Life, Sense and the Role of Information in Evolution

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Abstract

The present work purports to the design, implementation, discussion and implications of a Sense Enhanced Game of Life (SEGoL), which is essentially the original GoL, the most popular cellular automaton discovered. To achieve this, two grids, namely the Life Grid L and the Sense Grid S are defined, with L taking one of two values (alive or dead) and S taking one of three values (touch, sight and sound), and the value in a particular grid affecting neighborhood perceptibility as well as survival in the corresponding grid. Evolutionary patterns are studied for various rules, coupled with the entropy values and survival rates. It is seen that the proposed Sense Enhanced Game of Life (SEGoL), essentially adapting Conway's original Game of Life Rules, scaled for larger neighborhoods, and for enhanced perceptibility, displays a diverse range of interesting evolutionary dynamics, while also retaining the original features of the original Game of Life including the still-life and oscillating elements for the pure touch case. It is seen that if the conditions and neighborhood rules are conducive to retention of certain senses, the system is capable of effectively organizing its sense distributions and enhancing its perception, resulting in higher survival rates and sustaining life, and this gives an insight into higher evolved organisms of the planet, such as human beings.

1. Introduction

The dexterity with which various natural processes are carried out, from simple proliferations of a virus to sophisticated cognitive processes, has always fascinated the human intellect [1-3]. Among multiple approaches developed to study evolution and life, the informational approach stands out [4-7]. Of particular mention in this context is the concept of cellular automata, which essentially is a simplified representation of a grid of cells whose evolution in discrete units of time is determined by neighborhood "rules" [8-11]. This concept has enabled the study of evolution patterns corresponding to cancers, tumors and epidemics, spread of population and so on [12-15]. The most interesting cellular automaton ever developed is Conway's "Game of Life" (GoL), comprising of a two-dimensional Grid, where a "dead" cell is born, or a "live" cell survives only when a certain number of its neighbors are alive, so that neither overcrowding nor undercrowding occurs [16-19].

The central theme of the present work extends the Game of Life to include the concept of senses. Thus, two separate grids, a life grid and a sense grid are defined for a 2D collection of cells. The sense grid has one of three values – fundamental "sense of touch", where the life of a cell is decided only by its immediate Moore neighbors, a slightly advanced "sense of sight" with a Von Neumann neighborhood field of influence, and a more advanced "sense of sound", with an even more expanded neighborhood. Neighborhood Rules are derived for both grids, and evolution patterns in various cases of proliferation, stasis and decay are explored. It is seen that while the Sense-Enhanced Game of Life (SEGoL) proposed portrays a slightly more realistic yet sophisticated understanding of emergence and life, the conclusions have deep implications in our understanding of evolution of various species, including the dominance of the human species over other species in due course of time.

2. Design and Rule Definition

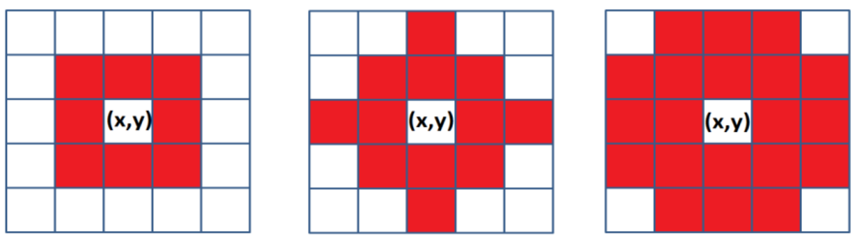
In the Sense Enhanced Game of Life (SEGoL), two grids, L representing the Life Grid and S, representing the Sense Grid, both of size MxM (M=50) are defined. All-pervading throughout the entire grid, "consciousness" is seen as the property that enables each cell, alive or dead, in both the sense and life grids to be aware of its existence depending on the neighborhood cell values.

Three kinds of neighborhoods are defined as follows and illustrated below, all of them defined with respect to a cell denoted by x and y coordinates as (x,y) [20,21]:

1. Moore-1 Neighborhood: Immediate neighboring cells having a Chebyshev distance of 1.

2. Von-Neumann-2 Neighborhood: Twelve cells are the set of cells with a Manhattan Distance of 2.

3. Extended Neighborhood: All 20 cells with Hamming Distances of 1, Sqrt(2), 2 and Sqrt(5).



Moore-1 Von-Neumann-2 Extended

Each cell in the life grid may have a value of either 0 or 1, corresponding to dead and alive respectively. Each cell in the sense grid may have one of three values, 0 corresponding to touch, 0.5 corresponding to sight and 1 corresponding to sound sense.

From an evolutionary standpoint, these three senses determine the way an organism receives and perceives information from various kinds of neighborhoods, subsequently leading to increased awareness about its own self, as well as potential sources of nourishment and danger around it.

The other two fundamental senses, namely taste and smell, are related to the manner in which an organism moves towards or away from nourishing/detrimental objects, and the implementation of these senses is succinct in the neighborhood rules, where underpopulation and overpopulation on either side of an optimal neighbor count causes death.

