Analysis and Synthesis of the Term System

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May 11, 2022

1 Analysis

Ackoff defines a system as "a whole consisting of two or more parts" [5], and categorizes systems into three categories: mechanical, organismic, and social. A mechanical system displays no choice nor any purpose of its own, and is dictated by its structure and the laws of nature [5]. Mechanical systems are either open, where events outside the system affect the system's behavior, or closed where outside events do not affect behavior. Organismic systems are inherently open systems with at least one purpose or goal of their own. Social systems also are open systems with at least one purpose of their own and have at least some parts that have their own purposes. Social systems are part of a larger system that also have their own purposes, like how the 50 states are part of the United States. Systems that involve people are best understood when categorized as social systems. Anything that can be defined as a system can fit into one of these categories, and those that involve people are best categorized as a social system.

Ackoff's definition comes from his experience as a manager. Despite this, his definitions are broad and provide a good basis to understand any type of system, whether it be a large business or a small computer. Understanding the internal purpose of a system is necessary to understand the system as a whole. While machine systems, like computers, have no internal purpose of their own, social systems like countries and businesses do. The absence of an internal purpose in a computational system is important to understand how they are designed. These systems are designed to fulfill external purposes, like Ackoff's example of business during the industrial revolution, where businesses were made of replaceable parts whose purpose was to make its owner money [5]. Understanding the internal purpose or lack thereof is vital to understanding the system being studied.

Reason defines a system as the organizations and rules that individuals fall under [4] . This definition comes from the system approach over the human error problem. The system approach to the human error problem is the belief that errors come from systemic factors, and while we cannot change the human condition, we can change the conditions humans work under [4]. This viewpoint is in stark contrast to the person's approach, which believes that the fallibility of human beings is to blame. Reason calls this approach dangerous, as it often takes emotional satisfaction by blaming individuals instead of fixing system problems, like the Soviet Union after the Chernobyl disaster. Reason's definition of a system comes out of a need to source the problem of human error.

Reason is correct in his analysis of the problem of human error. When decisions are made to punish an individual, rather than fix the systemic problem, more errors are often made. Reason's Swiss cheese model of system accidents provides the two factors that cause the holes that represent vulnerabilities: active failures and latent conditions [4]. Outside of malice, I believe that latent conditions, the weaknesses and pathogens within the system, represent the most dangerous causes of errors. For example, while human error was responsible for the meltdown at Chernobyl, the lack of safety precautions and emergency shutdown procedures caused the situation to go from bad to catastrophic. Systems must be built to withstand and manage human error, since there is no way to remove human error from the equation.

Parnas defines systems into two categories: digital systems and analog systems. Digital systems are made from components with a finite number of stable states, while analog systems are made from components with an infinite number of states, modeled by continuous functions [3]. Analog systems make up the core of traditional engineering and contain no hidden surprises (bugs). On the other hand, digital systems have a discrete structure that makes a complete understanding of them very difficult, if not impossible. The complexity of digital systems means that they do not have the same reliability as analog systems [3]. The two definitions that Parnas defines are at odds with one another, as analog systems are traditionally reliable and stable, while digital systems are not.

Parnas's definitions are vital to his argument that the Strategic Defense Initiative is not possible due to the limitations of software. Parnes is correct when he says that software and digital systems are inherently unreliable. Everyday we see new exploits and bugs appear in digital systems, even for mature software like Log4j. This is due to the unknowns that come with developing software. Parnes believes the unknowns surrounding enemy missiles and the lack of any ability to test for them makes the SDI impractical [3]. As long as there are future unknowns that software systems must account for, software will be unreliable.

2 Synthesis

The word system is a broad term that encompasses things that are made of two or more parts that work together in some way. This general definition is so broad that it encompasses almost everything in the universe, from cells to galaxies. The definition and rubric of a general system must be inclusive enough so that Ackoff's three types of systems, Reason's definition and swiss cheese model, and Parnas' digital and analog systems are all included, despite their differences.

While the definitions authors and researchers may give to the word system differ, there are a set of features that all systems have in common. The rubric of a general system states that in a general system:

1. There are two or more parts.
2. The parts all work together in some way.
3. There are a set of rules, protocols, or procedures that prescribe how the parts are supposed to work together.

