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MEMETIC ENGINEERING AND CULTURAL EVOLUTION

Hales D.
Manchester Metropolitan University, UK.

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Contents

Summary

The current status of "memetics" and the meaning of "memetic engineering" are considered. A set of artificial society models are summarised which attempt to capture in abstracted form certain memetic processes. The main qualitative results gained from these models are discussed. The problematic nature of artificial society methodology and the application of results to the real world are explored. It is concluded that both meme theory and artificial society modeling are at an early stage, but as a possible route to increased understanding of the social world, and the benefits that this may bring the area, they show promise. Much more work needs to be done.

1. What is Memetics?

Since the invention of the word "meme" by Richard Dawkins as a cultural analogy to the gene, a loose speculative and unproven area of enquiry termed "memetics" began to emerge. The meme is to culture as the gene is to biology. A meme can be conceived as a cultural unit of imitation. Within such a broad definition examples of memes might be stories, hairstyles, religious beliefs or popular songs. Indeed anything that is passed from individual to individual via some form of cultural imitation or learning may be seen to replicate over space and time. Spurred on by popular science writers such as Daniel Dennett terminology from genetics has been applied to cultural phenomena usually in a highly speculative and metaphorical way.

2. The State and Status of Memetics

The scientific status of memetics is still at this current time (mid 1999) a matter of intense debate and has been dismissed by some (notably Steven Jay Gould) as no more than an empty analogy failing to put forward falsifiable hypotheses and detailed empirical or theoretical work. A recurring problem within memetics is the ontological status of the meme itself. Some writers like Dennett conceive of memes as self-replicating entities which through their own self-interested propagation become the building blocks which form the "virtual serial machines" and "mental operating systems" of the conscious human mind. Such approaches have been termed "internalist" memetics since they attempt to construct a theory of mind within a memetic framework. Other researchers have taken a different emphasis, conceiving of memes from a behaviorist and functional position. Here memes are seen as behavioral rules that propagate through and shape a population. From this approach the detailed cognitive and ontological status of memes is not addressed and it has been argued that such a position is no more than "social contagion theory" (an existing empirically based area of social psychology) dressed-up in new nomenclature borrowed from genetics.

3. Memetic Engineering in Human Societies

The concept of memetic engineering (by analogy with genetic engineering) has been used to address the question of purposeful and planned generations of memes to serve some end. In the wider context of daily life the conception of memetic engineering generally signifies no more than any planned activity that produces cultural units that may be imitated. At this level of generality the term may be no more than a scientific sounding phrase applicable to most human activity. However the phrase has found some application in the advertising and management constancy industries when applied to planned and controlled attempts to change and influence human behavior.

4. Memetic Engineering and Artificial Societies

In the context of this article artificial societies will be described which address issues of culture change from a memetic perspective. Their implications (if any) for real human societies will be discussed at the end of the article. It must be noted that at present (1999) such models are limited and have limited input into the theorising that goes on at the general level in memetics. It has been claimed by some that one possible future direction for the formation and testing of new memetic theory is via construction, comparison and experimentation with computational models. However, methodology and practice within the field of artificial societies is also young and it is currently unclear as to how highly abstracted, theoretical computational models can be validated or even communicated to the satisfaction of sociological disciplines. Some have argued that increasingly computationally aware practitioners within the social sciences will come to embrace these techniques. Others have argued that a more grounded terminology and strict verification process is required and needs to be developed. In their weakest sense artificial societies of memetic processes and cultural change offer no more than computational thought experiments. These are complex "what-if" questions that are answered via empirical analysis of the output of computer programs. Minimally they give an "existence proof" of what certain stated assumptions can support. More importantly other researchers can attempt to reproduce, compare and merge models to verify results and test for compatibility (so called "docking experiments"). It would seem that such methods may begin to offer the social sciences at least some of the tools and techniques traditionally only available to hard sciences such as the possibility of a repeatable experimental method, the ability to exchange models of social phenomena within a formal language (computer programs) and to make real progress in the acceptance via existence proofs that certain assumptions do indeed support certain conclusion.

