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CulSim: A simulator of emergence and resilience of cultural diversity

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Abstract

CulSim is an agent-based computer simulation software that allows further exploration of influential and recent models of emergence of cultural groups grounded in sociological theories. CulSim provides a collection of tools to analyze resilience of cultural diversity when events affect agents, institutions or global parameters of the simulations; upon combination, events can be used to approximate historical circumstances. The software provides a graphical and text-based user interface, and so makes this agent-based modeling methodology accessible to a variety of users from different research fields.

Keywords: Cultural simulations; Agent-based models; Cultural diversity; Cultural resilience

Code metadata

Current code version	2.2
Permanent link to code/repository used of this code version	https://github.com/ElsevierSoftwareX/SOFTX-D-16-00048
Legal Code License	*GNU General Public License (GPL) Version 3*
Code versioning system used	*Git*
Software code languages, tools, and services used	*Java*
Compilation requirements, operating environments & dependencies	*JDK 1.7 (or 1.8)*
If available Link to developer documentation/manual	https://github.com/ElsevierSoftwareX/SOFTX-D-16-00048/blob/master/README.md
Support email for questions	roberto.ur@protonmail.com

Software metadata

Current software version	2.2
Permanent link to executables of this version	https://github.com/ElsevierSoftwareX/SOFTX-D-16-00048
Legal Software License	*GNU General Public License (GPL) Version 3*
Computing platforms/Operating Systems	*Linux, OS X, Microsoft Windows, Unix-like*
Installation requirements & dependencies	*Java 7 (or 8)*
If available, link to user manual - if formally published include a reference to the publication in the reference list	https://github.com/ElsevierSoftwareX/SOFTX-D-16-00048/blob/master/README.md
Support email for questions	roberto.ur@protonmail.com

1. Motivation and significance

The existence of diverse cultural groups is considered paradoxical given that we live in an interconnected world where individuals constantly share information with each other. Moreover, this diversity persists, despite confrontations with drastic changes over the course of population lifetimes. As an example, the Maya have often been recognized for their cultural diversity, although they have been victims of catastrophic events: pre-Hispanic collapses around 800 AD [1]; Spanish invasion after 1521 [2]; and genocide, 1981–1983 [3].

CulSim, the computer simulation software presented here, is a tool to explore proposed models of the emergence of cultural groups [4–6]. It introduces events that, upon combination,

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can simulate catastrophic situations such as wars, pests, invasions, or natural disasters. The results allow researchers to study the resilience of cultural diversity in the provided models. CulSim includes my own recently proposed model, which introduced institutions to explore their effects on cultural diversity [6]. Here, it offers the possibility to analyze events on an institutional level (e.g. institutional collapses). Although the institutional model shows some methodological similarities with other studies focused on mass media [7–9], it distinguishes itself for letting the agents build their institutions and for dividing the feedback loop of information into two processes: bottom-up (democracy) and top-down (propaganda).

The ubiquity of different human groups raises questions regarding the emergence and resilience of cultural diversity. Researchers have proposed models to study the emergence of cultural diversity under social influence [10]. Formal models demonstrated that everyone should, in the long term, converge to the same opinion when all individuals are connected to the same social network [11–13]. More recently, agent-based models have facilitated the study of multiple factors that have been shown to affect the emergence and preservation of cultural diversity. Initially, Schelling [14,15] used the idea that a small "dislike" for a dissimilar neighbor could lead to complete segregation between multiple groups. Conversely, Axelrod [4] proposed a model that successfully allows the emergence of cultural diversity by using categorical opinions (as opposed to continuous [11–13]) and homophily, i.e. the principle of "like attracts like" [16–18], to regulate social influence. In this model, initial parameters heavily impacted the emergence (or non-emergence) of cultural diversity. For example, a smaller population size was conducive to diversity [4], while an increase in neighborhood size increased cultural homogeneity [19].

Later on, Axelrod's model was found to be sensitive to perturbations, noise that was introduced in two forms: mutations [20,21], i.e., random changes in a feature of an agent's cultural vector, and selection error [5], i.e., occasional perception mistakes of a neighbor's similarity (error estimating homophily). Klemm et al. [20,21] found that even tiny mutation rates produced a convergence towards a monoculture without any diversity, while large rates produced anomie, a term introduced by Durkheim [22,23] to describe a state in which each individual is culturally different from its neighbors. Since then, several researchers have addressed the robustness of the emergence of cultural diversity against perturbation, for example by proposing a dynamic social network [24]; by using frequency bias [25], where social influence is multilateral, meaning one is influenced by several individuals at once, instead of dyadic, where influence occurs between just two individuals (based on Boyd and Richerson [26]); by combining frequency bias and homophily [5], or, most recently, by introducing institutions [6], following up on Durkheim's idea that institutions play a large role in group formation [22,23].

