Linking Autopoiesis to Homeostasis in Socio-Technical Systems

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Abstract. The paper considers two seemingly different fundamental theoretical concepts of autopoiesis and homeostasis and tries to apply them to the realm of socio-technical systems. The paper uses a so-called Fractal Enterprise Model (FEM) to explain how autopoiesis – a system constantly reproducing itself - and homeostasis – a system constantly maintaining an approximate identity while adapting to changes in its internal and external environment – works, and how they are connected to each other. The work presented in this paper is in its initial stage, and more efforts are required to convert the ideas presented in the paper to something that can be used in practice.

Keywords: socio-technical, autopoiesis, homeostasis, fractal enterprise model

1 Motivation

The term autopoiesis comes from biological cybernetics, first introduced in [1] to identify the particulars of living systems that differentiate them from other type of systems. The term means that a living system constantly reproduces itself. More exactly, an autopoietic living system/organism, according to the original authors who coined the term, consists of a network of molecular processes that constantly reproduce the components of the system.

Though the term autopoiesis was introduced for describing biological systems, it soon was reinterpreted for other types of systems, sociological systems in the first place. The most known application of the concept of autopoiesis to the realm of the social world is the one introduced by N. Luhmann [2]. Luhmann identifies two types of autopoietic systems, a system of communication, and a system of decision (an organization). The first one always produce new communication acts based on already existing ones, the second constantly produce new decisions based on already made ones. Luhmann was not the only one who applied the concept of autopoiesis to the social realm. The literature on this topic is vast; it includes books, e.g. [3], and articles, and it encompasses different ideas of what is being reproduced by a system. One of the most used ideas of what is to be reproduced, besides what Luhmann has proposed, is knowledge, see, for example, [4].

Using the concept of autopoiesis outside biology is still a controversial issue. The opinions on this issue range from disagreement from the authors of the concept, to considering any autopoietic system as being a social system. The latter is promoted by Milan Zeleny and his group, see, for example, [5] where they present examples of social system showing that they all satisfy the 6 point test suggested in [1]. In this respect, it is interesting to read [6] which includes post-reviews from the major personalities related to the concept of autopoiesis, including Humberto R. Maturana and Milan Zeleny.

Though the original concept of autopoiesis in biological systems was focused on the reproduction processes, what is being reproduced is also considered important. This is true even for biology itself, see, for example, [7], which argues that considering an autopoietic system just as a network of processes is not enough; the body of an organism should also be taken into consideration.

The question that we want to raise in this paper is whether it is possible to apply the concept of autopoiesis to socio-technical systems. As socio-technical systems are considered as consisting of two components social and technical, applying the concept of autopoiesis to such systems implies reproducing both components. Moreover, if we consider that each component can be split in two parts according to a classical Socio-Technical System (STS) matrix [8], applying the concept of autopoiesis means reproducing, people, structure, tasks and technology. In summary, when applying the concept of autopoiesis to a socio-technical system, such as an enterprise, we need to answer two questions:

1. What is reproduced (body)?
2. How is it done (network of processes)?

In parallel to the concept of autopoiesis that is focused on the system constantly reproducing itself, there is a seemingly different concept, called homeostasis, of a system maintaining an approximate identity despite it being made of unstable material and subject to an ever changing environment [9]. Despite the different focuses and different assumptions, e.g. close system for autopoiesis vs. open system for homeostasis, there is a connection between these two concepts. Therefore, in addition to the two questions we formulated above, we will consider a third one:

3. How the autopoietic activities help with homeostasis, i.e. adapting the system to the changes inside and outside the system while maintaining its identity.

To answer the above questions, we will be using a special type of enterprise models called a Fractal Enterprise Model (FEM) [10]. FEM has a form of a directed graph with two types of nodes *Processes* and *Assets*, where the arrows (edges) from assets to processes show which assets are utilized by which processes and arrows from processes to assets show which processes help to have specific assets in "healthy" and working order. The arrows are labeled with meta-tags that show in what way a given asset is utilized, e.g. as *workforce*, *reputation*, *infrastructure*, etc., or in what way a given process helps to have the given assets “in order”, i.e. *acquire*, *maintain* or *retire*.

