8ème congrès de l'Union Européenne de Systémique

# Trans-disciplinarity and meta-structures to meta-model complexity of social systems

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# SYSTEMS

In the *classic view* (we omit here for brevity reference to *quantum-systemics*) systems are intended as entities *possessing* properties which their elements do not possess.

In fact, a *necessary condition* for the establishment of systems and, consequently, of their retaining their properties, is that elements *continuously* interact.

The *maintaining* of systemic properties requires that elements continuously interact.

Examples are given by electronic devices acquiring and maintaining properties when powered on, i.e., elements are made to interact. When elements of a system stop to interact it *degenerates* into the set of components.
The same occurs with biological systems, where life needs to be continuously supported.

Examples of systemic properties, which component parts do not have, include: adaptive, allopoietic, anticipatory, autonomous, autopoietic, chaotic, deterministic, dissipative, equifinal, ergodic, far from equilibrium, goal-seeking, open-closed, oscillating, self-organized, symmetry breaking and so on.

Examples of non-systemic properties, i.e., possessed by elements not considered as systems include: age, weight, geometric measurements, numeric properties (e.g., odd-even, order, and results of computations), and speed or direction in classical physics.

# COMPLEX SYSTEMS

In the literature one of the several meanings of complexity relates to:

a)processes of establishing systems in a non-organised way, i.e., through processes of *self-organisation* and *emergence*;

In short, processes of *self-organisation* are considered here as corresponding to continuous but *stable*, for instance, periodic, quasi-periodic variability in the acquisition of new structures.
Examples are given by the Bènard rolls, structures formed in the Belousov-Zhabotinsky reaction, and dissipative structures such as whirlpools in the absence of any internal or external fluctuations.
*Stability of variability, e.g., periodicity, corresponds to stability of the acquired property;*

In short, processes of *emergence* are considered here as corresponding to the continuous, irregular and unpredictable, but *coherent* multiple sequences of structures.

Coherence is detected through the observer choice of a suitable cognitive model at a specific level of description.

Examples of processes of *emergence of systems* are given by the establishment of collective behaviour acquiring properties such as ferromagnetism, superconductivity, superfluidity and social systems such as flocks, swarms, markets and industrial districts.

*The challenge is detect such coherence by using suitable models and approaches, e.g., meta-structures introduced later.*

b) the occurring of such processes *within* systems leading them to *acquire* new properties.

Examples of *emergence of systemic properties within systems* (i.e., acquisition of new properties) are given by cognitive abilities in natural and artificial systems, collective learning abilities in social systems such as flocks, swarms, markets, teams, firms and functionalities due to machine learning and in networks of computers (e.g., in Internet) or black out in electrical networks.

*The latter are examples of complex systems, i.e., systems able to continuously acquire new properties*.

# MODELLING COMPLEXITY

Different approaches have been introduced in the literature when trying to model complexity *in general.*

We will focus here on approaches to model *sequences of multiple structures* occurring in processes of emergence as

- Multiple Systems (MSs) and Collective Beings (CBs),
- their properties through the Dynamical Usage of Models (DYSAM),
- property of the suitable cognitive system, i.e., *logical openness*, and
- their coherence through meta-structural properties.

# Multiple Systems (MSs)

A MS is a set of systems established by the same elements interacting in different ways, i.e., having multiple simultaneous or dynamical roles.
Within the conceptual framework of MSs concurrent/cooperative effects of different interactions affecting the same elements perturb the effects of single interactions.
Moreover, the action of concurrent interactions may be neither simultaneous nor regular.
The same interacting components may establish different systems through organization or emergence and at different times (i.e., simultaneously or dynamically).

Examples of MSs are given by:

- electricity networks where different systems play different roles;
- networked interacting computer systems performing cooperative shared tasks over the Internet;
- the output of an electronic component may simultaneously be also source of information for a security monitoring system and the reaction of a cell may also be a source of information to decide therapeutic actions.

## Collective Beings (CBs)

CBs are particular MSs established by agents possessing a (natural or artificial) cognitive system.

In CBs the multiple belonging is *active*, i.e., *decided* by the component autonomous agents. In the process of emergence of CBs agents interact by simultaneously or dynamically using, in the model constructivistically designed by the observer, *different* cognitive models.

Examples are *Human Social Systems* where (a) agents may *simultaneously* belong to different systems (e.g., behave as components of families, workplaces, traffic systems, as buyers, of a mobile telephone network).

## Dynamic Usage of Models (DYSAM)

The DYSAM approach was introduced to deal with the dynamical emergent properties of complex systems, i.e., when one single dynamic model is not sufficient.

Dynamic models model dynamical properties of a specific phenomenon, while DYSAM models change over time, i.e., the dynamic acquisition of different, emergent properties and properties of MSs and CBs as well.

DYSAM is conceptually based on approaches already considered in the literature and not based on the simplistic assumption of the existence of a unique, optimum solution.

Examples are the well-known Bayesian method, Pierce’s abduction, Machine Learning, Ensemble Learning and Evolutionary Game Theory.

Examples include

- multiple corporate modelling and multiple roles with reference to markets, structure and goals;
- processes of balancing and compensation in damaged systems, having reduces resources asked for new usages, e.g., disabled, aged, poorer;
- learning the *coherent* use of the five sensory modalities in the evolutionary age for children when the purpose is not to choose the best one, but to use all of them together;
- usage of one kind of modelling to influence another as for consent manipulation.

*An implementation of DYSAM based on Neural Networks has been introduced.*

## Logical Openness

While thermodynamic openness relates to the ability of systems to have permeable boundaries, the concept of logical openness relates to the constructivist role of the observer

- generating *n-levels* of modelling by assuming *n* different levels of description,
- representing one level through another,
- modelling a strategy to *move* amongst them, and considering simultaneously more than one level as in the Dynamic Usage of Models (DYSAM).

