Thinking in a complex or, in other words, robust and adaptive way, which is probably close to the thinking of the nature itself, is procedural, explorative and conditional, that is “computational”. “Computational thinking is using abstraction and decomposition when attacking a large complex task or designing a large complex system”, writes the computational thinker Jeannette Wing (2006, p. 33). It requires solid theoretical preparation of abstractions, which will be employed in a computational approach.

“Complexity Science” is a name, given to a transdisciplinary computational combination of theories from the known sciences and philosophies, their concepts, methods and methodologies for studying the phenomena of diverse guises, structures, contents, shapes, etc., in their interconnections of information, matter, energy exchange for the purposes of understanding life and its processes (Pines, 1985). Sometimes, Complexity Science is also called “Systems Science” or simply “complex systems” and uses uncountable variations of methodological combinations in its own research practice to solve epistemological problems of studying life (Strogatz, 2014; Waldrop, 1993), which none of sciences and humanities can solve independently. In contrast to any disciplinary and interdisciplinary fields of established natural and social sciences, Complexity Science is not a discipline.

As I learned at the Winter School on Complexity Science in Singapore, 2015, if Biology informs us about chemical structures, processes and mechanisms in a leaf, then Complexity Science applies to both leaves and other phenomena, recognizable in leaves, such as fractal structures and scales. We can notice that a leaf is fractal, because it consists of self-similar shapes, but, when complete, the leaf cannot grow anymore in size, because the size is limited in its scale. Laws of complexity hide also in the phenomenon of earthquakes, studied by Geography: you can understand the nature of a large earthquake by studying a small one in
applying conceptualizations of scalability and, eventually, nesting of diverse realities in one, and varieties of guises and self-organized forms hiding common simplicity. Complexity Science raises the challenging question “why?” very often: at the Complex Systems Summer School 2015 in Santa Fe, I learned that humans, drosophilae and elephants have almost the same heartbeat pattern during their lifetime, if we consider the length of their lifespans, weight and other body criteria proportionally; this means that for in nature these species are somewhat the same, but to answer “why?” requires generation of transdisciplinary approaches.

The interdisciplinary field “Information Systems” (or “Management of Information Systems”) has been lacking (before my dissertation) a holistic, bilateral, multifaceted approach to studying the phenomenon of mutual shaping between technologies and law, because there was no acknowledgement of the complexity and integrity of the technological and legal realms and their treatment with equal respect for understanding patterns of their interplay. That is why inspiration from Complexity Science and its transdisciplinarity have been useful here. In order to get methodological combinations philosophically orchestrated, Complexity Science employs the term “system” and that is why it is often also called “Systems Science” or “complex systems”, as an approach indication. This is because the term “system” is a key abstraction in Complexity Science. In the 1920s, an Austrian biologist Ludwig von Bertalanffy, who is the father of the General System Theory, formulated a set of key differences between a live and a dead dog as systemic – and the world learned what an open and a closed system was, though it took years to get the research published, because the community of biologists of that time did not consider his work as research in the discipline of Biology (Von Bertalanffy, 1950).

Since then, the transdisciplinary science of complexity has matured dramatically. In the special issue of the journal Emergence, with the question “What is Complexity Science?” in 2001, Steven Phelan (2001, pp. 129-130) explains Complexity Science as a phenomenon as follows:

*The first, and perhaps most distinctive, attribute of science … is correlation thinking, or the search for empirical regularities (or laws) … prediction arises from combining the law with a set of initial conditions to deduce an outcome … Laws may be either deterministic (for all X, Y) or probabilistic (for 80 percent of X, Y) … the identification of empirical regularities calls for theories to explain why these regularities occur. These theories, in turn, may give rise to additional novel predictions … a theory T’ improves on theory T when: T’ explains more facts than T; T’ predicts more facts that T; T’ makes fewer mistakes than T; T’ is simpler than T for a given level of explanatory power; and/or T’ solves more problems than T … New sciences are likely to arise as technology allows more areas to be mined for regularities or new human priorities arise. Complexity is a new*
science precisely because it has developed new methods for studying regularities, not because it is a new approach for studying complexity of the world … Consequently, rather than define complexity science by what is studied (i.e. a complex universe), the focus should be on the methods to search regularities… At the core of complexity science is the assumption that complexity in the world arises from simple rules. However, these rules (which I term “generative rules”) are unlike the rules (or laws) of traditional science. Generative rules typically determine how a set of artificial agents will behave in their virtual environment over time, including their interaction with other agents. Unlike traditional science, generative rules do not predict an outcome for every state of the world. Instead, generative rules use feedback and learning algorithms to enable the agent to adapt to its environment over time...

