settlement in Patagonia around 13000 BP was a slow process of exploration and colonization [10] [11], carried out by small groups, very mobile and disperse, with approximated site-catchments areas around 100 km [12]. What characterized those first groups would be then population low density and the absence of specialized uses of the ecosystem given the lack of social concurrence.

6000 years after the arrival of these populations, around 7th Millennium BP, archaeological data suggest demographic increase and population expansion of early human groups. At this time, it has been recorded an increasing use of marine and littoral resources [13][14][15]. Although coastal colonization was a planetary global phenomenon in the early phases of Holocene, there are traces of variability at the local level:

- Along Patagonian Atlantic coasts, a mixed production system was configured based on the concurrent exploitation of marine, littoral, and terrestrial resources in different proportions at different areas.
- Along Patagonian Pacific coasts and southernmost islands, archaeological evidence suggests an intensive exploitation and even specialization of productive systems in marine and littoral resources.

We do not know if this demographic increase and the resulting colonization of new geographical areas was the offspring of the same early population that colonized this area since 13000 BP, or the consequence of the arrival of some newcomers from the north. Different scenarios are possible. There is the possibility of the total extinction of first comers and their substitution by a minimum of three new groups: one located along the western and southern coasts and islands, another between the Pacific coast and the Andes Mountains, and the third one further to the east, from the Andes until the Atlantic coast and the Magellan Strait. Another scenario will consider that southwestern fishers and gatherers are the only remains of the original population, reckoned in the Big Island of Tierra del Fuego, and adapting locally to the specific situation in the island, once it separated from the continent 8000 years ago, leaving a small population in a very restricted and closed territory, with lowering game resources and compelled to develop new social and economic strategies for surviving. The success of a transformation that took place very locally would explain the further expansion of the new way of living to all coastal areas supporting it. We should simulate both hypotheses, using archaeologically dated evidence as background knowledge.

It has been argued archaeologically that 6000 years ago economic variability would have been consolidated all over Patagonia, defining a differentiation between some communities specialized in the exploitation of marine resources, some specialized in terrestrial resources, and those without specialization but exploiting both terrestrial and littoral ones. The separation would be so strong that it has been interpreted as the existence of different human populations at both areas. However, we must take into account that there is ethnographic evidence of inter-ethnic relationships, giving additional support to a permeable frontiers hypothesis.

To know whether this level of social aggregation was a result of environmental constraints or the consequence of a socially mediated decision, we need to experiment alternative scenarios in which simulated agents have social reproduction surrogates acting like kinship and political alliance mechanisms fixing the limits of the social groups. We need to take into account that:

- Social reproduction conditions biological reproduction.
- Social division of labor conditions group movements across diverse landscapes,
- Management of local sources of food and other resources are mediated by social decisions.

In the simulation, agents represent mobile populations. Once all agents are initialized, social agents engage in hunting, gathering, raw material acquisition, instruments making, labor collaboration and reproduction. From cycle to cycle of the simulation, simulated social agents should react like their counterparts of the early period of first human settlement in Patagonia, moving their plots or dwellings or both based on their success in meeting survival goals.

The hypothesis we need to test in our simulation is whether a territorially based economic variability configured some time around 6000/5000 BP, would have given support greater similarity between geographically proximal populations and increasing differences between groups that are further and further apart. If climatic gradients and ecological variability were the only factors explaining cultural and social variability, then geographic distance (in latitudinal sense) would be the main observable correlate to explain the differentiation of the human groups from Tierra del Fuego and Patagonia. In this scenario cultural distance would be strongly associated with spatial separation and ecological difference. However, environment should not be considered as a mere outer physical container inside of which people behave in certain ways. It is constituted through the performance of many different activities involving people and the circumstances and products of their work. We should take into account that social agents are involved in social and political relationships with other social agents, when meeting, collaborating, making or sharing instruments or goods. Social contexts should be implemented in the simulation as spatio-temporally related actions from many different agents with a diversity of goals, and behaviors, engaged in different labor activities, and using different instruments. “Survival” goals can be the same, but the way to attain them can be different. Consequently, we assume an historical trajectory characterized by a social fissional process generating increasing social and spatial aggregation levels. Therefore, group differences may emerge when social interaction between groups reduces.