5. What Are Artificial Societies?

Computational modeling and simulation of social systems has a history of almost 40 years. Recently a speculative and exploratory form of social modeling has emerged. Termed "Artificial Societies", such models address "possible societies", their general processes, dynamics, and emergent properties. In the same way that Artificial Intelligence is not limited to the accurate modeling of physiological brain processes so artificial societies research does not start from some given scenario or particular social system. The aim is to model features and processes that characterise societies in general such as co-operation, specialisation, group formation, and hierarchy.

Artificial Society work does not strive for superficial realism or direct correspondence with existing societies but for abstract logical relationships that characterise whole categories of phenomena. Generally such societies consist of multiple interacting agents. Each agent minimally consists of: internal state; sets of possible actions; percepts (or perceptual inputs); a shared environment and some form of decision process informing action selection. This latter component of an agent "architecture" may vary considerably. It may consist of simple hardwired rules (e.g. the Sugerscape, see the article within this topic for details), deliberative, planning and goal directed artificial intelligence systems; inductive learning (e.g. via connectionist models) or population level evolutionary methods (e.g. evolutionary game theory).

6. Memes in Artificial Societies

A number of researchers from various perspectives and backgrounds have implemented interpretations of memetic processes in artificial societies. Such models vary widely in their approach, abstraction level and focus of interest. Many may not explicitly utilise memetic terminology but all attempt to capture some form of cultural replication, variation and selection. Such models can be seen as a form of memetic engineering in which the questions: "In the given model which memes are successful?" and / or "In the given model which dynamics of memetic change occur?" are being asked. The results obtained from the models are obviously dependant on the set of assumptions which comprise the model. Those assumptions will be influenced by the particular perspective, focus and disciplinary background of the research. A more speculative form of memetic engineering is to reverse engineer specific pre-defined behaviors from the model via a search over some space of assumptions. In such an instance the question "From a space of assumptions which are sufficient to produce some given behavior?" is being asked.

It is important to distinguish the following models from the sometime used computer science term "memetic algorithm" which refers to a class of general local search algorithms which are applicable to problems requiring the searching of large spaces of solutions for some optimal or reasonably optimal solution. Although this latter class of algorithms has some connection with cultural processes they are at a tangent to the current article and will not be discussed further.

7. Evolutionary Game Theory Models

The Economics and Biology heritage of evolutionary game theory means models within this class start with the assumption that agents are utility maximisers adhering to the assumptions of the replicator dynamics. Effectively this means that each individual meme or behavioral rule (generally termed a strategy within this paradigm) is reproduced over some time unit in proportion to the product of its frequency and cumulative fitness over the population. The assumption within a cultural context is that memes (or strategies) are copied between agents when they are observed to be "better" (i.e. produce higher utility). Generally models within this tradition attempt to identify static or dynamic equilibrium states in which particular memes (or strategies) are stable within some strictly defined game.

Robert Axelrods' now classic computational tournaments between submitted programs implementing differing strategies in the two person "prisoners' dilemma" game were advanced at the time as evidence for particular organisational recommendations which could be used to foster co-operative interactions between agents. That is, the application of the "tit-for-tat"-strategy. This strategy states that one should copy the last move made in any previous encounter by one's opponent or cooperate if this is a first encounter. It should be noted that the usefulness of these conclusions have since been challenged by several game theoretic researchers notably Ken Binmore.

8. Memetic Models of Cultural Change

Those models which specifically use memetic terminology tend to break with the assumptions of the replicator dynamics in some way. Utility for example, is rarely explicitly represented within such models. Propagation of memes is generally modelled as a more passive process which does not necessarily entail utility comparisons between memes by agents.