Time is represented in the cellular automata by discrete steps, where values of all cells in both grids are updated as per the defined rules. The neighborhood rules for the L and S grids fall in three categories:

A. S(x,y)=0 (Sense of Touch)

This value is the least developed value for a sense cell. In this state, a cell in A is only sensitive to its nearest neighbors (Moore-1 neighborhood), and has no way of perceiving or being influenced by farther neighbors.

1. A dead L(x,y) (0) becomes alive (1) if and only if exactly 3 of its Moore-1 neighbors are alive (1).

2. An alive L(x,y) continues to live if the number of alive Moore-1 neighbors are within a range F0. By default, F0 is specified as the range [2,3].

3. Failing the above conditions, a living cell dies, and a dead cell continues to be dead. This is because more than F0 alive neighbors correspond to overcrowding and resource scarcity, whereas lesser than F0 alive neighbors correspond to undercrowding and loneliness.

4. S(x,y) "upgrades" to Sense of Sight, 0.5, if a certain range "a" of its neighbors have the value 0.5. By default, a is set to [3]. In the absence of the above condition, S(x,y) stays at 0.

B. S(x,y)=0.5 (Sense of Sight)

This value is more developed than sense of touch, since a cell now also has the capacity to perceive by sight, a select set of farther neighbors (Von-Neumann-2) corresponding to the 'line of sight'.

1. A dead L(x,y) becomes alive if and only if exactly 5 of its Von-Neumann-2 neighbors are alive.

2. An alive L(x,y) continues to live if a certain range F1 of its Von-Neumann-2 neighboring cells are alive. By default, F1 is set to the range [0,5]. This setup ignores the classical GoL undercrowding.

3. In the absence of the above two conditions, a live cell dies, and a dead cell stays dead.

4. S(x,y) may upgrade to Sense of Sound, 1, if a certain range "b" of its neighbors have the value 1. By default, b is set to [2,3].

5. S(x,y) may retain the Sense of Sight, 0.5, if a certain range "c" of its neighbors have the value 0.5. By default, c is set to [5,8]. In the absence of the above two conditions, S(x,y) "downgrades" to Sense of Touch, 0.

C. S(x,y)=0.5 (Sense of Sound)

Sound transcends line of sight communication as well as physical contact, making it the most advanced state possible for S(x,y), with perception covering the entire extended neighborhood.

1. A dead L(x,y) becomes alive if and only if exactly 8 of its extended neighbors are alive.

2. An alive L(x,y) continues to live if a certain range F2 of its extended neighboring cells are alive. By default, F2 is set to the range [0,8]. This rule also ignores GoL undercrowding.

3. In the absence of the above two conditions, a live cell dies, and a dead cell stays dead.

4. S(x,y) retains the Sense of Sound, 1, if a certain range "d" of its Moore-1 neighbors have the value 1. By default, d is set to low-ended [0,5]. In the absence of the above condition, S(x,y) "downgrades" to Sense of Sight, 0.5.

Applying these rules during a time instant "i" determines L and S grids for the next instant "i+1". The rules of L have been adapted from original GoL rules, with the ranges scaled to proportion for larger neighborhoods [16].

However, the Sense Grid concept is an entirely new addition, where senses are upgraded by influence of Moore-1 neighbors, senses are retained by virtue of an optimal level of use among the neighbors, and senses downgrading due to fall in usage (being made vestigial) or due to practical ineffectiveness due to other cells also developing the sense, thus reducing competitive advantage.

The configurations of any rule can in summary be described as the set R={a,b,c,d,F0,F1,F2}. The default rule set is then R0 = {[3],[2,3],[5,8],[0,5],[2,3],[0,5],[0,8]}.

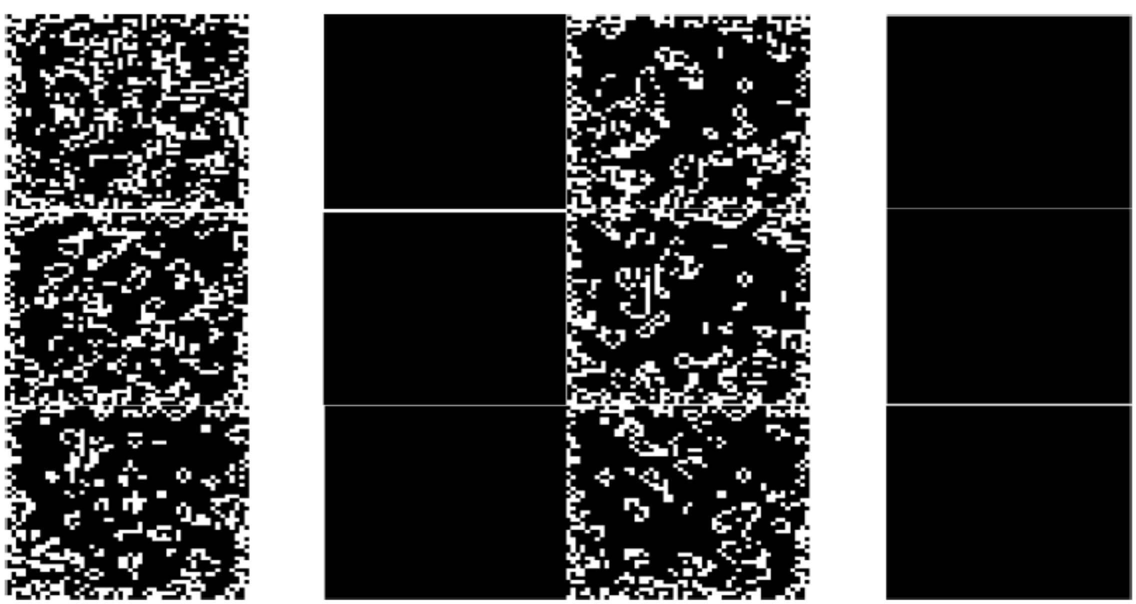
In each iteration, the entropy, an information theoretic measure of randomness and uncertainty, is calculated for the L and S grids. This value gives a quantitative indication of the underlying nonlinear and chaotic processes [22-24].

