Selfish Memes & Selfless Agents - Altruism in the Swap Shop

David Hales
(e-mail: daphal@essex.ac.uk)

Department Of Computer Science
The University of Essex,
Colchester, Essex, UK

Abastract

A "memetic" (Bura 1994, Dennett 1995, Hales 1997) approach is applied to a resource sharing scenario. “Agents" are represented as cells on a grid applying simple cultural learning rules which selectively replicate and repel memes from neighbours. The memes represent culturally learned traits (Axelrod’s 1995) but also influence resource sharing behaviours.

In the experiments presented, multiple cultural groupings which become altruistic towards "in-group" members via a form of group selection (Pedone & Parisi 1997) emerge.

This form of cultural evolution is offered as a unified approach to the study of group formation, cultural evolution, cooperation and altruism. Memes are viewed as the basic replicators upon which societies are constructed.

It is demonstrated that such methods can produce more optimal societies than conventional evolutionary methods in given situations. The memetic approach is inherently distributed and dynamic, offering the possibility of application to areas such as collective robotics and software agent co-ordination.

Topic Areas: Cooperative problem solving, Coalition formation & organisation self-design

1 Introduction

Within DAI and the game theoretical literature a fundamental question is often posed: Given bounded rationality and knowledge, what conditions produce cooperative and/or altruistic inter-agent behaviour?

One line of enquiry involves the application of simple learning rules within game theoretic environments (Liebrand & Messick 1996). This approach assumes that agents are individual satisficing learners. Another approach applies selective mimicry from a spatial "neighbourhood" based on maximum payoff (Nowak & May 1992). Although elegant, and able to produce cooperation, neither can produce sustained altruism - where individual needs are driven by the needs of a group to the individuals detriment.

Here, a fresh perspective on cooperation is applied which is a synthesis of these two approaches yet moves beyond them. A “memetic” (Bura 1994, Dennett 1995, Hales 1997) approach is developed which takes it’s inspiration from theories concerning the cultural evolutionary processes in human societies.

It seems that human societies manage to solve many co-ordination and group organisational problems although they appear to become ever more complex, interdependent and expansive. Yet archaeological evidence suggests that the emergence of complex societies is very recent (Mithen 1996). This is too recent for the process to be accounted for as a genetic evolutionary trend. Cultural processes operate at a higher level than genetic processes and are orders of magnitude faster. Is it possible to capture some of the dynamics of such processes? If so, could such processes be applied to MAS’s in order to evolve solutions to co-ordination problems?

I attempt to address these two questions using the “meme” conception (Dawkins 1976). If “cultures” are decomposed into units which can be communicated (replicated) and mutated, this can be a basis for a model of cultural evolution in the abstract. Such units of culture have been termed “memes”. A successful meme is one that gets replicated and becomes numerous in the population, not necessarily one that benefits those who hold it. Previous work (Hales 1997) has examined some of the conditions under which “harmful” memes (from the standpoint of resource use optimality) can become dominant and some of the mechanisms that can breakdown such processes. Here a model is presented that attempts to harness the power of “group selection” based on social influence (Pedone & Parisi 1997) in order to evolve efficient groups of co-ordinated agents where agents have only simple satisficing, learning rules.

In the experiments presented, multiple cultural groupings emerge. The groups become altruistic towards "in-group" members via a form of group selection. This selects for altruistic in-group behaviour, even when this is to the detriment of some individuals within those groups. Eventually the memetic approach produces a homogenous and altruistic culture, this is contrasted with a “genetic” approach which results in less optimal configurations of competing groups.

2 The Swap Shop Model

The Swap Shop (SS) is a Cellular Automata "type" model. Strictly, it is not a CA since it does not apply synchronous updating. An asynchronous implementation was chosen to avoid artefacts (see Hagselmann 1996). The framework of the SS is modelled after the Axelrod Cultural Model (Axelrod 1995). In ACM Axelrod investigated the emergence of spatial regions of shared "cultural attributes", from simple individual attribute propagation rules. Of primary importance in AMC is the concept of "cultural distance". Attribute propagation only takes place between cells when they share at least one attribute. In ACM cells are purely collections of attributes, the attributes have no behavioural impact. In SS the attributes are viewed as memes which can influence the behaviour of the cells.

2.1 Cells And Memes

The SS comprises a 2 dimensional grid of cells. Each cell represents a stationary agent and has four integer state variables associated with it: An energy level ($0 <= EL <= 9$), a sharing level ($0 <= SL <= 4$), a similarity level ($0 <= SSL <= 4$) and a cultural attribute ($0 <= C <= 4$). SL, SSL and C are treated as memes. Consequently they can be propagated and mutated. The values of the state variables determine the behaviour of a cell. The SSL meme indicates the minimum similarity required before the activation of resource sharing with neighbouring cells. Similarity is defined as the number of memes shared between two cells. The SL meme indicates the amount of resource sharing that occurs. The C meme has no direct behavioural impact.

