SYSTEM DUALITY: BIRATIONAL HIERARCHY

Ron Cottam, Willy Ranson* and Roger Vounckx
The Living Systems Project, Department of Electronics and Informatics,
Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium
* IMEC vzw, Kapeldreef 75, 8001 Heverlee, Belgium

ABSTRACT

System theory, and most particularly hierarchy theory, must be consistent with philosophy. In his book "Logic in Reality", Brenner reinforces the traditional philosophic position that an entity can only exist in relation to its non-existence. This leads to a duality in system theory which is consistent with the selective division of Nature into entity and ecosystem, where the two depend on different criteria and even different logics. A fascinating aspect of such a birational approach is that representations and properties only exist as intermediates between pairs of ideal extremes. Quantum logic, for example, no longer replaces post-Newtonian classical logic; it complements it, identifying all real entities as compromises between the two. This albeit philosophically non-traditional included middle is identical to that of the philosophical logic of Stéphane Lupasco, and to the implications of Brenner's "Logic in Reality". This presages a major philosophical change in the way Science can be carried out. What we wish to do is to bring all of Science under a generalized umbrella of entity and ecosystem, and then characterize different types of entity by their more or less important relationships with their relevant ecosystems. The most general way to do this is to move the ecosystemic paradigm up to the level of its encompassing logic, creating a complementary pair of conceivably different logics – one for the entity we are focusing on; one for the ecosystem within which it exists – and providing for their quasi-autonomous birational interaction. We present a representation of natural hierarchy which is itself dual in character, and counsel that monorational constructions are ineffective. As an example, we present a dual formulation of entropy. We conclude with an application of the model to large Organizations.

Keywords: scale, hierarchy, included middle, entropy, life.

LOGIC IN REALITY

Stephane Lupasco's (1900-1988) work on logical structures has only recently been widely acknowledged. An overview of his philosophical logic has been published by Brenner (2010), who has expanded Lupasco's work into a complete philosophical position in "Logic in Reality" (Brenner 2008). The fundamental postulate of Logic in Reality is that

> "*every real complex process is accompanied, logically and functionally, by its opposite or contradiction (Principle of Opposition), but only in the sense that when one element is (predominantly) present or actualized, the other is (predominantly) absent or potentialized, alternately and reciprocally, without either ever going to zero*" (Brenner 2008)

and

> "*the emergence of a new entity at a higher level of reality or complexity can take place at the point of equilibrium or maximum interaction between the two*" (Brenner 2008).

> "*A necessary concept is the categorical non-separability of, for example, individuality and non-individuality, part and whole, subjectivity and objectivity in relation to the experiment-experimenter pair*" (Brenner 2008).

The result is a complementarity between Brenner's 'A' and 'non-A'.

We begin from Brenner's (2008) position, but move to a related interpretation based on our own experience and investigations: namely that this also corresponds to a complementarity between entity and ecosystem, where neither of the two can be accessed independently, and where 'reality' is an intermediate emergence. By entity here we not only refer to organisms, but to *all* differentiated entities, both living and not living. We note a difference in methodology between the contemporary ecosystemic approach to living aspects of the natural world and the traditional reductive approach of the hard sciences. Our target here is to adopt the ecosystemic approach to *all* of science: first by organizing general ecosystemic relationships between differentiated entities and their relevant surroundings or precursors; second by recognizing where these 'ecosystems' can be simplified towards a classically scientific reductive approach where relevant, and where not. The natural result is a duality of system definition in its widest context.

SCALE

Brenner's (2008) proposition of "*the emergence of a new entity at a higher level of reality or complexity*" postulates *scale*. This is a dynamic reading of scale which addresses how different system scales come into being in reaction to prior contradictory states of a system. In this paper we will mainly refer to scaled systems which already exist, and not particularly to the dynamics of scale generation.

Different systems have different perceptual *bandwidths* through which they relate to their environments. Similarly, different parts of a system will relate to other parts of the same system through their individual perceptual bandwidths. We will presume for our argument's sake that these bandwidths are in terms of spatial *size*, although a similar situation will obtain for any measurable extensive parameter or property.

If a system's sub-element (for example a biological cell) can only directly relate to other entities of comparable size, we can say that its perceptual bandwidth is small. If, however, a sub-element (for example a biological cell) can also directly relate to other sizes of sub-elements (for example to a complete organ), we can say that its perceptual bandwidth is large. The overall character of a system is determined by its complete assembly of perceptual bandwidths, and to what extent they overlap[1]. A crystal, for example, is characterized by a small set of widely overlapping scales, indicating that the informational difference between its micro scale and its macro scale is small. An organism, on the other hand, is constituted by a larger set of narrow

[1] It is worth noting that if there is no overlap at all of individual sub-element bandwidths, then the system does not even exist!

scales which overlap minimally. This attributes a degree of autonomy to the individual scales – possibly the most important aspect of an organism.