A FEM is built recursively by using a so-called unfolding procedure and two types of archetypes: *process-assets archetypes* that show which kind of assets might be needed for running a process, and an *asset-processes* archetype that shows which processes are needed to maintain an asset in order. Unfolding starts with a primary process - a process that delivers value to a customer/beneficiary - by applying process-assets archetypes and alternating them with the asset-processes archetype.

The presence of such processes as *acquire*, *maintain* and *retire* makes FEM interesting when considering autopoiesis and homeostasis in socio-technical systems. These processes are the ones that constitute the net of processes responsible for autopiesis. They, also, are the ones that can inform the system of changes in its internal or external environment.

The rest of the paper is structured in the following manner. In Section 2, we present our knowledge base, which includes Zeleny's approach to describing processes in autopoietic systems [5], the notion of homeostasis and FEM. In Section 3, we use FEM to answer the first two questions posed above. Section 4 is devoted to answering the third question. Section 5 contains concluding remarks and plans for the future.

2 Knowledge base

2.1 General Processes in Autopoietic Systems

According to Zeleny [5], there are three general types of processes in an autopoietic system: (1) Degradation, (2) Production and (3) Bonding, see Fig. 1.

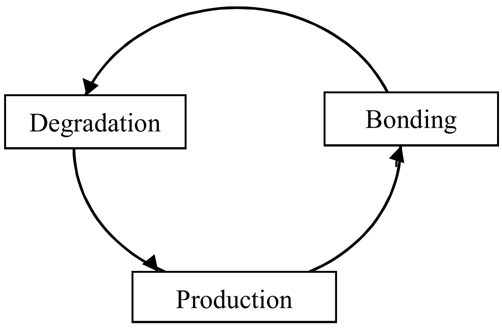

Fig. 1. Generic processes in an autopoietic system, adapted from [5]

Production is a process of creating new components. *Bonding* is a process of introducing new components into the system structure. *Degradation* is a natural process of components aging and falling out of the system structure, which requires production of new components to be bound into the structure. The specific meaning of these generic processes depends on the system in question. In a post-review by Zeleny [6] there are several examples of instantiation of the generic process.

2.2 Homeostasis

The concept of homeostasis predates autopoiesis by about 40 years. It was defined by Cannon in the 1920s [9] based on research done during the 19th century by Claude Bernard. Just like Maturana and Varela, Cannon (and other Physiologists) attempted to explain the mystery of life.

Cannon stipulated that what distinguishes the living organism is its ability to maintain constancy despite it being subjected to internal and external perturbations. This constancy, Cannon claimed, is the source of freedom of action [11], [12]. The better the living organism maintains its constancy the more it can take control of its environment. Mammals, for example, have better mechanisms than reptiles for maintaining the constancy of their body temperature and are therefore better able to function irrespective of the ambient temperature.

Autopoiesis can be seen as a special case of homeostasis because constantly reproducing itself is one consequence of the maintenance of global constancy. Homeostasis is also more general because it applies to any open system that is [9]: "compounded of unstable material and subjected continually to disturbing conditions." i.e. systems that are subject to the second law of thermodynamics, the increase of entropy (disorder) in any closed portion of the universe [12].

Autopoiesis, on the contrary, is principally applied to the description of living systems, which it defines as closed systems.

Cannon enounced 6 propositions that define a homeostatic system [[12]. The first one is sufficient for our present discussion. It says that [9], [12]:

> *In an open system, such as our bodies represent, compounded of unstable material and subjected continually to disturbing conditions, constancy is in itself evidence that agencies are acting or ready to act, to maintain this constancy.*

Thus, homeostasis explains both the process of degradation (unstable material and disturbing conditions), the need for process of replacement, production and bonding, (maintaining constancy). It also shows that both the internal environment and the external environment are sources of change, mostly unwelcome change, that the system attempts to deal with in order to maintain its constancy.

Cannon envisioned that the principles of homeostasis could be applicable by analogy to the study of social systems [11], [12] and even socio-technical systems [11]. He, for example, foresaw that technical innovations can remove the jobs of scores of people, leading to the need to restore (maintain the constancy of their life conditions) by providing unemployment benefits and retraining [11].