This rubric, much like the definition, is broad. An atom would fit into this rubric as it is made up of three parts: protons, neutrons, and electrons, that all work together under the laws of physics and nature. The US government would also fit into this rubric, since it is made of many branches and organizations that work together under the framework of the constitution. The rubric and definition of a general system serve as a basis for more specific types of systems to be built and defined on.

One of these more specific types of systems is a computational system. From its name, we can tell that a computational system is a system that performs computations or calculations. These computations and calculations can involve almost anything, from simple addition and string parsing to neural networks predicting whether a tumor is malignant or benign. On top of this, computational systems can be either mechanical or organismic. The computers and calculators we have today possess no internal purpose, and thus by Ackoffs definitions are mechanical systems [5]. However, the human brain is also able to perform calculations and computations and possesses the internal purposes of the human it resides in. These differences require a broad rubric that doesnt discriminate based on whether something is made of meat or metal.

The rubric of a computational system states that on top of all the requirements of a general system, a computational system must be able to:

1. Take in some type of information;
2. Perform computations or calculations with the inputted information; and
3. Output the results in some way or manner.

Without being able to take in any information, such as numbers or bits, a computational system would have nothing to calculate or compute. Without being able to output the results of the computations, there is no way of knowing whether or not the system computed anything in the first place. While being much more restrictive than a general system, these requirements still allow for both mechanical and organismic systems to be classified as computational systems.

3 Application

The internal combustion engine follows all three requirements to be considered a general system. According to the Wikipedia article, an internal combustion engine is made up of multiple parts, including pistons, rods, spark plugs, and valves, which work synchronously to convert chemical energy into kinetic energy [6]. On top of this, each type of internal combustion engine is designed to work in a specific way and follow specific procedures in order to perform its function. However, the internal combustion engine does not take in any information nor perform any computations or calculations on its own. It only performs the one task it was designed to do, convert chemical energy into kinetic energy [6]. As such, the internal combustion engine is just a general system.

The human brain follows all three requirements to be considered a general system and follows the additional requirements to be a computational system. According to Ballard, Somewhere between ten to one hundred billion brain cells act in ways unlike any other cells in the body, forming tangled networks of interconnections, and each of these cells is in itself a small factory of thousands of proteins that orchestrate a myriad of internal functions [1]. The fact the brain is made up of billions of independent cells that work together to perform complex tasks shows that it follows the requirements to be considered a general system. One of the examples that Ballard brings up on page twenty-two shows how the brain follows the requirements to be considered a computational system. In order to make a peanut butter and jelly sandwich, the brain must process the raw information obtained from the eyes and turn it into usable information.[1] It then must determine the exact muscle movements required to open the jars and make the sandwich. These outputs of muscle movement require intense calculations.[1] Thus, the brain follows all three requirements to be considered a computational system.

The world wide web follows the three requirements to be considered a general system, but does not follow the rubric to be a computational system. According to Berners-Lee, his vision of CERN and the World Wide Web is a decentralized system made up of connected nodes (computational systems) that allows for easy access to existing information. This protocol would allow for any type of system to access the same data. [2] While this definition follows all three requirements to be a general system, it doesnt meet the requirements to be a computational system. The World Wide Web is an information system that allows for easy access to data from any node on the network, but it doesnt perform any of the computations or calculations needed to create that data. Rather, the computational systems its made up of perform these calculations. The world wide web is the highway network that allows computers to access each others information.

References

[1] Dana H. Ballard. *Brain Computation as Hierarchical Abstraction*, chapter 1. The MIT Press, 2015.

[2] Tim Berners-Lee. Information management: A proposal. `https://www.w3.org/History/1989/proposal.html`, 1989.

[3] David Lorge Parnas. Software aspects of strategic defense systems. *Communications of the ACM*, 28(12):1326–1335, December 1985.

[4] James Reason. Human error: models and management. *BMJ*, 320:768–770, 2000.

[5] Russell L. Ackoff. Systems thinking and thinking systems. *System Dynamics Review*, 10(2–3):175–188, Summer–Fall 1994.

[6] Wikipedia. Internal combustion engine. `https://en.wikipedia.org/wiki/Internal_combustion_engine`, 2022.