Mentat: A Data-Driven Agent-Based Simulation of Social Values Evolution

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ABSTRACT

This work presents an agent-based simulation system dealing with the evolution of moral values together with other related parameters in a society. This model has been applied to the study of a 20 year period of the Spanish society. Analysing the evolution of values in society is a complex problem involving many different factors. Simultaneous analysis of all the factors makes it impossible to interpret the impact of each one. For this reason, the model should be able to allow the analysis of different aspects separately, and their mutual influence. The agent-based model is built by taking information from a common tool of sociologists: public surveys. Surveys are taken as input to build the model by following a data-driven approach. This has been formalised in a methodology for introducing microsimulation techniques, as well as importing data from surveys and other sources. It handles thousands of heterogeneous agents, which have a life cycle, reproduction patterns and complex social relationship dynamics including friendship. The emergence of a robust social network was a consequence of the system set up. Its output is consistent with respect to the ideological, religious and demographic parameters observed in real world surveys. Moreover, the implemented system has several extension modules: fuzzy logic for a smoother behaviour; natural language biographies generation, for a quasi-qualitative output; data mining for pattern finding; social network analysis techniques for extracting and tracking structural variables. Thus, Mentat is proposed as a framework for exploring complexity at different levels in the social process.

Categories and Subject Descriptors

I.6.5 [**Simulation and modeling**]: Model Development—*Modeling methodologies*; I.6.3 [**Simulation and modeling**]: Applications; I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Multiagent systems, Intelligent agents*; J.4 [**Social and Behavioral Sciences**]: Sociology

General Terms

Experimentation, Design

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Keywords

agent-based model, data-driven modelling, demography, social values, multi-agent based social simulation

1. INTRODUCTION

Agent-based social simulation has proven to be a useful tool for the study of complex social phenomena, as it facilitates a bottom-up approach for the analysis of macro behaviour in societies of interacting entities [2]. This aggregate behaviour is called emergent, as the collective and even individual behaviours could not be predicted or expected from the initial settings of the simulation [4].

As this technology gets mature, new approaches are needed for bringing it closer to the real world, and therefore with an increased potential of being useful for social sciences researchers. With this purpose, it has been developed an Agent-Based Model (ABM) for the analysis of the evolution of moral values in the postmodern Spanish society during 20 years. The particularity of this model, coined Mentat and based on the prototype of one of the authors [8], is that it tries to cope with several issues that are commonly neglected by a big part of the community of this field. In particular, most ABM in literature tend to be simple, following the Keep It Simple, Stupid (KISS) principle. However, recently other works [5] claim for a substantial increase on the complexity of the models, taking more into consideration real data.

In this line, Mentat applies a data-driven approach that tries to integrate drawing ng a new methodology for injecting empirical data into Multi-Agent-Based Simu- lations. Specifically, Mentat has been intensively fed with a typical source of information for sociologists: surveys. Besides, several sociologists have been involved in the design of the system, strongly basing the modelling decisions in sociological literature, and even giving some empirically-based equations which sustain the demographic dynamics.

Mentat also handles complex friendship dynamics, which lead to the emerging of a robust social network. The links of this network evolve over time, both topologically (breaking and creating links) and in strength (and strong and weak links can be identified). This process has been implemented with fuzzy logic techniques to obtain the smooth and continuous behaviour characteristic of friendship.

Another goal of this model is to provide ways to facilitate analysing different views of the system, with the ability to enable and disable different factors/aspects in the model, so a social scientist can analyse their impact in isolation or the mutual influence of some factors with others. Thus, it has been used as a framework where it has been possible to integrate, in a controlled way, several modules which represent different social processes, and different Artificial Intelligence techniques, obtaining hybrid systems with richer outputs. The social processes modelled are described along the paper, and the introduction of fuzzy logic is addressed in 4.2. However, other AI applications in Mentat fell out of the purpose of this paper. Nevertheless in section 7 some of them are drawn: natural language processing for agent-biographies; data-mining for hidden pattern finding and validation; social network analysis for extracting and tracking structural variables.

