The Evolutionary Approach of General Systems Theory Applied to World Wide Web

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Abstract. This article presents the application of general systems theory to web-based applications, with an emphasis on the evolutionary approach. The stages of web applications are discussed, according to their complexity, usage and historical appearance. Then the evolutionary approach as a framework is applied on web applications, in the meaning of their evolvement through time. This is expected to clarify a process of transformation from simple static websites to complex social web applications. The outline of these evolutional stages is followed by a suggestion of the current stage of web applications and future possibilities.

Keywords: Web applications · Evolution of the web · General systems theory

1 Introduction

Our lifestyle today is heavily influenced by available technologies, one of the most significant and also rapidly evolving is the internet. The World Wide Web undoubtedly belongs to major providers of information. It functions also as a communication platform, used by a wide range of different users [10, 11]. Considering an important role and continuous evolution of the web, it is useful to organize our knowledge of this evolvement into a known framework. With identifying individual stages of complexity in website development field, we can understand present tendencies and anticipate future possibilities. As the framework for this implementation was selected the evolutionary approach of general systems theory [5, 8].

General systems theory is a concept invented by biologist Ludwig von Bertalanffy, who identified similar principles across several fields of knowledge, such as biology, engineering, social sciences or management [7]. Yourdon applied general systems theory to the information technology and information systems [18]. Purpose of Bertalanffy's theory was to identify laws pertaining these many branches and thus create suitable conditions for their collective development [6]. One of the key aspects of this approach is investigating systems in the meaning of organizational units. Boulding defined two possible approaches to general systems theory, more of a complementary than competitive nature [4]. First of these approaches relies on picking out general

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phenomena across various disciplines and create relevant theoretical models. The key idea of the second approach is an arrangement of relevant constructs or empirical fields in a hierarchy, which defines organization of individual units within the system with a certain level of abstraction. We will use the second approach in this study and attempt to define a hierarchy of evolution stages of web applications according to their complexity, historical emergence and usage.

2 The Evolutionary Approach of General Systems Theory

A second approach towards general systems theory was defined by Boulding as a systematic approach leading to system of systems. Rapoport specified it as the "evolutionary approach", since levels of abstraction are of increasing complexity, marking the evolution of knowledge [3]. Each of these levels can be also defined by input, output, throughput or process, feedback, control, environment and goal or purpose, known as common elements of a system, which originated from Bertalanffy's types of finality [2, 13]. The input signifies an energy or a material which is transformed by the system through some process, resulting in an output as a product of system's processing. The feedback is also a product of the process, which returns to the system as an input. An evaluation of the input, process and input is encapsulated in a control element, an environment denotes the area around a system and a goal is a purpose of the system. Individual levels are described in (Table 1).

Similar development of stages in biology was conducted by Gerard, who did also divide concepts into nine categories of increasing complexity [9]. In this case however, entirely different approach was used. The author observes main criteria of Gerard's hierarchy as size of units, while Boulding's hierarchy can be defined as adding functional layers. Both approaches abide principle of rising complexity, yet in a different manner. In Gerard's hierarchy, every stage has defined its structural characteristics (architecture, relations, negative entropy) and equilibrium (dynamics and adaptive responses). Boulding integrated these constructs as a layers up to the third level (namely the structure level, the simple dynamic level and the control

Table 1. Arrangement of levels by Boulding [4], further specified by Rapoport [3]

Level	Name	Included entities
1	The structure level	Static structure, framework, arrangement
2	The simple dynamic level	Predetermined motions, simple machines
3	The control mechanism	Transmission and interpretation of information
4	The open system	Self-maintenance, self-reproduction
5	The genetic social level / Level of the cell	Division of labour, differentiated parts
6	The animal level	Increased mobility, teleological behaviour, self-awareness, specialized information-receptors
7	The human level	Self consciousness, self-reflexivity, speech
8	Human society	Social organizations, units as a role in society
9	The transcendental level	Ultimates and absolutes and the unknowables

Table 2. The levels of organization in biology by Gerard [9]

Level	Name	Description	*
1	Molecule	Particle made of two or more atoms	1,2
2	Organelle	Unit within a cell that has a specific function	3
3	Cell	Basic structural and functional unit of organisms	4,5
4	Organ	Unit with a common function in higher organisms	-
5	Individual	Organism with mind, feelings, consciousness	6,7
6	Small group	A small group of individuals	-
7	Species	A group of organisms capable of interbreeding	-
8	Community	Culture, community, institution	8
9	Total biota	Web of life in a space	9

* A reference to the items in (Table 1) - correspondence with the Boulding's hierarchy

mechanism). Gerard's organization is illustrated in (Table 2), including a comparison with the Boulding's hierarchy.

