Reductionism, Holism and System Dynamics

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Abstract: The objective of this paper is to examine the concepts of holism and reductionism as they relate to System Dynamics (SD) and to a lesser extent Systems Thinking (ST) then to relate the findings of that examination to some of the disillusionment with SD and the resultant lack of commercial take up. This paper looks at the concepts of Reductionism and Holism as applied throughout the SD literature in a broad range of academic areas from medicine and philosophy to physics and looks at different definitions of holism, and reductionism. Practical applications of Reductionist and Holistic principles are examined. From this analysis the fundamental nature of SD as a Holistic/Reductionist methodology is deduced and differentiated from the more generally holistic nature of ST. From this basis the conclusion that SD is a reductionist methodology in practice, though not necessarily described as such by practitioners, is postulated. The paper recommends that there be further work carried out in the field of theoretical and practical holism and greater awareness of these issues within the practitioner community. Within the conclusions there is a pointer for some further fundamental areas of work.

Keywords: “System Dynamics”, “Systems Thinking”, Holism, Holistic, Reductionism, Reductionist, Methodology.

Research context

This paper examines the lack of debate around the concept that holistic thinking, as opposed to reductionist thinking, is inherent in System Dynamics (SD).

System Dynamics (SD) as its name suggests is a philosophy and practical methodology for modelling and simulating the dynamic behaviour of systems; social, financial, ecological and otherwise over time. It is closely related to Systems Thinking (ST) but is often seen either as a subset of that philosophy or as an overlapping complement to it. ST itself is a philosophy that has emerged from Feedback theory and General Systems theory.

It is widely noted that System Dynamics adopts the 'big picture' viewpoint; attempting to capture the essence of systemic behaviour rather than that of the individual parts of the system see Anon 2 (date unknown) where this is described as 10,000 meter thinking. This 'big picture' viewpoint is also often described as the holistic view. In practice this could mean for instance looking at the overall behaviour of a system such as a business rather than looking at individual facets of that business. The sometimes contrary and oft described opposite of the holistic approach is the reductionist approach where an attempt is made to understand a 'system' from an examination of its individual parts. This latter approach is closer to the norm for existing systems analysis methodologies such as Structured Systems Analysis and Design methodology (SSADM), and the Object Modelling Technique (OMT) and any number of others. There are also specific techniques which adopt a mixed holistic/reductionist stance that could be examined but that do not 'belong' to any particular methodology. One example being Agent Based Modelling, Cannessa & Riolo (2006) Kuo et. al. (2005), further investigation of these techniques and methodologies is beyond the scope of this paper.

In adopting the systems approach there is often an implicit if not explicit assumption that the system and its behaviour comprise more than the sum of the individual component parts. This idea is often expressed as synergy or the synergistic viewpoint. It can also be readily appreciated that the holistic viewpoint is looked on as a top down approach whereas the reductionist approach is looked on as a bottom up approach.

This paper sets out to examine the detail behind these assumptions and terms by an examination of the literature and a sample of case studies where one or other of the two approaches have been applied (allegedly).

Note that throughout the paper I am using the two terms 'problem' and 'understanding' in an almost interchangeable way. The reasoning for this is that an attempt to gain understanding can be seen as a problem however in many definitions understanding a system, concept or issue is not seen as a problem merely an attempt to understand. Thus the two terms are largely interchangeable.

Defining the Reductionist approach

Reductionism is seen as the traditional means of approaching problem solving, at least in the large scale, and is common across many disciplines. Jackson (2005) provides a

useful overview of some of the underpinnings of reductionism. Reductionism also goes under many names including 'stepwise refinement', 'disaggregation' and simply 'breaking the problem down'. It should be noted that reductionism tends to refer to understanding rather than problem-solving but the latter seems more apt in this case.

Reductionism as a principle has one major thing going for it – it works. How do we know it works? We know it works because it has been used in practice for many thousands of years. Problems are broken down into constituent parts and are, possibly, reconstituted into a single whole solution or provide a single systemic understanding. Alternatively the individual sub-problems can acquire relatively self contained solutions with no reference to other parts of the understanding of the problem. Reductionism is the paradigm of understanding that has been applied by the human race to many differing scenarios with great success.

This idea of breaking problems into their constituent parts comes naturally to people and goes some way towards relieving the burden of bounded rationality, Simon (1957). That is, there are some large/complex problems, issues or concepts than can only be properly understood by first subdividing them into their constituent parts.

With this approach there is the implicit assumption that there is little need or attempt to understand the context or 'whole' problem or system.