The discussion of the sociological problem in the section 2 provides more insight on the motivation for this work and the issues to solve. In section 3 several innovative methodological issues will be commented. In the following two sections, the micro and macro levels of Mentat will be deeply described, including its internal dynamics. Section 6 discusses the output of the simulation, comparing it with the collected data. The paper ends up with some concluding remarks and future research lines that are being explored nowadays.

2. THE SOCIOLOGICAL PROBLEM

Many sociological problems are difficult to be addressed properly with traditional analytical and statistical techniques, due to the diversity and great number of factors involved (e.g. evolution of culture), complicated dynamics (e.g. social networks), non-measurable social processes (e.g. psychological processes, world-size phenomena). Those problems are likely to be handled under the scope of the Complex Systems theory. In this scope, agent-based systems have proved to be a proper framework to model and simulate these social processes [7].

The idea beneath Agent-Based Social Simulation (ABSS) is that we may be able to understand this huge complexity not by trying to model it at the global level but instead as emergent properties of local interaction between adaptive autonomous agents who influence one another in response to the influences they receive [17]. Because of that, the specification of characteristics and behaviour of each agent is critical, in what it can affect the dimensions of the studied problem.

To illustrate the issues with a specific example, this work has taken the analysis of the evolution of moral values, together with other interrelated factors, in a specific space and time. In particular, this work takes an existing sociological research [19] on the Spanish society between the years 1980 and 2000. This Spanish period is very interesting for social research, due to the big shift on moral values that the society bore then. At the time of the re-instauration of democracy in 1975, the country was far from Europe in all the progress indicators, including the predominant moral values and modernisation level. However, the observed trends of the moral values evolution since then are analogous to the ones found in its EU partners [15]. Furthermore, the change in Spain has been developed with a special speed and intensity during the studied period. The problem we are facing is to study this complex problem: the shift in the people's values and mentalities in this society, in this period.

This issue has two main faces: the intra-generational changes (horizontal influence) and the inter-generational changes (demographic dynamics). To better analyse the weight of each one in the global evolution, it has been decided to isolate the controlled simulation of each subprocess. Therefore, in this work the scope has been focused in studying to which extent the demographic dynamics explains the magnitude of mentality change in Spain. This demographic factor does not cause nor determines the change in values, but it does exert an important influence on the speed and intensity in which it manifests, and thus it holds an important predictive ability for its evolution. This is mostly due to the fact that the changes in values have been chiefly generational changes, hence the generational replacements (say, the death of elders, carriers of the most traditional and conservative values, and the arrival of youngsters, bearers of emerging values) constitute a strong sociological urge.

Thus, individuals moral values remain constant, as they are not interfered by external influences. However, there are social dynamics (emerging and strengthening of friendships, couples), together with demographical changes (aging, deaths, reproduction). As a result, the moral values aggregation in the whole society evolved over time. This clearly reflects the mentioned inter-generational changes, but not the intra-generational ones. However, this isolation is the only way to analyse and appreciate the predictor effect of the demographic dynamics.

The source for modelling and initialization of agents attributes has been the European Values Survey (EVS). This is performed every ten years in all European countries [6], and thus provides a representative sample of the Spanish population. Moreover, as the EVS offers a wide source of quantitative information and periodical results (once every 10 years), it can be used for validation of the simulation model: initialising with EVS-1980, simulating 20 years, comparing with EVS-2000. Besides, for the design of the model and the selection of the relevant attributes, we have counted with the help of an expert in the field and several research studies [9].

The individual attributes that will be taken into account have been selected acording to their high influence in the studied subject. Thus, they are considered: a general characterisation of the agents, like gender, age, education and economical level; moral values related attributes like ideology, religiosity, or tolerances to sensitive subjects like divorce, abortion or homosexuality; social relationships like their acquaintances, close friends, parents, couple or children.