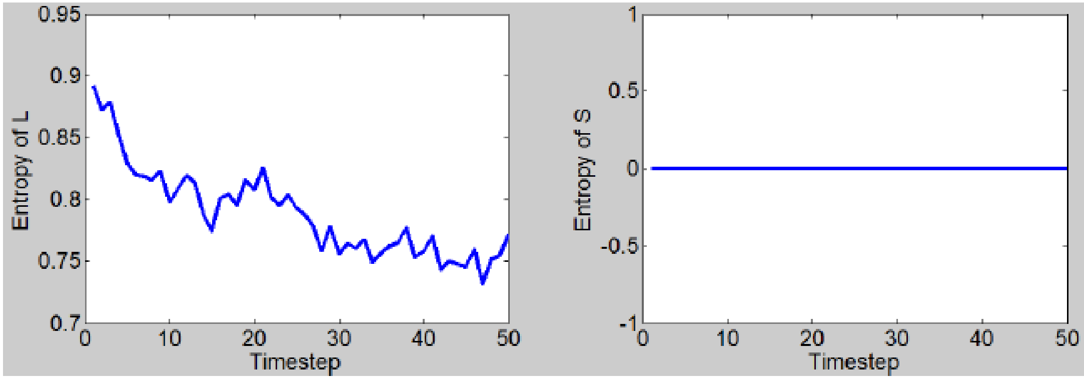
3. Results and Analysis

The design and rules detailed in the previous section are implemented using MATLAB, broadly grouped into two categories, semi-random category where the initial grids for either of S or L are non-random, and second a purely random category where the initial conditions for both S and L are purely random. Timesteps range from 1 to 50 and snapshots of the L and S grids during every ninth interval are shown. Black corresponds to 0, Gray to 0.5 and White to 1. “Survival Index” of L or S is defined as the Average value of all the cells in the grid taken during the final timestep.

A. Semi-Random Initiation

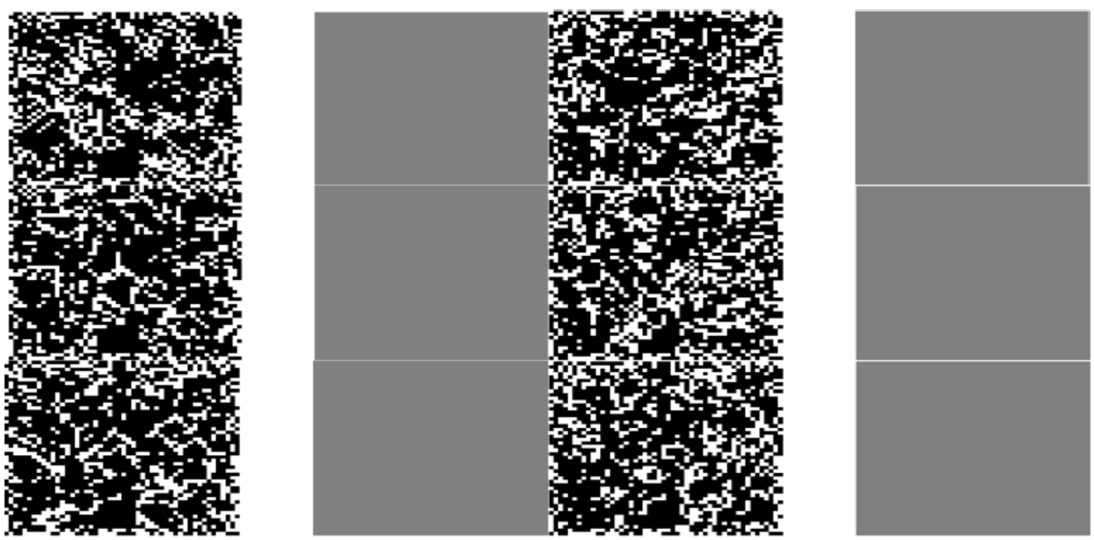
In the first case corresponding to “Pure Touch”, the default rule set R0 is used, with all initial values in the S grid initially set to 0 and L grid randomly set. The evolution and entropy plots are plotted.

