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AUTOPOIETIC THEORY AS A FRAMEWORK FOR BIOMETRICS

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ABSTRACT

Autopoietic theory which represents a framework for describing complex non-linear and especially living systems is described in a context of biometric characteristics. It is argued that any living system by performing an internal process of reproducing its structural components yields physical biometric characteristics. Likewise any living system when structurally coupling to another (eventually allopoietic) system yields a behavioral or psychological characteristic of the living system. It is shown that any system that can be considered as autopoietic can potentially be measured, authenticated and/or identified using adequate biometric methods, and thus biometrics is applicable to any autopoietic system: living beings, groups of living beings, social systems, organizations as well as information systems. In the end implications of such a conceptualization are discussed as well as possible applications.

KEY WORDS

autopoiesis, biometrics, structural coupling, component reproduction

CLASSIFICATION

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INTRODUCTION

Before starting any discussion a brief introduction as well as definitions of basic terms shall be provided. First of all **autopoiesis** is a pseudo Greek word coined from αυτό (auto) for self and πόιησις (poiesis) for creation, production or forming that was first introduced by the Chilean biologists Humberto Maturana and Francisco Varela in 1973 [1] to denote the type of phenomenon they had identified as a characteristic that distinguishes living systems from other types of systems [2]. They claimed that living systems are autonomous entities that reproduce all their properties through their internal processes. Later on this term was introduced into social theory as well as formal organization theory by Niklas Luhmann [3] who claimed that social systems are systems of communication that emerge whenever an autopoietic communication cycle comes into being that is able to filter itself out of a complex environment. Luhman argues that there are three types of social systems: (1) societal, (2) interactional as well as (3) organizational. Any social system has its respective information subsystem described through their communicative processes [4-5]. Systems that are not autopoietic (systems that produce something other than themselves) are considered to be allopoietic (technical) systems.

The term **biometrics** comes from ancient Greek words βιος (bios) for life and μετ ρον (metron) for measure, and thus it represents the measurement of the living. One can approach biometrics in a broader and in a narrower perspective. In the broader perspective biometrics is the statistical research on biological phenomena; it is the use of mathematics and statistics in understanding living beings [6]. In the narrower perspective we can define biometrics as the research of possibilities to recognize persons on behalf of their physical and/or behavioral (psychological) characteristics. We shall approach biometrics in the broader perspective in this paper.

A **biometric characteristic** is a biological phenomenon's physical or behavioral characteristic that can be used in order to recognize the phenomenon. In the narrower perspective of biometrics physical characteristics are characteristics that one is born with (like a person's face, iris, retina, finger, vascular structure etc.). Behavioral or psychological characteristics are characteristics that one acquires or learns during her life (like a handwritten signature, a person's gait, her typing dynamics or voice characteristics). Depending on the number of characteristics used for recognition, biometric systems can be unimodal (when only one biometric characteristic is used) or multimodal (if more than one characteristic is used).

A **biometric structure** is a special feature of some biometric characteristic that can be used for recognition (for example a biometric structure for the human biometric characteristic finger is the structure of papillary lines and minutiae, for the human biometric characteristic gait it is the structure of body movements during a humans walk etc.).

The word method comes from the ancient Greek μεθοδος (methodos) that literally means "way or path of transit" and implies an orderly logical arrangement (usually in steps) to achieve an attended goal [7]. Thus a **biometric method** is a series of steps or activities conducted to process biometric samples of some biometric characteristic usually to find the biometric characteristic's holder (in the narrower perspective) or a special feature of the biometric sample (in the broader perspective).

A model is a (not necessarily exact) image of some system. Its main purpose is to facilitate the acquiring of information about the original system [8]. A **biometric model** is thus a sample of a biometric system that facilitates the acquiring of information about the system itself as well as information about biometric characteristics. In [9-10] we showed that

biometric models consist of biometric methods for preprocessing and feature extraction, quality control as well as recognition.

A sample is a measured quantity or set of quantities of some phenomena in time and/or space. Thus a **biometric sample** represents a measured quantity or set of quantities of a biological phenomenon [10].