The simulation also includes some external factors that may have affected all Patagonian populations. For instance, climatic anomalies would have increased aridity rates causing the reduction of available fresh water sources, and animals. Human settlements become spatially constrained and forced to concentrate, socially specializing the uses of physical space. The nucleation of human settlement would contrast with the opening of social exchange networks to compensate for the reduced mobility of residence patterns.

Data used to define the behavior of our simulated agents come from ethnographic, historical, paleolinguistic and archeological research. The three modern linguistic families of specialized foragers on marine resources of western and southern coasts and islands (*chono, kawesqar, yaghan*) were related among themselves in the past, but seem totally unrelated with languages spoken by terrestrial hunters from continental areas (*mapudungun, chon*) [16]. This fact suggests the historical possibility of a common language in the southwestern coasts and islands spoken 6000 years ago by a single human group that would have begun to diversify 5000 years ago, into a minimum of 3 different groups. The existence of further linguistic variation at the level of dialect suggests that a similar economic specialization did not prevent an increasing diversification at the local level, when interaction between groups reduced given the nature of territorially induced division of labor.

The spreading process itself can be simulated by a repeated generation of social agents in space. The spreading surface will represent a combination of environmental parameters that are considered fundamental to the dispersal of early hunters across Patagonia. These parameters will be evaluated for their influence on the movement of human groups, reclassified, and combined to obtain a spreading surface that represents local resistance to the process of spreading. As a result:

- Every location in the landscape may have an underlying raster value simulating the level of each resource and its exploitation value.
- Every generation this underlying value decreases simulating the drain on resources and its degree of over-exploitation.

- The number of descendants at each place in each generation depends on the value of the underlying raster. The higher the value ("better conditions"), the greater will be the number of descendents in the next generation.

The actual spreading distance ("how far a new generation will go") also will depend on the underlying raster value. The lower the raster value at a specific point, the higher the spreading distance.

The generation of people is another work activity, unequally distributed between both roles [17] [18]. Figure 2 illustrates the basic social reproduction procedures.

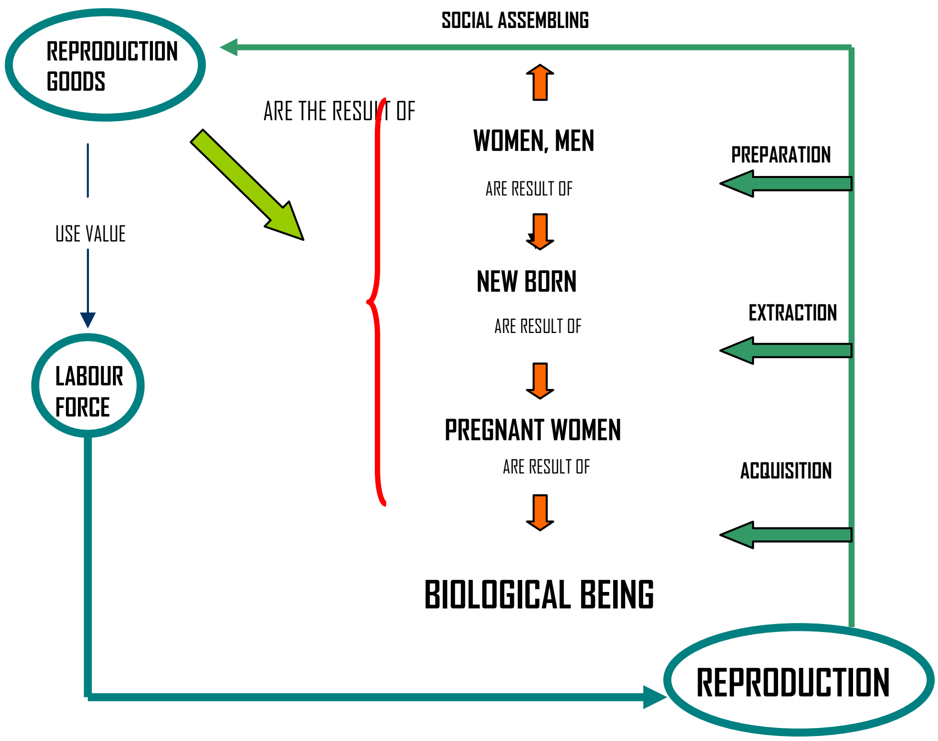

Fig.2 A dependency network between social agents, instrumental agents, and produced goods in the case of the economy of social reproduction.. Based on the theory argued in [9].