HIERARCHY

In our context, a hierarchy is "*a system in which people or things are placed in a series of levels with different importance or status*" (Merriam-Webster). Its characteristic form is that of a pyramid, with a large base and narrow apex, and exhibiting a number of intermediate levels. Conventionally this would be represented with the apex 'at the top': for reasons which will become clear we prefer to represent a hierarchy by lying it down – arbitrarily so that the apex is on the right hand side (see Figure 1).

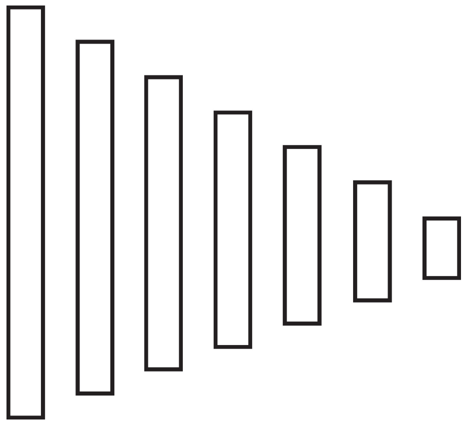

Figure 1. The modified orientation of a hierarchical representation. The apex of the structure is here presented on the right hand side and not on top.

Traditionally, it would be assumed that control in a hierarchy is exercised from the apex, trickling down finally to the base. More recently, in human Organizations[2], this has become progressively modified, with the flattening of Organizational structures, but to a large extent control is still exercised in a top-down manner. The classical example of a hierarchy in Nature is that of a *compositional hierarchy* (Salthe 1985), where different levels are related to different physical sizes, and levels are nested within each other – for example in the sequence 'atoms, molecules, biomolecules, cells, organisms'. We believe that a much better representamen for natural systems is that of a *model hierarchy*, and we will maintain that this is also a good representamen for human Organizations.

MODEL HIERARCHY

We can construct a system hierarchy by setting each level as a different *model* or description of *the entire system*. For example, we could describe a tree by the set of descriptions [a tree as atoms], [a tree as molecules], [a tree as cells], … [a tree as branches], [a tree as itself]. This also illustrates a common characteristic of a model hierarchy: different levels of description are often related to different elemental sizes, but the different levels are *not nested into each other*. Figure 2 illustrates this particular hierarchy of a tree. The apex (on the right) constitutes the tree as an *identity*.

[2] We will capitalize the word Organization when it refers to businesses, industries…

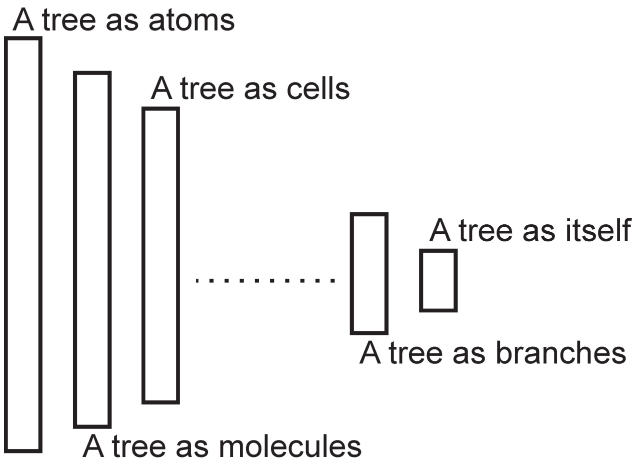

Figure 2. Model-hierarchical representation of our example of a tree. Each level corresponds to a scaled model of the entire tree. This, unsurprisingly, makes the most complicated models on the left un-computable within short timescales.

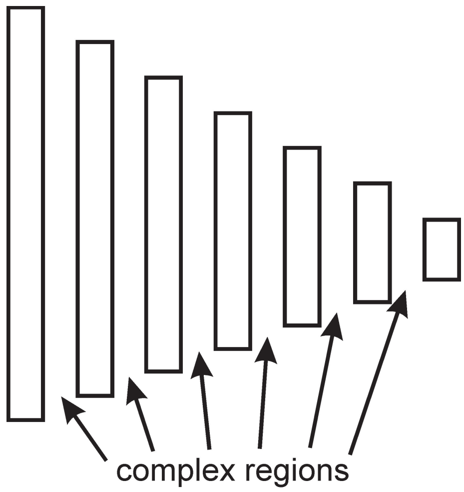

Figure 3. The appearance of complex regions between the levels of a hierarchy. These regions correspond to the un-characterizable character of Rosennean complexity.