2.2 Events And Behaviours

During execution of the SS one of three events can occur: life tax, resource reward and cultural interaction. A life tax event involves a cell's energy level EL being reduced by one energy point (to a minimum of zero). If a zero level is reached then memes may be mutated. A resource reward event involves a cell being awarded four energy points. These are divided between neighbours and the awarded cell in proportions dictated by the SL and SSL values. This is achieved by selecting random neighbour cells (from the Moore neighbourhood) which satisfy the SSL value of the sharing cell and awarding a single energy point if required (i.e. EL of the neighbour is less than maximum). This process is continued until SL points have been shared or some maximum number of neighbours has been selected[1]. A cultural interaction event involves a cell and a neighbour harmonising a single meme given that they have at least one other meme in common. When both cells are culturally identical (i.e. have a similarity of three) cultural interaction will have no effect. Additionally a cell with EL = 0, can never propagate a meme, and a cell with EL = 9, can

[1] Neighbours are selected at random (with replacement) until all resource rewards have been made or a total of 16 neighbours have been selected. This models a form of "noisy" sharing, where some needy cells may get more than others or nothing at all, but that each has an equal chance of receiving resource rewards.

never receive a new meme. This captures the notion that a “satisfied” cell does not change it’s memes whereas an unsatisfied or “dead” cell can not propagate memes.

Note “neighbours” are defined as the eight cells surrounding a cell (the so called Moore neighbourhood). The edges of the SS are not wrapped into a torus, cells at edges therefor, do not have a full complement of neighbours.

2.3 The System Cycle

A single "cycle" of the system is implemented as:

```
LOOP for the total number of cells in the grid
  with probability PT (life tax event):
    select a cell (z) at random
    IF EL of z>0 THEN deduct one from EL value of z
    IF EL of z=0 THEN mutate each of SL,C,SSL with probability PM
  with probability PR (resource award event):
    select a cell at random
    award energy points to the selected cell (increase EL by 4)
    based on cell SL,SSL values, distributed points to neighbours
  with probability PC (cultural interaction event):
   select a cell (z) at random
   select a neighbour (n) at random
   calculate the similarity (s) between z and n
   IF s>=1 AND EL of n>0 AND EL of z<9 THEN
     propagate a randomly chosen (differing) meme from n to z
END LOOP
```

For all the experiments presented here, the system cycle was iterated 2000 times. Experiments indicated that beyond this, no significant changes occurred. Mutation involves increasing or decreasing a meme value by one (values out of range are rest to the nearest value in range).

3 Four Experimental Scenarios

Four experimental scenarios were designed (A to D). These compare “cultural” with “genetic style” evolution in both uniform and “sparse” reward environments. This later environment designates some minority of cells as “productive” and others as “non-productive”. Resource rewards are only made to “productive” cells. Each scenario is described below.

3.1 Scenario A - “Cultural” Evolution

The parameters are set to PT = 1, PM = 0.2, PR = 0.25, PC = 1 with a grid size of 20x20 (400 cells). 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.

3.2 Scenario B - “Genetic” Evolution

The same settings as scenario A are used but a “genetic” style of evolution is applied instead of a cultural one. All cultural interaction is turned-off. When a cell's EL equals zero (after a life tax event), all memes from the neighbour with the highest EL level are copied into the "dead" cell with PM mutation on each meme. This implements a form of local asexual evolution where fitness is based on EL. In this scenario the memes can be viewed as "genes".

3.3 Scenario C - “Cultural” Evolution With Sparse Rewards

The same settings as scenario A are used but resources are distributed only to designated cells rather than to all cells. Only cells with even row and column numbers are awarded resources. This means that cells receiving resources have no neighbours who also receive resources and therefor can not benefit from sharing behaviours by others.

3.4 Scenario D - “Genetic” Evolution With Sparse Rewards

The same settings as scenario C are used, but the “genetic” style of evolution is used as in scenario B.

4. Results

For each scenario 100 individual simulation runs were executed for 2000 system cycles each. Tables 1 and 2 show a synthesis of all the runs for each experiment. These results are discussed below.

Table 1 and Table 2 about here!

4.1 Experiment A – Single Region with Total Sharing

Within a few hundred cycles spatial regions of shared meme bundles form. Those regions which satisfy more of their members (i.e. keep them from falling to zero EL) tend to grow more quickly since they are less likely to be invaded through cultural interaction with other regions or mutation. Consequently, the regions with higher SL levels outperform those with lower SL levels. Also, those regions which act selfishly by only sharing resources within the region (SSL = 3) outperform those regions that allow resources to be shared with other regions. Eventually, (usually within about 1500 cycles) the grid becomes dominated by a single region composed of cells which

share all their resources (SL = 4) with those holding identical cultural attributes (SSL = 3). Figure 1 and tables 3 and 4 show a typical simulation run.

Figure 1 & Tables 3 & 4 about here!

4.2 Experiment B – Multiple Regions with "In-Group" Sharing

Similar results are obtained as those for experiment A, except that regions form more quickly but don't break down so easily. Because the "genetic" style of evolution can only replicate information when cells die, this means that barriers to resource sharing, which are created by the C meme, persist and reduce the optimality of the population. Figure 2 shows a typical simulation run.