Energy will be incremented by one unit not when the individual reaches a food element but when it is able to do some work to process it and attaint the goal of "eating". This activity not only included individual procedures, but also collective behavior between different agents (men and women). We also need a mechanism simulating social consensus between a "man" and a "woman", to generate new individuals (offspring) which will be assigned a genotype encoding their role as a "man" or a "woman", with the addition of some random changes to the quantitative value of some of their abilities. As a result, the agents are not more efficient, but develop a more efficient mechanism of social reproduction, allowing better rates of survival for groups of interrelated agents. Additionally, instead of reintroducing food in the landscape, we should program the evolving dynamics of the environment. It is expected that the simulation may validate the assumption that if an environment regenerates at fast rates, the population of social agents distributes itself homogeneously in the environment. However, when the environment is too slow to change to modifications generated by social agents moving in it, we should observe the same oscillatory migratory waves of the agents in the environment, we considered in the simpler scenario.

Since hunter-gatherer productivity may vary greatly from year to year, agents need to adapt mechanisms to reduce their uncertainty of future yields. In our simulation, one such mechanism will be reciprocity between agents both at the individual level and at the aggregate one (between households). After a reasonable model of agent planning is constructed, agents should be endowed with balanced reciprocity behaviors, placing the households into a social and an economic network. This network should be flexible enough to evolve according to agent interactions and changes in the world environment. Through simulation, we should keep track of who is connected to whom through a mapping of the network and the specializations of each agent, testing the effects of simplified individual motivations for exchange, and abstract representations of basic ideological dispositions such as the belief in private ownership. The aim is to test whether specialization and wealth inequalities are natural, self-organizing qualities of a small-scale economy.

Although very simple in their parameters and assumptions, these preliminary scenarios allow testing the general principle that when moving across the environment, social agents induce changes in their physical context, but also in their social environment. The agents periodically modify their output behavior when they *learn to predict* how the action at a previous step modifies the input at the next step. A kind of social order is expected to emerge, which should equal the institutionalization of social life, and the historical formation of social and ethnical conscience. This is the key aspect of the simulation, and therefore, we have to add social factors constraining and mediating human behavior in an evolving landscape characterized by changing resources and changing relationships with other social agents.

In a new scenario we plan to build a group of agents that has to reach a target in the environment but to be rewarded they must approach the target by maintaining reciprocal proximity. If the agents are initially dispersed in the environment, they may be unable to perceive each other and therefore they may be unable to aggregate and then move together toward the target. The solution is to evolve some signaling behavior –a surrogate of ethnic identity: language, for instance- that allows the group to aggregate. In this way, the resulting groupings of simulated agents in the simulated environment equal the formation of social and ethnical frontiers.

Spatial aggregation can be a favorable pre-condition for the emergence of social behaviors such as communication and economic exchange among individuals that happen to find themselves near each other. By introducing gender, marriage rules, and other procedural enhancements we will allow individual agents to co-exist and reproduce. In general, we assume that kinship tends to configure well-defined groups with clear borders, whereas political alliance is much more flexible and instable, tending to configure irregularly shaped social communities of interest.

Kinship networks are baseline networks linking each individual household to its parents, siblings, children, and other relatives. We intend to program our social agents based on the assumption that they were organized at the level of extended families with their relatives and strong exogamy. These groups were diverse according to territory, activity, wealth and number of people. From ethnographic sources, we know that organization was predominantly patriarchal, where men had the possibility of as many wives as they could maintain. Division of labor was strongly marked between men and women. The exploitation of women work by men has been well documented during the ethnographic present, and we are interesting in exploring its particular historical trajectory [19].