3. METHODOLOGICAL STANCE: DEEPENING THE DATA-DRIVEN APPROACH

Along this research project, we had the opportunity of devoting some thought to how social simulation is conducted and how it should be conducted to enhance the confidence we can deposit on the obtained results. The search through the space of possible designs of the agents involved in the simulations, as well as their organisation (society) and the experimental set up (the simulations themselves) must be conducted with some guiding principles in mind. To some extent, this search is similar to the Lakatos [16] description of scientific progress through research programs. Several methodological innovations were developed during or concomitantly with this project. In this section we only briefly address some of them.

Our starting point was Gilbert's "logic of simulation" [7], in which a target phenomenon is modelled, and simulation data is validated against collected data. We have advocated that when data are available from the real phenomenon, there are more steps in the simulation process that can be informed by their judicious use. In particular, data should be used instead of idealised theoretical random distributions, in an effort to bring the model closer to the real phenomenon. Another use of data is to inform the design and calibration of the model (cf. [10]).

In the search of the appropriate modelling stance, namely in terms of abstraction level and accuracy to the target phenomenon, two main perspectives have been emphasised in recent years: KISS [2] and KIDS [5]. KISS stands for "Keep it simple, Stupid!" and stems from Occam's razor: the idea that things should be kept as simple as possible and made as little more complex as explanation purposes demand. KIDS reads "Keep it descriptive, stupid!" and argues that too much simplicity yields useless models, so we should make models as close to the real target as possible, and then progressively remove things deemed not essential for the model. The move from KISS to KIDS can be based on more intensive use of data that helps remove the many arbitrary assumptions and abstract simplifications of KISS models.

However, both approaches seem quite unrealistic in terms of the purposes we envisage for social simulation: explanation of phenomena at both micro and macro levels to the point that they can be used for accurate prediction of real world phenomena, and finally used to prescribe policy measures to accomplish desired political outcomes. Starting from Gilbert's principles, the authors have proposed a methodology for multi-agent-based exploratory simulation that proposes series of models designed to progressively tackle different aspects of the phenomena to be studied [1]. This new approach coined "Deepening KISS," amounts to start from a KISS model, following Sloman's prescription of a 'broad but shallow' design [20]. Then, through the use of evidence and especially data, a collection of models can be developed and explored, allowing for the designer to follow the KIDS prescription without really aiming at more simplicity or abstraction. This exploration of design space allows to pick the best features of each model in the collection to design a stronger model, and the process iterated. Deepening KISS with intensive use of data can be placed middle way in terms of simplicity versus descriptiveness, whilst it acknowledges the role of the experimenter as guide the search for the adequate models to face the stakeholders purposes [10].

4. ZOOMING IN: THE MICRO LEVEL

4.1 Autonomous Individuals

As it has been mentioned previously, the Multi-Agent System Mentat was developed using agents with a wide collection of attributes related to the social under study. Most of the attributes are loaded from the EVS (except social relationships, that of course do not appear in the survey). But while some are used mainly to be controlled in the final aggregated output (in the form of graphics and statistics), others constitute the key to their micro-behaviour in the demographic dynamics: age, gender and their relationships (together with the position and the neighbourhood, but those are completely random). The friendship dynamics are fed with the aggregation of all the characteristics, as it will be explained in the next subsection.

The population in the agents' society (as in real societies) evolve demographically: individuals are subject to life cycle patterns. Thus, they are born inheriting the characteristics of their parents; they relate to other people that may become their close friends; they can find a couple, reproduce and die, going through several stages where they follow some intentional and behavioural patterns. Therefore, every agent can be child, adult or elder, and for instance a child cannot have a spouse, only adults can reproduce, and only the elder have chances to die at some point.

4.2 Neighbourhood Interaction

4.2.1 Understading Friendship

The most fundamental part of the agents' micro-behaviour is the social processes they develop. Each one can communicate with their wide Moore neighbourhood, and depending on their rate of similarity one-to-one, occasionally lead to a friendship relationship. Reaching to a certain period of their lives, the agents can search for a couple among their friends, and if they succeed, they could have children. However, the friendship choice and evolution is a complex process that is developed as follows.