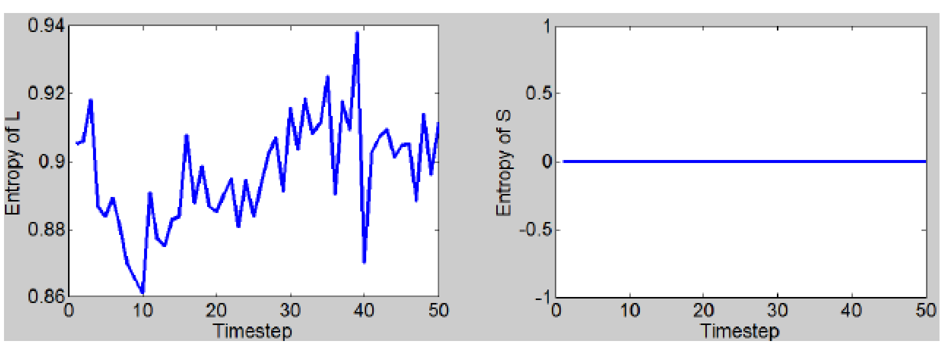




This case corresponds to Conway's Original Game of Life design. Consequently, still-life and oscillating patterns seen in Conway's GoL are also observed here. In general, the population decreases to a less than average concentration of Live cells. The entropy curve shows slightly decreasing entropy with progress of time. The L-Survival Index is low at 0.2192.

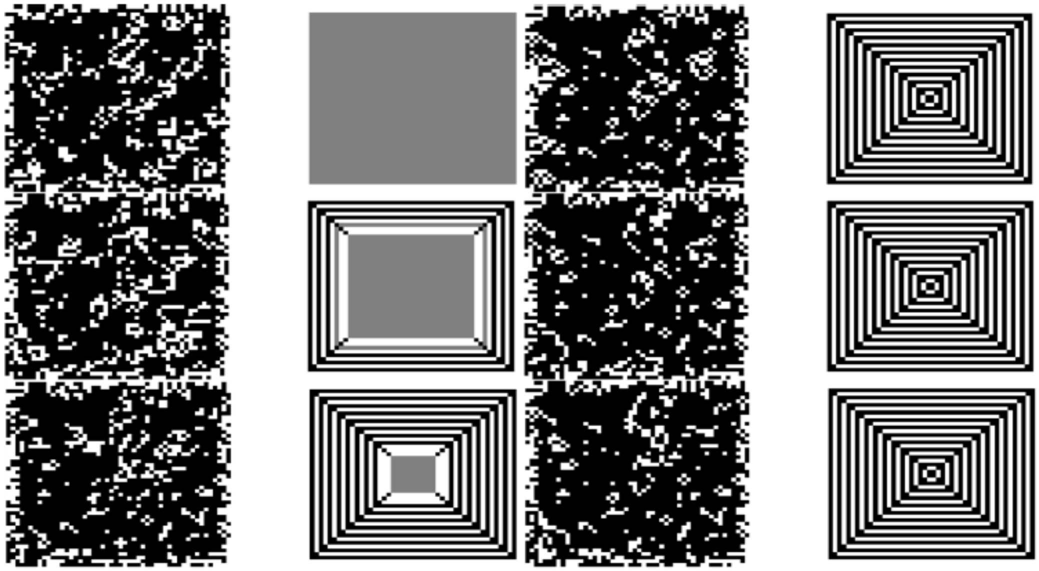
Next, the evolution with default rule set R0 but initially gray S grid, corresponding to "Pure Sight" case is studied.

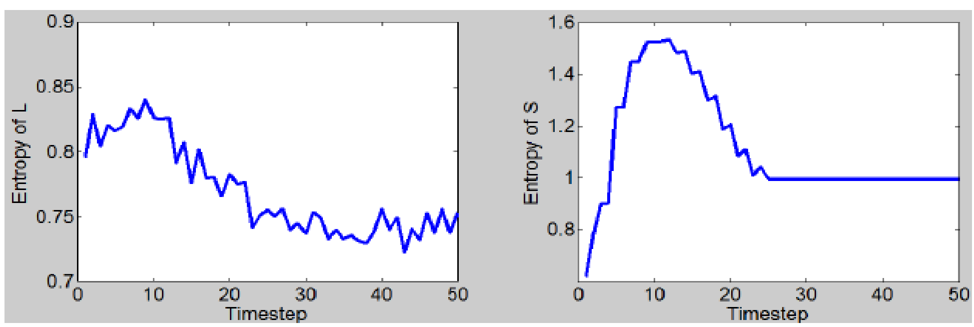




Entropy is more or less maintained around 0.9, and the L-Survival Index is much higher at 0.3268. In this case and the previous case, the S Survival Index is maintained at 0.5 and 0 respectively.

Next, the default rule set R0 is applied to a random initial L grid and an S initial grid defined purely by 1, a “Pure Sound” case. The results are as shown.