Defining the Holistic approach

As has been noted in the introduction above SD is often referred to as a holistic, or more closely aligned with a holistic, approach to understanding the dynamic behaviour of a system than existing methods of problem definition and solution. We find evidence, or support, for the holistic approach from a number of sources across many disciplines, some examples follow; from the cultural domain we have Hofstede et al (1993) and from the medical domain Roberts et al (2002). Hofstede describes the benefits of a holistic approach by using the metaphor of a number of blind men studying an elephant the resultant confusion about the overall structure being an illustration of "the need for pooling subjective patterns". That is if the blind men were to share their individual insights they may perhaps understand that it is an elephant that they are dealing with and not a "snake, a stick, a disk, a column, a wall or a rope" of course they may not arrive at this understanding. Roberts describes evidence from secondary statistical sources of the links between mind and body and a determination of medical success based on an appraisal of the patient's mental attitude to illness. From this viewpoint a method of treating physical illness by changing mental attitude is described. On a governmental scale there is evidence that the creation of the American Department of Homeland Security is an holistic attempt to address security issues, Baranoff (2004).

There are of course some challenges to the concept and definition of holism. Popper provides us with a view on holism in general when commenting on the behaviour of a swarm of gnats "this 'whole' can be used to dispel the widespread 'holistic' belief that a 'whole' is *always* more than the mere sum of its parts. I do not deny that it may sometimes be so" and in a somewhat challenging assertion "the cluster of gnats is an example of a whole that is indeed nothing more than the sum of its parts" Popper

(1979, p. 210). This is somewhat counterintuitive at first glance for the swarm can see in more directions, determine threats with greater sensitivity and generally behave in a fashion which suggests that the swarm is in some way acting with greater overall ability. Popper counters this idea with the argument that the movement of the swarm is simply the "sum of the movements of its constituent members, divided by the number of members". It is this author's contention that both views are correct, the swarm cannot be any more than the sum of its parts, in the way Popper describes, but it is also apparent that the swarm can sense more keenly and in a more comprehensive fashion than any individual member and in this fashion it has characteristics as a swarm that no individual member possesses; for example the swarm can see what is ahead and behind at the same time. In this latter example each member acts as a sensory organ for the whole.

In addition to general arguments about holism there are detailed arguments about the nature of holism in general and distinctions between different types of holistic relationship, Stanford Encyclopaedia of Philosophy (2006).

The major benefit of thinking/understanding in holistic terms is that it is completely intuitive for most systems. Hence we view an elephant as an elephant not as 4 limbs, tail, trunk and head. The same applies in business; externally we see a business as a business not as the individual silo's or components of its operations. The internal view is likely to differ.

There may be a further challenge to holism from Chaos theory which introduces concepts of the unpredictability of systems which in a holistic sense is not acceptable. In any case it may not be possible to produce definitive answers using holistic or ST methods but nonetheless patterns are observable which at some level rebuts Chaos theory.

With this holistic approach there is the implicit assumption that there is little need or attempt to understand the individual components of the system so long as an understanding of the overall behaviour is gleaned.

A third view of holism - reductionism

There are many other means and methods of defining holism and its uses, Rebernik and Mulej, (2000). One further definition of holism that will be examined here could be that it is an attempt to understand each of the parts of the system by first understanding the whole system. In a similar fashion reductionism can be seen as an attempt to derive a holistic understanding from an understanding of all of the constituent parts of the system. Both of these methods of defining holism and reductionism are something of a compromise from the two definitions presented above. Nonetheless these latter two definitions are in common usage, see http://en.wikipedia.org/wiki/Reductionism and http://en.wikipedia.org/wiki/Holism for examples.

The advantage of this (pair of) view(s) is that it represents something of a continuum and as both perspectives are somewhat interchangeable and have similar outputs, an understanding of the overall system and the constituents thereof, it is very flexible.

The role of Holism in System Dynamics

System Dynamics can be viewed as a tool which on its own will describe the behaviour of a system over time. The latter part of the previous sentence is of course a truism as without the temporal dimension there is no behaviour. The simple bathtub example is presented below as typical of a model than can be developed directly in SD with no reference to further modelling techniques or more comprehensive surrounding methodology. As a representation of a real world system the model can still produce useful insights and outputs as it stands.

