Modelling Sustainable Systems and Semantic Web

Systems and their Development

Lecture in the Module 10-202-2312
for Master Computer Science

Prof. Dr. Hans-Gert Gräbe
http://www.informatik.uni-leipzig.de/~graebe

April 2022

What is a System?

See also the Handout on "Systems, Organisations, Mangement".

System definition

A *system* is a *delimited set of components*. Their interaction realises a *qualitatively new function* (emergent property) and thus constitutes *a new unified whole*.

Example: An aeroplane consists of many parts. None of them can fly, only the aircraft as a unified whole can fly. Flying is an emergent property of the system as a whole only.

The systemic approach is a form of reduction of the complexity of the totally interconnected real-world (*reality* for short).

What is a System?

Three dimensions of reduction to the essentials.

(1) Outer demarcation of the system against an *environment* (the *context*), reduction of these relationships to input/output relationships (specifications and interfaces) and guaranteed throughput.

(2) Inner demarcation of the system by combining subareas to *components*, whose functioning is reduced to "behavioural control" via input/output relations (specifications and interfaces).

(3) Reduction of the relations in the system itself to "causally essential" relationships.

What is a System?

This reduction is essential for both the *description* of real-world contexts and for its *operational control*.

In this understanding, systems are to be considered both as a **unit of analysis/description (modelling)** and **a unit of execution (operation)**.

Every system approach contains a **central contradiction:** Analysis emphasises the *structuredness* and thus *decomposability* of the system. Operation emphasises the *interdependence* and thus *indecomposability* of the system.

In the assembled system in addition to the components, the *connections* also play an important role. They mediate the *flow of energy, material and information* which is required for the operation of each component and thus for the viability of the system.

Systems and Practice

Systems are a part of the complex relationships of practice.

Analysis and modelling as human thinking activities do not only have a *mental quality*, but also a *practical* one. The goal of modelling is to influence real-world processes.

In such an understanding, the *criterion of "truth"* is not related to an "idea" that precedes all experience, but rooted in the practical experience itself. It expresses, how successful the *justified expectations* from the mental modelling and the *experienced results* of the transformation of the real-world according to that plan are related.

Practice and Language

However, this experience itself can only be communicated intersubjectively in language form and has thus itself mental quality.

A coherent concept of a system must combine both dimensions – language shapes expressiveness of practical cooperative action, expressive practices shape language.

Thus language means above all the *common conceptual penetration* of real-world processes in cooperative action and thus the *formation of common conceptual systems* in cooperative action spaces.

Systems and Autonomy

The linguistic concentration on essentials in the description suggests a certain closedness (*autonomy*) of a system.

However, this autonomy is always *relative* to existing or assumed *operating conditions* provided by the environment, the *context*.

System descriptions are therefore never absolute, but *always to be contextualised*, even if this contextualisation itself often falls victim to the reduction to essentials.

Components are for Composition

In this understanding, the environment of a system is itself systemically structured, even if it may still be insufficiently mentally conceptionalised. This raises the question of the *genesis and development of systemic descriptive structures*.

The system concept is well suited for such a task since it is self-similar – components can again be considered and analysed as systems. However, this is done under a *different reduction to essentials* than for the system composed from these components.

In such an understanding, the *main task of systemic modelling* is the composition of components into new systems (system genesis) or the improvement of the interaction of components in a system (system development).

Viable Systems are Open Systems

The feedback loop of justified expectations and experienced results which drives systemic development presupposes *"living" systems*, i.e. systems which are *implemented* and *operated* in the real world.

For the operation of a system a qualitatively and quantitatively determined **throughput of energy, matter and information** is required.

On the other hand, such a throughput has great influence on the inner structure of a system.

Examples:

- Rayleigh-Bénard cells
  `https://www.youtube.com/watch?v=9Ru_bjW3eL8`
- Metabolism of biological systems
- The "global" geo-biological system Earth

Development Patterns of (Technical) Systems

Altshuller's Law of Energy Conductivity.

A necessary condition for the viability of a technical system is the flow of energy through all its parts.

This external throughput is often constitutive for the inner system structure through resonance and dissonance phenomena of amplification and extinction of inner dynamics.

Altshuller's Law of Coordination of the Rhythm of the Parts.

A necessary condition for the viability of a technical system is the coordination of the rhythms of all parts of the system.

Changing the World in a Planned Way

The system concept is a tool in the hands of humans who want to **change the world** following their (intentions, goals and) plans.

11th Feuerbach Thesis (Marx)

Philosophers have only interpreted the world differently, it is a matter of changing it.

Die Philosophen haben die Welt nur verschieden interpretiert, es kömmt darauf an, sie zu verändern.

But: The world is in constant motion and also permanently changes itself.

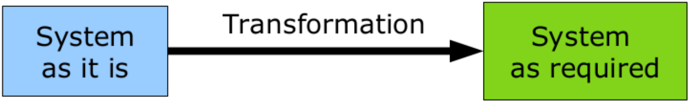
So more precisely: It is a matter of **influencing the development of reality**.

System Development

Two practical tasks:

(1) Build new system
(2) Improve existing system

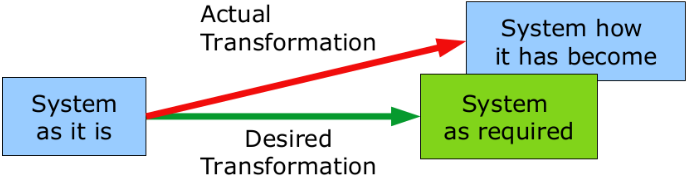
(1) can be consideres as a special case of (2), since every need for a new system comes with at least rough ideas about that new system, so there is also under (1) an at least rough description form of the system to be created.