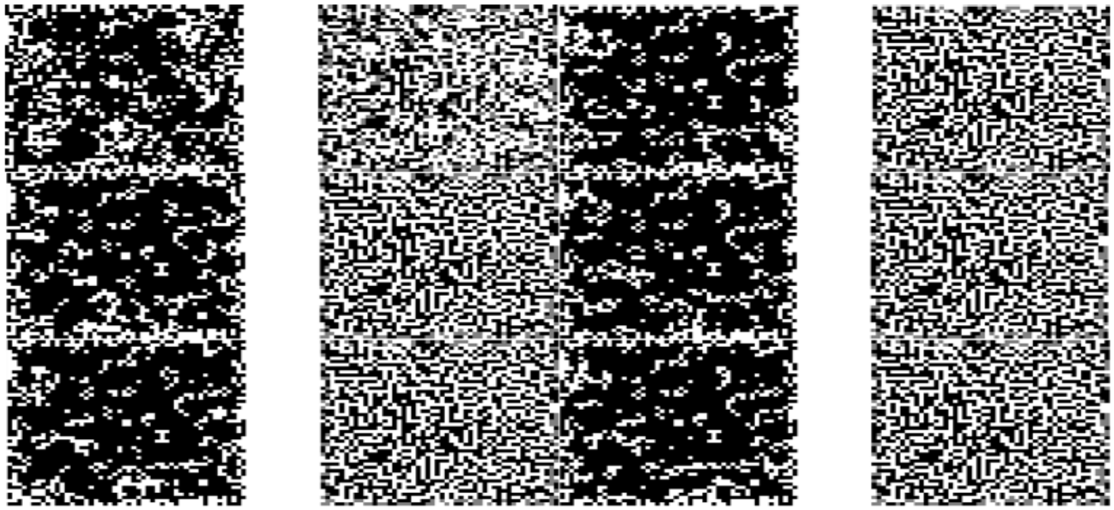


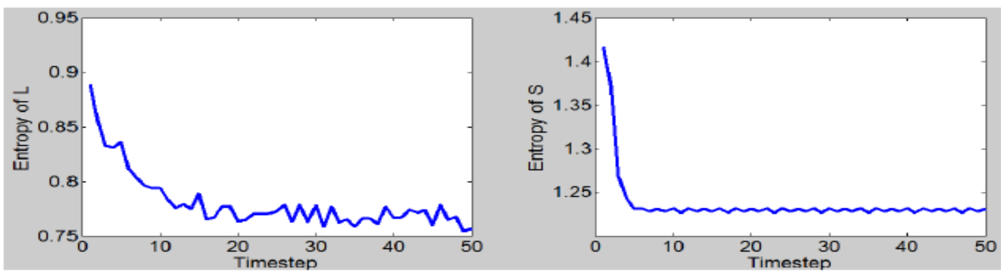
The Pure Sound case shows a very interesting self-organization phenomenon of the S matrix. Subsequently, the S entropy increases to an enormous 1.5 before falling and settling down to a value of 1. However, the L entropy shows a general decrease over time. The L Survival Index has decreased to 0.2164, while the S Survival Index marginally increases to 0.5408.

Thus, from the above results, while an increase in sensory capabilities correspond initially to an increase in survival rates, a full-fledged development in sensory capabilities quickly gives rise to social organization, with survival rates and entropies decreasing to stable values.

B. Fully Random Initiation

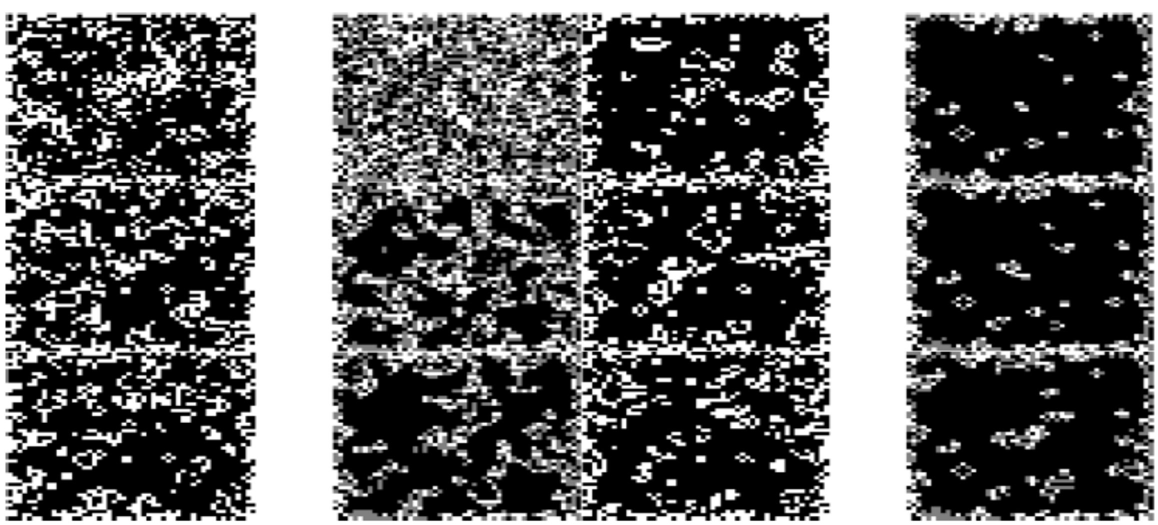
The default rule set R0 is applied with randomly initiated L and S grids. The results are shown.