2.3 Fractal Enterprise Model

A Fractal Enterprise Model (FEM) includes three types of elements: business processes (more exactly, business process types), assets, and relationships between them, see Fig. 2 in which a fragment of a model is presented. The fragment is related to a hypothetic management consulting company. Graphically, a process is represented by an oval, an asset is represented by a rectangle (box), while a relationship between a process and an asset is represented by an arrow. We differentiate two types of relationships in the fractal model. One type represents a relationship of a process "using" an asset; in this case, the arrow points from the asset to the process and has a solid line. The other type represents a relationship of a process changing the asset; in this case, the arrow points from the process to the asset and has a dashed line. These two types of relationships allow tying up processes and assets in a directed graph.

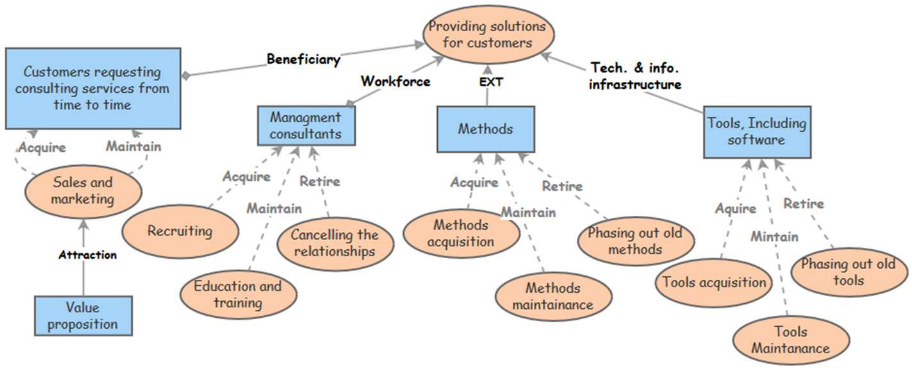

Fig. 2. A fragment of a FEM for a management consulting company

In FEM, a label inside an oval names the given process, and a label inside a rectangle names the given asset. Arrows are also labeled to show the type of relationships between the processes and assets. A label on an arrow pointing from an asset to a process identifies the role the given asset plays in the process, for example, *workforce*, and *infrastructure*. A label on an arrow pointing from a process to an asset identifies the way in which the process affects (i.e. changes) the asset. In FEM, an asset is considered as a pool of entities capable of playing a given role in a given process. Labels leading into assets from supporting processes reflect the way the pool is affected, for example, the label *acquire* identifies that the process can/should increase the pool size.

Note that the same asset can be used in two different processes playing the same or different roles in them, which is reflected by labels on the corresponding arrows. It is also possible that the same asset can be used for more than one role in the same process. In this case there can be more than one arrow between the asset and the process, but with different labels. Similarly, the same process could affect different assets, each in the same or in different ways, which is represented by the corresponding labels on the arrows. Moreover, it is possible that the same process affects the same asset in different ways, which is represented by having two or more arrows from the process to the asset, each with its own label.

In FEM, different styles can be used for shapes to group together different kinds of processes, assets, and/or relationships between them. Such styles can include dashed or double lines, or lines of different thickness, or colored lines and/or shapes. For example, a diamond start of an arrow from an asset to a process means that the asset is a stakeholder of the process (see the arrows "Workforce" in Fig. 2).

Labels inside ovals (which represent processes) and inside rectangles (which represent assets) are not standardized. They can be set according to the terminology accepted in the given domain, or be specific for a given organization. Labels on arrows (which represent the relationships between processes and assets) can be standardized. This is done by using a relatively abstract set of relationships, such as, *workforce* or *acquire*, which are clarified by the domain- and context-specific labels inside ovals and rectangles. Standardization improves the understandability of the models.

While there are a number of types of relationships that show how an asset is used in a process (see example in Fig. 1), there are only three types of relationships that show how an asset is managed by a process – *Acquire*, *Maintain* and *Retire*.

To make the work of building a fractal model more systematic, FEM uses archetypes (or patterns) for fragments from which a particular model can be built. An archetype is a template defined as a fragment of a model where labels inside ovals (processes) and rectangles (assets) are omitted, but arrows are labelled. Instantiating an archetype means putting the fragment inside the model and labelling ovals and rectangles; it is also possible to add elements absent in the archetype, or omit some elements that are present in the archetype.

FEM has two types of archetypes, process-assets archetypes and an asset-processes archetype. A process-assets archetype represents the kinds of assets that can be used in a given category of processes. The asset-processes archetype shows the kinds of processes that are aimed at changing the given category of assets.

