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SYSTEM DYNAMICS IN A G.S.T. FRAMEWORK

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SUMMARY

Systems Theory has developed without inner coordination.

The General Theory has been general in the sense of trying to reach a global viewpoint from the perspectives of science and philosophy. But it has not perceived its structure as a whole. It has grown in complexity without integrating its parts.

Systems Dynamics has expanded in relative isolation. It has developed into a closed methodology with fixed principles and structure. To a great extent it has been equated to the Forrester's methodology applied to industrial, urban and global systems.

It would be valuable to place the Dynamic approach in a wider context. It is assumed here that in a General Systems methodological framework the same system can be considered from three different, but complementary, viewpoints: Static, Dynamic and Dialectic. It is also assumed that closeness and openess of systems are relative states and that analysis and synthesis should have analogous methodological weight.

Systems Dynamics appears as a central node in a systemic methodology that should integrate different approaches and viewpoints into a coherent whole.

THE THREE TIME SCALES

The limitations of our mental structures induces us to sequential thinking. In this way, in order to describe systems we are obliged to consider consecutively a system in different circumstances and from different time perspectives. When we make abstraction of time, the system does not change during the period taken into account; when the interaction with the environment aims to preserve the system, without changing its structure, the system behaves in a dynamic way; when inner changes or the interchange with the environment transforms the system into a different one, we may speak of a dialectical change.

The Static approach

Every system can be described as static. From this viewpoint, change from time 0 to time 1 would be zero. Autopoietic systems are considered, in certain relationships, as closed networks (Maturana and Varela, 1980).

Static models are defined by constants. Atoms, for instance, are represented by means of formulae or models that do not change through time, like He, P, K. Helium atoms from a distant galaxy and from a remote time are described in the same terms that helium atoms in the Earth. Molecular structures are represented by fixed linkages among atoms (H20).

Anatomy deals with average structures of living beings. Organic components are considered as permanent for a given species or family. Anatomic atlases are necessary for medicine students and practitioners. They are indispensable for surgeons. DNA codes, in genetics, are represented by maps.

Geographical charts, maps and plans are static models of seas, mountains, valleys, rivers or lakes; cities and villages; roads, highways, railroads, streets.

Social structures, enterprises, Public Administration organisms, etc. reflect their fundamental structure by means of organigrams that are invariable during certain periods of time.

Psychological mapping, totally necesssary to orient living beings in their environments, would not be possible without recognaissance of relatively static structures.

The Dynamic approach

In order to expand the Systems Dynamics concept that prevail in current literature it will be necessary:

a) to redefine System Dynamics, generalising its meaning, and

b) to find a place for System Dynamics into a general systemic taxonomy which would integrate specialised systemic disciplines into an unified whole

Generalisation of the Dynamic Approach

The dynamic approach has its roots into ancient philosophical movements:

Heraclitus, among the Presocratics, thought that everything changes. (panta rhei). But the Universe -and its changes-, for the Greek philosophers, was perfect only if it was cyclic. Heraclitus insists in this idea speaking of movement as "beautiful circular", concept that pervades the Greek philosophy. (García-Bacca, 1954)

Another root of the dynamic approach can be found in the oriental philosophies and, above all, in the Tao school of thinking (Capra, 1977). Perpetual movement, for Taoism, is cyclic. Night and day, for instance, repeat an iterative circular movement.

The T'ai-Chi symbol or "mantra" represents the movement of opposites that change one into the other. Inside the white sector that represents anything positive, there is a black point -the negative- that grows until it covers the white sector. A paralell process takes place in the mirror-like black sector. In this way ceaseless change, unified by the limiting circle, transforms each part into its contrary without innovation. The following is the graphic representation of this philosophical concept of iterative change.

In its modern version, the dynamic approach considers the system as homeostatic. Movement tends to maintain the system's constants. The system reacts and adapts itself to environmental changes trying to reach a stable or ultrastable state. It is defined as a "machine" that "may change with time" (Ashby, 1954)

Every dynamic system is open to its environments. It interchanges with them matter-energy and information at different levels and through different subsystems. The internal elements of the system are also in perpetual change. From this perspective systems can be formalized through sets of interrelated variables that mantain a dynamic equilibrium, tending to preserve the established structures and to compensate the action of the internal and external noxious agents.