4.3 Experiment C – The Majority Benefits At Minorities Expense Through Strong Altruism

When resources are awarded only to selected cells (only those cells with even row and column addresses), this does not select for selfish cell resource behaviour as might be assumed. Ironically, those cells which actually receive the resources give them all to their neighbours, thus "starving" themselves. The cultural evolutionary process selects for strong altruism. This may initially appear to be counter intuitive, since a cell which is starved of resources is more likely to mutate or take on new memes. However, if such a cell is surrounded by cells with high values for SL, they will tended to continually re-propagate these high SL values to the altruistic cell. The majority "unproductive" cells in the Moore neighbourhood, benefit at the expense of the minority cells. By becoming "repositories" of altruistic memes the majority cells, via social influence, keep the minority "productive" cells altruistic. Figure 3 shows a typical simulation run.

4.4 Experiment D – Altruism Hampered By Boundaries

Although strong altruism is selected for in the majority of cells, it is hampered by the lack of cell homogeneity. Also a significant minority of cells are less "altruistic" sharing only some of any resource reward. Figure 4 shows a typical simulation run.

Figures 2,3,4 about here!

5. Observations

5.1 Cultural Groups and In-Group Bias

Regions of shared cultural attributes can be seen as cultural groups. It should be noted that under cultural evolution (experiments A and C) these groupings emerge from the propagation of individual attributes which are initially set to arbitrary values. The mechanisms by which groups become successful (outperforming other groups) involves maximum in-group sharing and minimum out-group sharing. This appears as the emergence of an artificial form of "in-group bias", a

phenomena which pervades most real social systems (Kramer & Brewer 1984). Ironically, this process which quickly produces sharing behaviour can become an obstacle later when the population is composed of several competing groupings.

5.2 Reciprocal OR Real Altruism?

Can the sharing behaviour that emerges in the above experiments be viewed as altruism? The sharing that does emerge is always strictly within the group. In this sense it could be argued that the sharing behaviour is a form of reciprocal altruism since sharing within a group, by definition, means that those other members may reciprocate in the future (since a group is defined as those with the same memes and hence sharing behaviours). However, in experiments C and D where resources were never awarded to some designated cells (unproductive cells), sharing still emerged. This kind of altruism emerges because individual cells can't distinguish between those that acquire resources and those that don't. Never-the-less, the experiments demonstrate that individual satisficing learning rules, via social influence, can produce altruistic behaviours.

5.3 Tags and Group Conflict

The C meme used in the experiments has no direct behavioural impact (a tag). Cultural groupings tend to form which are distinguished purely by different values of the tag attribute. It would seem that the more values a tag could take, the more groups would form, which would increase the time required for a single group to dominate the population due to the increase in inter-group conflict. This may not however, be the case when the number of tags are increased (see Axelrod 1995).

5.4 "Genetic" v. Cultural Evolution

The "genetic" experiments B, D produced similar results initially when resources were distributed equally (experiments A and B) but failed to become dominated by a single group. This results from the reduced communication of attribute information, since this only occurs when a cell on a group boundary "dies" by reaching an EL of zero. Also, copying of attribute information (reproduction) implies mutation, which was here set at a fairly high level. With sparse rewards the process is exaggerated, such that in experiment D a major difference is observed between the optimality of the resource distribution in comparison with experiment C.

6 Conclusions and Future Work

The experiments presented here, demonstrate that group selection can operate on groups created via social influence to produce altruistic behaviour (as speculated, but not demonstrated, by Pedone & Parisi 1997). Moreover, it has been demonstrated that in the simple scenarios presented, a genetic method of evolution produces less optimal results than a memetic method.

This form of cultural evolution is offered as a unified approach to the study of group formation, cultural evolution, cooperation and altruism. Memes are viewed as the basic replicators upon which societies are constructed. The memetic approach is inherently distributed and dynamic, offering the future possibility of application to areas such as collective robotics and software agent co-ordination when highly changeable and dynamic environments demand unsupervised, self-organising and socially oriented solutions.

The SS model presented here is purposefully simplistic. It is an initial attempt to capture some aspects of cultural evolution and apply them in a productive way. In keeping with the KISS (Axelrod 1997) principle it tries to capture the process under investigation at the simplest possible level. One powerful aspect of cultural evolution which is missing from the model is the process of specialisation. Future work will attempt to explore minimal mechanisms that allow for the productive emergence of specialisation within and between groups. Also, a relaxation of the "cultural closeness" metric allowing for a more realistic case of "hidden memes" will be explored. This line of enquiry offers the potential to forge links with work already done using tags or labels (Holland 1993, Riolo 1997) and richer models of social selection (Simon 1990).

References

Axelrod R. (1995), "The Convergence and Stability of Cultures: Local Convergence and Global Polarization.", *Working Paper 95-03-028*. Santa Fe Institute, Santa Fe, N.M.

Axelrod R. (1997) "Advancing the Art of Simulation in the Social Sciences" in Conte R. & Hegselmann R (Eds.), Simulating Social Phenomena - LNEMS 456, Springer, Berlin.

Bura S. (1994), “MINIMEME: Of Life and Death in the Noosphere” in Mayer J. & Wilson S. (Eds.), *From Animals to Animats 3: Proceedings of the 3rd International Conference on Simulation of Adaptive Behaviour (SAB94)*, MIT Press, London.