Selecting a friend is among the most personal of human choices, and thus it is not surprising that friendship groups tend toward social homogeneity. Members of the working class usually associate with other workers, and middle-class individuals generally choose friends who are middle class. This is modelled in the important homophily principle in social networks of [18]. Principles of meeting and "mating" by which strangers are converted to acquaintances, acquaintances to friends, and even maybe friends into a partner, follow the same rules. Meeting depends on opportunities alone (that is, to be in the same place at the same time); instead, mating depends on both opportunities and attraction. How readily an acquaintance is converted to close friendship depends on how attractive two people find each other and how easily they can get together.

The "proximity principle" indicates that the more similar people are, the more likely they will meet and become friends [22]. Therefore, features like social status, attitudes, beliefs and demographic characteristics (that is, degree of "mutual similarity") channel individual preferences and they tend to show more bias toward homogeneous friendship choices.

4.2.2 Friendship Evolution

We should note that similarity, proximity or friendship are vague or blurry categories. For this reason, a formal model of friendship dyads was developed using the general framework presented above, but considering similarity and friendship as continuous variables. Besides, because friendship occurs through time, we have considered our model in dynamic terms. As it is deeply explained in [11], to model formally the friendship evolution a specific logistic function [3] is used:

$$\frac{dF}{dt} = F(t) \times K(t) \times r \tag{1}$$

Thus, at each point of time, *F(t)* defines the minimum degree of friendship that is given as an initial condition ($0 < F(t) < K$); K is the maximum degree of friendship that agents can reach (K can be understood as the level of "close friends"), and finally r value defines the growth rate of friendship. However, this equation does not include the

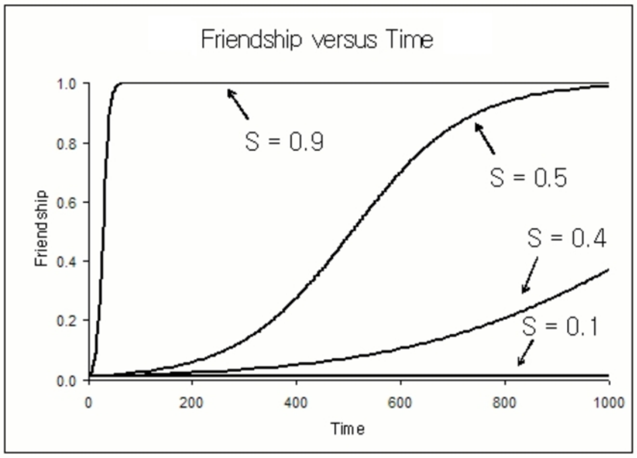

Figure 1: The logistic function chosen for the evolution of friendship, for several one-to-one similarity values

"proximity principle" described above. We can include this principle in equation 1 by modifying the growth rate r and stating it as follows: the more similar in social characteristics two individuals are, the higher the growth rate of their friendship is (we need to make r sensitive to the similarity value). Further equations of r and an analysis of the values in each formula can be found in [11].

4.2.3 *Fuzzy logic in a fuzzy environment*

However, similarity and friendship degree are blurry concepts, as it has been already mentioned. To model this uncertainty more accurately, fuzzy logic has been used. Fuzzy logic is oriented at modelling the imprecise modes of reasoning in environment of uncertainty and vagueness, an usual feature in the social sciences realm [21].

Therefore, fuzzy sets over each agent attribute have been defined, and a fuzzy similarity operator that influences friendship emergence and partner choice. The friendship relationship is turned into a fuzzy relationship, evolving through the defined logistic function, and letting it influence in the partner choice as much as the similarity rate. This fuzzification of the operators improves the proximity of the results to the qualitative assessments of the theory, achieving a smooth global behaviour. This fuzzification is carefully detailed in [11].