3 Evolution Stages of Web Applications

Essential stages of web applications are suggested and discussed in this part, in a form of an analysis on a history of the web. The stages are identified in accordance with general systems theory evolutionary approach, as an introduction to a research part of the article. Therefore, numbering of stages, which also follows a complexity of web development, comply with an arrangement of levels in general systems theory by Boulding and Rapoport [3, 4]. Identification and allocation of these levels was done according to the author's professional opinion after an elaborate analysis [24–32].

(1) World Wide Web, as an open field for web applications, had started its existence in 1993. First browsers displayed only text, next generation, starting with browser Mosaic, was capable of displaying also graphics [1]. Static structure of web applications is generally accomplished by HTML (HyperText Markup Language), eventually XML (Extensible Markup Language). Appearance of the static page is not changing after loading, until a user clicks on a link to different webpage, which is displayed next. This is considered a static webpage from a view of a user, which represents the first level of web applications.

(2) Next stage of web applications can be defined as an interactive website, which is usually powered by a combination of HTML, CSS (Cascading Style Sheets) and scripting. In this case, a scripting language is client-side, most commonly used is JavaScript, alternatives are VB Script or JScript. Purpose of CSS is mainly styling of HTML documents, but it can also convey interaction features like a hover effect. JavaScript can manipulate HTML page elements through use of DOM (Document Object Model). Combinations of these techniques (HTML, CSS, JavaScript, DOM) is commonly named as Dynamic HTML or DHTML [14].

(3) Dynamic website, as a third complexity level of web applications, features server-side scripting, which is often accompanied by a database system. Server-side scripting is accomplished through a server-side language, such as PHP (PHP: Hypertext Preprocessor), ASP (Active Server Pages), Java or Perl, and a database

system as a data source, e.g. relational database management system MySQL or MSSQL. Dynamic feature made it much easier for websites with extensive amount of content, since it enables to use the same page structure and design for dynamically loaded content from data source [15].

(4) The next stage of web applications can be characterized as a social web application, featuring a strong social aspect while technologically based on previous three stages. This advancement is covered by the term Web 2.0 and underlines foremost a socialization of the web. Popular activities include blogging, tagging and social bookmarking [1].

From the technological point of view, Web 2.0 is also associated with AJAX (Asynchronous JavaScript and XML) arrival, which enables enhanced functionality without reloading a webpage. We can summarize that core aspects of Web 2.0 are data (mash-ups), functionality (AJAX) and socialization (community) [1, 12].

(5) Fifth level of web applications can be represented by an aspiration for semantic web. Apart from Web 2.0 blogging tendency without an elaborate organization of data, semantic web aims to implement a logical structure with help of taxonomies and ontologies. The term Web 3.0 is emerging as a possibility of combining today's web with semantic technologies and architectures [16]. Embedding web content in a logical structure provides for not only machine-readable data, but also machine-understandable data [17].

A substantial feature of this level is heading towards a data integration. Web 2.0 leads to an information redundancy as the same data occur in many variations across the web. Databases contain similar data only named and formatted differently, applications are copying data from other applications and thus create another instance of this data etc. Semantic web aspires for providing information models and languages that embed semantic contexts and metadata to enable automated processing of data [1].

(6) Adaptive web applications are suggested as the sixth level of web applications. An "adaptive" has several meanings in this context. Considering an expansion of mobile devices with an internet access and other electronic devices, which can be connected to the internet in the future, an adaptation of web applications is necessary. This adaptation can be relevant to visual appearance, since desktop computers, notebooks, tablets, mobile phones etc. have different range of screen dimensions and control possibilities [22]. Evolution of web applications in this direction is closely connected to a development in ambient intelligence [33, 34], which builds on ubiquitous computing and intelligent user interfaces [19]. Web applications are in this stage becoming a context-aware pervasive systems [37], which has three basic functionalities - sensing, thinking and acting [20]. A research on sensors is thus also closely connected with this stage, e.g. sensing movement, light, location, proximity or biological signals [21].