To my knowledge, no research has investigated how events that can affect many individuals at the same time might impact cultural diversity in these kinds of models.

Table 1
Social mechanisms used by the models. The first column provides the identifier used in CulSim. The other columns indicate main social mechanisms that distinguish the models.

Identifier	*Homophily*	*Frequency bias*	*Institutions*
M1	Yes	No	No
M2	No	Yes	No
M3	Yes	Yes	No
M4	Yes	No	Yes

CulSim includes four models, all based on Axelrod's. The main social mechanisms that distinguish the models are indicated in Table 1. The description of the algorithms of models M1–M3 can be found in Flache and Macy [5, p. 975]; the algorithm of model M4 can be found in Ulloa, Kacperski and Sancho [6, p. 10].

CulSim supports eleven parameters. Seven (rows, columns, radius, features, traits, mutation, and selection error) can be applied to all models, and four (institutional influence, agent's loyalty, democracy and propaganda) are exclusive to the institutional model (M4). The Initial Parameters section of CulSim's user manual describes the parameters in depth, and summarizes some known effects according to previous studies. The user manual also presents a table with recommended values to start explorations [27]. Finally, the user manual describes in detail the ten configurable types of combinable events of CulSim (including population-related events, institutional-related events and parameter change events). The software provides a graphical user interface to visually explore singular scenarios or multiple repetitions, and a command-line interface to configure comprehensive experimental designs in computer servers. Video 1 gives a brief overview over the functionality of CulSim available at http://dx.doi.org/10.1016/j.softx.2016.07.005.

2. Software description

CulSim allows users to test different hypotheses about cultural diversity, in particular which conditions can sustain it, or which factors promote globalization instead. It is based on previous research on agent-based models [4–6,20,21,24,25]. In this line of research of agent-based models, also known as artificial societies [28], a world is represented by a number of agents interacting with each other on a grid layout (a $N \times M$ matrix). In CulSim, each cell of the grid represents an agent (which can be imagined to represent an individual). This agent has a list of F cultural features. Each feature can contain one of T cultural traits, for example a music feature could contain rock, salsa, or jazz ($T = 3$). Two agents are said to belong to the same cultural group if the agent's cells are adjacent to each other, and if they share the same trait for each of the possible features. An interaction occurs when an agent accepts (copies) another agent's trait (or group of agents' trait — when influence is multilateral) which could occur depending on the conditions imposed by the model, e.g. the homophily between the agents. The two agents that participate in an interaction have to be in a "Von Neumann" neighborhood of radius r; e.g. agent b is in the Von Neumann neighborhood ($r = 2$) of agent a in Fig. 1.

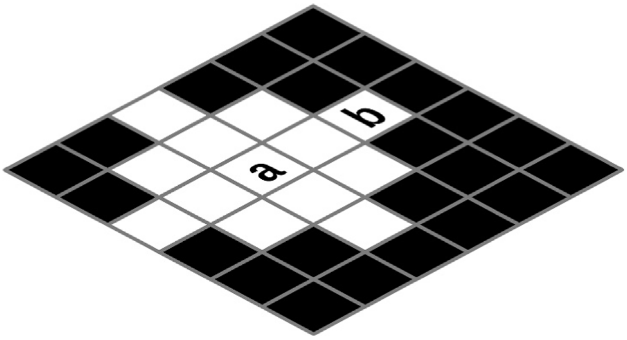

Fig. 1. Von Neumann neighborhood of radius 2. In the grid, white cells represent the "Von Neumann" neighborhood of agent a. All agents (e.g. agent b) in this neighborhood can potentially influence agent a, or vice versa.