5. ZOOMING OUT: THE MACRO LEVEL

5.1 A Stable Environment: some Technical Details

Due to the relative simplicity of the agents, the system can manage thousands of them, reaching the necessary amount for observing an emergent behaviour that results from the interactions of individuals, leading to the appearance of social patterns than can be studied [2]. Thus, Mentat handles 3000 agents in a grid of 100x100 cells. The agents are spread randomly (uniform distribution) around the space. Thus, with a resulting density of one agent per 3.3 cells, and a Moore distance of 6, each agent can communicate with around 35 agents. This number is consistent with the sociological conceptions of the average personal network sizes (with strong and medium-strength ties). [13] The time scale is *one year = 50 steps*, so the total simulation time is 1000 steps (20 years).

The program has 8 configurable free parameters (like thresholds, Moore distance or probabilities), together with 10 parameters that enable/disable model stages (like fuzzy friendship or empirical initialisation). The rest of the choices have been empirically grounded (like the probability equation for knowing how many children a Spanish middle-age woman may have).

The model has been implemented in Java using the Repast framework, importing the EVS spreadsheets and generating a collection of graphs (which reflect the evolution of the main attributes of the social system) and aggregated statistics. Note that as the system is non-deterministic, the graphical results have some variations at each execution: the outcome should not be taken as a static output. In every execution the trends were very similar, even though the exact data have some small comparison errors. Therefore, the system executions have structural similarity, as defined in [7].

5.2 Demographic Dynamics

It must be pointed out that, as long as Mentat analyses the evolution of moral values and socio-cultural phenomena during a long period of time (20 years), and it pretends to achieve a simulated output in equivalent quantitative terms to their real evolution, it becomes a need to implement an analog demographic pattern of the Spanish one. This demographic dynamics are synthesised here, though they are deepened in [9].

As it has been mentioned, the ABM is initialised with the Spanish section of the European Values Survey of 1980. However, there is an structural problem here: children don't make surveys, but the ABM needs the initial children corresponding to 80's Spain. Those children would grow in the simulation and maybe reproduce, altering significantly the output. In 1980 there was a 30% of children in the country, so 700 new agents have been introduced, together with the 2303 of the EVS, filling the important gap. Those agents were statistically generated by the sociologist from the EVS-1980 data.

Another structural change has been carried out because of another problem of the EVS: the lack of information related to the links among people. However, a proper simulation of 1980's behaviour should take into account that then the people *was already linked*. A simulation that begins with isolated people that must find their "first friends" makes no sense. Therefore, a new stage was introduces in the simulation, popular in the field: a warming-up stage, where the individuals have time to relate to each others, but the "timer" does not count (there is no aging and current year is always 1980). When it is considered "enough" (the length of this stage is another parameter) the actual simulation begins, but already with initial friendships and marriages.

A third important point in the demography is that Mentat was first tested with Normal distributions for the typical demographic decitions (life expectancy, birth rate, age for having first child...). However, it was improved replacing them with empirically based probability equations.

With this demographic dynamics, as time goes by, agents will die and be born. Even if there is no horizontal influence (inter-generational changes), the deaths of the elder ones and the new children of certain couples will reveal a change in the global aggregations of the main parameters in the model (intra-generational changes). This change will be further explained in section 6.

5.3 Social Networks: Family and Friendship

Typically, in MABS models, complex social networks emerge from the micro agent rules. In Mentat's case is not different, and a robust social network can be observed, emerging from the micro-interactions of individuals. But there are two types of links (visually colored) and therefore two related dynamics can be analysed: friendship and family.

Each agent continuously compares itself with its neighbours, using the fuzzy similarity function. The more similar two individuals are, the bigger are the chances of becoming "friends", i.e. create a friendship binary link between them. However, the intensity of the link matters, and the friendship will become stronger depending on two factors: again the similarity among them and the time that went by. The logistic function described in section 4.2 represents this evolution: as time goes by, the bigger the similarity/likeliness, the faster the growth on friendship intensity. Thus, some people, even if there are a link with them, will always be acquaintances, while others will quickly become very close friends.

By the end of the simulation, nearly every agent have a lot of links, but not a lot of close friends. However, some "hubs" exist: agents with lots of friends, because they are close to the "average of their surroundings". Also, some isolated outliers can be found, though very rare, depending on configuration and thresholds chosen.