The most important facet of such a hierarchy is that it is difficult to 'transit' between adjacent levels of description. This is in common with the hierarchical nature (!) of an arithmetic equation, such as 1+1=2. Having transited from left (1+1) to right (2) we have lost information about the exact content of the left hand side (it could have been 1+1, 2, 0.9+1.1, 8/2, …). Similarly, transit upwards in level in our hierarchy (i.e. from left to right) we lose information. In fact, the situation is even worse than that, because we have no way of deriving one model level (e.g. the tree as cells) from its precursor (e.g. the tree as biomolecules). This difficulty has the same impossible character as that of trying to derive the properties of water (i.e. H_2O) from the properties of the individual atoms (i.e. hydrogen H and oxygen O). Consequently, the inter-level regions (indicated in Figure 3) are un-characterizable. We believe that these inter-level regions are complex in the sense indicated by Rosen (1991):

> "*A system is simple if all its models are simulable. A system that is not simple, and that accordingly must have a non-simulable model, is complex.*"

In a natural context, we believe that individual model-levels evolve towards simplification, as a way of promoting computation-like processes, and that the net result will be the ejection of complexity from the model-levels into these inter-level regions. Not only will the individual model-levels evolve towards simplification, but the entire system of representations will do so by inter-level communication and correlation, producing a unified systemic character.

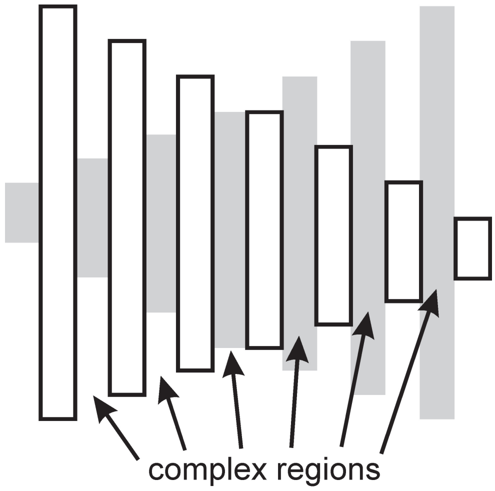

Figure 4. The dissociation of a natural hierarchy into two sub-hierarchies. Note that the model-level hierarchy is reductive towards the right hand side, while that of the complex regions is reductive towards the left.

BIRATIONAL HIERARCHY

Logically, if all the individual levels of a model hierarchy correlate to correspond to the most 'computable' form, the inter-level regions will also themselves become correlated into a second hierarchical structure. More concretely, the entire natural model hierarchy we have described dissociates into two distinct and complementary partially independent systems of rationality. One is associated with the Newtonian-potential-wells of the model levels, and is (conventionally) reductive towards perfect localization (i.e. towards the right hand side of the assembly: see Figure 4). The other is associated with the inter-level complex regions, and is reductive towards nonlocality (i.e. towards the left hand side of the assembly).

It is vital to note that this applies to a natural model hierarchy (for example, that describing an evolved living organism), where the model-levels have evolved to their most parsimonious form. In a human Organization, the individual scales of the hierarchy are externally imposed with little opportunity for common evolution across the complete assembly. A valid question would be whether some kind of 'artificial evolution' could be applied to human Organizations to simulate the inter-level evolution experienced by a natural assembly of levels.

System duality: Birational Hierarchy

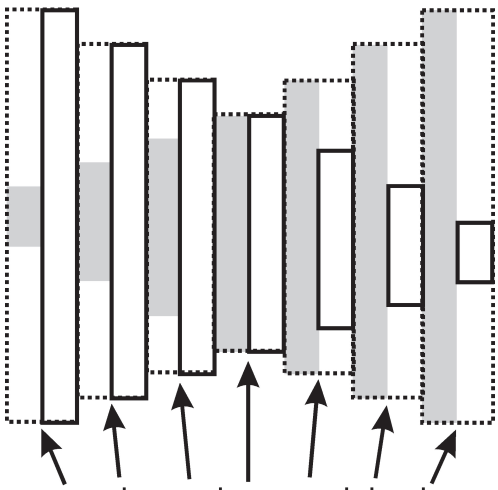

Figure 5. The scaled pairings of complex ecosystemic regions and models. Each pair describes the entire system at its particular scale.

