7th International DAAAM Baltic Conference
"INDUSTRIAL ENGINEERING
22-24 April 2010, Tallinn, Estonia

SELF – ORGANIZING SYSTEMS IN NATURE AND TECHNOLOGY

Katalinic, B.; Cesarec, P. Stopper, M. & Kettler, R.

Abstract: *Selforganisation is wide used concept of organisation of material, energy and information in space and/or time. In this article the different aspects, definitions and characteristics of the selforganisation in the nature are analysed. The first complex selforganising assembly system, proposed by Professor Katalinic in 1999, and known as Bionic Assembly System is shown. The difference between the selforganisation in the nature and technology is discussed.*
Key words: self–organization, Bionic Assembly System (BAS), self-organising production system, assembly

1. INTRODUCTION

The self-organization is one of the main patterns of the organization of material, energy and information in the nature. It is a present in inanimate and in the biological systems. The phenomena of the self-organization is a present in the whole range of the size from less than atom till the whole universe.
The self-organizing is a very complex phenomena with many different phases. At the moment there is no one unique definition of self-organizing. But there are many definitions which are describing particular characteristics, affects and forms of self-organizing.

2. DEFINITIONS

Self-organisation has many different faces and characteristics. In order to find out as close as possible what self-organizing can be, the different definitions are studied to find out characteristics, affects and forms.
There are many definitions of self-organisation, here are typical five:
Definition 01: *"Self-organization is a process whereby pattern at the global level of a system emerges solely from interactions among the lower-level components of the system. The rules specifying the interactions among the system's components are executed using only local information, without reference to the global pattern"* [1].
Definition 02: *"Self-organization is a process of attraction and repulsion in which the internal organization of a system, normally an open system, increases in complexity without being guided or managed by an outside source. Self-organizing systems typically (but not always) display emergent properties" [2].*
Definition 03: *"Self-organization is a set of dynamical mechanisms whereby structures appear at the global level of a system from inter-actions of its lower-level components. Self- organization relies on four basic ingredients:*
1. *Positive feedback, or amplification, that promotes the creation of structures.*
2. *Negative feedback that counterbalances positive feedback*
3. *The amplification of fluctuations (random walks, errors)*
4. *In social insects, self-organization relies on multiple interactions, either directly among individuals, or among elements that can be manipulated by them"* [3].

Definition 04: *"The essence of self-organization is that system structure often appears without explicit pressure or involvement from outside the system. In other words, the constraints on form (i.e. organization) of interest to us are internal* *to the system, resulting from the interactions among the components and usually independent of the physical nature of those components. The organization can evolve in either time or space, maintain a stable form or show transient phenomena. General resource flows within self-organized systems are expected (dissipation), although not critical to the concept itself."* [4].

Definition 05: *"Self-organization is a basically a process of evolution where the effect of the environment is minimal, i.e. where the development of new, complex structures takes place primarily in and through the system itself. As argued in the section on evolutionary theory, self-organization can be understood on the basis of the same variation and natural selection processes as other, environmentally driven processes of evolution. Self-organization is normally triggered by internal variation processes, which are usually called "fluctuations" or "noise".*

Self-organization is usually associated with more complex, non-linear phenomena, rather than with the relatively simple processes of structure maintenance of diffusion" [5].

3. CHARACTERISTICS OF SELF-ORGANIZATION

From above mentioned definitions is possible to extract following key words which are describing most important characteristics and substance of self-organizing phenomena. Such it is possible to tell following:

Self - organization is a process. / There are interactions. / Self - organisation is present on and between local and global levels. / Local information plays very important role. / Emergence from small and simple to big and complex. / Self – organisation evolve in either time or space. The key words are defined as:

a) Process - a set of transformations of input elements into products with specific properties, characterized by transformation parameters.

A system engineering process is a process for applying systems engineering techniques to the development of all kinds of systems. Systems engineering processes are related to the stages in a system life cycle. The systems engineering process usually begins at an early stage of the system life cycle and at the very beginning of a project [6].

b) Global level – level that is above the system or that is the level at which different objectives are achieved as a result of mutual actions of individuals at a lower level.

c) Interactions - are different actions (effects) between components (individuals), if talking about self-organizing system, then it is interaction of components (individuals) at a lower level that leads to achieving the goal on a global level.

d) Lower-level - is the level at which the interaction of individuals and goal-oriented action comes to goals at the global level.

e) Local information - is information which individuals change between itself at the local level in order to achieve a certain goal.

f) Global pattern – are the pattern at global level

g) Emergence - In philosophy, systems theory and science, emergence is the way complex systems and patterns arise out of a multiplicity of relatively simple interactions. Emergence is central to the theories of integrative levels and of complex systems [7].

h) Time & Space - Evolve in either time or space – the organization can increase the number of components in either time or space maintains a stable form or show transient phenomena

4. EXAMPLES IN NATURE

In nature there are many examples of self-organization. Some of these examples are swarms of bees, schools of fish, herd of sheep, zebra's coat etc.