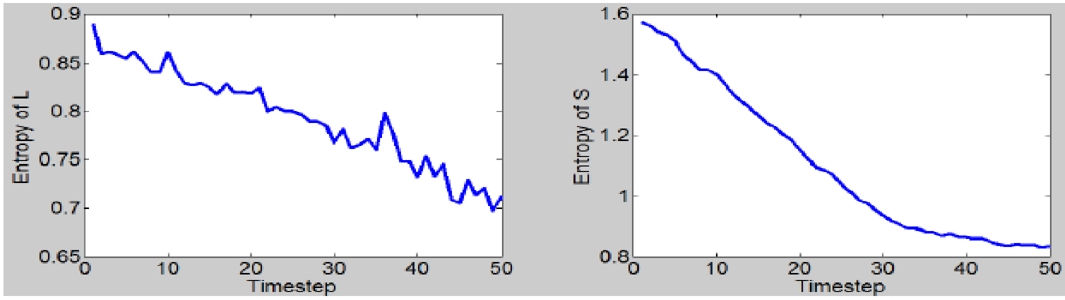




After an initial decrease, the entropy of L maintains almost constant, ending with a L Survival Index of 0.2184. S however, organizes the initial randomness into some sort of complex intricate pattern, with the final survival index of 0.5038. The entropies of both L and S show an initial steep decrease followed by stability.

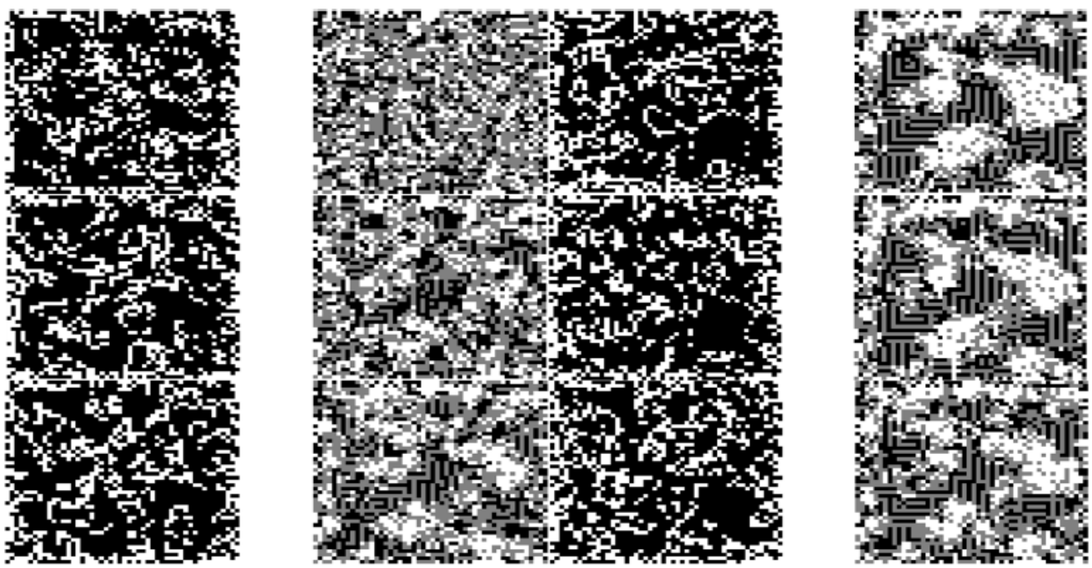
Next, a rule set R1 is defined as R1 = {[3],[2,3],[5,8],[4,8],[2,3],[0,5],[5,8]}, differing from by R0 that it does not declare sound retention d as a low-ended [0,5], but rather as a high-ended range [4,8].

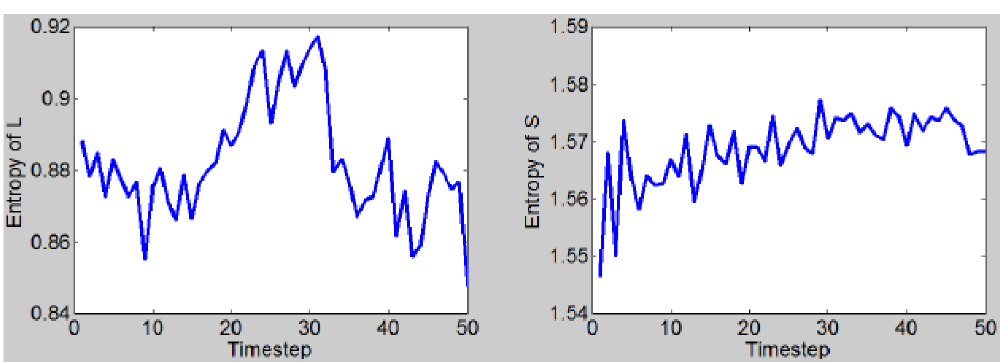




This case shows a gradual decrease in survival of both L and S, with the Final Survival Indexes obtained as 0.1956 and 0.1270 respectively. The entropies of both grids show an almost monotonous decrease.