Dawkins R. (1976), *The Selfish Gene*, Oxford University Press, New York.

Dennett D. (1995), *Darwin’s Dangerous Idea*, Simon & Schuster, New York.

Hales D. (1997), "Modelling Meta-Memes" in Conte R. & Hegselmann R (Eds.), Simulating Social Phenomena - LNEMS 456, Springer, Berlin.

Holland J. (1993), "The Effect of Labels (Tags) on Social Interactions." Santa Fe Institute Working Paper 93-10-064. Santa Fe, NM.

Kramer R. & Brewer M. (1984), “Effects of Group Identity on Resource Use in a Simulated Commons Dilemma.” Journal of Personality and Social Psychology, 1984, Vol. 46, No.5, 1044-1057.

Liebrand W., & Messick D., (1996), "Game Theory, Decision Making in Conflicts and Computer Simulations: a Good-Looking Triad." in Troitzsch K., Mueller U., Gilbert N., Doran J. (Eds.), *Social Science Microsimulation*, Springer, London.

Mithen S. (1996), *The Prehistory of the Mind*, Thames & Hudson, London.

Nowak, M. & May R. (1992), "Evolutionary Games and Spatial Chaos." Nature, 359, pp826-929.
Pedone R. & Parisi D. (1997) "In What Kinds of Social Groups can Altruistic Behaviour Evolve?" in Conte R. & Hegselmann R (Eds.), Simulating Social Phenomena - LNEMS 456, Springer, Berlin.
Riolo R. (1997), "The Effects of Tag-Mediated Selection of Partners in Evolving Populations Playing the Iterated Prisoner's Dilemma." Santa Fe Institute Working Paper 97-02-016. Santa Fe, NM.
Simon, H. A., (1990), A Mechanisms for Social Selection and Successful Altruism. Science, 250(4988):1665-1668, December 21 1990.

Description	Tng	Zng	Mng	CZng
Exp.A - “cultural” evolution	2631	15	116	4843
Exp.B - “genetic” evolution	2520	22	109	5221
Exp.C - “cultural” evolution with sparse rewards	2486	42	134	10532
Exp.D - “genetic” evolution with sparse rewards	1854	79	69	18804

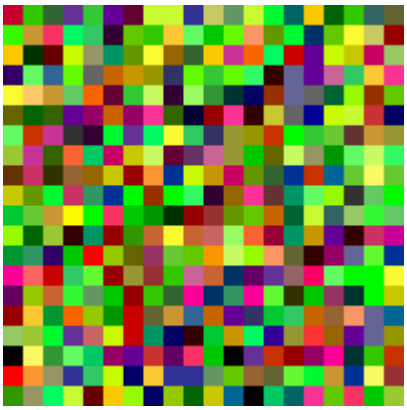
Table 1 - Energy Levels and Optimality

This table shows the averaged results of 100 simulation runs for each experiment. In all cases each individual simulation run was terminated after cycle 2000. The Tng column shows the sum of all the energy in all the cells of the population, Zng shows the number of cells with a zero energy level (which might be considered as “dead” cells), Mng shows the number of cells with the maximum energy level (i.e. 9 energy points) and CZng shows the cumulative number of zero energy cells observed over the entire run (all 2000 cycles with a count of zero energy cells collected every 10 cycles). CZng is intended to give a measure of the optimality of the system over the entire run, whereas the other statistics give only a snapshot of the system at the end of the run (cycle 2000).

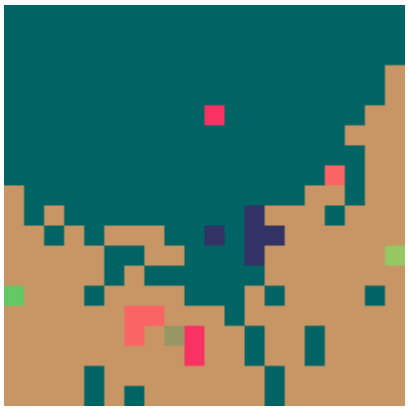
Meme	SL					C					SSL				
Value	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
Exp.A	0	0	0	4	396	90	65	65	74	107	0	0	0	400	0
Exp.B	0	0	0	6	394	107	63	65	55	110	0	0	1	399	0
Exp.C	0	0	1	14	386	140	54	49	53	104	0	0	0	400	0
Exp.D	0	0	6	78	316	75	87	90	83	66	0	0	1	398	1

Table 2 - Meme Values

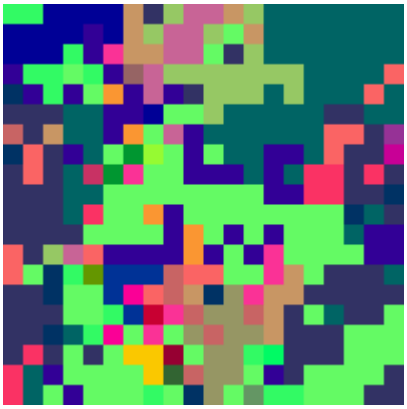
Here the averages of the distributions of meme values are shown. For each experiment 100 simulation runs were performed. Each run was terminated after cycle 2000. The averages are calculated from the distributions of memes at termination. Notice that in all simulation runs, SSL=3 is strongly selected for (indicating sharing with identical “cultures” or “meme bundles”). SL=4 is also selected for (indicating full sharing of resource rewards). Notice however that the “genetic” style of evolution (experiment D) provides niches for less altruistic sharing behaviours with over 20% of cells not sharing all their resources.