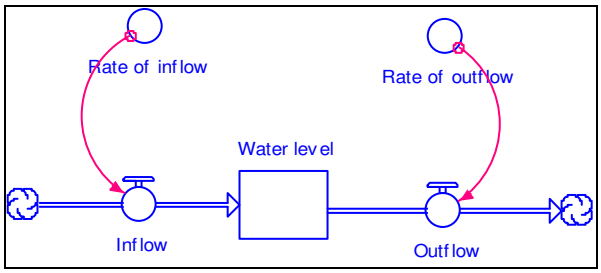

Figure 1: The bathtub model in Stella 7

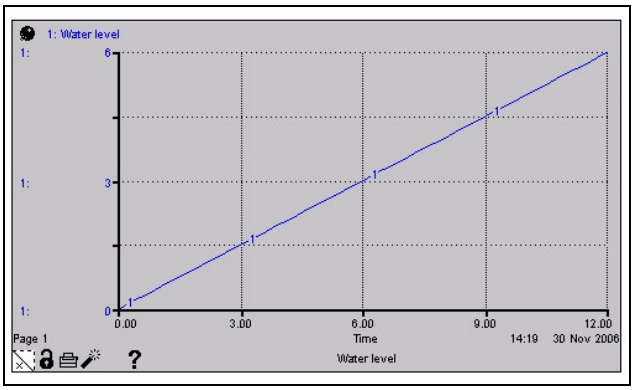

Figure 2: Behaviour of the water level in the bathtub model, given Inflow Rate = 1 and Outflow Rate = 0.5

A more typical and comprehensive approach to developing a SD model is typically structured around the following steps; Problem recognition, Conceptual modelling, Causal Loop Diagramming, System Dynamics models, Experimentation (sensitivity analysis) and finally implementation, distilled from, Sterman (200, p89) and Towill (1993, p205).

Focussing for now on the modelling aspects of this approach we can define an inverse pyramid of holism-reductionism. This is shown in figure 3 below.

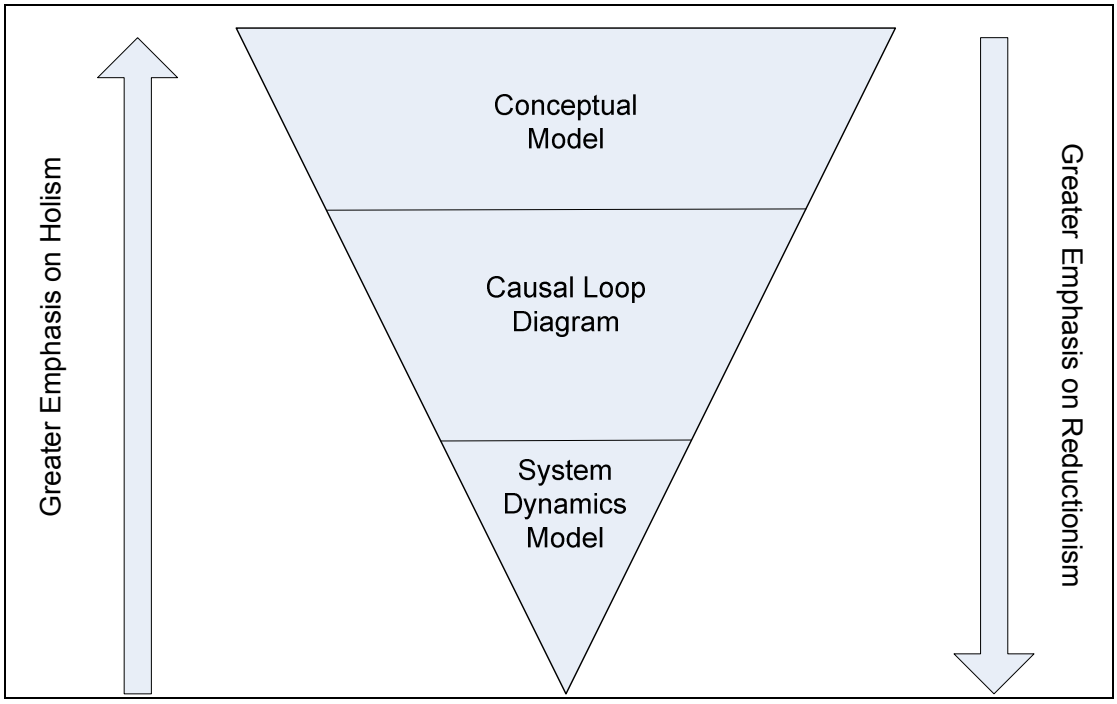

Figure 3: Inverse pyramid of holism-reductionism for differing levels of modelling

Relating the SD process to holism – reductionism

There are many books and papers that describe a process such as that outlined above for moving from problem definition to completed SD model, Sterman (2000), Towill (1993). The vast majority of these describe a process that moves from an understanding of the whole to an understanding of the parts. That is they take the first of our third definitions of holism given above and apply that process to the problem or issue at hand. It is the contention of this paper that the definition of holism used in these cases and described above in the third definition is not the kind of approach that most people would understand to be holistic.

Why is it important to get the definition right?