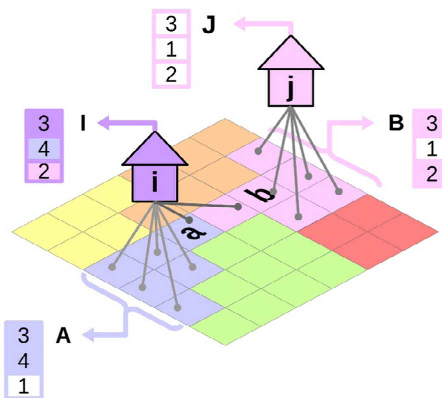

Fig. 2. Overview over a world state in CulSim using the institutional model. The grid shows 6 cultural groups (yellow, orange, blue, pink, green and red) in a world of size 6 × 6. Since all agents (cells) of each cultural group carry exactly the same cultural traits, vector A is representative of each agent of the blue cultural group, and vector B representative of each agent of the pink group; in reality, each agent has its own cultural vector. Each cultural vector in this case contains 3 features ($F = 3$), and each feature could contain 1 of 4 possible traits ($T = 4$). The houses i and j on top of the grid represent two institutions. Gray lines connect institutions to the agents that belong to them. The vector I represents the cultural vector of the institution i (purple), and J represents the cultural vector of institution j (pink). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

When the institutional model (M4) is used [6], an agent can belong to an institution that also contains a list of F cultural features. Institutions do not occupy any position on the grid. Fig. 2 represents all elements within an institutional model. It illustrates a situation in which the institution's cultural vector (termed I) shares the first two features (out of three) with the blue cultural group (vector A) — both cultural vectors carry traits 3 and 4 in the first two positions). Vector I also shares two features (the first and the third one) with the pink cultural group (vector B) — both cultural vectors carry 3 and 2 in the same positions. This similarity can explain why one of the agents (located between agent a and agent b), who is part of the pink group, belongs to institution i. At some point, this agent can change its institution to j, or it can become part of the blue group if it lets institution i influence it down the line.

In the example, an interaction of agent a with agent b (in which one of vector B's traits would be copied to a's cultural vector) depends on the similarity of vectors A and B (this similarity requisite is called homophily [24,29]), and also the similarity with its institution j. The institutional influence, denoted by α, controls the importance that the agent–institution similarity has over the agent–agent homophily, and the agent loyalty controls the likelihood of agent a changing its institution towards b's – depending on the similarity between a and j, and a and i – given that agent a accepted b's trait. The institutions are also at the center of two social mechanisms regulated by their corresponding parameters. First, propaganda is a top-down process in which an institution sends a message to convince its subscriber agents of a particular trait, and second, democracy is a bottom-up process in which the agents vote for a particular trait to become part of the institution's vector. For a full description of the institutional model and parameters, see Ulloa et al. [6].

In this context is where CulSim can be used to execute events in order to affect the current state of the simulation. The events were conceived by exhaustively considering possible ways of targeting the information stored in the simulation. First, it is possible to target the cultural vectors of the institutions, or the agents. In terms of institutions, the cultural vector of one institution could be targeted *fully* (e.g. remove all traits of the institution according to certain probability), or *partially* (e.g. for each trait, remove it according to certain probability). Also, the traits can be targeted by removing them (*content removal*) or by replacing them by foreign (external) ones (*conversion*), i.e. traits that do not exist in the simulation. In terms of individuals, it only makes sense to fully target the cultural vector to either simulate death (full traits removal, called *decimation*), or the arrival of a foreign agent[1] (full traits conversion, called either *settlement* or *immigration* depending if the foreign agents are associated to in institution or not respectively). Second, it is possible to attack the connections between the institutions and the agents. On one hand, an institution could be destroyed and all the agents that belonged to it become stateless (*institutional destruction*); on the other hand, some agents can leave the institution (*apostasy*). CulSim allows for the configuration of the events according to different (probabilistic and non-probabilistic) distributions (e.g. uniform or normal distributions) across the grid, and there is the option of combining events to represent compounded social catastrophes (e.g. an invasion involves at least *settlement* and *decimation*). For full details on events, please refer to the Events section of the user manual [27].

All of the above is accessible through the graphical user interface. Additionally, the interface includes a batch mode to run experimental designs in personal computers. For servers, a command-line interface is available with access to the same functionality. When multiple simulations are being run, CulSim takes advantage of all the cores available in the machine by running one simulation on each core. For the sake of efficiency, the implementation of the models was done using static data structures (instead of dynamic ones).

[1] Partial conversion is possible through other agents or institutions inside the system, but not a collective change of mind towards an unknown trait. Alternatively, mutation provides a mechanism for random conversion.