In astronomy, the celestial mechanics of Newton established dynamic models whose eliptical trajectories follow fixed patterns in correspondence with universal physical laws. The atomic Bohr's model defines eliptical electron trajectories around the nuclei, whose movement tends to preserve the atomic structure. Living beings maintain their stability through homeostatic processes. Circulation circuits of blood, food, information ana other elements tend to preserve vital equilibrium. The echological systems that interrelate predators and their victims through complex circuits, tend to preserve natural equilibria.

In a more limited technical sense Forrester's systems dynamics represents a method for building up models of systems, describing their interrelationships by means of flows of matter, energy and information. In 1961 "Industrial Dynamics" was published. It describes a model of enterprise in which interact production, sales and jobs. In 1969, Forrester applies his method to the modelling of an urban area. In 1971 he makes the design of a world system in which "limits of growth" are defined. (Forrester, 1961, 1969, 1971). The same instrument is applied later to Latin America through the "Bariloche model",that proposes a new kind of society in which socio-political structures are more valued than the socio-economic ones.

Aracil (1978) considers a dynamic system as a formalized concept related to information processing and to a specialized mathematical branch: the "mathematical theory of dynamic systems", leading to the simultaneous development of many application fields, like Systems Engineering and Automatics. When evolution is taken as the basic characteristic for studying a system, the dynamic behavior model is considered by Aracil as a "dynamic system" and used for computer simulation of the temporal evolution of a real system. This behavior depends of the system's structure.

However, Systems Dynamics, which has a very definite usefulness in certain situations, is not a suficient tool to explain physical transmutations, biological mutations and social transformations.

Ilya Prigogine's school, at the Free University of Brussels, explores a new field.

Prigogine (1979) shares the idea of continuous flow and change in the universe. But flux do not follow a continuous line. It is submitted to small scale changes or fluctuations, eliminated or dampened by means of negative feedback that maintain the systems equilibrium. In positive feedback situations some fluctuations can be amplified, threatening the systems equilibrium. The growing fluctuation of the system can reach a point in which the systems structure is broken. Rapid growth of entropy produces chaos.

In certain cases, the states far away from equilibrium originate a totally new structure, more differentiated, interactive and complex than the previous one, needing more energy, materials, information and other resources to preserve its superior level of equilibrium. In this way, in certain unforeseable cases, appears "order through chaos".

System Dialectics

Prigogine's ideas fluctuate between the classical concept of System Dynamics -to which it is related- and a new perspective that can be considered as "Systems Dialectics".

I propose (Rodríguez-Delgado, 1985) to consider Systems Dialectics not as the study of cyclic homeostatic processes but as the study of the transformation processes of natural and conceptual systems.

The qualitative transformations of atoms, planets, stars and galaxies; the biological processes of birth, growth, development and decay; the mutations and evolution of living beings; social changes of animal and human groups; the succession of civilisations; the sudden apparition of new political and economic structures; the technological revolutions, are processes that may show certain isomorfisms if they were investigated from systemic viewpoints.

It is also necessary to investigate the processes of ideological mutations, or "conversions", that change radically the behaviour of entire human societies. Methods for transforming closed systems of ideas into open ones are of vital importance in our times.

Systems Dialectics would be, in another direction, an attempt to supersede the classical dialectical conceptions: -dialectical idealism, dialectical materialism and scientific dialectics- integrating them into a wider framework.

In this way, Systems Dialectics would find applications in Philosophy, in Natural and Human Sciences and in Methodology, contributing to explain physical transmutations, living beings mutations, wars, revolutions, and social qualitative changes from the perspectives of the contemporary sciences.

DEFINITIONS AND FRAMEWORKS

Definitions

Systems Dialectics can be defined in several ways:

a) As a philosophical attempt to integrate the different historical approaches to dialectics, from the Pre-socratic thinkers to dialectical idealism and materialism, including scientific dialectics.

b) As a scientific activity that investigates qualitative systems transformations: creation, mutation, evolution, development and dissapearance of natural, conceptual or artificial systems;

c) As a deductive-inductive-experimental method to investigate the laws or general principles that govern transformation processes of systems.