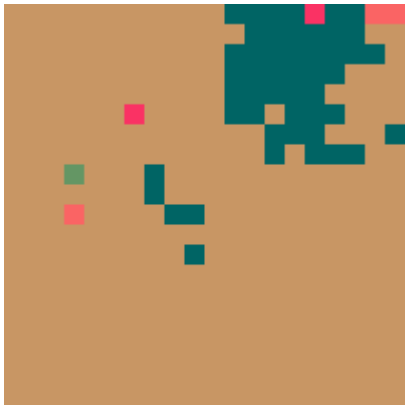
Cycle 0



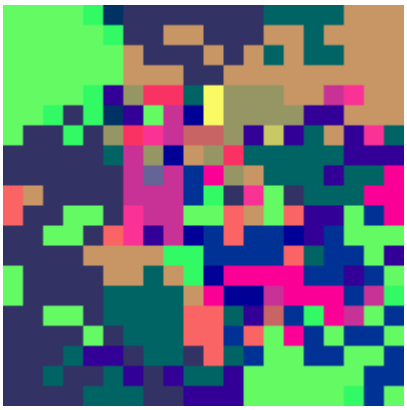
Cycle 500



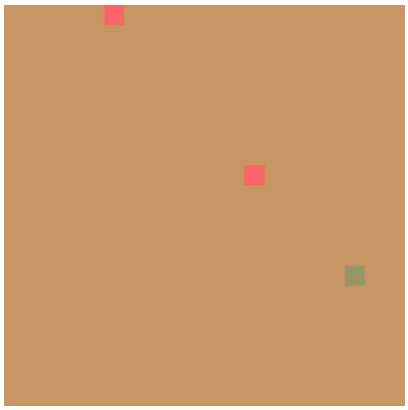
Cycle 100



Cycle 1000



Cycle 200

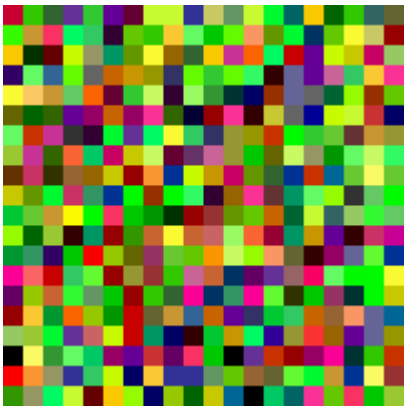


Cycle 1500

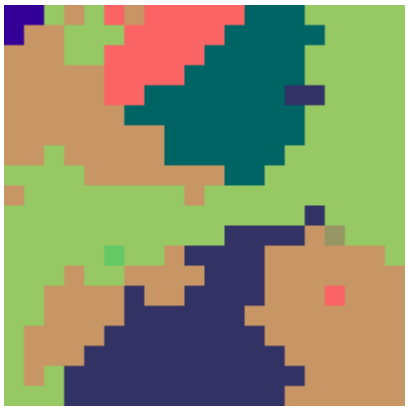
Figure 1

Experiment A - Example of A Typical Run.

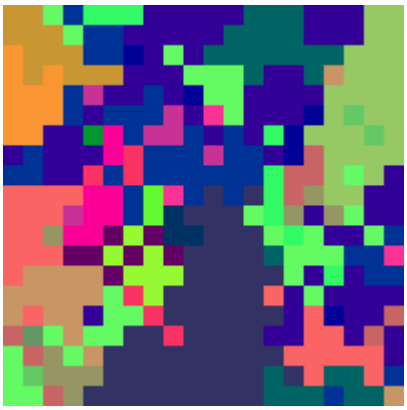
A simple "cultural" evolutionary process produces maximum resource sharing behaviour. The colour of each cell represents the values of the three memes held. Notice the formation of spatial regions with shared meme bundles and the scattered "mutant" cells. By cycle 1500 most of the grid is occupied by a single meme bundle. The continuing existence of mutant cells is a result of the scenario - which tends to "starve" some cells because energy is distributed uniformly but stochastically. Cells from the dominant "culture" resist invasion by sharing resources with each other but not the mutant cells.