When allowing agents more opportunities to exchange resources, the simulation should produce more complex network structures, larger populations, and more resilient networks of social exchange. Over such networks, generalized reciprocal exchange can be implemented to enable the agents to mutually cooperate and exchange resources in order to survive. A small world differentiated conscience of the individuality of the group should emerge and we expect the resultant identities be more resilient to changes in external factors affecting social mobility. In the case of Patagonia, the intrinsic mobility of the main resources (seasonality of migratory movements of hunted preys –*lama guanicoe*-) suggests the relocation of agents closer to the most productive kin. Over time, the clustering of individuals closer together around the most productive mobile groups of people can reflect the emergence of hierarchically organized social exchange networks.

By observation of which agent first acquired each resource, agents came to recognize particular resources as "owned" by particular agents or groups, which implies that a form of territoriality can be displayed. This can produce emerging collective phenomena in the spatial distribution of the population. Many individuals can end up near each other simply because they tend to approach the same localized resource such as food or a water source. According to this view, an isolation-by-distance mechanism would make that simulated groups of agents reflect geographic separation in the pattern of their between-group distances.

In these circumstances, simulated agents must be able to plan the coordination of many agents. This requires them to undertake complex forms of planning, what leads to more complex forms of political relationships, social reproduction and hence hierarchy. Agents should select and invite other agents to join the plans they have created, selecting first their own followers and allies. Agents will adopt those plans that they judge most potentially beneficial to themselves in terms of their own current beliefs: either they persist with their own plan, or they join another agent to execute its plan. The expected effect is that, with some delay, the more highly rated plans are adopted wholly or partially for execution by groups of agents. One of the agents in each group is the originator of the plan, and is therefore viewed by the others in the group as, potentially, a leader. After multiple instances of cooperation between two agents, an alliance should be formed. When two agents are in an alliance, they exchange information about their needs, and give priority to incorporating one another in their plans. In these new conditions, an instance of a leader/follower relationship, however, will come into being when cooperation is consistently "one-way". If Agent *X* is constantly recruited to Agent *Y*'s plans over a limited period, then both *X* and *Y* will come to see themselves as in a leader/follower relationship with *Y* as the leader. Note that a leader/follower relationship can evolve from an alliance, and that both types of relationship can break down if the agents involved lose contact with one another for a sufficient time.

Our simulation is predicated on the assumption that a limited number of asymmetries, such as differential control over productive resources, can explain the emergence of institutionalized inequality. We do not deny any possibility of collectively beneficial outcomes or directionality to sociopolitical evolution, but rather we are interested in showing how it emerges from the interaction of individual agency, social structure, and environmental constraints. In the computer simulation, some agents will control limited areas with greater per capita resource endowments, and can trade access to these for services from less fortunate agents. We plan to introduce an additional set of isolated agents which simply defend richer patches for their exclusive use, while others share any resources on their patch with other non-territorial agents. In this scenario, population density per area will depend on both area richness and agent behavior. Agents would reproduce at a rate proportional to their per-period income, which is a function of their home patch's productivity, modified by any costs and benefits they accrue from social interactions.

The simulation should assume that dominant agents can have multiple subjects (but not vice versa); dominants will maintain exclusive control of resources on their local area, but are willing to exchange some share of area richness with their subjects for any profitable return. Subjects are dominated agents willing to expend labor costs in exchange for profitable returns from the dominant offering the best deal. Resource control (via territorial patch defense) is critical to such patron-client scenario. Territorial agents will pay a cost to defend sole occupancy of their local area, regardless of its productivity. A territorial agent cannot colonize a poor area. Other strategies do not defend, and will thus equally share the productivity of their patch (but not other income) with co-resident non-territorial types.