Note that in FEM each process node is connected to assets representing different sides of a sociotechnical system, e.g. people (workforce), technology (technical and informational infrastructure). However, there is no explicit mentioning of these assets being aligned with each other. Implicitly such alignment is necessary for a process being able to function. Moreover, changes in any of the assets connected to a particular process node, e.g. people or technology, require readjustment of other assets connected to the node. This issue is covered in more details in [13].

3 What Components are Reproduced and How?

The basic idea of FEM is that any process (type) needs assets in order to be able to run its instances with a required regularity. These assets age/become depleted with time and need renovation/service or substitution with new ones. The substitution requires retiring old/depleted assets along with the introduction of the new ones. The assets management processes are attached to each asset with a dashed arrow and the labels *Acquire*, *Maintain* or *Require*. Without the management processes in place, the asset will be depleted and the process(es) that uses this asset will no longer be able to run new instances.

Note that a primary process in FEM also serves as an asset management process. For example, the root process in Fig.2 can be considered as a process of acquiring monetary funds and reputation of a reliable management consultant. The first is an asset that is needed for all processes, while the second is needed for sales and marketing – a customer acquiring process.

Based on the discussion above, we can conclude that a FEM model of an organization describes both the "body" of the organization – its assets, and the processes that are responsible for reproducing the body. Note that the concept of a body derived from FEM includes more than a traditional drawing of an organizational boundary, as it may include assets that strictly speaking are outside its full control, such as customers or partners (e.g., suppliers).

The generic reproduction idea in FEM is similar to the one suggested by Zeleny in Fig. 1, but is slightly different. Firstly, our *acquire* processes fulfill both purposes – getting new entities for an asset pool, and introducing them in the structure of the functioning organization. As an example, in Fig. 2, both processes *Recruiting* and *Education and training* are connected to asset *Management consultants*. In terms of Fig. 1, the first process can be roughly considered as *production*, and the second – as *bonding*. The other difference from Zeleny's generic framework – the latter does not name the maintenance processes explicitly.

From a systems perspective, a process node of FEM, with supporting assets, represents a work system responsible for initiating and finishing process instances of the given type. We call this system a Business Process Work System or BPWS for short. BPWS can be regarded as a socio-technical system as it include people, methods, e.g. manuals that prescribes the process flow, technology and structure – distribution of responsibilities between the members of the team responsible for the process. Note that the term *work system* was introduced by S. Alter, see, for example, [14], and BPWS can be considered as a particular class of work system.

A process instance is initiated based on a combination of external and internal conditions. An example of an internal condition for an *acquire* process is a resource depletion, real or expected. Let us illustrate how internal conditions work using the example in Fig. 2. When some of the management consultants suddenly leave, the pool of consultants becomes somewhat depleted, which gives a signal to starting an instance of the *Recruiting* process. Another internal signal to this end is when some consultant(s) is nearing the retirement age, and will need to be substituted. Recruiting a new consultant gives a signal to the *Education and training* to start an instance of this process.

Note that a Business Process Instance (BPI) can also been considered as a system that is created to handle a specific situation defined by a condition for creating an instance. This system can be considered as a respondent system in terms of [15] which is created to handle a specific situation and which is disbanded when the situation is resolved. When creating a BPI, BPWS gives it some of its assets to be engaged in the BPI. It also follows the work of BPI, and if needed can give more assets. After the BPI is finished, all assets are returned back to the BPWS. Note that assets may not be given exclusively, but may be shared with other BPIs.

4 Linking Autopoiesis to Homeostasis

In this paper, we consider homeostasis as an ability of a socio-technical system to (a) adapt itself to changes in the dynamic environment in which it operates while (b) maintaining its identity. These two sides of homeostatic behavior are considered in the following sub-sections. Note that, the reproduction of the body that can be considered as part of the homeostatic activities is not considered in this section, as it was already discussed in Section 3.

4.1 How the Adaptation Happens

While Section 3 explains how autopoiesis - body reproduction - works in a socio-technical system, it does not explicitly refer to the need for adaptation. The procedure of reproducing the system's "body" seems to work in a way that the body does not change. The depleted assets are being replenished by the same kind of entities, i.e. the same kind of customers, employees, technology, etc. This is not true in reality, as the replenishing the assets is often done by obtaining components from the outer world and bonding (the term used by Zeleny) them into the system.