On the other hand, each agent, in a certain period of their lives, can try to find a couple. The list of "candidates" consist in its adult single friends of opposite sex. And the more "compatible" among them will be chosen, with compatibility defined as the aggregation of the friendship degree and the similarity value. When a couple is finally found, there is a chance of having children. Those children will be born spatially close to their parents, and as the couple, the children and the brothers are all connected through family links, family nuclei are built all over. Big concentrations of families and the previously mentioned "hubs" are deeply interrelated, as the more friends an agent have, he bigger probabilities it has a family. And the more families a sector have, the more populated it will be and more friends the neighbours will have.

6. RESULTS AND DISCUSSION

As it is further analysed in [9], the system's output can be compared in several indicators with the EVS of 1990 and 1999/2000. The aggregated parameters evolve over time as it can be observed, due to the intra-generational demographic changes: some people die, others are born, but those who disappear do not have the same values as the newborns. Besides, there are more births than deaths, so the population grows and the means and percentages change continuously.

The measures of the table 1 have been extracted from the three different EVS of the indicated years, together with the statistical calculations (over several executions) in Mentat, in those years. All variables are calculated considering only the individuals over 18 years, so they can be directly compared with the EVS. Even though for an easier comparison only a restricted collection of indicators (means and percentages) are shown, the system calculates more than a hundred

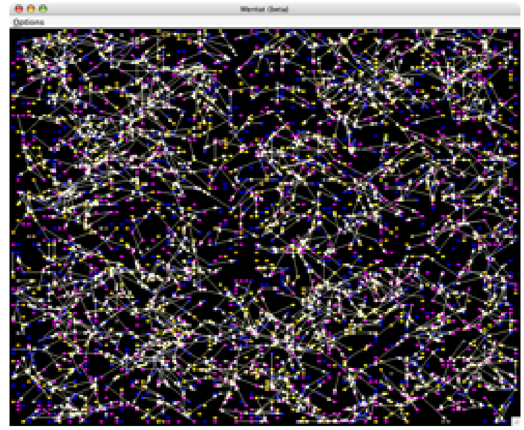

Figure 2: A screenshot of Mentat's main visual output

statistical measures. The high stability of Mentat has simplified the analysis, so it can be assessed that these values have a minimum error between executions.

The analysis of the results can begin with simple parameters like the elder percentage. It can be observed how the system follows a good projection till the 90's. However, as expected it cannot predict that since 1990 Spain gradually received a young immigration that decreased the percentage of old people in the total population. Therefore, Mentat shows an approximation of the percentage that the Spanish society would have without that increase of immigration.

The percentage of single individuals in the population is a factor related to the agents network. A single individual is the one that or a) does not have single adult opposite-sex friends to have as a couple, or b) it does not want to have a couple (for example, because it is a child). In the beginning, the agents find the problem (a), but with time the network should grow in complexity and cohesion, so the predominant problem is (b). We can see that the percentage of singles should remain quite stable near 30.

However, in the beginning Mentat shows N/A because it needs the explained warming-up stage before it can give a proper result in this matter (otherwise it would return 100% of single people, as every agent is isolated in the start). Obviously, the size of the warming-up is crucial for this variable: the more time you leave them to interact, the more couples you will have. After it, the network acquires consistence and approaches a lot to the ideal value (that is just measuring the connectivity between nodes). We can see how a wider size gives more cohesion: with 500, we achieve the ideal after 1500 steps (500 of "warming" plus around a thousand of the nearly 20 years of simulation), and logically it can be achieved before with 1000, after the same 1500 steps (1000 of "Warming-up" plus 500 of 10 years). The stability after that objective is achieved matches accurately the observed reality, and can lead us to the situation where the problem (b) is the widely dominant. From the Social Network Analysis point of view, we could say that this is a property of small-world networks.