Cultural transmission in the Sugarscape model is effectively an extension of the Axelrod Cultural Model (ACM) which can be compared to Social Impact Theory (SIT) models. These models are implemented within a cellular automata framework (a two-dimensional grid of agents interacting within some small spatial neighborhood). Sugarscape, ACM and SIT work on a passive representation of culture focusing on the spread of memes that are often termed "cultural attributes".

Cultural attributes in such models are equated with observable features such as language and clothes style. They are passive in the sense that they do not have direct behavioral impact but may have indirect effects via their recognition by other agents. In the Sugarscape for example, the presence or absence of certain designated attributes (represented as bit strings) attached to an agent may trigger an attacking action from another agent. In the ACM the distance between two agents (in differing attributes) affects the attribute propagation process itself. However it is important to note that the attributes themselves are not equated with behavioral rules. An interesting distinction can therefore be made between evolutionary game theoretic models, which focus on the spread of behavioral rules or strategies which determine the behavior of the agent possessing them, and the cultural attribute models, which focus on the spread of passive attributes, labels or tags. In the wider scope of memetics both can be described as memes. Behavioral rules or strategies are generally not visible to other agents but cultural attributes generally are. These may be termed "hidden memes" and "visible or surface memes" respectively.

8.1. The Axelrod Cultural Model

The ACM consists of a fixed two-dimensional grid. Each grid point contains a single agent. Agents can exchange memes with their four (north, south, east and west) adjacent neighbor agents (or less if agents are placed on edges or corners). The ACM starts from the assumption that the transfer of ideas occurs most frequently between individuals who are similar in certain attributes such as beliefs, education, social status and the like. Each agent holds a fixed number of attributes or "features". Each distinct value of an attribute is called a "trait". The features can therefore be viewed as dimensions of culture. The cultural similarity between any two neighbors is calculated as the percentage of corresponding features that share the same trait. The dynamics of the model are described by the following rule: -

Repeat the following steps for as many events as desired.

Step 1: At random, pick a site to be active, and pick one of its neighbors.
Step 2: With probability equal to their cultural similarity, these two sites interact.

An interaction consists of selecting at random a feature on which the active site and its neighbor differ (if there is one), and changing the active site trait on this feature to the neighbor trait on this feature.

Axelrod conducted various experiments over a space of models by varying parameters controlling size of neighborhood, number of features and number of traits. Counter to intuition most runs of the model produced stable cultural regions. This means that a single culture does not overtake the whole population but rather, groups emerge with shared in-group culture but no shared out-group culture. Homogenisation stops when all boundaries between differing cultures share no features/traits in common and hence can no longer exchange traits. Another counter intuitive result indicates that as the number of features in the model is increased, the number of stable groups produced decreases. This is due to the positive effect the increase in features has on the probability of interaction via increasing the probability of feature/trait correspondence between neighbors. Conversely increasing the number of traits that each feature can take increases the number of stable regions via the opposite of this effect. Unsurprisingly as the range of interaction was increased the number of stable regions was reduced. The qualitative conclusions of this work are that; 1) Local convergence can lead to global stable polarisation; 2) The interplay between different features of culture can shape the process of cultural change; 3) Intuition about simple mechanisms of change can be quite misleading.

8.2. The Swap Shop Model

In the Swap Shop (SS) model David Hales uses the conception of "cultural relatedness" and the transportation of utility in order to model the success of culturally learned altruistic behavioral rules. Several authors have proposed cultural mechanisms that may support altruistic behaviors but none had produced computational models.

The SS model is based on the ACM (above) but with several additions which model the ability of agents to exchange utility. Each agent has an associated energy level. The level is increased by random resource reward events from the environment and decreased by random life tax events. Energy can also be increased by receiving a donation from a neighbor or reduced by making a donation to a neighbor. Two of the memes (features) effect the level of energy-sharing an agent will engage in with needy neighbors. Agents with low energy may mutate their memes (i.e. change them at random). Agents with no energy are unable to propagate memes and agents with maximum energy are unable to receive new memes. The dynamics of the model are described by the following rule: -

Repeat the following steps for as many events as desired.