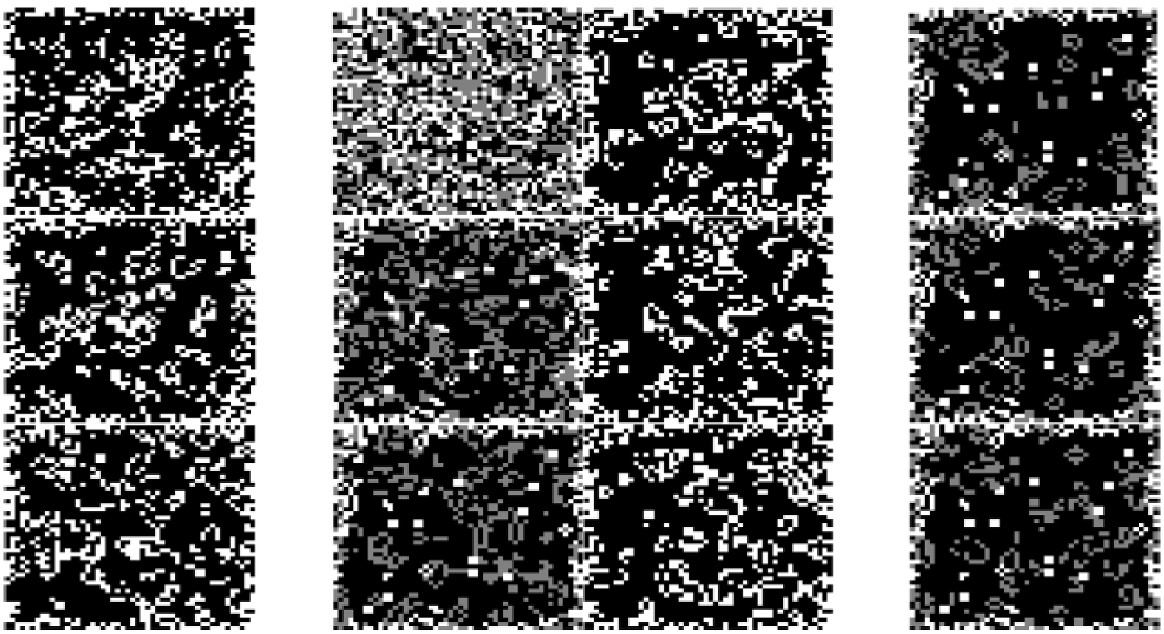
The next case is defined by R2 = {[3],[2,3],[0,4],[4,8],[2,3],[0,5],[5,8]} for purely random initiation, with R2 differing from R1 in the range of c. The results are plotted.

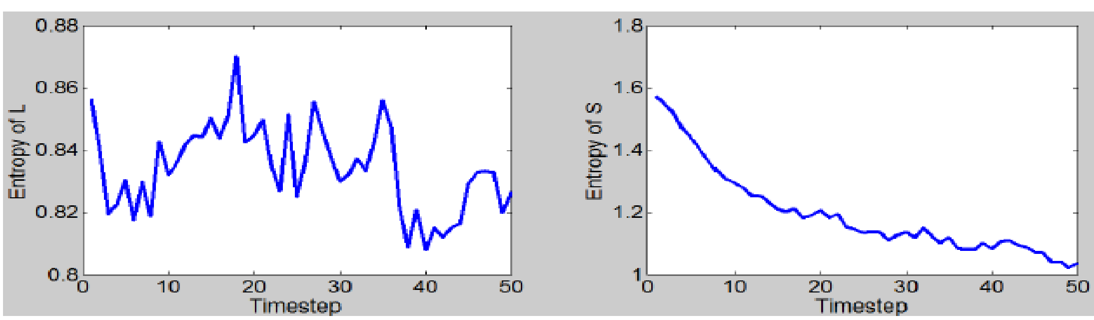




While the L grid shows a constancy of survival, the Sense grid shows a remarkable self-organizing accompanied by clustering of the most evolved sense (sound). This phenomenon can be attributed to the reduction of c from [5,8] to [0,4], which implies an adverse sensitivity to the sense of sight to overcrowding causing the gray cells of S to organize into a pattern of maximum entropy, followed by a clustering of sound sense due to long range similarity in the pattern formation. The L and S Survival rates are given by reasonably high 0.2744 and 0.5424 respectively.

Finally, the last case is given by R3 = {[3],[3],[2,3],[2,3],[2,3],[0,5],[0,8]}, differing from the earlier cases by having limited ranges for a, b, c and d, all four sense determining variables. The results are shown.





The L and S Survival Indices obtained as 0.26 and 0.1712 indicate that restrictions in the values of a, b, c and d considering both overcrowding and undercrowding results in a reasonable increase in Survival with fluctuating L Entropy, while causing a gradual degradation in the sense grid, accompanied by monotonously decreasing entropy.

4. Discussion: A new perspective on life, evolution and human species

We start with the premise that a life, or a living organism, is essentially a setup of multiple organs and systems working in an interconnected fashion, with life consisting of a local region of higher organization among lower organization in the surroundings.

However, in accordance with the second law of thermodynamics, one understands that it is easier for nature to be incoherent and random, than coherent and organized. For instance, how many times do 4 dice thrown together form a well-organized rhombus shape with a sequential pattern of numbers such as 1,2,3,4?

However, from a different perspective, rather than saying that nature lacks organization, one might say it is all part of a more complex pattern, and thus will not fit into the limited basic shapes of man's understanding.