On the other hand, the warming period length has another logical effect: the more couples we have, the more children will be born. Anyway, as the most part of the young couples find always someone, it does not have a big influence in the

Table 1: Comparison between EVS and the ABM

	EVS			Mentat		
	1981	1990	1999	1981	1990	1999
% 65+ years	16	18	12	15	19	23
% Single*	28	29	29	N/A	34	30
% Single.**				N/A	29	28
% Ideology						
Left	29	33	31	29	33	36
Centre	18	19	23	18	18	17
N/A	30	25	24	30	29	27
Right	22	23	21	23	22	20
Religious T.						
Ecclesiastical	33	25	22	33	29	25
Low-Intensity	22	26	23	22	23	22
Alternatives	14	17	19	14	16	16
Non-religious	31	32	35	31	34	37
P. Growth*			+8%			+8.6%
P. Growth**						+10%

*,**: Warming-up of 500 or 1000 steps

population growth. As we can check in the end of the table, the side effect of the extra 1000 steps yields a bigger error here. It has to be mentioned that there are no other important side effects, so we have not shown the other variables with other sizes different than the usual one of 100 steps.

The political ideology follows a similar trend but with some more slope, in the means and in the different percentages. This is due to several facts. First, we have not modelled the intra-generational changes, so the agents main attributes remain static over time (and these variables are quite sensible to those influences). Second, the simulation is not able to display the slight move to the right that occurred in the Spanish society during the conservative governments (1996-2004). But that would be too much to ask from a simulation drawn from 1981 data, while Spain was still in the period of democratic transition.

One of the best indicators for the evolution of values that we have available here is the religious typology, strongly based on them. As we can see, the values are predicted with a very good accuracy, regardless the different curves that each type follows (rapid fall, hill, smooth rising and smooth growing, respectively). This is due to the fact that religious evolution is deeply related with intra-generational evolution, and not with the horizontal influence along life. Other values are more volatile than these ones: e.g. a 30 years old woman may increase her tolerance against homosexuals, but it is very difficult that she will stop believing (or begin to believe) in her religion.

7. CONCLUSIONS AND FUTURE WORK

This paper has described a Multi-Agent-Based Simulation Model of the evolution of social values across 20 years in the postmodern Spanish society. We have explained the wide sociological underground on which it is based, and the new data-driven methodological approach that it follows and encourages. This approach facilitates the construction of the model by using data from surveys (for the initial agent attributes) and equations from social theory (for the demographic dynamics), and it is deeply interrelated with several sociological research results and theories.

Mentat is proposed as a modular framework where each stage can be enabled or disabled so it can be studied in isolation, *ceteris paribus*. Thus, the system can disable the empirical initialisation and test the output with random agent attributes [12]. Or enable/disable the fuzzy logic module to check the improvement in the compatibility of the couples [11]. Each improvement, each new stage, can be enabled or disabled and therefore compared with the other versions, exploring the models space [9].

A thorough sociological analysis showed that Mentat highlighted the importance of demography in the twist in social values that happened in the Spanish society in the studied period. The high correlation of the output with observable data is counter-intuitive, as it does not take into account the horizontal influence in values among people (intergenerational evolution). Even if other statistical techniques on this issue can be used as well for sociological explanatory purposes, ABM can deal with the social networks of individuals and their emergence dynamics.

However, it could be interesting to extend Mentat with new stages that handle some sort of horizontal influence. Even though complexity could significantly increase, making harder to find the real causes of the different processes, it could still be managed with the ability of the ABM to enable and disable particular stages, and therefore simplify the design temporarily even with a complex implementation. There are already many works developing models on opinion dynamics [14] but the values issue is, unfortunately, a much more complicated matter which does not have to obey the same laws.

As open issues for Mentat, we are considering the extension of the model by integrating other Artificial Intelligence techniques. Mentat already generates a collection of statistics from the simulation. But this output could be substantially incremented using Social Network Analysis techniques. There are plenty of methods and measures available that could throw new light over the social processes happening there: density, topology, centrality, transitivity, cohesion, structural equivalences and more [23].

Another way of approaching the huge amounts of data available is Data-Mining (DM). DM can be useful in many ways: it can search for patterns in the EVS data, to confirm the patterns found in the sociological literature. It can find hidden patterns in the output of the model, that did not appear visually or in the statistics collected. Or even it could help in the re-design of the ABM, giving more insights in a spiral way [24].