What Phelan (2001) calls “generative rules” are exploratory, conditional, computational logic of Complexity Science, enhanced, as he fairly notices, by development of new technologies. The abstraction of “system” is where the rules can be found. Simply speaking, a “system” is a set of interconnected elements, but another definition of “system” might be “a certain object with certain qualities … which is efficient, sustainable and adaptive to changes in conditions of operation” (Skliarov, 2013, p. 11). Simultaneously, complexity scientists realize limitations of their epistemological capacities – Rosenblueth and Wiener (1945, pp. 320-321) claim that “the ideal… model would be one which would cover the entire universe, which would agree with it in complexity … This ideal theoretical model cannot probably be achieved. Partial models, imperfect as they may be, are the only means developed by science for understanding the universe. This statement does not imply an attitude of defeatism, but the recognition that the main tool of science is the human mind and that the human mind is finite.”

Since the term “system” is centrally important for Complexity Science, let us ask ourselves here what “system” means, for example, to researchers in the interdisciplinary field “Management of Information Systems”. This would be a useful exercise to rock and roll the communities, which think that their understandings should prevail over achievements of the overall human knowledge, which Complexity Science covers and, therefore, represents. […] In 2013, Steven Alter published an article “Work System Theory” which was subsequently awarded. Alter (2013, p. 73) confirmed that “the fundamental term ‘system’ is problematic in the IS discipline”, adding that an editor-in-chief of the top IS journal MIS Quarterly recognized that the word “system” meant basically something technical made for electronic information processing – “technical artifacts, configurations of hardware, and software that are used by users”. Already nine years before that, in 1994, a systems theorist in organizational studies Peter Checkland (1994, p. 29) criticized organizational science for the following: “organizational theorists have
been so complacent with their conventional wisdom that they have failed to notice a nearby intellectual revolution which is highly relevant to their concerns ... systems theory.” [...] Although the key abstraction “system” has no concrete definitions, and may also be defined as “ordered imaging of an object of research from the ends point of view” (Kachala, 2012, p. 55), this would mean calling “system” a research object, based on the found research problem to be solved. In other words, I can call the phenomenon of mutual shaping between technologies and law as a system that might be approached for studying.

Brian Arthur (2015), an external professor at the Santa Fe Institute, claims that research of complexity prefers to look at those phenomena that are spread beyond situations, that is, if to rephrase, beyond those limited organizational contexts and situations – because of immeasurable number of situations and possible variations of patterns as alternatives for the situations. In the real world, any situation may be important. That is why a “case study” may bring questionable results, so a case should rather be approached as a dataset, and let it be many datasets. A scientist goes through the data a path by trial and error, and, in result, a computational study is delivered. Computational thinking is algorithmic: it employs a variety of available methods, where structures of a phenomenon are studied state-by-state, stepwise as inspired from contexts (situations, cases): if A, B, F, not G are currently true, then execute R, and S, and T – as a simple example of exploring a context for decision-making in a complex system. Exploring the world across situations makes a scientist create one more “situation” of this exploration. The “logic of situation” makes Complexity Science procedural: internal processes change the contexts, and those change the processes, so that some ex ante conclusions can be made (Arthur, 2015). Computation is approximate, but it is running and replicable, because computational processes can learn, just as the mind can. [...] Designing technologies in the legal environment is an activity that goes beyond organizational scopes. There is an ongoing informational exchange, tension between technological ideas, designed structures, plans and legal regulation in its imperfection. Information travels between technological elements and legal norms and values, and in both realms for particular causes. Conceptual preconditions have been developed to apply complex systems in technology-design research for studying the phenomenon of mutual shaping between technologies and law. For example, Feng and Feenberg (2008) claim that design of a technology happens in a complex, “black-boxed” process from quite socially-neutral technical elements to a strongly-biased finished device. They imply that designing activity is a process that consists of elements in interactions that are difficult to analyze because of their complexity. The authors define “technical elements” as “the most elementary technical ideas and corresponding simple implementations that go into building devices and performing technical operations”; technical
elements can also be decontextualized and simplified objects “to highlight those qualities by which they are assigned a function” (Feng & Feenberg, 2008, p. 113). Thus, we can conceptualize a technical element as a detail, a formal principle, a method, etc., which in itself is a meaningful part in a ready device, when it has gone through the process of reasoning and composition by its designers. As Feng and Feenberg (2008, p. 114) state, such composition depends on the designers’ interaction with the social environment and their own personal/professional backgrounds: “once the technical actor begins to combine these elements, more and more constraints weight on design decisions”. In other words, “these elements” are technological elements of information, as well as elements of the social or legislative environment, and elements of describing the experts themselves. All these three types of elements, therefore, are equally important analytically, and their “weight” is measurable to the quantity and quality (defined by conditions of the explorative computational systems approach) of their relationships with each other, established as time goes.