Step 1: At random, pick an agent to be active, reduce its energy level by one unit to minimum of zero. If at zero energy then mutate memes with some low probability.

Step 2: At random, pick an agent to be active, increase its energy level by four units. If neighbors are needy then share agent energy as directed by sharing meme values.
Step 3: At random, pick an agent to be active, and pick one of its neighbors.
Step 4: With probability equal to their cultural similarity, these two sites interact.

In the above sequence step 2 is only executed one quarter of the time stochastically. This implements a scenario where stochastically, energy is taken out and put back, in equal proportion. However, the "life tax" is more evenly distributed than the "resource reward" (specifically in the proportion of 4:1). Initially each cell in the grid is initialised with random values for each of the state variables. Movement of energy between agents is determined by the values of two memes held by the potential donor agent. One meme encodes a "sharing similarity level" indicating the cultural similarity between two agents below which sharing will not occur. The other meme encodes the "sharing amount" indicating the maximum number of energy units the donor agent is willing to pass on to needy neighbor agents. A needy agent is one that is below the maximum energy level.

Hales conducted various experiments over a space of models by varying parameters controlling evolution method (memetic or genetic) and resource reward (sparse or uniform). When sparse rewards were made only agents with even row and column locations were chosen for resource rewards. When genetic evolution was selected agents asexually reproduced based on the neighbor with the highest energy level surrounding a newly dead agent (a dead agent being one which has an energy level of zero).

In all runs the memetic method of evolution quickly converged on a single uniform and completely altruistic culture (all agents shared all resources with neighbors) whereas the genetic method produced competing groups with altruistic behavior towards the in-group but non-altruistic behavior towards the out-group. The difference between the two modes of evolution was most noticeable with sparse rewards. In this scenario each agent which receives rewards (a productive agent) is surrounded by neighbors that never receive rewards (unproductive agents). Never the less in the memetic mode of evolution a single altruistic culture emerges quickly but the generic mode fails to eradicate selfish behavior and group boundaries.

The qualitative conclusions of this work are that: 1) A simple memetic mode of evolution quickly converges onto an altruistic resource sharing scheme but a simple genetic mode does not; 2) The convergence process involves emergent cultural groupings which are in-group altruistic and out-group selfish; 3) Such a process may be viewed as "cultural group selection".

8.3. The Open-Mind Model

In order to model meta-memes Hales builds on a previous memetic model of meme spread (Minimeme) which ascribes levels of confidence to memes.

Confidence is mediated by a satisfaction function and a form of frequency-dependent bias. This kind of bias refers to the phenomena whereby agents are more likely to accept a meme which is already frequent within a population. The experiments include "open-mindedness" meta-memes. These directly affect the meme process at the individual level impacting on the agents' receptivity to memes. The model is applied to a minimal resource harvesting co-ordination scenario in which a set of adjacent yet independent territories with fixed amounts of renewable resource (carrying capacities) comprises the environment. A small number of agents each host two memes (features) each with ten possible trait values (low to high). Agents have an energy level based on previous resource harvesting. Each agent occupies one of the available territories and attempts to harvest resources from that territory. Overpopulated territories lead to some agents receiving less resource than is necessary for their survival. Agents evaluate their performance based on a binary satisfaction function. In the model agents are only considered "satisfied" if they have a maximum energy level. Agents culturally interact by communicating memes with those in the same territory. When agents culturally interact they reinforce their confidence in a particular meme if they already share it (increase the confidence attached to that meme by some factor) or decide to accept the new meme (overwriting the existing meme) with a probability inversely proportional to the confidence attached to the existing meme. Agents periodically perform a satisfaction test, increasing the confidence in all memes if they are satisfied or decreasing the confidence in all memes if they are not. . The dynamics of the model are described by the following rule: -

Repeat the following steps for each agent in the population until a stability of memes is reached across the whole population.

