CAvsSF: ODD protocol

To describe our ABM, we use an extension of the standard ODD protocol consisting of the model's overview, design concepts, and details (Grimm et. al., 2006; Grimm et al. 2010; Grimm et al., 2013). To better describe the human-like behavior of our model, the extension adds a section on decision making - therefore ODD + D protocol (Müller et al., 2013). As decision making processes are the most complex component of our model, we postpone its description until the details section. The goal of the protocol is to make the model understandable without reading anything else. Therefore, some information from the previous section will be repeated here, but in a more technical form and order.

Overview

Purpose

The model serves as a theory-building conceptualization of the transmission dynamics of collective rituals inside a population of interacting individuals as driven by two non-deliberative decision-making factors – cognitive attraction and social function. It creates an idealized environment for a bottom-up cultural selection of two ritual forms reflecting the two factors. The model aims to show specific dynamics associated with the two factors, revealing ratcheting effect towards the ritual form characterized by cognitive attraction.

Entities, State Variables, and Scales

The model consists of an environment of discrete **ritual places** divided into **two** even groups ("SFg, "CAg"). In these places a **population** of human agents[1] holds gatherings - **encounters** each turn. Each **agent** has constrained memory for ritual **experiences** gained from such encounters. Each group of ritual places affects the experience differently. The agent is bound to use one from **three** ritual experience seeking **strategies** (random, conservative and

adaptive). The usage ratio of strategies is fixed in the population (10% random, 50% conservative, 40% adaptive) and for individual agents changes each turn randomly.

There are **two main** exogenous **drivers:** *social-function-coefficient or SFc* (value 0 - 1) and *cognitive-attraction-coefficient or CAc* (value 0 - 0.1). They represent simple abstractions of targeted factors used to compute the outcome of the adaptive strategy while shifting the tendency to gather to at a ritual place from the respective group. Time moves in discrete ticks. At each tick a ritual encounter is held in one of the ritual places. In the model, each tick represents a time unit of a **week**. The model does not end up with any equilibrium state, due to the hardwired variation resulting from the constant presence of random experience seeking strategy. However, the configuration of the coefficient associated with the two factors can create a significant preference for one or other ritual form over time.

Process Overview and Scheduling

Time is modelled in discrete steps – "ticks" – and the same process repeats each tick. At the beginning of each tick, each agent adopts one experience seeking strategy, by which acts. This strategy is randomly allocated along a fixed distribution (10% random, 50% conservative, 40% adaptive). The behavior driven by the adopted strategy results in choosing one ritual place and moving there. For the agent, this place becomes his ritual encounter place for that time step. The process of agent allocation differs according to the experience seeking strategy. Randomly acting agents choose a random place from all possible places. Conservatively acting agent chooses the same place as his last encounter place. Agent with "adaptive" strategy computes his choice on the basis of his encounter memory and actual situation in ritual places – he tries to optimize his choice with an aim to maximize his ritual experience, i.e. to meet his "best" acquaintances, where best is the most known from previous encounters. In this computation the two main driving factors come into play and influence decision making. At the end of the

turn, every agent adds his actual encounter to his memory, where a number of previous encounters is already stored.

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Design Concepts

Individual Decision Making - Each agent does one decision in each tick, i.e. decides which from the all ritual places he wants to visit. For this he uses one of the experience seeking strategies (random, conservative, adaptive) (see below sections on "Agent memory" and "Experience seeking strategies computation").

Learning - The agents form social relationships based on the ritual experience. This experience further influences the decision making during the experience seeking strategy with adaptive computation.

Sensing - While located in a place during the ritual encounter, the agents sense and remember the present agents and the type of the respective ritual place. Further, when deciding according to the adaptive experience seeking strategy, the agents have an unrestricted view of the world in the sense that they have full access to the information about allocations of the already located agents (those who behave according to the random and conservative strategy during the given tick).

Interaction - The interaction of agents is limited to sensing each other during the ritual encounter. In that sensing, the most basic social relationship (familiarity) is established and held in individual memory.

Stochasticity - The stochastic sources of the simulation variation are the 1) initialization, where agents get their first experience and 2) the random experience seeking strategy, which is followed by 10% agents each tick.

Collective - During the simulation, the agent becomes part of emergent collectives (networks of interconnected agents) based on his encounter experiences (memory). The analysis of these collectives is not part of this article.