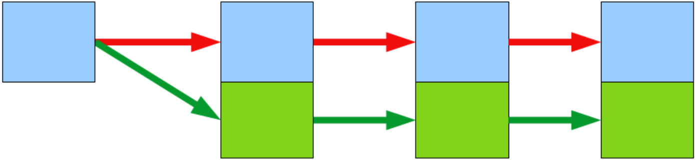
System Development

This basic scheme fits not only technical systems, but also the modelling of social, socio-ecological and cultural systems, so it is sufficiently universal.

How does such a system evolve over time?



System Development

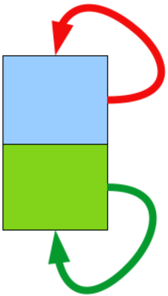


Transitional development as *different versions* of the system over the time.

System Development

But this can also be understood as development in time *of the same system*.

Transitional management versus adaptive management.



Development of Systems

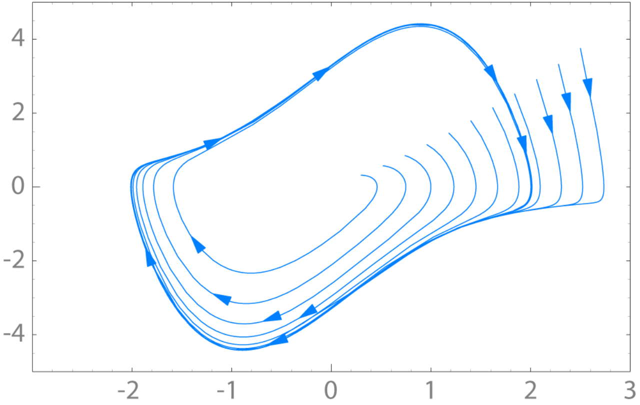
The development of a system can therefore be conceived as a contradiction between an *ideal line of development* and a *real line of development*.

This idea is reflected in the **TRIZ concept of the Ideal Final Result** (IFR – Ideales Endresultat).

In the Theory of Dynamical Systems, system development is conceived as a progression of states, which can be described by a function $f(t)$ with values in a phase space.

The *ideal behaviour* is described by mathematical relationships, such as differential equations of the laws of motion and geometrically displayed as *trajectory*.

Trajectories and Limit Cycles



Source:
`https://de.wikipedia.org/wiki/Datei:VanDerPolPhaseSpace.png`

System Dynamics

These differential equations and trajectories are part of the *description form of the system* and thus have already been created by *reduction to essentials*.

In the modelling it is assumed that everything essential is taken into account, i.e. that the *real temporal development* $r(t)$ of the system (as *experienced result*) differs from the *ideal temporal development* $f(t)$ (as *justified expectation*) only by a small difference $d(t) = r(t) - f(t)$, which is *insignificant for the selected essential*.

While $f(t)$ enables a *quantitative prediction* of the development of the system, the statement that $d(t)$ is "small" or "damped" is a *qualitative statement* of the description form itself.

System Dynamics

Often one also restricts oneself with $f(t)$ to a *qualitative statement* about the exact position of the trajectories as invariants in the solution space and thus to the statement that $r(t)$ oscillates around these trajectories in a damped manner.

These trajectories seem to "magically" attract the real states and are therefore also called *attractors* (steady state equilibrium).

For example, the Earth moves on an elliptical orbit around the Sun in the sense that real deviations from this orbit are compensated. Such patterns often only become visible when systemic motion is approximately repeated in such *steady states*.

System Dynamics

How do small disturbances influence the path behaviour in a quasi-periodic motion? An important answer is given by the Kolmogorov-Arnold-Moser (KAM) theorem.

From the English Wikipedia:

The KAM theorem states that if the system is subjected to a weak nonlinear perturbation, some of the invariant tori are deformed and survive ..., while others are destroyed (by even arbitrarily small perturbations ...). Surviving tori meet the non-resonance condition, i.e., they have "sufficiently irrational" frequencies. This implies that the motion ... continues to be quasiperiodic, with the independent periods changed (as a consequence of the non-degeneracy condition). The KAM theorem quantifies the level of perturbation that can be applied for this to be true.

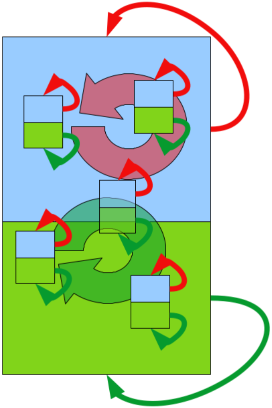
KAM tori that are destroyed by perturbation become invariant *Cantor sets* ...

The non-resonance and non-degeneracy conditions of the KAM theorem become increasingly difficult to satisfy for systems with more degrees of freedom.

Coevolution of Systems

What is the relationship between the development

- of the system itself,
- of the components in the system and
- of the relationships in the system?



Coevolution of Systems

The coupling of developments between components is driven by resonance phenomena and coupled to eigentimes and eigenspaces of the inner equations of motion, different for different components.

Altshuller's Law of Non-uniformity of the Development of the Parts of a System.

The parts of a system develop non-uniformly; the more complicated the system, the more non-uniformly develop its parts.