1 Abstract

This paper makes three main contributions: first, it presents a conceptual model to guide thinking about the structure of society using as a base, contemporary viewpoints about emergent, self-organisation and complex systems. Second, social action and its content value is modelled as a feedback loop between a group via stratified differentiation. Thirdly, quantification occurs by modelling social actors, data types, and operators as state variables that define the value-content of social interaction. We examine how the fractal dimensions used to index value accumulation between 500-1000ppm is also captured by the sum of terms. A forthcoming publication will extend these results using the AGIL which Parson’s outlined as follows: (a) Adaptability: The capacity of a society to form contingency plans; (b) Goal-Attainment: The capacity of a society to design and meet goals; (c) Integration: The generation of movement through inclusiveness and incorporation (d) Latency: Or pattern-maintenance, that is, the generation of loyalty through consistency. Further work by Alexander [3] and Habermas [4] developed into neofunctionalism where systems of social action also tend towards equilibrium, and social change is the movement from one state of equilibrium to another, achieved through differentiation. Hence, social actors both individuals and institutions, while data types are communicative or instrumental because actions surrounding money, power, influence and respect can be quantified. This extends the physical, social and personal lifeworld analogy of Habermas [4].

2 Introduction - Sociology

The theoretical social method known as functionalism has dominated American sociology from the 1940s until the early 1960s. We shall premise our experiments on Parson’s Theory of Action [1-2], which is a general system for analysing society, and has been actively developed to explain how people interact with each other, as individuals, and as parts of multiple, collective modes of social interaction to structure society by combining analysis of individual action and also of large scale social order. The key feature is the relationship between actors and their environment (social or natural), with the most important factor being the role of other people. Social action and social systems are bridged by pattern variables, defined as the fundamental dilemmas that face actors. Social systems are then characterised by those combinations of solutions necessary to solve dilemmas (i.e. particularism versus universalism; performance vs quality; affective vs neutral; specificity vs diffuseness). Such pattern variables aren’t particularly useful in forming a sociological typology since they are highly subjective and not particularly prone to empirical studies. According to Parsons, these pattern variables structure any system of interaction. However, social systems also have their own functional requirements (AGIL) which Parson’s outlined as follows: (a) Adaptability: The capacity of a society to form contingency plans; (b) Goal-Attainment: The capacity of a society to design and meet goals; (c) Integration: The generation of movement through inclusiveness and incorporation (d) Latency: Or pattern-maintenance, that is, the generation of loyalty through consistency. Further work by Alexander [3] and Habermas [4] developed into neofunctionalism where systems of social action also tend towards equilibrium, and social change is the movement from one state of equilibrium to another, achieved through differentiation. Hence, social actors both individuals and institutions, while data types are communicative or instrumental because actions surrounding money, power, influence and respect can be quantified. This extends the physical, social and personal lifeworld analogy of Habermas [4].

3 Introduction - Mathematics

The aim of this work is to provide a methodology for making distinctions. Firstly, can a particular way of making quantitative observations allow us to infer properties about their behaviour? Second, is choice predictable - especially when it is viewed as part of an adaptive response based on neighbour interactions? Experimentally, we have approached this study of social interaction by looking at how a biological system responds to stress, and how the positive accumulation of useful products can be indexed by measuring the fractal dimension, as one measure of complexity to assess integration and anticipation in social systems using concepts of self-organization [5-6].

4 Cell Biology & Social Typology

This approach is analogous to an intelligent agent simulation [7], but uses live cells in a closed, controlled environment to test two hypotheses. Full details about the microbiology, biochemistry and mathematical analysis used in the original experiment with the filamentous fungus Pycomyces cinnabarinus is available [8]. Experimental variables for this experiment are then compared against the set properties of their continued fraction representations, calculated using Mathematica. The key features of this experiment are summarised: (i) This social system is composed of growing fungal cells in an increasingly hostile nutrient environment. (ii) Each cell is a discrete unit that grows by division to form an interconnected branching cell mass called the mycelium that is made up of millions or one this system. (iii) The shape of the mycelium can be evaluated by measuring the mass fractal dimension, Df, where 1<Df<2 for two dimensional projections. (iv) The fungus is forced to adapt to a concentration gradient of an organic dye which can be used as a food source. Value accumulation is monitored over 6 days. (v) The amount of oxygen consumed and biomass increase during adaptation in different environments was also measured. Table 1 shows how branch complexity changes in different hostile environments.