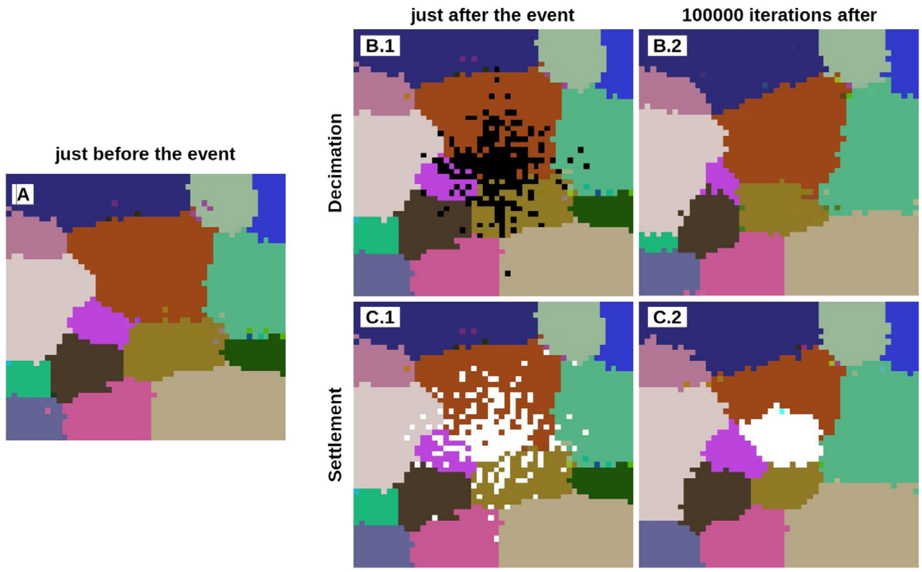

Fig. 3. Cultural spaces before and after decimation and settlement. Left column shows the cultural spaces just before the event. The middle and right columns show the state just after the event and 100,000 iterations after; the top row corresponds to decimation, and the bottom one to settlement. The black cells in (B.1) represent the dead agents, and the white cells (C.1) represent the settlers.

3. Illustrative example

In the here proposed example, I compare the effects of two events, decimation and settlement. Decimation is represented by removing all cultural traits from a group of agents leaving them empty (new-born). Settlement is represented by replacing all traits from a group of agents with foreigner traits; i.e. the settlers take previously occupied positions. The group of agents are selected by configurable events distributions; in this example, both events are assigned to cells (agents) in the grid, using a normal probability distribution function (standard deviation = 0.2) with its maximum value (1.0) at the center of the grid. The scenario uses the institutional model [6] with the following fixed parameters: institutional influence of 0.65, grid size of 50 × 50, 6 cultural features, 14 cultural traits, Von Neumann neighborhood of radius 3, mutation and selection error with probability 0.001, agent loyalty to 0.5, and no propaganda or democracy. Fig. 3 illustrates the cultural spaces at different times for the two events: (A) before the event, (B.1) just after decimation, (B.2) 100,000 iterations after decimation, (C.1) just after settlement, (C.2) 100,000 iterations after settlement. Each agent is colored according to its cultural traits.

High similarity exists between the states before and 100,000 iterations after the events, although some changes are noticeable. For example, in B.2, the pink cultural group located near the center is smaller compared to A, and the green group on the right hand side has vanished completely; in C.2, the settlers (white cells) stabilized themselves in the center.

CulSim also displays the progression of 20 different response variables as the simulation runs its course. For example, Fig. 4 shows how to track the evolution of cultural similarity (i.e. a comparison of the cultural vectors of all the cells, agents, between two states) between the cultural space just before the events (decimation or settlement) and 50 iterations after they occurred (green lines).

In Fig. 4, the similarities between the 50th iteration after decimation and settlement are .99 and .92 for decimation and settlement respectively. From this exploration, a hypothesis emerges: it is possible that cultural groups are resilient against decimation as they can recover successfully after the event, but might not be able to recover as well when settlers arrive, bringing their own culture.

As with all stochastic processes (such as the simulation example I present here), a single iteration that is obtained by tracking the simulation via main interface cannot be taken as representative of a general trend and needs to be repeated for reliability and validity purposes. Using the batch mode dialog of CulSim, we can run many repetitions in order to statistically test whether the observed effects reflect replicable trends. In our example, the experiment was repeated 10 times, and based on the analysis of the generated data files, Fig. 5 exhibits the average similarities found between the state of the simulation just before the events occurred, and the one reached 50 iterations after the events were applied. We can confirm the observation to establish that the chosen scenario is resilient against decimation, but unable to recover the area taken by settlers.