Cycle 0

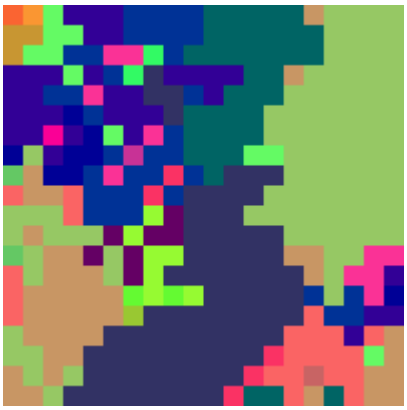


Cycle 500



Cycle 100

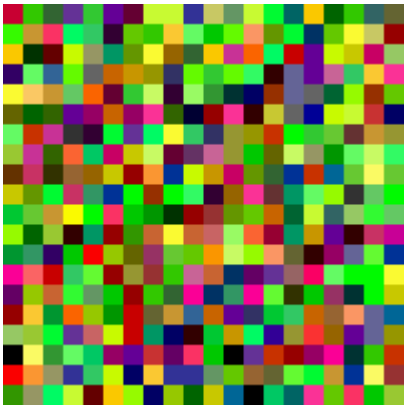
Cycle 1000



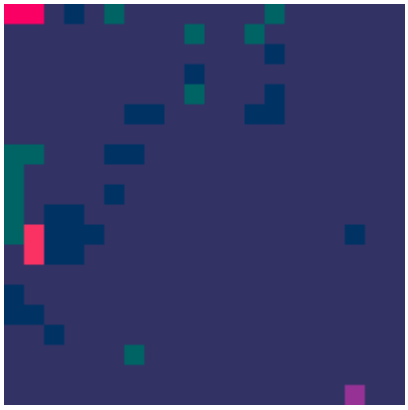
Cycle 200

Cycle 1500

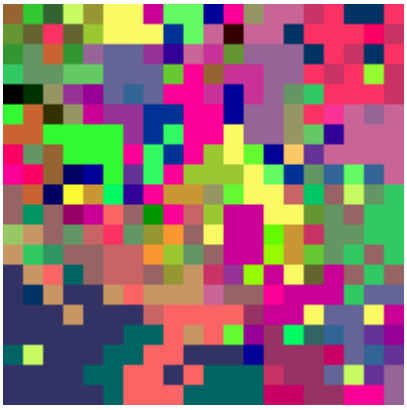
Figure 2
Experiment B - Example of A Typical Run.
Here an asexual form of "genetic" evolution is used in place of the "cultural" evolutionary process. The colour of each cell represents the values of the three memes held. Notice the formation of spatial regions with shared memes. These regions form more quickly than in Experiment A, but once formed tend not to break down.