At each model-level there is an associated precursor ‘ecosystem’ which is established according to the model scale itself. In our example of a tree, the level [a tree as cells] is associated with a scaled [cellular ecosystem] which takes into account the perceptual bandwidth of cells. Although the locally-scaled model will be a representation of the entire system at that scale, it is the combination of model and ecosystem which completely defines the system. Consequently, the simplest model will be associated with the most complex, largest ecosystem, and the most complex model will be associated with a very simple ecosystemic representation. The net result is indicated in Figure 5, where at each scale there is a pairing of locally-scaled model and locally-scaled complex ecosystem. We can now see that the two different hierarchies we have described point in opposite directions, coincidentally with their directions of reduction we indicated earlier.

Each of the two hierarchies we have described will be associated with its own characteristic logic. The model-levels operate within the logic structure we have used to describe them – that is, according to ‘normal’ classical (post-Newtonian) logic. On the other hand, the second complex hierarchy’s strange nature of ‘reduction towards nonlocality’ begs the question as to what logic is involved in its operation. The characteristic underlying logic here is that of quantum mechanics – which is fundamentally nonlocal in derivation. Fascinatingly, we discover that the logic of classical physics is in no way *supplanted* by that of quantum mechanics: the two form a *complementary pair*.

SYSTEM DUALITY

Our derivation started with a single hierarchy, which on careful consideration turned out to be binary in character. This is then the automatic nature of hierarchy: monorational hierarchy is incomplete as a description of natural processes and entities, and the birational hierarchy we have derived is always the more complete formulation.

A hierarchical system is always dual in two distinct ways:

System duality: Birational Hierarchy

- It is established through emergence between dual extremes

  (note that this corresponds also to Brenner's derivation of an emergent state)
  e.g. between localization and nonlocality
  e.g. between part and whole.

- At every scale there is a duality of representation

  e.g. between local entity and its local ecosystem
  e.g. between structural and communicative domains (model and complexity) .

This dual-duality of character is ubiquitous in Nature. We question in what ways this binary derivation should be applied to human Organizations.

Figure 6. The two extremes of order in a two-ball system. (a) corresponds to the traditional definition of high order; (b) corresponds to the alternate definition.

DUAL ENTROPY AND LIFE

Conventional physics identifies entropy as the major driver of evolutionary development in its most general guise. However, recognition of the ubiquitous dual nature of systems raises questions as to the correctness of its usual singular portrayal.

A major formulation of entropy is as the inverse of system order, and this itself is also assumed to be singular. We can visualise this in a context consisting of two kinds of ball – black and white (see Figure 6). The arrangement illustrated in Figure 6(a) is that which would normally be described as highly ordered, and therefore with the lowest entropy. This arrangement corresponds to the configuration of, for example, a single crystal of silicon, where all the atoms are the same. However, the arrangement illustrated in Figure 6(b) corresponds to the atomic alternation in, for example, a single crystal of gallium arsenide, which is certainly ordered – and therefore has a low entropy comparable to that of a silicon crystal. Consequently, we now have two extremes of order rather than just one, and both of these are associated with low entropy. So where is now the disordered state?

Figure 7 shows a hypothetical relationship between the two ordered states of a single system and their associated dual entropies, where disorder constitutes the region between the two. The total entropy will then be a summation of the two independent ones, and in the eventuality that the relationships between order and entropy follow the forms indicated we might expect the summation to exhibit a dip in the mid-region – as indicated by the dotted line. Does life colonise this mid-range dip, as the lowest overall entropy state? This would approximately correspond to the much referred to 'edge of chaos' location of living systems (e.g. Gutowitz and Langton 1995), but now this 'edge of chaos' has a dual formulation.

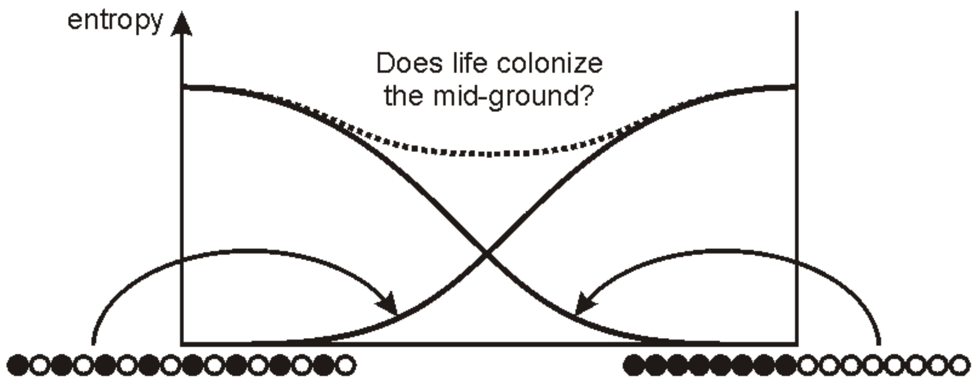

Figure 7. The hypothetical relationship between dual orders and entropies in a dual-ball system.

