Practical Systems Thinking

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Abstract. System is a dynamic and complex whole, interacting as a structured functional unit. Systems thinking provides tools for understanding a such system structure and its dynamic behavior. Practical systems thinking course teaches first year bachelor students basics about systems and how open problem can be formulated to system task.

1. Introduction

Systems thinking is the process of understanding how things influence one another other within a whole. Systems thinking has been defined as an approach to problem solving, by viewing problems as parts of an overall system, rather than reacting to specific part, outcomes or events and potentially contributing to further development of unintended consequences.

This paper discusses of systems and systems thinking with the course directed to first year bachelor students – practical systems thinking. This is a course in which we try to hook students to study automation and measurement technology. Almost every problem can be addressed through systems thinking and this course teaches students to think first before doing.

Metrology consists also lot of different systems – measurement models and systems. What to measure and how often. Students should learn to think systems as dynamic whole with internal and external relations. Also modelling is important subject which is addressed in this course.

This paper is organised as follows: first system and systems thinking are explained and furthermore the practical systems thinking course is described with objectives and implementation. After that three examples of the posters made by students are presented. Paper ends with some conclusions.
2. System

System is a dynamic and complex whole, interacting as a structured functional unit. From analytical point of view system is (stochastic) entity defined by (partial) differential equations.

In nature, system examples include ecosystems in which various elements such as air, water, movement, plant and animals work together to survive or perish. In organizations, systems consist of people, structures, and processes that work together to make an organization healthy or unhealthy.

Basic concepts and operations of systems include: flow, separation, combination, conversion, feedback, delay, tank/storage, disturbance, measurement and causality. [1 – 4]

Example of the system [4] – Animal species coexistence, where species compete exactly same nutriment. Breeding is assumed to follow (exponential) differential equation, \[ \frac{dN(t)}{dt} = \lambda N(t) \], and mortality includes effects from natural loss and nutrition then causal loop diagram looks like following:

![Causal loop function of animal species coexistence example.](image)

Mortality (\( \mu \)) depends on how sufficient nutrition is for two species, \( \mu_i = \gamma_i + \delta_i(N_1 + N_2) \). Combining birthrate and mortality we get:

\[
\frac{dN_1}{dt} = (\lambda_1 - \gamma_1)N_1 - \delta_1(N_1 + N_2)N_1 \\
\frac{dN_2}{dt} = (\lambda_2 - \gamma_2)N_2 - \delta_2(N_1 + N_2)N_2 
\]

Differential equation pair is not solvable analytically but it can be simulated and when feeding exactly same nutriment only one species can survive. This is what happens in nature – species living in same area develop specific diet.
2.1. Systems thinking

Systems thinking provides tools for understanding a system structure, system as a whole and dynamic behaviour of a system. Contrary to traditional analytical thinking elements of the system cannot be examined only as distinct elements but also the examination of interaction between system elements is essential. With systems thinking we try to understand something about the real world by building a causal loop models with components that are interacting at system under study. In systems thinking studied system is understood (and described) as a whole, as systems in which recognizable limits, elements and actors can be determined. Concept model of the system is essential part of systems thinking. [1-4]

Open system is interacting with its environment and deals information and energy with it. Closed system is self-sufficient. System can have subsystems, it can be part of bigger system and systems can have interactions.

Basic elements of systems thinking are:
- State variables
- Causal loops
- Delay
- Loops by interaction (feedback)

Process of systems thinking [3]:
- Definition of problem and concept analysis
- Dynamic hypothesis
- Formulation of simulation model
- Testing
- Improvement and evaluation
- Start over

3. Practical systems thinking course

This course is planned for first year students and it is mandatory for students studying automation technology. This includes also students studying metrology and measurement technology.

3.1. Objectives of practical systems thinking course

Objective is to develop and learn an ability that student can formulate an open problem to systematic task. In this course there is no need for mathematics yet, although it is shown what kind of mathematical tools is needed later when tasks are solved.

3.2. Implementation

Students are divided to small groups (approx. 7) and tutor is assigned to every group. Tutor in this case is senior member of faculty staff. Normally there are 8 – 10 such groups with different system problem. Work in the groups teaches group dynamics and team work. Tutor is a guide giving directions but not providing answers to student group.

Exercise subjects vary from house building process to vaccination protocol of swine flu and from optimization of elevators to stream of fashion goods. Also the constraints conditions vary from group to group. But basically the given problem is not well defined, only couple of sentences long.
Lectures include 6 sessions, 2 hours each, with subjects – introduction, basic concepts and operations of systems, examples of different systems and their behavior, large and detailed example of system building, and from structure to solutions: how much mathematics a student should study. These lectures give a basic vision to student what is system, what are the building blocks and how they behave.

With tutor there is also six sessions with group meetings between these weekly sessions.

1. Familiarize yourself with given problem and conduct a concept analysis.
   - The problem is illustrated and opened with the tutor. Students write down concepts of given problem and try to group and prioritize them.
2. Find the correspondence between concepts of given exercise and basic concepts of system.
   - What affects and where? What flows and what accumulates? What causes these?
3. First sketch of a system model.
   - Partial models and hierarchy. Inputs and outputs of partial models.
4. Creative work
   - Structure of system with alternatives.
5. Finishing the system model (block diagram)
   - Convergence of system model. Testing and thinking of different use-cases.
6. Improve the solution and designing a poster
   - Self-assessment and group assessment. Practical issues for making the poster

This all leads to public poster session, where students present their exercise and solution to other tutors and students.

4. Posters

In poster session student groups presents their exercise and solution in a form of poster to other students and tutors. In this chapter we will present three examples of these student posters. Common in all posters are certain system elements – concepts, variables, measurements, constraints and system model – as well as background information about the task given.

In first poster (figure 2.) topic is house building and idea was to simplify house building process from planning to actual building. Poster shows two part block diagram with different tanks, feedback loops and valves. Also delays, possible error locations as well as measurements and disturbances are presented.
Background for second poster (figure 3.) is how fashion clothing is distributed from wholesale to shops so that almost all clothes are sold to customers and there is no need for sale. Poster shows block diagram of how money and merchandise moving and affecting to the whole system. There is also discussed what inner and outer competition are meaning and what are the means for this competition.
Figure 3 Poster 2 -

Third poster is about the small family company which are fishing rare but delicious fish. Now there are also other fishers around and some regulations of when and how small fish you can try to catch. Poster shows concepts, different stages of the work and three block diagrams (recourses, fishing and fish stocks) as well as some concluding remarks.
5. Conclusions

This paper has been discussing systems and systems thinking. We have presented a course - practical systems thinking in which learning events are implemented as small groups with supervising tutor. This course teaches students a basic about the system and systems thinking and encourages them to think. Furthermore students learn about the group dynamics and how to work in a supervised group. The result of student group is a poster and this paper has presented three examples.
This course has now been implemented two times and time will show how good it is for hooking students to study automation and measurement technology.

References
[1] Boardman J and Sauser B 2008 *Systems Thinking: Coping with 21st Century Problems* (CRC Press)
[2] Gharajedaghi J 2006 *Systems Thinking: Managing Chaos and Complexity* (Elsevier)
[3] Sterman J D 2000 *Business Dynamics: Systems Thinking and Modeling for Complex World* (Irwin McGraw-Hill)
[4] Ritala R et al 2010 Lecture notes