ENES 489 Exercises Institute for Systems Research
Last updated: September 13, 2012.

Homework 1

Students may work in pairs. Due date: September 13.

Systems Thinking

Although there are no hard-and-fast rules for determining exactly what a system is, we are nonetheless motivated to study systems as a means of understanding and dealing with the complex world within which we live. For our purposes, a system is:

> **... a collection of components (some of which can be modules and subsystems) that are interconnected so that the system can perform a function which cannot be performed by the components alone.**

Systems may consist of products, people and processes. In some scientific endeavours (e.g., biology, astronomy) the principle objective is to observe a system with the goal of creating simplified models of behavior and structure. Systems engineers are concerned with design – we want to create new things out of things that already exist – and, as such, we need to work with representations of system structure, system behavior, and the relationship of behavior to structure.

System Structure. To understand and deal with complex systems as a whole, we must impose some structure on it.

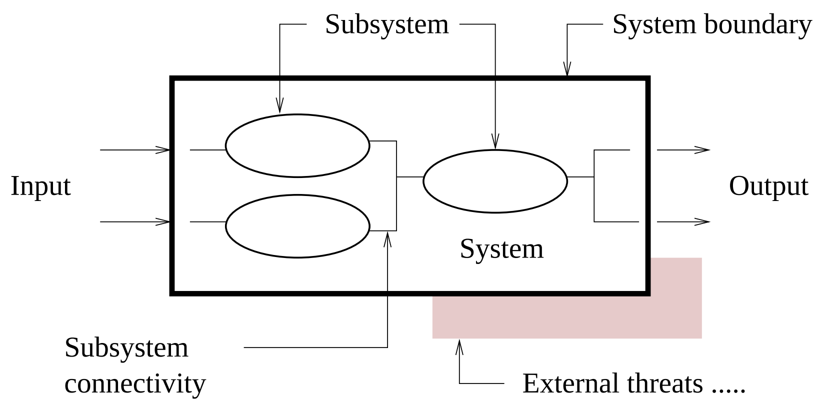

Figure 1: A system and its boundaries.

Figure 1 is a schematic of a system, its boundaries, inner components and subsystems, and mechanisms for communication with the surrounding environment (via inputs and outputs).

Transformational System Behavior. A system is a process that receives one or more system inputs **I** from an external environment, transforms them with process **T**, and then releases them as system outputs **O** to an external environment. See Figure 2. This input-output (I/O) relationship can be expressed symbolically as

$$T(I) = O \quad \text{or} \quad T : I \rightarrow O. \tag{1}$$

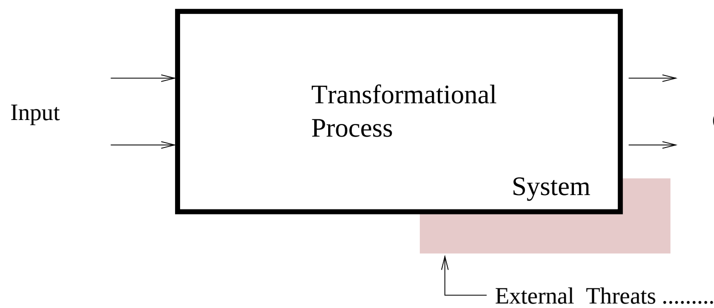

Figure 2: A transformational system.

A transformational system generates an output and then terminates. When a transformational system interacts with the environment, usually it is to gather information to produce the output.

Reactive System Behavior. A reactive system is a system that, when turned on, is able to create desired effects in its environment by enabling, enforcing, or preventing events in the environment.

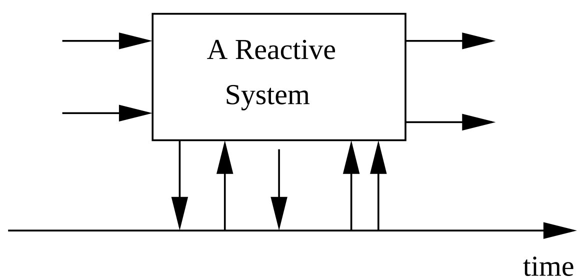

Figure 3: Elements of a reactive system.

As illustrated in Figure 1, reactive systems are involved in a continuous interaction with the environment. The environment:

...generates input events at discrete intervals through one or more interfaces

and the system reacts by changing its state and possibly generating output events.

Reactive systems typically exist to collaborate or interact with some entity or entities in the environment (e.g., traffic controllers; process control).

They never have all of their inputs ready – rather, the inputs arrive in endless and perhaps unexpected sequences.

Things to Do

Question 1. Figure 4 is a schematic of the TEM 4500 Egg and Muffin Toaster, a do-it-all kitchen appliance that is advertised as being able to poach or boil two eggs to perfection in 4 minutes, while simultaneously toasting 4 slices of bread, bagels, English muffins, crumpets, or whatever else you can fit into the extra-wide variable toasting slots.

Figure 4: TEM 4500 Egg-and-Muffin toaster. Source: http://www.ohgizmo.com/2008/03/24/ egg-muffin-toaster-part-of-this-balanced-breakfast/

Things to do:

1. Create a list of system functions that might be of interest a potential customer.

2. Draw and label a schematic of the system structure.

3. Describe the system inputs and outputs.

4. Describe the system boundary. What things will be outside the boundary, what things will be inside the boundary?

5. Create a flowchart to illustrate usage of the TEM 4500 from a customer's point of view.

6. Create a flowchart to illustrate reactive (machine) behavior of the TEM 4500.

7. Briefly describe how elements in the systems structure will support elements of the system behavior.

8. For at least one feature of the system, describe either an alternative design or a range of variability. Compare the alternatives to the chosen system.

Question 2. Most real-world systems have structure and behavior that is a lot more complicated than implied by Figures 1 - 3. Two common sources of complication include the existence of multiple system structures (and, hence, they must be designed to satisfy a multiplicity of physics), and the existence of concurrent subsystem behaviors. With this observation in mind, briefly describe the system structures and concurrent system behaviors that might be important in design of the F/A-18 Hornet Aircaft shown on the front cover of the Lecture Notes.