Dialectical processes can be ontogenetic -that is, qualitative transformations of individual beings like those that begin with fecundation and end with the birth of a living being- and philogenetic, like transformation of living species through time.

System Dialectics, together with System Dynamics, would be useful to investigate and orient qualitative changes of socio-technical systems, and to create models of postindustrial societies.

Dialectical openess

The present version of Systems Dialectics appear in a definite social and scientific context. We are in a conflicting and complex world conditioned by opposite ideologies or Weltanschauungen born in previous centuries.

System Dialectics belong to a new image of universe and man. Since the end of the XIXth Century new ideas of synthesis emerge in the historical and natural sciences. In 1905 the relativity theory of Einstein changes drastically our idea of the universe. The clasical oppositions between matter and energy, space and time, dissapear. The complementarity principle of Bohr supersedes the oppositions between corpuscle and wave, brain and mind.

Research and discovery have changed many times our ideas about nature and man. They may change again our present systems of ideas. System Dialectics must be open to any change or mutation, in relation to new concepts in scientific or philosophical thinking.

Dialectical frameworks

The previous dialectical framework was closed and absolute. Thesis - Antithesis - Synthesis was a sacred logical triad whose structure had no epistemological foundation. Natural and thinking processes were included in a mental straitjacket. Man and nature were artificially obliged to adapt to a rigid logical scheme of three terms.

We can represent this situation by the following figure:

$$T_1 \longrightarrow A_1 \longrightarrow (S_1)$$

$$(A_2) \longrightarrow T_2 \longrightarrow S_2$$

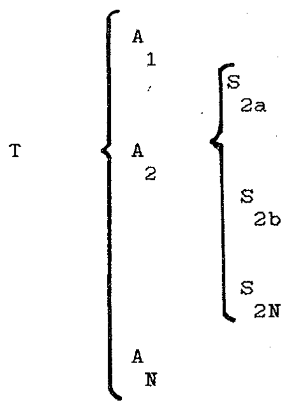
$$A_3$$

Thesis, Antithesis and Synthesis were repeated in endless cycles. Every Synthesis gave birth to an unique Thesis.

However, real things are more complex. Every situation or state (Thesis) may produce an unlimited series of different situations (Antithesis). Every Antithesis, may produce, equally, an unlimited number of Synthesis

The triadic representation appears as a case among many other possibilities. The Hegelian charm is broken.

This situation may be schematically represented as follows:



Real processes could show "n" differentiated states or phases, in relation to the structure of each process..

For instance, a biological process that shows four clearly differentiated states, like egg, chrysalid, worm and butterfly, are better described as a circuit of four phases that ends in the multiplication of eggs, or in the interruption of the process in any of the four states

The same process can be represented through different series of variable states or situations. The representations are not objective. They represent the viewpoint, the interests, the convenience or the preferences of the observer. Even in the series egg-butterfly -that has an objective component- other intermediate states could be observed.

The life cycle of man, for instance, can be represented by different situations, in relation with the methodology employed, from boy-adult, to new-born - baby - infant - child - adolescent - adult - old, by age groups, or by other means.

In the same way, social classes can be described or ordered in several forms.

A diadic representation could reduce the description to

Owners-------------Slaves

Capitalists-------Workers.

Triadic representations can be used, like the following:

Bourgeosie--------Farmers----Industrial proletariat

Employers---------Employees-----------Unemployed

Tetradic representations would be:

Farmers---Merchants---Industrial workers--Office workers

Shareholders----Managers------Technicians------Workers

Executives---Research-staff---Line-staff---Operative-staff etc.

Each representation would depend of different viewpoints or perspectives, whose combination would be richer in meaning that an isolated classification

Network representations

All previous representations are lineal. However, in order to describe complex systems it is necessary to use superimposed networks describing economic positions, social roles, levels of knowledge, technical skills, world conceptions and many other variables. From the many possible networks -whose number may be considered limitless- it is necessary to choose network sets of interrelationships submitted to wide fluctuations in order to foresee inflexion points that can produce change into a new structure. The understanding of interactions between the interrelated dynamic and dialectic aspects of complex systems could be used to dampen some oscilations and to amplify others. Managing such interrelated variables we could be able to influence the direction of change in systems.