Step 1: Culturally interact with some randomly chosen agents in current territory.
Step 2: Move to a new territory if desired.
Step 3: Attempt to harvest resources.
Step 4: Perform a satisfaction test.
Step 5: For each meme mutate the meme with probability inversely proportional to confidence.

At any time if an agent runs out of energy it is deemed "dead" and is replaced with a new born agent which takes its memes from a randomly selected member of the territory. The behavior in step 1 and step 2 is mediated by the particular trait values held against each meme by the given agent. In step 1, the "conversion process" described above (whereby memes are accepted inversely proportionally to the confidence of the existing meme) is modified by one of the memes (the meta-meme) held by the agent. A low meta-meme signifies "close-mindedness" and biases the agent to repel new memes. A high meta-meme biases the agent to accept new memes (open-mindedness). Essentially the confidence values are biased so that a low meta-meme causes all new memes to be rejected whereas a high meta-meme causes all new memes to be accepted. It is important to realise that the meta-meme itself is a meme to which this biasing process is applied. In step 2, the agent decides how to move based on a desirability ranking of all territories mediated by the standard (group value) meme. This meme indicates an optimal size group preference. The agent selects the territory which most nearly matches this optimal size. Ties are resolved by random choice. Agents therefore have a complete view of all territories and their current level of crowding but only compete for resources and culturally interact with those agents in their own territory.

Various experiments were conducted over a space of models by varying parameters controlling carrying capacities (just enough food, too much food, not enough food) and the inclusion or not of "predators" (punishing agents in under occupied territories). The model was also run with and without the open-mindedness meta-meme. In each case several hundred runs were performed for each type of scenario. They were allowed to run until convergence of the noosphere (the space of all memes in the population) to a steady unchanging state.

The qualitative conclusions of this work are that: 1) Without meta-memes agents tended to suffered from participation in a "self-catalytic" process in which high "group size" memes predominated. Agents would gather in a single territory exhausting the resources and reinforcing the very meme that brought them there. The simple satisficing scheme was not enough to break this killing cycle of meme reproduction; 2) With the introduction of meta-memes however, this process was reduced. Most runs lead to more optimal agent distributions and less deaths before and after noosphere equilibrium; 3) The meta-meme process that broke down the "self-catalytic" process was complex but essentially involved a system by which high death rates produced more noopshere instability, leading to memetic change and population migrations; 4) Contrary to intuition complete closed-minded memes did not predominate.

8.4. The Stereotypes Model

Hales produced a memetic model to investigate the relationships between stereotyping, group formation and co-operative agent interaction. Stereotypes might be defined as generalisations such that certain (positive or negative) opinions are attached to individuals who have never been previously encountered. For an individual to utilise stereotypes some method of categorising other individuals is required. Ignoring fixed, assumed, deduced or imagined characteristics the model minimally captures stereotyping based on culturally learned behavioral rules and observable features. Here a distinction is made between observable "surface memes" and non-observable "hidden memes". The stereotypes in the form of behavioral rules, which map generalisations over observable characteristics to game interaction strategies, are hidden, whereas the characteristics themselves (representing tags or "cultural markers") are represented as surface features. Agents interact within a large population and store a number of stereotypes within their memories. Memes are updated in a similar way to the open-mind model (above). Two distinct forms of interaction occur: economic interaction via games of the "prisoners dilemma" and cultural interaction via the exchange of memes (both surface and hidden). Many of the assumptions of the society have been parameterised. Of specific interest are the conditions (specific assumptions) that produce distinct groupings of agents with various economic relationships: e.g. where one group systematically exploits another or where groups become altruistic towards their in-group as in the swap shop model (above). In order to explore the large parameter space of the society an automatic searching system has been developed. A large space of models can therefore be searched to find the required specific range of parameters (assumptions) that give rise to behaviors and phenomena of interest.