A **biometric template** or extracted structure is a quantity or set of quantities acquired by a conscious application of a biometric feature extraction or preprocessing method on a biometric sample. These templates are usually stored in a biometric database and used for reference during the recognition, training or enrolment processes of a biometric system.

Having the basic terms defined one can observe a clear connection between autopoiesis as a framework for describing the living and biometrics as a framework for measuring the living. To underline this connection we shall provide an in depth discussion of component reproduction as well as structural coupling with respect to physical and behavioral biometric characteristics.

COMPONENT REPRODUCTION

Varela gave the following definition of autopoietic systems ([11] adapted from [2]):

> "An autopoietic system is organized (defined as a unity) as a network of processes of production (transformation and destruction) of components that produces the components that:
>
> (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and
>
> (ii) constitute it (the machine) as a concrete unity in the space in which they [the components] exist by specifying the topological domain of its realization as such a network."

One should observe that there is a distinction between structure and organization (in Maturana's and Varela's sense). While structure is something that is visible (observable) from the outside, organization is unobservable and inside of the system. Structure comprises of a set of components or elements that are exchangeable (that is components change during time) and the mutual interactions between these components. Organization comprises of the relations between processes that produce these components and is stable over time. One can say that the structure resembles the visible image of the internal (non-observable) organization of the living being.

The important concept that shall be outlined here is the internal component reproduction process. One can easily depict this process in living systems which feed themselves with food from their environment that eventually after certain processes becomes an integral part of the living being, facilitating thereby the regeneration of the process.

Thus the only thing that can be observed and likewise sampled or measured from an observer is the structure of components reproduced by the internal organization of the autopoietic system. Since these components are considered to be integral parts of the system they will comprise biometric structures due to complex non-linear processes inside the system. These structures yield physical biometric characteristics. Using adequate biometric methods these structures can be sampled, processed and recognized. Depending on the uniqueness of the internal processes as well as environmental factors these characteristics will be more or less unique for the measured system.

STRUCTURAL COUPLING

The connection between an autopoietic system and its environment is denoted as structural coupling (shown on Fig. 1). "The result of structural coupling is an autonomous and strictly bounded system, that has nevertheless been shaped extensively by its interactions with its environment over time, just as the environment has been shaped by its interactions with the system" [12].

The interactions between an autopoietic system and any other (eventually allopoietic) system shape the behaviour of the autopoietic system during time depending on the characteristics of the environment. If an autopoietic system is structurally coupling to another autopoietic system, language emerges. Language is an important feature between autopoietic systems that is a requirement for the emergence of groups, social systems, organizations and information systems.

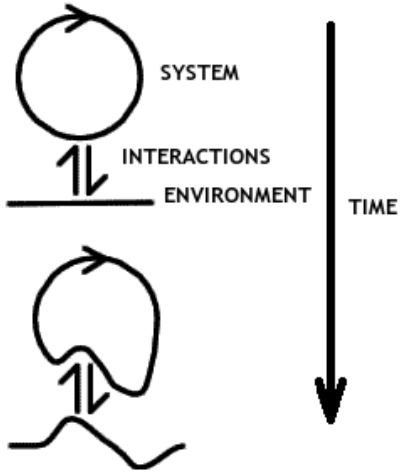

Figure 1. Structural coupling [12] (reproduced with friendly permission of T. Quick).

Thus there will be a clear connection between the autopoietic system's internal characteristics and the characteristics of the environment. This connection is usually described through behavioural or psychological biometric characteristics. Depending on the intensity of structural coupling as well as the on the uniqueness of the internal processes of the system these characteristics will be more or less unique.

This argument lets us conclude that any autopoietic system when structurally coupling for a certain amount of time to another system will acquire some behavioural or psychological characteristics which in turn depend on the environmental system. This is especially true for any human-machine interactions (e.g. typing dynamics, mouse move dynamics, hand grip characteristics).