Finally, an innovative research line is to apply Natural Language Processing technologies in Mentat for providing facilities to interpret simulation results. Roughly, the process consists in tracing the sequence of micro-actions of every agent, exporting them as a XML file and processing it with a context-dependant NLP tool. This has been applied for different purposes. First, debugging the MABS: the common output of these systems is aggregated in the macro scale, but this makes difficult to know what is going on in the micro level. However, improving the NLP for the generation of simple text phrases increases the applications of the module. Thus, this module can be interesting for a pseudo-qualitative output, as it can provides a "biographic story" of the selected agents. It allows to focus on their life-events instead of the aggregated variables, and it can provide a better insight of what are the micro-effects of the emerging phenomena. If the most representative agents of each subgroup are selected, then the possibility of using them for explaining the studied social process to non-modellers (or even stake-holders) opens up [8].

8. ACKNOWLEDGMENTS

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9. REFERENCES

[1] *Article by one of the authors.* [Work deleted for blind review].

[2] R. Axelrod. Advancing the art of simulation in the social sciences. *Complex.*, 3(2):16–22, 1997.

[3] P. Blanchard, R. L. Devaney, and G. R. Hall. *Differential Equations.* Brooks Cole, 2 edition, 2002.

[4] R. Conte and C. Castelfranchi. *Cognitive and Social Action.* UCL Press, London, 1995.

[5] B. Edmonds and S. Moss. From kiss to kids - an 'anti-simplistic' modelling approach. In P. Davidsson, B. Logan, and K. Takadama, editors, *MABS*, volume 3415 of *Lecture Notes in Computer Science*, pages 130–144. Springer, 2004.

[6] European values survey: http://www.europeanvalues.nl.

[7] N. Gilbert and K. G. Troitzsch. *Simulation for the Social Scientist.* Open University Press, Apr. 1999.

[8] *Article by one of the authors.* [Work deleted for blind review].

[9] *Article by one of the authors.* [Work deleted for blind review].

[10] *Article by one of the authors.* [Work deleted for blind review].

[11] *Article by one of the authors.* [Work deleted for blind review].

[12] *Article by one of the authors.* [Work deleted for blind review].

[13] L. Hamill. New communication technologies & travel: A simulation. In *PG Autumn School in University of Surrey*, 2007.

[14] R. K. Hegselmann. Opinion dynamics and bounded confidence models, analysis and simulation. *Journal of Artificial Societies and Social Simulation*, 5, 2002.

[15] R. Inglehart. *Modernization and postmodernization. Cultural, economic and political change in 43 societies.* Princeton University Press, Princeton, 2001.

[16] I. Lakatos. History of science and its rational reconstructions. In *Proceedings of the Biennial Meeting of the Philosophy of Science Association*, pages 91–136. The University of Chicago Press, 1970.

[17] M. W. Macy and R. Willer. From factors to actors: Computational sociology and agent-based modeling. *Annual Review of Sociology*, 28:143–166, Aug. 2002.

[18] M. McPherson, L. Smith-Lovin, and J. M. Cook. Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, 27:415–444, Nov. 2003.

[19] *Article by one of the authors.* [Work deleted for blind review].

[20] A. Sloman. Explorations in design space. In *Proc. of the 11th European Conference on Artificial Intelligence*, 1994.

[21] M. J. Smithson and J. Verkuilen. *Fuzzy Set Theory: Applications in the Social Sciences: 147.* Sage Publications, Inc, Apr. 2006.

[22] L. M. Verbrugge. The structure of adult friendship choices. *Social Forces*, 56:576–597, Dec. 1977.

[23] S. Wasserman and K. Faust. *Social Network Analysis: Methods and Applications.* Cambridge University Press, 1 edition, Nov. 1994.

[24] I. H. Witten and E. Frank. *Data Mining: Practical Machine Learning Tools and Techniques, Second Edition.* Morgan Kaufmann, 2 edition, June 2005.