ORGANIZATIONAL HIERARCHY

Hierarchy appears in a number of forms, from the preferred configuration of most living systems to that of human Organizations. Is the birational natural hierarchy we have described appropriate as a model for the latter?

Figure 8 illustrates adaptation of the birational hierarchy to human Organizations – to business and industry. The 'top' of the hierarchy (as usual on the right hand side) corresponds to the representation of the Organization by its CEO. Mid regions of the structure correspond to the organizational levels of middle management, and the left hand side corresponds to operation on the shop floor. The most interesting aspect is the putative relationship between all the inter-level organizational regions. In this context these regions correspond to inter-level communication, much as they do in the natural hierarchical instantiation. But now we are referring to communication between externally imposed levels – those put in place by the system management in general. So can we again expect these inter-level regions to be in overall hierarchical correlation? It would be nice to be able to do so, but in a conventional situation this would be overly optimistic.

Clearly, if our model is to have any relevance to human Organizations the 'locations' of the different middle-management levels themselves would need to be correlated in the self-organising manner of the scales of a natural system. In the latter case, levels are developed over long periods of time by evolution to conform as closely as possible to this ideal, but such is not the case for human Organizations. Is it possible to formulate a kind of quasi-evolution for the middle-management levels? To some extent this corresponds to current good practice in business and industry, in that a progressive development of inter-level communications for efficiency will alter the apparent 'location' in the general management scheme of things. But it would be nice to explicitly formulate this process in evolutionary terms, thus tending towards implementation of the dual-duality of natural systems.

System duality: Birational Hierarchy

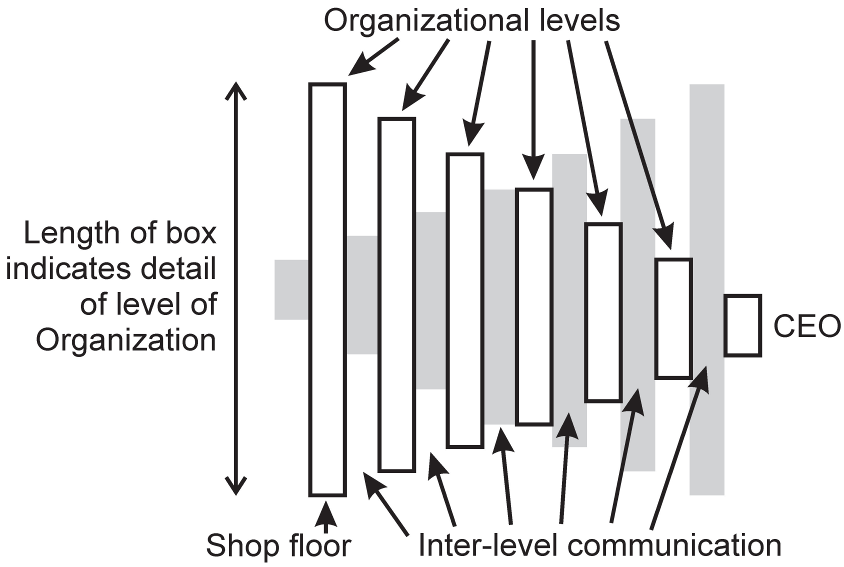

Figure 8. Application of the natural birational hierarchical model to business and industrial contexts.

REFERENCES

Brenner, J. E. (2008). *Logic in Reality*., Springer, Berlin.

Brenner, J. E. (2010). The Philosophical Logic of Stéphane Lupasco, *Logic and Logical Philosophy*., 19:243-284.

Salthe, S. (1985). Evolving Hierarchical Systems., Columbia University Press, New York.

Gutowitz, H. A., and Langton, C. G., (1995). Mean Field Theory of the Edge of Chaos. In: Proceedings of the Third European Conference on Artificial Life, Granada, Spain, June 4-6: *Lecture Notes in Computer Science*., 929:52-64.

Rosen, R. (1991). Life Itself., Columbia University Press, New York..