To obtain new components to replenish assets, when an acquire processes needs to get some material from outside the system, the process might need to undergo some changes. For example, to acquire new customers (beneficiaries in terms of FEM), there might be a need to change the value proposition. This in turn, will require changing the products and/or services assortment, which will initiate changes along the design and delivery branch of the FEM tree. Note that the needs to adjust the offering may also be discovered by the customer maintenance process, i.e. the offering might need to be changed to retain the existing customers.

The same process for adapting to changes can be invoked by an acquire process for any other assets that require input from the environment. For example, when new equipment is purchased (the infrastructure type of assets), it may be more advanced than the previous one. This can lead to the need to retrain the staff (a *maintenance* process), and/or lead to the need to decrease the number of people employed (activates the retiring processes).

Summarizing the discussion above, any of the acquiring processes that needs to incorporate components from the environment into the system may initiate a chain of changes that leads to the system adapting to the induced change. The components that are obtained from the outer world may concern any side of the socio-technical system: people (hiring), technology (purchasing), methods (executable templates) and structures (organizational infrastructure, not shown in Fig. 2). Moreover, the change initiated in one place may affect other parts of the system. Some ideas about how such change can be propagated through the FEM structure are presented in [13].

4.2 What remains constant

In the previous section, we used FEM to explain how adaptation happens while the system reproduces itself by acquiring components from the outer world. This however, covers only one side of the concept of homeostasis – adaptation. The other side is the system maintaining identity while adapting itself to the changes in the environment. This, in turn, leads to the question of what constitutes identity of a socio-technical system. There is a vast literature on the concept of organizational identity starting with the seminal work [16] from 1985, revisited in [17] by one of its authors in 2006. However, in this work, we prefer to stay with the FEM model when discussing organizational identity.

From a FEM perspective, we can consider that the structure of the root fragment of FEM may represent the identity of the organization. The root fragment of FEM represents a primary process (in terms of FEM) that delivers value to the "external" beneficiaries (e.g. customers). As long as it stays the same on an abstract level, such as in Fig. 2, we can consider that the system has not changed its identity. For example, the root fragment in Fig. 2 shows the typical structure of a management consulting company, which will be the same as long as the company functions as a management consultancy. Note, however, that an organization can have several roots (primary processes) which can lead to a question whether the organization remains the same as some roots disappear or new roots are added.

In case of a radical transformation, the root fragment may change. In this case, we can consider that the identity has changed. Actually, this change will be seen by an observer. Assume, for example, that the company in Fig. 2 has an internal tool used for consulting, and it decides to become a tool provider and stop the management consulting activities. This decision can be considered as changing the company's identity. The company will no more provide management consulting services, but provide a tool for others, including their former competitors[1]. For more examples of radical transformation and how they can be depicted in FEM, see [18].

Note, however, that whether the identity has changed or not depends on the observer. In the example above, the identity change will, most probably be detected by potential customers and competitors, both old and new ones. A company that provides financial services to our management consultancy, e.g. bookkeeping, most probably, would not classify the change as identity change. Though they will observe the change, as the source of income changes, they may not consider that the company changes its identity. The same can be said about an internal observer who works on tool development. For him/her the company may look the same, though it depends on the scope of observation of a particular person.

Another way of defining identity comes from the concept of structural coupling, a concept closely related to autopoiesis [19]. The idea of structural coupling is relatively simple. There are elements of the environment that are more tightly connected to the given system (organization) than other parts of the system's environment. The system focuses on reacting to changes in these elements or trying to change them, while more or less ignoring other elements (systems) in the environment. Applying the idea of structural coupling to defining organizational identity was suggested in [20]. It amounts to defining the maintenance of identity, as maintaining structural coupling with the important elements of the environment.

Assume that that each acquiring process that relies on external components takes them from some external "pool" of such components produced by other systems in the environment. Then, we can consider that the system is structurally coupled to such a pool, or systems producing components for it. Continuing the deliberation, we can say

[1] For more examples of radical transformation and how they can be depicted in FEM, see [18].

that the identity of the system stays the same as long as all, or the most important, acquiring processes work with the same pools. Changing a pool constitutes structural recoupling, which may lead to changing the identity. Going back to the example when a management consultancy becomes a tool provider, this example constitutes a structural recoupling from the pool of organizations that need consulting help to the pool of organizations that needs a management tool (including other management consultancies).