4.1 Honeybees

Colonies of bees perform community tasks by a distributed function that doesn't seem to require a central organizer. The two observed characteristics of interaction are:

- Hierarchical - one insect asssumes a dominant role and the other submissive
- Thropic - a community "decision" is made

Agile teams need to make community decisions. To be a good Agile teammate, it is important to develop an instinct for the signals of when to exercise dominance and and when to be submissive. You must be capable of both behaviours as events dictate [8].

4.2 Schools of fish

In biology, any group of fish that stay together for social reasons are said to be shoaling, and if, in addition, the group is swimming in the same direction in a coordinated manner, they are said to be schooling. Fish derive many benefits from shoaling behaviour including defence against predators. [10]. In this defence each individual follow simple rules that keep the group alert:

- stick together,
- avoid collisions
- swim in the same direction (Figure 1)

Fig. 1. Fish schooling

4.3 Herd of sheep

Sheep are the same as the bees an example of self-organization in nature where in the herd of sheep, each sheep behaves the same or similar as well as other sheep which leads to the appearance of movement of herd at the same time in the same direction.

4.4 Zebra's coat

Zebra's coat is also one of examples of self-organizing systems in nature where is very interesting striped pattern (Figure 2). This pattern are results of applying of some simple rules which are constantly carried out between components of system.

Fig. 2. Zebra's coat

4.5 Sand dunes

Sand dunes arise from a sand deposition behind a small wind shelter (Figure 3); this increases the wind shelter and thereby accelerates further sand deposition - a clear self-enhancing reaction [9].

Fig. 3. Sand dunes

5. EXAMPLES IN TECNOLOGY

The self-organizing is used for very long period of time at simple technical devices.
Very typical examples are devices for separation and orientation of the parts; for example during the process of the assembly. The most fascinating technical devices are based on the different uses of the magnet. Magnet as a such is a maybe

the best example of the use of self-organizing in the technology. Ferro magnetically materials have very strong self-organizing behaviour in the magnet field.

At the level of complex technical systems the self-organizing is one of the promising development directions. This development is at very early stage of development. One concept of self-organizing assembling system is proposed by prof. Katalinic in 1999. This concept is known as Bionic Assembly System (BAS). The main structure and behaviour of this system is as follow:

- Basic Algorithm (Figure 5)
- Start/Restart of the system
- Shutdown of the system
- Reconfiguration of the system

BAS is based on the concepts of autonomy, co-operation and intelligence and composed of two subsystems (Figure 4); the core subsystem and the supplementary subsystem. These subsystems are divided by the system border. The core subsystem is the central part of the assembly system. It includes all assembly cells, mobile robots, and assembly pallets, repair stations and quality control stations. The supplementary subsystem surrounds the core subsystem. The main activity in this subsystem is the storage of parts and components. The main activity at the system border between the core and supplementary subsystems is the supply of assembly cells with parts and components, which are used in the assembly process of the final product.

The self-organizing complex flexible assembly system is composed out of the following basic components [11]:

- Assembly cell (basic machine for completing one assembly operation)
- Repair station (It can happen that some products of one run have to be repaired during assembly.
- Quality Control Station (the quality control based on the measurement of mechanical and electrical parameters of the product)
- Packing Station (function: the removal
- of good products and packing for transport, reset and restart of the assembly pallet)
- Mobile robot (Lineless mobile robots are the basic transport mean for the assembly pallet through the assembly system during assembly cycles of one product)
- Assembly pallet (The assembly pallet is the basic carrier for the product during assembly cycles. Assembly pallets in the system are moved by the lineless mobile robot).
- Loading / unloading station for assembly pallets (bringing new assembly pallets to the system or taking out existing assembly pallets from the system)
- Pool of pallets: (storage of pallets)
- Storage for parts and components: (storage of parts and components)

The basic concept is that all entities, which are in the subsystem and connected by an interface, should get orders from a primary control unit and should work it out by themselves. In addition it has to be considered that the technological environment and the BAS affect each other [12].

Bionic assembly system is a part of the factory. At the factory level there are defined targets, as what have to be produced, at what time and for whom. The factory is controlled by factory control system and this system defines what has to be assembled by bionic assembly system.

Factory control system gives that to bionic assembly system in the form of assembly orders. Assembly order contains information about product, priority and quantity. Such one order is a control and target input for bionic assembly system. Bionic assembly system is assembling products one by one. Factory order system is one centralized system and bionic assembly system is a self organizing system. The bionic assembly system is subordinated to the factory control system.

The interface between factory control system and bionic assembly system is called access point. The access point is getting the orders from the factory controlled system what has to be assembled but not in which way. The bionic assembly system completes the order in a self organizing way. The information about the activities and results is given back by the access point. This feedback is used by the factory control system to support the BAS. The collected factory data gives the factory control system a possibility to react on scenarios [13].