Thus, nature's preferences of highly intricate patterns speak a higher geometrical language, characterized by more chaos corresponding to a less organized state with more entropy obeying the 2nd law. However, to have life, for organs to work together, atleast locally this has to be reversed.

In the pure touch case, sense grid is always set to 0 and thus has no involvement in evolution, whereas the life grid is exactly same as Conway's original GoL. Here, rather than having equal amount of life (white) and death (black), evolution favors lesser white – an example of the **"survival of the fittest"**. Correspondingly, entropy decreases from equally likely black-white maximum (bipartite) to a lower unipartite-like value. In this context, certain patterns identified in Conway's GoL such as oscillations and still-life have an optimal life-death mix and structure conducive to sustaining life for long periods of time – a very primitive example of self-sustaining societies.

However, with non-zero values of S, corresponding to R0 case, each sense upgrades, retains or downgrades if certain number of neighbors possess higher, same or lower sense respectively. However, here again, it favors downgrading to touch more - probably a concept of **"survival of the smartest"**, with 'smartest' referring to the few cells that were able to acquire/retain the senses of sight and sound. Here, the R0 Life entropy decreases, similar to pure touch case, except that the decrease is much steeper and faster. Thus, addition of sense enhances capability to organize and thus evolve, though this includes killing unwanted elements faster.

However, on changing the rules such that it gets tougher to retain the highest sense, sound, as in R1, sense entropy starts with a tripartite 1.5, quickly dwindles down to bipartite.

With further change to the Sense rules favoring sight retention as in R2 ({[3],[2,3],[0,4],[4,8],[2,3],[0,5],[5,8]}), one sees entropy hovering around tripartite values full time indicating more amount of information (due to the extra information available from the sight sense enhancement) as well as a good distribution of senses at the end of the simulation.

In essence, **the system has found a new way to sustain itself with maximum possible entropy** – a higher state of evolution seen in a higher survival rate. How is this possible? This is entirely because of several factors, highlighted in the following points:

1. The enhanced perception of not just immediate neighbors, but farther cells, which is possible with advanced senses of sight and sound.
2. Conditions conducive to retention of sight, even though sound retention, made tougher in R1 remains tough in R2 as well.
3. Given that an optimal distribution of senses needs to be maintained, so as to avoid becoming vestigial or losing competitive advantage, the system in R2 has learnt to coordinate its sense distributions, clustering the highest sense in selected regions. This is why the sense entropy always remains tripartite.
4. As a result of enhanced perception and better handling of information, the system is able to improve its survival rate to 0.27, the highest seen in all the four random cases. This is an example of how social organization and mutually beneficial living increases both sustainability and the quality of life, and becomes a characteristic trait of higher evolved organisms.
5. Why do human beings rely most on their sense of sight (nearly 80%), even though sound helps them perceive even things that cannot be seen? The answer lies in the difference between R1 and R2 where it is seen that it is ease of sight retention, and not ease of sound retention that helps increase of survival rate.

Thus, though in R2, the L entropy increases initially, the system has organized itself to a lower entropy state, possible only because of the extra neighborhood information available with all the senses.

As a final exercise, let us assume that humans are not in one of the more organized evolved states of the planet, similar to R2. In this case, the human entropy ought to be much lower than lesser evolved beings, which also means that human survival is lower than such beings. However, domination of humans across the entire planet proves this is not the case, implying that the original assumption is wrong.

5. Conclusion

Based on the concept of senses, and the ability to perceive both immediate and non-immediate neighbors using advanced senses such as touch, sight and sound, a Sense Enhanced Game of Life (SEGoL) is proposed and designed using two grids, a Life Grid and a Sense Grid. With the Life Grid taking one of two possible values (dead or alive), the sense grid takes one of three values corresponding to touch, sight and sound. Based on the values of the Sense Grid cells, the perceptibility and hence the values of Life Grid Cells are determined, with the Sense Grid values themselves determined by proximity, utilization and competitive advantage. Based on these rules, various evolution patterns, both involving semi-random initialization and purely random initializations are explored. Among the results, three interesting facts stand out. Firstly, the semi-random initialization with a Pure Sound based Sense Grid results in a remarkable self-organization of the sense grid, albeit with decreased survival in the life grid. Secondly, altering sensitivity of light from overcrowded to undercrowded configuration results in self-organization of sense grid into interesting patterns accompanied with clustering of the sound sense. Thirdly, it is seen in general that survival rates, both in life and sense, are largely mirrored by corresponding changes in entropy values.

In conclusion, it is seen that the proposed Sense Enhanced Game of Life (SEGoL), essentially adapting Conway‟s original Game of Life Rules, scaled for larger neighborhoods, and for enhanced perceptibility, displays a diverse range of interesting evolutionary dynamics, while also retaining the original features of the original Game of Life including the still-life and oscillating elements for the pure touch case. It is seen that if the conditions and neighborhood rules are conducive to retention of certain senses, the system is capable of effectively organizing its sense distributions and enhancing its perception, resulting in higher survival rates and sustaining life, and this gives an insight into higher evolved organisms of the planet, such as human beings.

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