5 Concluding remarks

The goal of this paper was to apply two systems concepts, autopoiesis and homeostasis, to the realm of socio-technical systems. More specifically, we wanted to clarify how autopoiesis and homeostasis work in such a system and, hopefully, find a linkage between the two. To achieve our purpose, we used FEM to model the operational activities of an organization on a high level. The model helped to define the notion of a body of a socio-technical system, and underline the processes used to constantly reproduce it. It also helped to explain how the adaptation to changes in the internal and external environments happens, i.e. through the reproduction processes discovering a change and initiating changes in other parts of the system's "body".

Note that this work is an initial stage, and more investigation is required to be able to use the ideas presented in this paper in practice. In particular, the mechanisms of propagating the need for changes throughout the whole body needs special attention. Some ideas on this issue are presented in [13].

References

1. Varela, F., Maturana, H. R., R., U.: Autopoiesis: The organization of living systems, its characterization and a model. BioSystems 5(4), 187–196. (1974)
2. Luhmann, N.: The autopoiesis of social systems. In Geyer, F., van der Zouwen, J., eds. : Sociocybernetic paradoxes. Sage, London (1986)
3. Magalhaes, R. ., ed.: Autopoiesis in organizational theory and practice. Emerald Group, Bradford (2010)
4. Blaschke, S.: The Autopoiesis of Organizational Knowledge, Learning, and Memory. In Magalhaes, R. ., ed. : Autopoiesis in organizational theory and practice. Emerald Group, Bradford (2010) 215-231
5. Zeleny, M.: On Social Nature of Autopoietic System. In Boulding, K., Khalil, E., eds. : Evolution, Order and Complexity. Taylor & Francis Group (1996) 122-145
6. Cadenas, H., Arnold, M.: The Autopoiesis of Social Systems and its Criticisms. Constructivist Foundations 10(2) (2015)
7. Virgo, N.: The necessity of extended autopoiesis. Adaptive Behaviour DOI: 10.1177/1059712319841557, 1-4 (2019)
8. Bostrom, R., Heinen, J.: MIS problems and failures: A socio-technical perspective. MIS Quarterly 1(3), 17-32 (1977)

9. Cannon, W. .: Organization for Physiological Homeostasis. Physiological Reviews IX(3), 399-431 (July 1929)
10. Bider, I., Perjons, E., Elias, M., Johannesson, P.: A fractal enterprise model and its application for business development. Software & Systems Modeling (2016)
11. Cannon, W. B.: The Wisdom of the Body. Norton & Company, New York (1939)
12. Regev, G., Hayard, O., Wegmann, A.: What We Can Learn About Business Modeling From Homeostasis. In Shishkov, B., ed. : LNBIP 142. Springer (2013)
13. Bider, I., Perjons, E.: Using Fractal Enterprise Model to Assist Complexity Management. In : BIR Workshops 2018, CEUR, Stockholm, vol. 2218, pp.233-238 (2018)
14. Alter, S.: The Work system method: Connecting people, processes, and IT for business results. Work System Press (2006)
15. Lawson, H.: A journey through the systems landscape. College Publications (2010)
16. Albert, S., Whetten, D.: Organizational identity. In : Research in Organizational Behavior 7. Elsevier, Oxford (1985) 263-295
17. Whetten, D. A.: Albert and Whetten Revisited. Strengthening the Concept of Organizational Identity. JOURNAL OF MANAGEMENT INQUIRY 15(3), 219-234 (2006)
18. Bider, I., Perjons, E.: Defining Transformational Patterns for Business Model Innovation. In : Perspectives in Business Informatics Research: 17th International Conference, BIR 2018, Stockholm, Sweden, LNBIP, vol. 330, pp.81-95 (2018)
19. Maturana, H.: Autopoiesis, Structural Coupling & Cognition. Cybernetics & Human Knowing 9(3-4), 5-34 (2002)
20. Hoverstadt, P.: Defining Identity by Structural Coupling in VSM Practice. In : UK Systems Society, Oxford (2010)