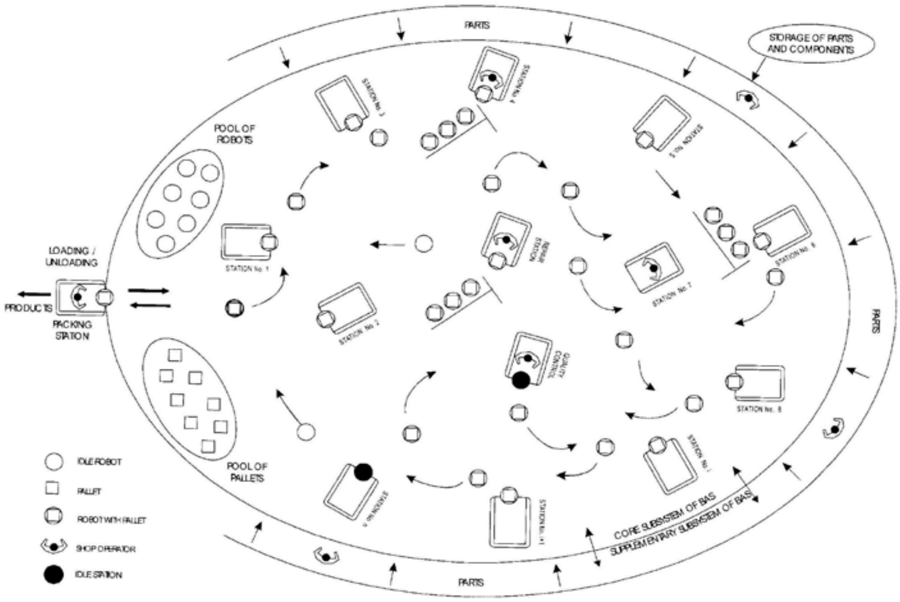

Fig. 4. Layout of a Bionic Assembly System

Start
{
robot state after the last operation {the type of the assembly pallet, the status of pallet, the type of product, the next step of assembly, the quality state of product}

if {the next step of assembly is packing}
then {the new assembly order, a robot has to go to the loading/unloading station}

if {the quality state of product is negative}
then {the robot has to go the repair station. wait to the shop floor operator. the shop floor operator will try to repair the product. if this is not possible, he will remove it from the system, and will prepare the pallet and the mobile robot for assembling of the next (new) product. the results of repair operation: the state of assembly and the quality state}

if {a cell becomes active or passive}
then {the rearrangement of the queues of alternative cells}

if {the quality state of product is positive and the next operation is assembly operation}
then {find out which cell(s) can perform the next assembly operation; if there are more than one, find out which is better, taking into consideration existing queues and priorities}

if {the mobile robot is present and the cell is busy or there are waiting robot(s) with equal or higher priority or there are robot(s) of equal priority which are waiting for longer time}
then {the mobile robot has to wait in the queue of the cell for the next operation}

if { the cell is free and there are no robot(s) with higher priority in the queue}
then {docking, execute assembly operation, check the quality of results of the assembly operation, write the new state of assembly and the quality state of product, undocking}
robot state after the last operation
}
End

Fig. 5. Basic algorithm of mobile robot working scenario

6. CONCLUSION

1. Self-organization is one of the fundamental principles that appear in nature.
2. Self-organization is characterized by tendency to order and it can manifest form, structure and behavior.
3. Self-organization is a complex furnishing of form, structure or behavior at the global level, which arises from the goal directed behavior of system components at the local level.
4. Self-organizing systems in nature do not have a predefined global goal which should be achieved. They reach the goal,

which is the result of interaction and goal directed activities at the local level, and interference from the external environment.
5. Self-organization in the technique has long been known at the level of simple devices, such as separator, the orientation of the montage, the montage separation, magnetic circuits, etc. These devices follow the principle idea of reducing the level of chaos and increase the level of order.
6. In recent years, appear the concepts of self-organizing complex production and assembly systems. One of them is shown in this paper who proposed Katalinic 1999.
7. Key differences between self-organizing systems in the nature and those in the technique is that these in the technique have predefined global goal, such as the production plan. This is the key difference that makes a barrier to taking a solution from the nature in the technique.
8. In the future is fundamental needed work out restart, shutdown and reconfiguration of the system.

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8. ADDITIONAL DATA ABOUT AUTHORS

Professsor Dr. sc. Dr. mult. h.c. **Branko Katalinic,** President of DAAAM International, TU Wien, IFLT-IMS, Karlsplatz 13/311, 1040 Wien, Austria, Europe E-mail: president@daaam.com katalinic@mail.ift.tuwien.ac.at

Dipl.-Ing. **Paulina Cesarec**, PhD Student, Secretary of DAAAM International, TU Wien, IFT-IMS, Karlsplatz 13, 1040 Wien, Austria – Europe, E-mail: cesarec@mail.ift.tuwien.ac.at

Dipl.-Ing. Dr. techn. **Markus Stopper,** Böhnelstr. 2/4, 2531 Gaaden, Austria, EU, markus@stopper.co.at

Dipl.-Ing.(FH) **Roman Kettler,** PhD Student, TU Wien, IFT-IMS, Karlsplatz 13, 1040 Wien, Austria – Europe, E-mail: kettler@mail.ift.tuwien.ac.at