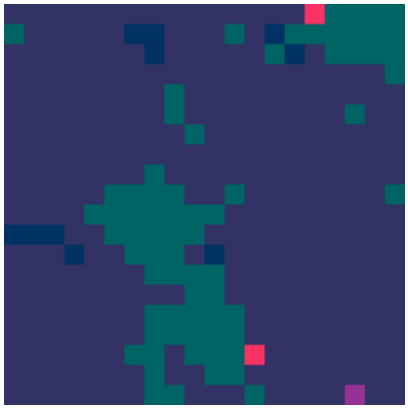
Cycle 0



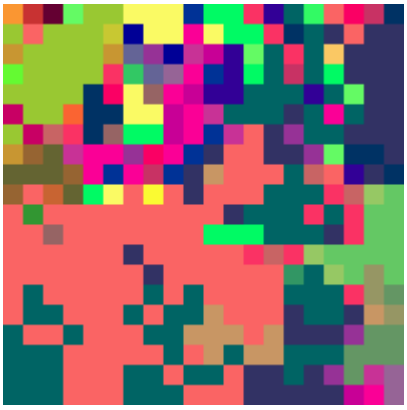
Cycle 500



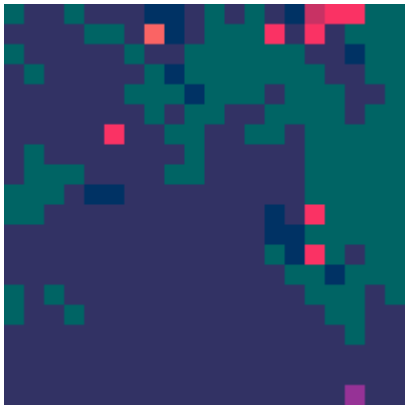
Cycle 100



Cycle 1000

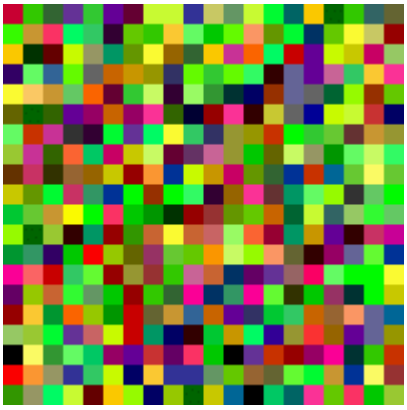


Cycle 200

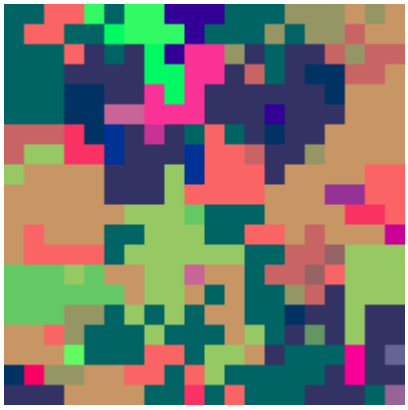


Cycle 1500

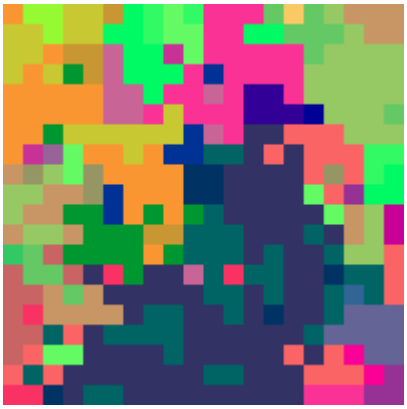
Figure 3
Experiment C - Example of A Typical Run.
When resources are awarded only to selected cells (only those cells with even row and column addresses), this does not select for selfish cell resource behaviour as might be assumed. Ironically, those cells which actually receive the resources give all to their neighbours, thus "starving" themselves. The cultural evolutionary process selects for strong altruism. Also, note that there is a more rapid domination of the population by a single "culture" (compared with figure 1) but there is more tendency to drift in the C meme.



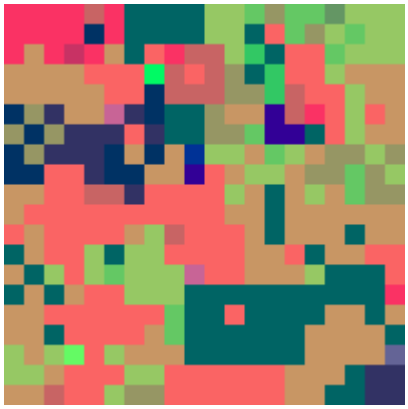
Cycle 0



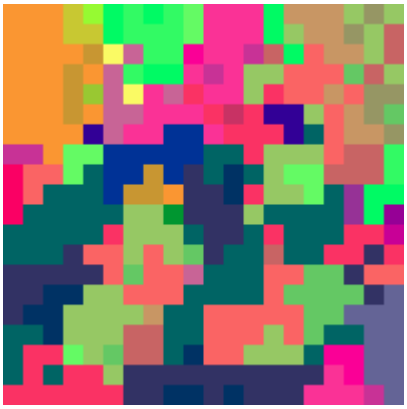
Cycle 500



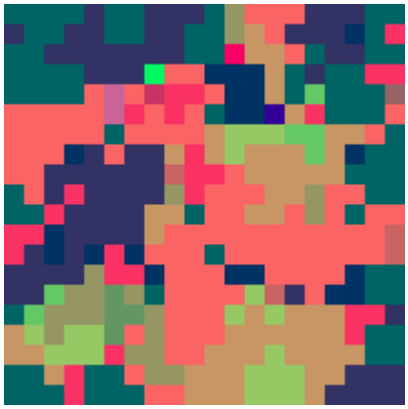
Cycle 100



Cycle 1000



Cycle 200



Cycle 1500

Figure 4
Experiment D - Example of A Typical Run.
Resources are awarded only to selected cells (only those cells with even row and column addresses), and a "genetic" style of evolutionary process is used in place of the "cultural" process shown in figure 3. Diversity is high. Although cell altruism is selected for in the majority of cells, it is hampered by the lack of homogeneity. Also a significant minority of cells are less "altruistic" sharing only some of their resource reward.

0315	0010	4415	1349	1227	0243	3212	0427	0421	0342	0046	2333	0421	1327	4138	4012	2205	0019	0232	0028
1113	3127	3130	2046	2439	2210	1013	0016	0327	4047	4402	2110	0435	0407	1323	3030	1018	1429	0045	3002
4011	1100	2001	4112	3330	0331	0402	1429	0305	4411	4018	3341	2303	2048	4007	0248	4117	3016	1033	4436
3422	4040	1449	2118	1235	1308	2409	1407	4031	2112	1228	2111	3045	1004	2448	0247	4448	2434	0329	4341
1426	1041	3122	3430	2308	3215	1225	1142	2214	0142	0127	2311	2426	4100	2440	1236	3412	3118	4103	1011
4201	2203	3200	0243	0037	1304	0037	4348	3205	1218	3008	4345	1006	4227	1234	3146	4113	0428	1413	2421
4047	0206	3343	3318	2216	1322	1345	2046	1420	2438	4032	2121	1404	0201	0113	1223	2220	4310	3128	2121
3226	3342	3204	3027	1434	1034	3015	1141	3213	0130	4443	2126	4407	4209	1143	3334	3300	4044	1149	3049
3107	2136	2108	1026	0305	3013	3004	4129	4246	4114	2404	1032	0408	4410	4243	0206	0444	2226	2147	2227
3018	0409	1327	2134	1338	4247	0119	4101	0119	3042	2214	0309	4340	4319	0330	4046	3117	3316	3431	0112
0220	2229	3123	0211	0111	3137	4404	3307	1109	3005	0419	0407	1014	1302	3411	0429	0238	4439	2321	3430
3112	2207	3227	1002	0332	3000	4301	2026	1425	2022	3231	0148	3026	4214	0336	2400	0249	1008	2135	2243
4022	1331	3422	4406	0103	2011	4203	1139	2225	1015	3402	1145	3115	0430	0028	1005	0037	2442	3329	4246
3243	4238	4004	2434	3328	3005	2122	0419	0016	4440	2027	3038	4422	1343	2234	2033	4044	0117	0111	1421
4426	2011	2028	2328	2339	4400	3009	0011	4415	3244	3035	1333	3241	3320	2109	4401	1138	2316	0113	3019
3000	0324	4028	2303	2019	3302	4001	0020	3121	1447	1305	0247	4034	0225	2438	1303	1021	0430	2441	0446
4435	3220	1329	1344	3231	4115	4001	0334	2429	1008	0223	2407	2041	4140	2122	2410	0300	0244	2449	1407
0001	2145	0129	4044	1432	0037	0242	1416	4429	3139	4409	0005	1348	0203	3009	0031	3247	2319	0014	0208
0106	4123	3335	0343	2436	4110	2427	0329	0340	0348	2334	1013	1026	0028	3325	1321	3122	4249	2143	0418
4305	3332	2042	0422	2007	4017	3111	2426	2015	2204	3011	0445	0000	1436	4135	4349	1011	3131	4405	3223