Law and the legal system is a social environment – the environment of socially generated norms in form of laws and bylaws, which are also information for designers. To each other, the designers are information carriers as well – they transfer knowledge shaped by their own professional paths and experience. Emergence of constraints in decision-making, based on skills and experience, would have triggered the designers to explore the environment from the situation they find themselves and across situations, in which they have already been as experts – in order to decide on a proper response to this environment. Acknowledging such a logic in the behavior of actors in a phenomenon would stipulate computational character of an approach (Arthur, 2015), which would be useful in understanding of the mutual shaping and simply the co-existence of law and technologies.

In accordance with Feng and Feenberg (2008), the design process is an emergent, path-dependent and heterogeneous phenomenon, because designers are not limited to interaction only within their own group – information comes largely from the outside experts. People inside the design team (in situ experts) and outside it (ex situ experts) are carriers of information about technological and legal elements in the “black-boxed” design process targeted for delivering a ready device. Experts reason on information when they interpret it, based on their own skills and experience, but information comes to them beyond their own will, because it is objectively transferred from other experts in the due course of interaction, when a technology is been designed. Feng and Feenberg (2008) claim that it is difficult to determine concrete boundaries of information input. To understand the exchange of information in between seemingly “different” realms, such as law and technologies, we have to focus on the “environment” in between them as a holistic space, as real as law and technologies themselves. [...] We should
set our mind in the “uncomfortable” area “at the edge” of the information realms – of technologies and law – which we will explore as a “primeval forest” and formulate the logic of our explanation into conditional rules (Phelan, 2001; Wing, 2008), so that others can walk this path after us, enrich the conclusions and program the solutions, applicable to reality. [...] Complexity Science is curiosity “at the edge” of knowledge, aspiring to the unknown by use of transdisciplinary methodologies and knowledge transfer, based on understanding mechanisms of this world. This should not be confused with positivism only, which has a “belief in total objectivity … [where] there is no reason to interact with who or what researchers study … researchers should value only the scientific rigor and not its impact on society or research subjects” (Denzin & Lincoln, 2011, p. 103). Procedural, computational Complexity Science, in contrast to positivist research, is highly applied: from studying dynamic processes of nature, Complexity Science provides enhanced understanding of the reality in its uncertainty, be it the human genome, principles of micro-economics, reputation in society, kidney exchange matching, astronomical maps, quantum computing, election processes in politics, semantics, etc. (Wing, 2008), and even metaphysics (Kauffman, 2010). Complexity Science implies certain “openings” for transdisciplinary bottom-up learning “that can mimic real-world behavior” and “help scientists predict, control, or explain hitherto unfathomable systems (such as the stock market)” (Phelan, 2001, p. 131).

Nevertheless, Complexity Science is neither “a postmodern science”, such as post-positivist, feminist or constructivist social-science directions – because of its “infinite ways of knowing about the world” – nor “a set of metaphors or analogies based on resemblance thinking” (Phelan, 2001, pp. 132-133), where “the widespread use of inappropriate metaphors can only damage complexity science in the long run by destroying its credibility and consigning it to history of another management fad” of no “testing, confirmation, or falsification” (Phelan, 2001, p. 134). Complexity Science would allow symmetrical theorizing about thinking modes and their application to data in simultaneous, acknowledging of the epistemological asymmetry of these modes. Due to its “infinite ways of knowing” (Phelan, 2001, p. 133), Complexity Science can address both positivist “logico-scientific” and interpretivist “narrative” modes within one study (Tsoukas & Hatch, 2001), since these are complementary rather than contradictory: categorical, ahistorical and consistent qualities of the former can directly be addressed by the experiential, sequential and paradoxical character of the latter. Thinking at multiple levels of abstraction just as humans think, limited only by their own curiosity and creativity (Wing, 2006), is thinking in complexity. After all this, we may fairly wonder: are there any limits to Complexity Science? No, there are none. Are there any structures, necessary for a research project, which is usually constrained with time and budget? Yes, there are.
At the European Conference on Complex Systems in 2014, I was fascinated by a presentation “Can the plants inspire future technologies?” by Stefano Mancuso. He showed videos from long-term experiments on plants, adapting, competing with each other and overcoming obstacles, where the most astonishing thing was the fact that plants have no brains. Thus, one can definitely state that adaptation, competition and fitness are not just natural science phenomena or social phenomena – these are universal behaviors.