At the beginning all agents are passive non territorial, randomly distributed over a heterogeneous environment, so each agent has different probabilities to become a dominant or a subject depending on its behavior and the productivity of the area it is placed. Under default parameter values, non-territorial strategies dominate, and isolated and dominant types are about equally represented in the remaining areas. Obviously, environmental heterogeneity is critical, as dominant agents capitalize on their relatively rich patch endowments to participate in exchanges with dominated agents, and hence variation in property endowment, provides the initial opportunity for the emergence of inequality. Yet this is not sufficient, nor can this be glossed as "environmental determinism", since alternative strategies, interacting with similar resource heterogeneity do not generate socioeconomic inequality. Demographic parameters may also have a strong effect on the relative success of territorial and non-territorial strategies. When mortality is high or reproductive rate low, the initial non-territorial population expands slowly so that isolated and dominant agents are able to spread and control rich patches. Conversely, low mortality or high reproductive rate allows non-territorial behaviors to proliferate rapidly, and territorial agents are locked out. Increased change rates are favorable to the spread of asymmetric strategies, but only because this retards the initial proliferation of non-territoriality.

Although the scenario may be considered as too restricted and limited, it would allow exploring the hypothesis that a limited number of asymmetries can explain most cases of emergence of institutionalized inequality. These might include asymmetries in control over productive resources, control over external trade, differential military ability (and resultant booty and slaves), or control of socially significant information. These asymmetries need not be employed coercively, as long as they are economically defensible and can provide an advantage in bargaining power sufficient to allow the concentration of wealth and/or power in the hands of a segment of the social group or polity. Such asymmetries can be self-reinforcing, and thus quite stable to moderate perturbations over time.

In this way, we pretend to understand how and why, at the end of their historical trajectories, political systems in indigenous Patagonia were based in competitive polities, they were irregularly shaped and flexibly in their numeric composition. Social organization was expressed through territoriality rights, and social membership [20]. We intend to build our simulations to discover how authority was restricted through kinship, and legitimized through the use of rites and symbols.

In a last scenario, groups of agents acting as surrogates of the colonizers from the industrial world will also be introduced in the model, showing the transcendental social and economical transformation induced by the European contact (16th century). Historically, colonial encounter was a relatively slow process that increased the global trend of increasing hierarchy and complexity in socio-political organization of indigenous groups, but at the end appeared to be catastrophic, especially when it led, at the end of 19th century to violent conflict. We intend to simulate this upheaval changing the directivity of social exchange networks. What at the very beginning were random contacts, conditioned by social decisions at the local level become globally oriented exchange and social reproduction networks oriented to the main colonial centers. Historical data suggest a resulting progressive homogenization of languages and cultures across continental Patagonia, caused by the increase in frequency and intensity of long-distance exchange mechanisms [21] [22].

All these social transformations seem to coincide with the adoption of the horse. Wild horse was introduced from Spanish domesticated animals, and indigenous populations tamed those animals and stored them in privately owned little herds. There is a debate whether this control of animals can properly be called pastoralism. In northern Patagonia, a proper pastoralist way of living can be argued, but in southern regions, the local control of horse reproduction did not arrive to produce the number of animals that were socially needed, so the only possibility was to obtain them from the north through exchange or robbery.

Simulated horses will be introduced in the environment as wild animals flight from distant colonial centers, with their own ethology and behavior, or as exchanged/stolen elements travelling through indigenous social networks, which were older than European contact.

As a result, we should observe in the simulation that at a specific moment (historically determined around 17th century or even a little before) *aónik'o aish* language use –whose core area seems to have been the southernmost extreme of continental Patagonia, i.e. the Magellan Strain area- began to expand northwards (and probably also east- and westwards). This language became a common language among different groups and later substituted their own languages (i.e., *teuschen* among others) until a common culture, the "tehuelche complex", reunified culturally and socially what have been in a process of diversification at many levels for more than 3000 years.

The possibility for the adoption on an innovation like horse herding is highest in the direct neighborhood of prior acceptance of innovation. Therefore, social agents should cluster spatially more frequently around those areas, with a parallel increase in social complexity. At such places, the intensity, and frequency of between-group social interaction flows emerges as a consequence of the transformation of traditional means of social reproduction and political order. Mechanisms for collective decision-making began an ever-increasing hierarchization process, simultaneously to the increased size and more diverse composition of human groups. Social relations of production began to acquire some characteristics related with domination.