Table 3 - Experiment A.

The initial random starting values for each cell of the gird (as shown in figure 1, cycle 0). The first 3 digits represent the 3 memes. The final (right-hand) digit represents the cell energy level. The first digit represents the SL (sharing level) which specifies the number of energy points to share with neighbours when an energy reward is received. The third digit represents the SSL (sharing similarity level) which specifies the level of cultural similarity (specified in identical memes) required for a neighbour to be considered for a share of an energy reward. Note that the second digit has no direct behavioural significance.

4339	4338	4337	4331	4333	4230	4335	4335	4336	4339	4339	4338	4334	4335	4337	4335	4339	4336	4336	4332
4336	4339	4338	4338	4335	4338	4334	4338	4338	4339	4339	4337	4337	4338	4339	4337	4339	4339	4338	4330
4338	4339	4339	4339	4338	4339	4335	4336	4338	4336	4335	4338	4332	4334	4333	4336	4338	4338	4335	4333
4339	4339	4339	4337	4334	4339	4334	4339	4339	4339	4338	4339	4332	4338	4338	4339	4339	4339	4336	4335
4337	4339	4339	4336	4339	4338	4337	4339	4336	4339	4338	4336	4335	4339	4339	4339	4339	4339	4339	4333
4338	4339	4339	4339	4339	4339	4337	4339	4338	4339	4336	4339	4336	4338	4339	4337	4339	4338	4338	4334
4339	4339	4339	4339	4339	4339	4339	4337	4338	4339	4339	4334	4335	4330	4337	4339	4338	4339	4338	4331
4339	4339	4339	4339	4337	4339	4338	4335	4338	4336	4336	4336	4339	4332	4335	4336	4336	4330	4335	4337
4338	4337	4339	4339	4338	4337	4338	4337	4337	4337	4339	4336	4230	4335	4332	4330	4335	4336	4336	4334
4339	4339	4339	4339	4339	4339	4339	4338	4339	4335	4339	4338	4332	4330	4337	4334	4332	4334	4339	4336
4338	4338	4339	4339	4339	4338	4339	4338	4339	4336	4338	4338	4338	4338	4338	4338	4332	4331	4330	4336	4332
4335	4339	4339	4336	4338	4339	4338	4339	4338	4339	4339	4338	4331	4334	4338	4339	4336	4331	4335	4331
4336	4338	4337	4338	4334	4338	4339	4337	4338	4339	4339	4339	4334	4330	4337	4332	4335	4333	4336	4334
4335	4339	4338	4339	4336	4337	4334	4339	4335	4339	4338	4334	4338	4332	4338	4335	4335	3330	4337	4330
4336	4337	4333	4330	4330	4330	4332	4337	4334	4337	4337	4331	4334	4335	4333	4338	4338	4331	4335	4330
4335	4339	4336	4339	4334	4338	4334	4333	4337	4332	4337	4332	4336	4337	4334	4336	4331	4337	4339	4331
4335	4335	4336	4338	4333	4330	4338	4335	4339	4337	4335	4338	4337	4339	4337	4339	4336	4339	4339	4338
4337	4333	4339	4336	4337	4338	4332	4338	4337	4331	4337	4334	4338	4337	4334	4339	4334	4335	4339	4339
4338	4339	4337	4338	4338	4338	4337	4337	4337	4338	4339	4330	4337	4334	4335	4336	4335	4339	4338	4334
4338	4336	4338	4337	4337	4330	4338	4330	4335	4339	4337	4335	4335	4332	4337	4335	4330	4331	4333	4330

Table 4 - Experiment A.

The values for each cell of the grid by cycle 1500 (as shown in figure 1, cycle 1500). The dominant meme bundle or "culture" is 433. This indicates that all resources are shared with neighbours (SL=4) and that neighbours receive a share of a resource only if they share all 3 memes with the sharing cell (SSL=3). This means that 433 cells only share resources with other 433 cells thus avoiding invasion by mutant "cultures". The culture is "selfish" in the sense that it only shares resources with itself but the individual cells are "altruistic" since all resources are shared with culturally identical neighbours.