Heterogeneity - The agents have the same probabilities to use one of the three strategies. But what differs is their ritual experience changing from tick to tick.

Observation - The measured output of the simulation is the total difference of visits between the two ritual group places. The outcome can have three different states: (1) The random variation beats the underlying forces of ritual activity and none of the group of ritual places representing the two ritual forms becomes significantly preferred, i.e. none of the group has more visits than the other; (2) the ritual places with SF quality have more visits; (3) the ritual places with CA quality have more visits.

Details

Initialization

At the beginning, a population of 200 agents is randomly and evenly distributed over 10 ritual places and each agent forms his first encounter memory with the other agents at their ritual place.

Ritual activity

At each tick each agent choses a place of his ritual encounter using their experience seeking strategy, which is randomly distributed among the agents at the beginning of each tick.

The assigned experience seeking strategy leads the agent to find an appropriate ritual place and to move there. The agents assigned with random and conservative strategies proceed first, the agents with adaptive strategy follow. The agents behaving according to the adaptive strategy base their decision upon their access to information about locations of the previously located agents behaving according to the random and conservative strategies. At the end of the tick the memory of agents is updated by the type of the ritual place and those encountered there.

Agent memory

The agent memory is a fixed 5-positional stack filled with information about his past encounters, where the freshest memory is at the top of the stack and where each position represents one of the past ticks. When the stack exceeds 5, the most time distant memory is deleted.

The memory consists of two parts, the ritual quality memory and social encounter memory. The first is responsible for remembering the ritual quality of the visited place, that is to which group of places the place belongs. The second is responsible for memorizing all individual agents which were present in the place during the encounter. Both parts are crucial for computing the values on which is based the adaptive experience seeking strategy.

The social encounter memory is constrained to limited capacity of 150 slots for memory of encounter with individual agents. More recent encounter memories hold more space in this memory than older onward. Formally represented, the count of agents from the most recent encounter is multiplied by 3; in the case of the second most recent encounter, the count of agents is multiplied by 2. In the case of older encounters, the count is represented in the memory as one by one. As a result of this, the agents met over older encounters are pushed out of the memory as the memory capacity is depleted by those met more recently.

Experience seeking strategies computation

Random and *conservative* strategies follow simple heuristics. When adopting the random strategy, the agent chooses randomly from all possible places. In a conservative strategy, the agents move to the same ritual place that they occupied in the previous tick.

In the *adaptive* strategy, the agents decide by considering each ritual place in terms of its prospective encounter value, which consists of a combination of the social value (familiarity with agents located in the ritual places based on past encounters) and affinity for cognitive attraction value (see further). All ritual places are marked with the prospective ritual encounter value and the place with the highest mark is chosen and the agent moves there.

The marks of the ritual places are computed by measuring a fit between the content of agent's memory (i.e. visited places and encountered agents over the last 5 ticks) and places visited by a proportion of agents using random or conservative strategies. Here the main two drivers (SFc and CAc) influence the computation in a different way.

The score of a ritual place is ascribed in several steps. First, the agent examines all ritual places and checks their visitors while comparing them with those which he holds in memory from previous encounters. Whenever he recognizes an agent on the examined ritual place as someone in in his memory, he increases the score of the ritual place by one. In a null model (i.e. when the effect of SFc and CAc are set up to zero) he goes into a place scoring highest in that respect. When the SFc is higher than zero, the agent takes into consideration previous encounters with other agents at the ritual space. For each agent that was previously encountered on SF place, the score is increased by 1 and multiplied by (1 + SFc value). Thus, the agent pays higher attention to encounters formed on the SF places than to encounters formed on the CA places.

Second, when the CAc parameter is higher than zero, the agent modifies the marks of all ritual places on the basis of what type of places he visited over the past 5 ticks. The most recent memory has the strongest impact again. Thus, if the agent visited a CA place one week

back, he multiplies the overall mark of all current CA places by (1 + [CAc value * 5]), where 5 reflects the fact that it is the most recent memory from the 5 slots. Further, if he visited a CA place two weeks back as well, he multiplies the overall mark of all current CA places again, now by (1 + [CAc value * 4]) etc. Thus, in agreement with the theoretical framework, past visits of CA places make the agent cumulatively more motivated to visit this type of places again and again over time, regardless with whom he can meet there.