4. Impact

CulSim extends the use of computer simulations to the emerging area of digital humanities, in particular to cultural studies, by providing a tool that addresses a non-technical audience. The software has a default configuration that allows its immediate use to quickly grasp the concepts behind this type of research, and it allows storage of interesting configurations, events and simulation states that can be shared among users. In this sense, CulSim makes available a methodology that

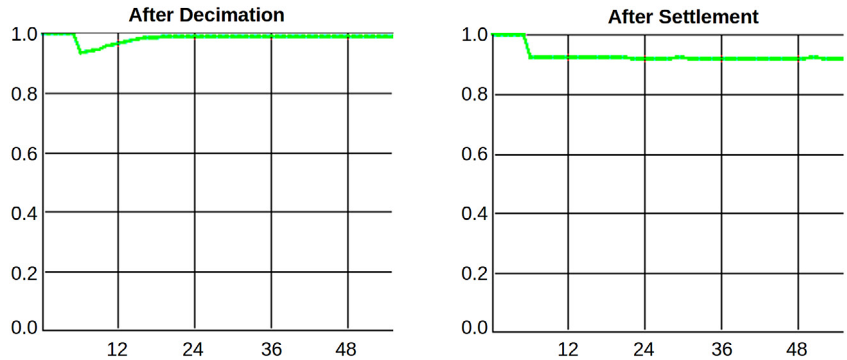

Fig. 4. Progression of cultural similarity and energy after decimation and settlement. Green lines show the similarity between the state just before the event (left, decimation, and right, settlement) and the state of the 50 consecutive iterations (x-axis) after it. The similarity is calculated by comparing the cultural vectors of each cell in two states of the simulation. The blue lines show the energy of each state of the iterations. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

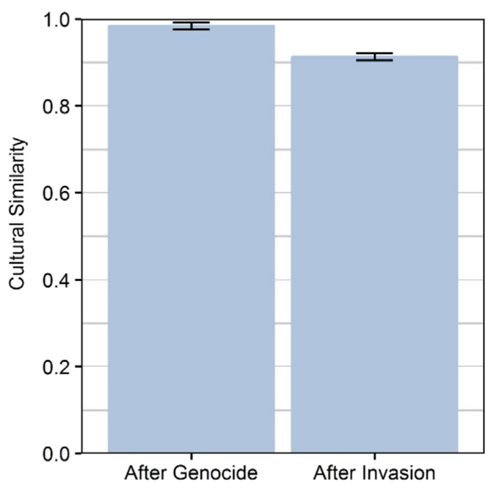

Fig. 5. Similarity after applying the events. The graphs show the average similarities (over 10 repetitions) between the state of the simulation just before the events occurred, and the state reached after 50 iterations. The y-axis shows the cultural similarity, and the x-axis the type of event applied. On top of each bar we see the confidence intervals at 99%.

has proven fruitful in other fields of study such as physics, biology, and sociology. Within the here proposed methodology, complexity of culture is taken literally, i.e. it is understood as a complex system [30] in which macro behaviors can be explained from micro behaviors, as is the case with the models implemented in the project: agent-based simulations that model essential mechanisms and concepts that have been described in theoretical works.

In the field of social sciences, CulSim can expand our understanding of how cultural diversity persists throughout catastrophic events that target human populations, and is, to the best of my knowledge, the first tool available to study these types of scenarios on models based on Axelrod's [4], focusing on the effects on cultural diversity. CulSim enables the study of combinations of various events, approximating scenarios that have occurred to societies in the past, as is the case of for example the Maya peoples, whose cultural diversity has persisted despite the historical events that have befallen their population. For example, to simulate the Spanish invasion into Mexico and Guatemala that devastated the Maya, historians can review the available documentation and find appropriate values and distributions to configure events such as decimation, institutional conversion (to Spanish beliefs) and destruction, on top of the introduction of (Spanish) settlers into the population.

CulSim also becomes relevant in the context of contemporary controversial discussions about globalization. It has been claimed that a global (mono-)culture is necessary in order to promote world peace [31], while at the same time, we celebrate the importance of cultural diversity as a source for ideas to overcome a variety of problems facing our world today [32]. In particular, the inclusion of an institutional model [6] gives opportunity to explore the role of these two concurrent discourses, which can provide insights into how to shape institutions that favor a peaceful global community while at the same time promoting cultural diversity.

5. Conclusions

CulSim will help researchers answer novel questions related to the emergence of cultural diversity based on existent models from the sociological literature. It allows the exploration of ranges of parameters and interactions that have not been yet studied in the literature. CulSim makes agent-based models accessible to researchers of different fields, and brings new questions related to resilience of cultural diversity, by introducing different types of events that target populations, institutions and global parameters. The possibility of combining events offers the opportunity to approximate circumstances of historical scenarios within the simulation.

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