Examples of logical openness in Systemics relates to the multiple processes of acquisition of properties in complex systems and particularly for MSs and CBs.

With reference to the concept of systemic complexity, i.e., the occurrence of the acquisition of new properties within a system through processes of emergence or multiple dynamic roles of components, as for MSs and CBs, we recall that the number *n* of levels of modelling assumed by the observer may be assumed as a *measurement of the complexity* of a system.

## Meta-structures

A further theoretical approach to model processes of emergence, such as flocks, swarms and markets is under investigation, being based on considering collective behaviours given by coherent sequences of different structures ruling interactions between composing elements rather than by coherent changes of the *same* structure.

Such coherence is considered represented and modelled by the mathematical properties of sets of values taken by some suitable *mesoscopic variables.*

When considering, for instance, swarms we consider number of elements having the maximum, minimum or *same* (at a suitable threshold) distance; the same speed, the same altitude and the same topological position *at a given point in time* rather than variables related to single agents. Other global variables are macroscopic such as volume, surface and density.

Mathematical properties, e.g., statistical, periodicity and quasi-periodicity , of sets of values assumed by such variables are intended as meta-structural properties and are proposed to model process of emergence of collective behaviours.

## INTER- AND TRANS-DISCIPLINARITY

We consider now the approaches mentioned above to specify and characterise *systems research* dedicated to introduce theoretical generalisations related to systemic properties, their establishment through single or multiple structures (emergence), and, in their turn, their properties.

# Inter-disciplinarity

It is not a *usage* of different disciplines, but a theoretical issue consisting of formulating a disciplinary problem by using the models of another discipline.

It deals with the study of the *same* systemic properties in *different* disciplines (e.g., openness, adaptability and chaos in physics, economics, biology and psychology).

It *is about* dealing with concepts, approaches, theoretical issues, and models suitable for usage within different disciplinary contexts.

It occurs in education when teaching one discipline by using another (for instance, teaching history while dealing with geography, mathematics with physics, and medicine with chemistry).

Examples of issues in interdisciplinary research are:

•'How models used in physics may be used in the social sciences',

•'How models describing processes of biological aggregation may be used to model socio-economic processes',

•'When Game Theory is sufficient to model decision-making processes and when the cognitivist view must be adopted'.

*The approach usually consists of using the same models but change the meaning of variables, for instance in econophysics.*

## Trans-disciplinarity

We consider Trans-disciplinarity to arise when systemic properties are studied *per se*, i.e., considered in general as properties of models and representations without any reference to specific disciplinary cases.

Trans-disciplinarity also studies the relations between systemic properties, e.g., models of dissipation, equilibrium, openness, adaptability and chaos, and their relationships.

Examples of issues in trans-disciplinary research are:

-‘Is it possible to formulate a theory about the *relationship* between systemic properties?'

-‘How can processes of emergence in systems be induced, maintained and varied?’

-'How, *in general*, can systemic properties be induced or regulated?‘

-'Is it possible to identify a *general* way to measure systemic properties?'

- 'Using mathematics for modelling is a way to represent systemic properties. Are there other *equivalent* ways of representing the same systemic properties?'.

In this conceptual framework we consider approaches like

- Multiple Systems (MSs) and Collective Beings (CBs) modelling,
- Usage of the Dynamical Usage of Models (DYSAM),
- logical openness as general methodology, and
- modelling coherence of emergent phenomena through meta-structural properties

as suitable trans-disciplinary approaches to meta-model (since we model usage of models) complexity of social systems.

## CASES

We list some simple case as examples where to apply the approaches introduced above.

### Growth and development

While growth may be considered as a process of a quantitative increase, different models of developments are possible, such as:

- harmonic processes of increases in different processes of growth;
- sequences of different versions of the same processes of growth through optimisation;
- sequences of different processes of growth through innovation and, finally,
- emergence of new processes.

Specifically, emergence from sets of processes of positive and negative growth. In this case examples are given not anymore by stability and equilibrium, but by regularities of changes like periodic, quasi-periodic or around attractors.

## Health

The concept of health in medicine, considered from a dynamical modelling point of view, no longer refers *only* to the ability to *resume* a biological state assumed as health, but to the management of the available resources to make health emergent by using new cognitive models to *continuously establish coherence as health*.

## Architecture

Architecture may be considered as the disciplinary design of suitable structural conditions to induce processes of emergence, to *influence the emergence of collective behaviour* within social systems such as

- cities, crowd in normal and emergency situations, traffic, structures of homes inducing life styles,
- hospitals and schools inducing ways of thinking (e.g., health to be *repaired*, knowledge *divided* into disciplines), and
- populations of buildings acquire properties which a single building does not have, e.g., ecological, safety, harmony.

# CONCLUSIONS

We mentioned some approaches to model and manage complexity by using meta-modelling.

It is particularly suitable for processes of emergence and related dynamical and hierarchical acquisition of new properties when a single model is, in principle, insufficient to model the complexity of such subsequent, multiple properties.

In this case focus is no longer only on the *dynamics of systems*, but rather on the dynamics of usage of models constructivistically adopted as suitable by the observer and of subsequent coherent structures as in meta-structures.

We have presented some specific approaches such as considering Multiple Systems, Collective Beings, Logical Openness, Dynamic Usage of Models (DYSAM) and meta-structures suitable for modelling social systems within the framework of trans-disciplinarity.

We concluded by mentioning specific cases such as the modelling of Growth and Development, Health and Architecture.