Table 1. Each of the different environments consists of a background nutrient level supplemented with a concentration gradient of a coloured organic dye (remazol brilliant blue). This represents the environment stress level. The mass fractal dimension Df measured the branching complexity of the mycelium in each different environment. The linear branching resistance is shown to the right.

<table>
<thead>
<tr>
<th>Environment Fractal Dimension, Df</th>
<th>Stress Level</th>
<th>Continued Fraction</th>
<th>Sum of Terms</th>
<th>Decimal Equivalent of the Given Df Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (0 ppm)</td>
<td>1.5 +/- 0.15</td>
<td>1.50</td>
<td>1.50</td>
<td>1.5</td>
</tr>
<tr>
<td>100 ppm</td>
<td>1.63 +/- 0.05</td>
<td>1.63</td>
<td>1.63</td>
<td>1.63</td>
</tr>
<tr>
<td>200 ppm</td>
<td>1.72 +/- 0.05</td>
<td>1.72</td>
<td>1.72</td>
<td>1.72</td>
</tr>
<tr>
<td>300 ppm</td>
<td>1.82 +/- 0.04</td>
<td>1.82</td>
<td>1.82</td>
<td>1.82</td>
</tr>
<tr>
<td>400 ppm</td>
<td>1.78 +/- 0.06</td>
<td>1.78</td>
<td>1.78</td>
<td>1.78</td>
</tr>
<tr>
<td>500ppm</td>
<td>1.71 +/- 0.03</td>
<td>1.71</td>
<td>1.71</td>
<td>1.71</td>
</tr>
<tr>
<td>1000 ppm</td>
<td>1.63 +/- 0.05</td>
<td>1.63</td>
<td>1.63</td>
<td>1.63</td>
</tr>
</tbody>
</table>

5 Results and Discussion

From Mandelbrot [10]: for a given set S, there exists an indicator function J(x) for some observable, where J(x)=1 if x ∈ S and J(x)=0 when x ∉ S. For many populations some other function such as the conical function C(x) is a better estimate, since C(x) is the randomly weighted average of the indicator function of the gaps of S. This may be thought of as the duality between an actor’s or object’s behaviour and of the gap of the environment x is in. As such, collecting data about a society of cells (or people) amounts to counting set membership of J(x) or C(x). We want to see how fractal dimensions relating to social variables might be connected with their continued fraction expansions, and how this in turn can be used to infer from the initial conditions how organisation might change over time in specific environments.

The continued fraction expansions for the main Df values were calculated, and the sum terms used as a descriptive index. A striking correlation is evident in the trend of the Df values for branching in Table 1 and Sum of Terms in Table 2. See how the control environment has a Df halfway between a line and a plane (=1.5) and the sum of terms at 1/5 starts the series at 1/5 on the inset graph from Table 2). The whole Df sequence (0-400ppm) is an easy match against terms progression. The trend for enzyme accumulation between 500-1000ppm is also captured by the sum of terms.

This suggests there is a strong correlation between the complexity of the continued fraction partial quotients and fractal dimension actually measures, in environments that select for an adaptive response. Therefore we conclude that the continued fraction for Df values from 1.5 onwards through 1.8 mimics the trend for the enzyme response and inversely the oxygen usage curves, measured in the different cell populations. In summary, the initial conditions of the systems available for a social group to adapt within. If fractal values can be assigned to other variables of social worth, then predictions about future performance might be usefully informed based on their continued fraction expansions. A forthcoming publication will extend these results using other examples to model social action issues like: multilevel interdependence, state political demand, consensus formation and regional cooperation.

8. SAGE Publications, USA.

Figure 1. Plots of enzyme yield, oxygen use, and biomass gain for the first 6 days of the experiment. Day 5-6 are not shown but displayed the same trends. The mass fractal dimension, Df, grows by division to form an interconnected branching cell mass called the mycelium that is made up of millions or one this system. The shape of the mycelium can be evaluated by measuring the mass fractal dimension, Df, where 1<Df<2 for two dimensional projections. The fungus is forced to adapt to a concentration gradient of an organic dye which can be used as a food source. Value accumulation is monitored over 6 days. The amount of oxygen consumed and biomass increase during adaptation in different environments was also measured. Table 1 shows how branch complexity changes in different hostile environments. This model social action issues like: multilevel interdependence, state political demand, consensus formation and regional cooperation.