SD has been around for a long time and ST for a long time before that; even if it went under other names. SD has not however been adopted into the mainstream of systems analysis, understanding, decision support or problem solving tools and techniques. Its degree of deployment does not compare in any way, for example, to that of object oriented modelling, Goth (2002). Further there is support for the view that there is a lack of growth in the field from within the SD community, Stevenson (2007) and this disquiet is not new Towill (1993, p204).

It is important to get the definition right because to move the field of SD forward as a credible tool for the enhancement of understanding we need to sell that tool to people out there in the real world who are grappling with real world problems. If we give people a definition of SD as a holistic systems approach to problem solving without mentioning or properly explaining that the definition of holistic is not all it might at first appear to be then we are not selling what we say we are.

This lack of clarity and others of a similar type has done and will lead to disillusionment and ultimately rejection of the field of SD as a whole by the public and perhaps practitioners as well.

Reductionism in SD

To illustrate the potential confusion between reductionism and holism figures 4a and 4b below show the two generic looping structures that characterise SD. (Both figures were created in Stella 7)

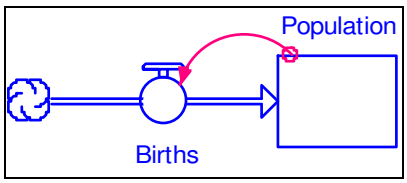

Figure 4a: A reinforcing loop

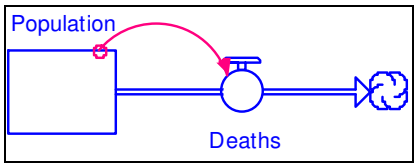

Figure 4b: A balancing loop

In figure 4a as population increases this feeds back to births which also increase. In figure 4b as Population increases, Deaths increase, causing a negative change in population. The latter example assumes some other factor which is increasing population, such as births, this has been omitted for clarity.

Now you know what each of the systems in figures 4a & b are because I have given a description and labelled them as reinforcing or balancing loops. However the smallest unit of structure that is visible is not the loop but any of the components of the loop and beneath this level is a further level of detail which is the equation and within the equation individual expressions and then individual terms. In fact to get either of these structures to perform as I have described I **need** to adopt a reductionist viewpoint and get in there with the equations and produce the underlying mathematical structure that determines behaviour, almost regardless of how I draw the loops.

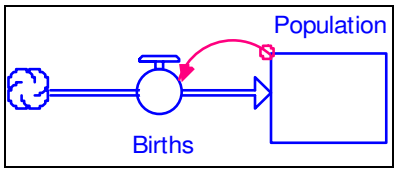

Figure 4c: a loop

To be contrary I could use the loop drawn in figure 4a change the underlying equations and permit negative inflows so that as population increases births decrease which turns the reinforcing loop back into a balancing one. I accept that these loops are simplistic however the fact that they do exist and will work as described illustrates the object of this exercise which is to make the confusion between a high level (holistic) system view and a low level contradictory (reductionist) one evident. Note that the determination of loop polarity follows the rules in Sterman (2000, p143-147).

The reductionist viewpoint is therefore necessary to convert the graphical (holistic?) description of the system to one that matches my preconceived ideas of same.

Conclusions and policy recommendation

Being pragmatic about it this paper does not set out to produce any startling conclusions or bring about any paradigm shifts it seeks simply to produce a little clarification on an area of SD and ST that is sometimes taken for granted. As Sterman points out "all models are wrong" and there is no attempt here to preach perfection or the 'right' way to do things, Sterman (2000, p846). Further support comes from Towill "there is an undoubted 'art' side to building a system dynamics model because establishing the 'truth' requires creativity", Towill (1993a, p206).

My conclusion is therefore that SD is not an holistic means of systems modelling except that it is partly and the other part of it is reductionist and the two are inseparable. A logical extension of this is that holism and reductionism are themselves inseparable other than as subjective viewpoints.

I further conclude that ST is a purer holistic modelling technique than SD and by definition I am differentiating the two.

I am also concluding that the fact that SD is not a purely holistic method of systems modelling is not a problem; selling it as if it were is.

I hope that I have illustrated in a meaningful and straightforward way the necessity of truly understanding the fundamental nature of SD as a blended continuum of holism and reductionism. Due to the subjective nature of both concepts neither (label) description is likely to be satisfactory on its own to cover the entire scope of options for development within SD.

This has been a somewhat abstract look at the debate between holism and reductionism, though with a practical message at its heart, and several other similar topics are available for further work in the same vein. We might for instance think of the mantra that 'reinforcing loops produce exponential behaviour' as worthy of examination as it appears to be incorrect in specific cases and therefore incorrect as a rule. This and several other concepts at the heart of SD would be well worth a re-examination.

The message in any further work would be the same - get it right before we sell it or it will get returned as it has been in the past.

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