New social systems can be designed through models in which opposite interests and values could be transformed, permitting the integration of their complementary aspects. Emergent new activities and synergic actions can be planned if we understand the interrelationships between Static, Dynamic and Dialectic approaches.

Computer aided modelling in which constants, variables and "transformables" could be interrelated would constitute a very useful tool for inteligently oriented change.

Systems analysis and systemic synthesis

Complementary methodologies for the above mentioned instruments are systems analysis and systems synthesis.

Frequently analysis is considered as an end by itself independent of synthesis, as if they were separate processes.

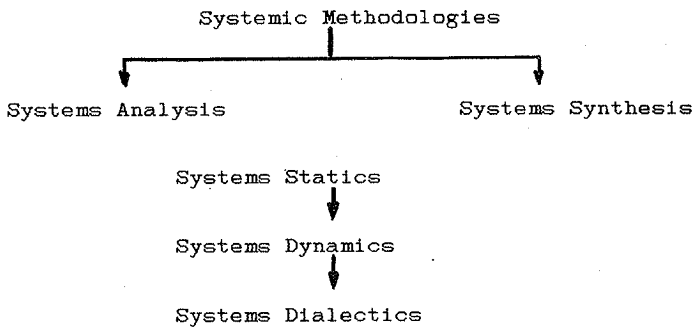
If we consider them as complementary, we would have a cybernetic circuit in which analysis can produce many synthesis and each synthesis may induce many new ways of analysis .

There are many methodologies for physical, chemical, biological and social analysis. There are also methodologies for physical, chemical and even biological synthesis, but methodologies for social synthesis are almost inexistent, probably because its complexity exceeds our present capabilities and the difficulties of experimentation are considerable.

In consequence, research should be oriented towards the possibilities of integration of different methodological approaches

As a first integrative attempt we could consider Systems Dynamics as a central point of a systemic complex methodology.

Its position could be represented by the following graph:



Surely it would be necessary to develop Systems Dialectics and to devise ways in order to interrelate homeostatic processes with processes of qualitative transformation of systems.

The fifth generations of computers and artificial inteligence techniques would offer us new possibilities for realizing this complex task. But the work on theory and the establishment of methodological principles should not be delayed.

CONCLUSIONS

A study of the place that Systems Dynamics occupies in a General Systems framework reveals that Systems Dynamics is an useful partial approach to the study of complex systems and processes.

It also shows that Systems Dynamics has a definite place between Systems Statics -that isolates systems and centers the attention on their constants or invariants-, and Systems Dialectics that considers qualitative transformations of systems and situations.

Iterative processes of analysis and synthesis of systems should be considered complementary methodologies.

The concurrent utilization of several methodological tools has the disadvantage of its complexity. Powerful interdisciplinary resources -physical and intellectual- should be needed to implement an integrated systemic methodology.

Its great advantage, however, would be the opening of new possibilities for research and action.

An important application of this integrated methodological approach may be the design of models for postindustrial societies.

A first step could be the elaboration of simple pilot experimental models by means of interdisciplinary groups and the design of an adequate software.

This is a challenge that we should face.

REFERENCES

Aracil, J. (1978). Introducción a la dinámica de sistemas. Alianza Editorial, Madrid.

Ashby, W. R. (1954). Design for a brain. John Willey, New York

Capra, F. (1977). The TAO of Physics. The Chaucer Press.

Forrester, J. W. (1961). Industrial Dyanmics. M.I.T. Press

Forrester, J. W (1969). Urban Dynamics. M.I.T. Press.

Forrester, J. W (1971). World Dynamics. Wright-Allen Press.

García-Bacca, J. D. (1954). Fragmentos filosóficos de los presocráticos. Universidad Central de Venezuela.

Maturana H.R. and Varela, F.J. (1980). Autopoiesis and Cognition. Reidel Publishing Co.

Prigogine, I. et Stengers, I. (1979). La Nouvelle Alliance. Metamorphose de la Science. Editions Gallimard.

Rodríguez- Delgado, R. (1985),. La dialéctica de sistemas, instrumento para crear empleo. CITEMA, Noviembre-Diciembre 1985, No. 121. pp 59-91.