DISCUSSION

As one can see from the previous discussion there is a clear connection between concepts form autopoietic theory and biometric characteristics. The internal process of component reproduction of an autopoietic system yields physical biometric characteristics whilst the external process of structural coupling between the system and its environment yields behavioural or psychological biometric characteristics.

While this is obvious when talking about living systems and especially humans, this connection implies a whole new field of research in biometrics when taking other autopoietic systems into consideration. The previous discussion showed that one can apply insights from biometrics to groups of living systems (e.g. swarms, flocks), social systems (groups where

living systems are mostly humans) with respect to societal (villages, towns, cities, communities, etc.), organizational (companies, syndicates, teams, etc.) and interactive (demonstrations, concerts, happenings, chat rooms, etc.) social systems as well as their respective information systems.

Thus one can measure (sample), process (preprocessing, feature extraction) and recognize any autopoietic system on behalf of their physical and behavioural characteristics.

POSSIBLE APPLICATIONS

As indicated above the connection between autopoietic theory and biometrics implies a whole new area of research for biometrics, but an eventual application area as well. One can observe the main areas of biometrics application in biology and medicine as well as information system's security. By introducing autopoietic theory a new light is thrown on this interdisciplinary field allowing us to apply insights from biometrics in other fields like social and organization theory as well as information systems.

Since, according to Luhmann [3], social systems are autopoietic there are potential application areas of biometric methods in social phenomena. One could use biometric methods (like pattern recognition) to identify social phenomena (e.g. crime, social instability, war) by measuring certain social processes and avoid such unwanted events or facilitate wanted ones.

On the other hand organizations could use biometric methods to identify their certain wanted (teamwork, organizational learning, individual initiative etc.) or unwanted behaviour (groupthink, plant blindness, employee fluctuation etc.) inside them to facilitate or avoid it, respectively.

Of course on should have in mind that this work is theoretical in nature and thus requires additional efforts to find application areas that would be potentially interesting for industry. Such efforts are subject to future research in this area.

CONCLUSIONS

A clear connection between autopoietic theory and biometrics was provided using the concepts of component reproduction and structural coupling. It was shown that the internal process of component reproduction of autopoietic systems yields physical characteristics. Likewise the external process of structural coupling yields behavioural or psychological characteristics.

This new framework allows us to define the difference between physical and behavioural biometric characteristics in the broader perspective of biometrics as follows:

(i) **Physical biometric characteristics** are special features of a biological phenomena's structure which are derived through the internal process of componental reproduction.

(ii) **Behavioral or psychological biometric characteristics** are special features of a biological phenomena's behaviour which emerge due to the external process of structural coupling to environmental systems.

The clear connection implies that any autopoietic system can be subject to biometrics and represents a paradigm shift from traditional systems security perspective as well as other approaches hidden under terms like biometry, biological statistics, biostatistics, behaviometrics etc. to new fields of research and creates a bridge between biometrics and sociometrics as well as other social and organizational sciences.

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AUTOPOIESIS KAO OKVIR ZA BIOMETRIKU

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SAŽETAK

U radu je sa stajališta biometrijskih karakteristika opisana autopoietska teorija, okvir za opisivanje kompleksnih nelinearnih i posebno živućih sustava. Diskutirano je kako bilo koji živući sustav izvođenjem unutarnjih procesa reproduciranja svojih strukturalnih komponenti rezultira fizičkim biometrijskim karakteristikama. Slično tome, bilo koji živući sustav strukturalno povezan s drugim sustavom (alopoietskim) rezultira karakteristikama ponašanja i psihološkim karakteristikama živućih sustava. Pokazano je kako bilo koji sustav, kojeg se može smatrati autopoietskim, može biti mjeren i identificiran primjenom prikladnih biometrijskih metoda. Zbog toga je biometrika primjenjiva bilo za koji autopoietski sustav: živa bića, grupe živih bića, organizacije kao i informacijske sustave. Na kraju su diskutirane posljedice takve konceptualizacije kao i moguće primjene.

KLJUČNE RIJEČI

autopoiesis, biometrika, strukturalno vezanje, reproduciranje komponente