One of the main consequences of colonization among indigenous groups was the emergence of war and violence, although there is historical evidence that there were violent conflicts between indigenous polities well before 18th century. The simulation also takes this fact into account as a higher level of territoriality and concurrence.

4. Conclusions

A multi agent-based simulation has important advantages compared to more traditional simulation techniques:

- It supports modeling and implementation of pro-active behavior, which is important when simulating humans (and animals) able to take initiatives and act without external stimuli. In short, it is often more natural to model and implement humans as agents than objects.
- It supports distributed computation in a very natural way. Since each agent is typically implemented as a separate piece of software corresponding to a process (or a thread), it is straightforward to let different agents run on different machines. This allows for better performance and scalability.

Since each agent typically is implemented as a separate process and is able to communicate with any other agent using a common language, it is possible to add or remove agents during a simulation without interruption. It is even possible to swap an agent for the corresponding simulated entity, e.g., a real person during a simulation. This enables extremely dynamical simulation scenarios.

Agent-based modeling is a mindset more than a technology. With the possibility of simulating past social systems, a new methodology of social and historical inquiry becomes possible. The target is no more a natural society but an artificial one, created with its own structure and behavior (the simulation itself). The value of creating artificial societies is not to create new entities for their own sake, but observing theoretical models performing on a test bed. Such a new methodology could be defined as “exploratory simulation”. Exploratory research based on social simulation can contribute typically in any of the following ways:

- Implicit but unknown effects can be identified. Computer simulations allow effects analytically derivable from the model but as yet unforeseen to be detected;
- Possible alternatives to a performance observed in nature can be found;
- The functions of given social phenomena can be carefully observed
- “Sociality” that is “agenthood” orientated to other agents can be modeled explicitly

As the emphasis shifts from describing the behavior of a target system in order to understand natural social systems the better to exploit the behavior of a target for its own sake, so the objective of the research changes to the observation and experimentation with *possible social worlds*.

An important aspect of this way of understanding historical causality is that it forces the analysis to pay attention to the flux of ongoing activities, to focus on the unfolding of real activity in a real historical setting. We do not pretend to simulate social action as a free exercise. We intend to create artificial societies according to social theory to test the observable consequences of such theory and to be able to create the appropriate measuring instruments and to test the theory in the real world. Additionally, we plan to create an artificial society using known data of societies that once existed. Ethnoarchaeology is the interplay between archaeologically observable evidence and ethnographically observable actions. The ethnographical present offers us the possibility of implementing the motivations, intentions and the “apparent” lack of economic rationally (compared to our actual standards) in a hunter-gatherer society. Archaeological data from the territory where this society once existed offer us the possibilities of introducing time, transformation and evolution into the explanatory model.

By simulating societies that may have existed somewhere and somewhen we can approach the understanding of social activities in the past in terms of a "pure" system and analyzing then the space of possibilities which are open to the system. By introducing "constraints" to the pure system we approximate the simulated model’s behavior to the behavior of some real social system. Therefore the starting point of the analysis of social systems by means of computer simulation is not the simulation of one particular system but the investigation of the logically and statistically possible development of specific classes of model systems (pure systems). As these pure systems usually generate a lot more different paths of development than are known from real human history, we have to limit these possibilities by introducing social constraints which are known from social reality. The sociologically interesting question is then why these constraints appeared in reality. Therefore the introduction of constraints is both a methodical tool to limit the logical possibilities and a way to make the models valid for the mapping of social reality.

Obviously, not everything can be simulated with a computer, because of the many limitations of the approach, notably the non-uniqueness difficulties that arise when describing social mechanisms. Non-uniqueness means in effect that the true input-output mapping cannot be selected from among a large set of possible mappings without further constraints imposed. This undesirable behavior may be due to different factors, among them: noise in the measurements, insufficient number of measurements, but specially, because of the non-linearity of the social activity itself: different actions can produce the same observable archaeological features, or the same action may not produce always the same archaeologically observable features.

Fortunately, however, satisfactory computer simulations can sometimes be given for effects resulting from social mechanisms whose operations are too irregular to enable the archaeologist or social scientist to reliably predict their future performance, or to systematically explain why they sometimes fail to produce the effects they produce on other occasions.

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