On-going experimental work is at an early stage. However, the following tentative and qualitative observations can be made. Extreme spatial localisation of game interaction promotes co-operative economic behavior, whereas extreme spatial localisation of cultural interaction promotes exploitative behavior. Group formation (defined here as sets of agents sharing all their labels) promotes co-operative economic behavior. Interestingly, it is rare for agents to hold stereotypes that categorize themselves (a form of self-recognition). Even with extensive searching of the parameter space, societies could not be found which contained significant numbers of agents holding stereotypes that applied to themselves. This latter finding appears to refute an early hypothesis concerning the formation of in-group altruism through positive self-recognition of the in-group. However, a revised hypothesis suggested by some initial results contends that agents tend to hold negative stereotypes against other agents which are very similar to themselves (e.g. differing by only one label). In this way it may be possible for "groups" to form based not on positive self-recognition but on negative recognition of group boundaries. This hypothesis forms part of on-going investigations with the model.

9. Conclusions

Artificial societies do not aim to model real societies in any direct sense. They can be seen as an aid to intuition in which the researcher formalises abstract and logical relationships between entities. When constructed computationally they can be investigated empirically by producing explanations and hypotheses that can be refuted by observation. More interestingly, since the assumptions upon which the society is constructed can be changed there is no need to simply observe. Other modes of investigation are possible in which assumptions are changed to produce desired behavior. Whatever the relationship between real societies and artificial ones (a problematic area) it is argued that such systems can be used as an aid to theory construction by sharpening intuition in the formulation of hypotheses which may ultimately be testable against real data. Many of the models constructed within the artificial society mould have tended to be strictly "bottom-up" (i.e. highly skewed towards a form of methodological individualism) and consequently illuminate the micro-macro link. This skew appears for many reasons, not least that many researchers are interested mainly in this link. However, given agents inhabiting societies that maintain a meme-pool that contains ideas about the structure and form of that very society, it appears that such a skew can be alleviated. Such models can attempt to illuminate the micro-macro-micro feedback links that regulate social structures.

As for the applicability of the knowledge gained within these abstract models to the construction of general memetic theory, the main conclusion to draw is that it is still early days for both memetics and artificial society methodology. It is not clear how to apply much of the knowledge produced by these models and methods to the real word. It is clear that the open-mind model demonstrates that the intuition-- "killing memes" cannot prosper in a population-- is not true for the simplified scenario given. If such "killing memes" can prosper in that scenario, why not in the real world? Evidence of "suicide cults" might suggest a similar process. Such cults tend to be highly insular with regular acts of "memetic reinforcement" (collective worship, chanting, encouragement of the reading of agreed texts etc.). The swap shop model also demonstrates minimally how it is possible for individual agents to unwittingly form groups and become out-group hostile by following simple memetic learning rules. Do such processes bare comparison with human group formations and tribal hostilities? More importantly can such models give policy makers and general social actors any leverage in the struggle to temper and re-channel social forces for the betterment of all? Perhaps such models and approaches are the first steps on such a road. It would appear however that the road is long and winding though perhaps some can see the glimmers of possible futures on the horizon.

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Glossary

Artificial society	: computational model of a social process not necessarily reflected in any real existing society.
Culture	: totality of inherited artifacts and behaviors in a society not coded by genes.

Meme : a unit of imitation, a unit of culture.

Memetic engineering : the purposeful construction of memes to some end.

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Biographical Sketch

David Hales is a research fellow working in the areas of Social Simulation and Artificial Societies. The general focus of his work involves modeling processes of cultural transmission and evolution in populations of agents. Use is made of the emerging Meme paradigm as a basis for computational modeling. The general thrust of the work is to explore those situations in which cultural evolutionary processes appear to be better than genetic evolution or individual rationality in sustaining pro-social behaviors. One specific area of focus centers on the emergence of "meme bundles" or "cultural packages". Such processes are of particular significance when "tags" or "cultural markers" are combined with behaviors that transport utility between individuals possessing similar markers. He received a BSc in Computer Science from Aston University and MSc in Artificial Intelligence from Essex University. He holds a PhD in Social Simulation (Essex University).

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