In March 2015, I attended the conference “Emerging Patterns” at the Complexity Institute in Singapore. There were many exciting presentations, which provided deep insights into the synthesis of sciences, and one of the brightest was about Big History – a hybrid knowledge area between History, the narrative approach and, eventually, all sciences. The speaker was David Christian (2015) from Macquarie University in Sydney, Australia. It is amazing how the narrative approach is universal – possibly because of its linear causality “first X, then Y” (Tsoukas & Hatch, 2001), which invites complexity. The discipline History, as Christian claimed, used to be completely anthropocentric – it has been conventional to think that when humans emerge, history starts, but what was before humans is to be of interest to Archeology and Biology. In contrast, the Big History knowledge goes back in the narrative to the emergence of the universe and physics of gravitation, energy and space. When stars die, they generate chemical elements that interact and build matter. Chemical elements introduce information. Chemistry and Physics then “work” together in the Big History knowledge to explain the birth of Earth, temperature and water. Information amounts increase: it leads to bacteria and the period of the interest to Biology – about shaping of life forms, including the human.

All natural phenomena in increasing complexity, information and fractal replication, shape the complexity of brain – and intelligence emerges: information is getting processed faster and faster. The speaker highlighted that, to his knowledge, according to Archeology and Anthropology, we are not smarter, than those people, who lived centuries ago, but what makes us “smarter” is collective intelligence – which explains technological revolution, the use of tools, and learning from what we have achieved. All this stimulates the growth of connections in/with natural and social systems, and shapes our individual and connective-collective behavior. We have got cities, sicknesses, industrial revolutions, transportation, communication, information systems, and we extend ourselves to those, repeating former fractals, etc. The Big History knowledge provides us with meanings, saturated with new philosophical and scientific questions we have to ask (Christian, 2015). Combinations of existing and emerging tools, whatever they are, including the narrative approach itself, are necessary to contextualize and de-contextualize, and for going to the past and to the future via the present.
Igor Skliarov (2013), in his textbook for Russian students in ICT, provides an explanation of what the “systems universe” looks like in application to transdisciplinarity, and concrete research projects, constrained with time and resources. All the systems we know so far are interconnected, somewhat nested and “work” all together – and have an approximate structure: e.g. a regular element of one system may be among the most complex ones in another one, so it belongs to both of the systems. The “systems universe” is based on knowledge we have about ourselves and nature, and, therefore, its structure is approximate, but it yet helps to understand the exchange and flow of information, matter and energy in the universe.

Skliarov (2013) begins by claiming that, roughly speaking, there are four types of natural systems: field systems, matter systems, biological systems and social systems. Field systems are, at least, quants consisting of smaller particles, quarks. They are phenomena, which are so far not completely researched, and there may be systems of higher and lower levels around those. The second type – matter systems – comprises elementary particles, atoms, molecules, chemical compounds, rocks, kernels and mantles of space objects, star systems, galaxies, galaxy systems, meta-galaxies, and other so far unknown forms of organization. The third type – biological systems – comprises complex organic molecules, viruses, organoids, cells, organs, functional sub-systems, organisms, populations, biocenosis, ecosystems, biosphere, and maybe there are no more higher levels. The fourth type – social systems – is social individuals, families, groups and collectives, states, etc., and mankind. All of these systems are nested into each other, and are also tightly related between types: quants from field systems are also elementary particles in the matter systems (Figure 1).

![Figure 1: Natural systems (adapted from Skliarov 2013, p. 119)
It is interesting to highlight for transdisciplinarity purposes that quants are of a middle level in field systems, but are the lowest level in matter systems. From elementary particles are built higher levels of matter systems. In turn, chemical compounds of matter systems are complex organic molecules in biological systems. Organisms in biological systems are like humans in social systems. This would be an approximate structure of the systems universe with something like a transcendental field (Skliarov, 2013) or the simplest information (Kauffman, 2002) keeping it organized. We can observe basically only what we can reach from our place by methods we develop, and the more we learn the more questions we generate.

Systems of different levels and types have a tendency to help each other in recovering. Decay and death is an increase of entropy, when high-level systems get disorganized into lower levels. This is the First Law of Thermodynamics: energy can be transformed from one form to another, but cannot disappear or be destroyed. Skliarov (2013) highlights that there is no “unsystemic thrash” in nature – matter is getting re-organized due to a process, opposing to decay – the process of increasing complexity. This is the Second Law of Thermodynamics (Figure 2). Memory of the universe is possessed in morphic resonance of organizational re-birth (Sheldrake, 2011), and that is why there is some stability in existence, such as history, distinguishable, but steadily changing shapes and forms of species, behavior patterns, etc.

**Figure 2:** Systems universe in increase and decrease of entropy (adapted from Skliarov 2013, p. 120)

Our intelligence may be a product of increasing complexity over the big-history narrative (Christian, 2015) and the shaping trends in the systems universe (Skliarov, 2013). The model of the systems universe has also technical systems as the fifth type in the systems universe – the artificial and socially created systems. Skliarov (2013) claims that at the lowest levels of technical systems are details, and then assemblies, component units, mechanisms, machines,
technical complexes and complex technological systems – these are “systems” like something understood in the field “Management of Information Systems”, as I reviewed in the beginning, and “technos” as a whole. The sixth type of systems can be programming systems (Skliarov, 2013). The simplest contents there would be code commands, then programs in code, programming languages, algorithmic languages, languages and programs of high levels, and e.g. global programming constructions such as Internet (Figure 3).

![Figure 3: Natural and artificial systems (adapted from Skliarov 2013, p. 121)](image)

Although technical systems and programming systems also have a hierarchy in their complexity, they have inherent processes only in one direction – increasing entropy and decay (so far). These are artificial systems, created socially. In the structure of the systems universe, given by Skliarov (2013), we do not see legislation and economics, but they are implied – these are artificial systems as well. Humans, working on technologies and laws, and using them, are natural systems here, and humans belong to social systems, but the human is one of the most complex elements in biological systems. To social systems, we may also refer other animals, which have their own social organization forms: wolves, ants, sheep, etc., but humans succeeded in creating other, artificial systems after themselves, such as technical, programming, economic and legal systems. If for the purpose of a research project we want to study how laws and technologies shape each other, we speak of shaping between two artificial systems – laws and technologies – and since the only diving force of their progress are humans, a natural system, we may say that the interaction between the two artificial systems happens via one natural. The interaction process among them would be a complex systems process. Since John Holland in his work “Adaptation in Natural and Artificial Systems” (1992) proved that both types of systems share some mechanisms of adaptation, with some specificities, then the interaction area between technologies and law, with its human component, is a complex adaptive natural-artificial system. To call it socio-technical would be a too rough simplification.
The natural social system of expert interaction in designing ICT transfers information *between* the artificial social system of law, its formalities and imperfections as regulatory-normative information *and* the artificial technological system of technologies, their hardware, software and operation principles as matter and information. This transfer happens at meetings, consultations, in e-mail and letter exchange, and finally decisions are taken, which can be studied with application of complex systems’ conceptualizations, such as memory, adaptive plan, etc. Then, in collection and processing of data, there would be required at least the following knowledge areas to balance “at the edge”: design of ICT, management of ICT, Law, Legal Informatics, probably Economics and Politics – and anything else, which will help with precision and does not object to be recognized as an integral part of the systems universe. Here we see that the interacting systems exchange information, which shapes matter and information.

Speaking of relationships between external environments and situational environments in designing *information* systems, Kovács and Ueno (2004) claim that environment can be considered as a complex adaptive *information system*, which also contains one or several nested complex adaptive information systems. By “information system”, the authors mean organized interacting bits of information, which are structurally coupled with their environments so that they influence each other. The nested environments have normally two kinds of pressures: a bottom-up one to manage and explore the randomness of elements they come across, and a top-down one for elaboration of coherent behavior as a strategy. As Kovács and Ueno (2004) state, the nested environments may indirectly influence each other via their shared environment, because the latter is a shared memory, storing and exchanging information with the former. In other words, what others did may cause influences on the third environments. Surprisingly, but this idea corresponds with the conceptualization of “legal futurology” and the *ex ante* principle in Legal Informatics. The shared environment can be called a “relationship package” (Mitchell, 2001) or “enabling substrate” (Rocha & Bollen, 2001). Both law and technologies learn from practices, whereas practices are relationships between them and beyond any imaginable boxes.

Asymmetries in knowledge, understanding and approaching things in, say, design and management of ICT, Law, Legal Informatics, Economics, Politics and anything else, necessary for the purposes of the research project, would be acknowledged in the structure of a complex systems phenomenon and, therefore, in visualizing its interactions. From there, we may see different perceptions of time flows, pattern formations and uncertainties with response variations – bottom up and top down. There is no knowledge, which is unimportant to a complex system. Elements and relationships are treated with equal importance in approaching, until the data itself highlights the asymmetries and the answers, real and workable in one, holistic world.
References