4 The Evolutionary Approach Applied on Web Applications

Stages of web applications were suggested in Sect. 3 Evolution Stages of Web Applications, which correspond with Boulding's hierarchy. The evolutionary approach of general systems theory will be applied on web applications in this section,

Table 3. Stages of web applications in relation to the Boulding's hierarchy

Level	Type of website/output	Essential feature/input
1	Static website	Markup language, creating a static structure
2	Interactive website	Scripting client-side language, styling language (hover), creating simple dynamics
3	Dynamic website	Scripting server-side language and a database, creating a control mechanism
4	Social web application	Creating and sharing content in a community, forming a living system
5	Semantic web application	Established logical structure, ensuring differentiation of the content types
6	Adaptive web application	Adaptation and context-awareness - ability to function correctly in any environment
7	Autonomous web systems	Encapsulating functionality and decision-making with internal expert systems
8	Cooperative web systems	Communication among autonomous web systems without human intervention
9	The transcendental level	-

on the basis of an analysis from Sect. 3. Additional characteristics and underlying processes will be also described in this section. A summary of conclusions from Sect. 3, completed with remaining stages, is presented in (Table 3). The use of evolutionary approach for web applications is justified by Yourdon's four basic principles of GST [18], which can be applied to information systems and consequently also to web-based applications.

Suggested ordering of stages doesn't strictly follow a historical emergence and usage, e.g. idea about semantic web was developing rather simultaneously with Web 2.0 features, however its development will probably surpass further development of a social web. Emergence of suggested stages is also not of an equal timing. The first three stages of web applications (static, interactive and dynamic websites) occurred and came to usage nearly simultaneously, while the fourth stage with pronounced social aspect emerged in a more revolutionary way as Web 2.0. The first three stages are also based foremost on technological development, underlying principles of next two stages are rather of social nature, and the sixth stage unites both.

A timeline of usage for presented types of web applications is also different for each one of them. E.g. amount of usage for static websites goes in an opposite direction than usage of dynamic websites - while number of static websites is rapidly declining, newly created or redesigned projects are almost always of dynamic nature, which eliminates the static nature. Different situation present websites with interactive features, which can coexist with either static or dynamic websites. Interactive features also declined in usage for many years, yet they experienced rapid expansion with design trends of Web 2.0 and possibilities with AJAX techniques and JavaScript libraries such as jQuery [23]. This trend of an interaction between a user and a website is even more pronounced with an arrival of HTML5 and CSS3 specification.

(1) The first level is defined by Boulding as a static structure, also a framework or an arrangement. The static website is fully consistent with this concept. A markup

language, such as HTML or XML, forms a structure of a web document. The website is called static, as it does not change once loaded. HTML markup, such as marking the parts of a webpage or a notation of classes, creates a static base for additional styles and interactions.

(2) The evolutionary approach describes the second stage as a simple dynamic level with predetermined motions. This level is represented by simple machines. In relation to web applications, the second level corresponds with an interactive website. This type of website uses a scripting and a styling language in order to interact with a user. This interaction proceeds as a reaction of a website to a predetermined event on the client side. This reaction is usually a visual effect of a website. This effect is also predetermined, according to a triggered code, which is associated with the event.

(3) The third level is characterized as the control mechanism, with a purpose of transmission and interpretation of information. The dynamic website corresponds with this description. This type of website uses a scripting server-side language, usually accompanied by a database. This system enables inserting, updating and a retrieval of information, required by a user. It dynamically delivers information, according to the interpretation of criteria, which are defined by user's choices and behavior. It also provides mechanisms for validating inserted data. A content management system is a great example of a control mechanism, which is a fundamental description of the third level in the Boulding's hierarchy.

(4) The open system is a fourth stage according to Boulding, defined by an ability of self-maintenance and self-reproduction. A Web 2.0 application can be perceived as such an open system. Every user can be a contributor to this kind of application, so its content is growing and being maintained without directed interventions. Social networks and wiki sites are great examples on self-maintenance. Self-reproduction of applications can be viewed e.g. in the form of mash-ups. If an API or RSS is provided and application or information is worth spreading, it is usually being replicated across the web usually without control of an original source. Boulding also defined this stage as a level at which life begins to differentiate itself from not-life [4]. The social web application isn't a first type of website with pronounced social aspect. Comments and discussion forums have been popular before Web 2.0 emergence. However social networks such as Facebook creates truly living systems, which are changing our social behaviour [1]. The social web application adds an act of sharing among users into the web application mix, which can be defined as a social aspect with none or loose terms and structure [35, 36].

(5) The genetic social level is the fifth level of the evolutionary approach, defined by a division of labour and differentiated and mutually dependent parts of a system [4]. The semantic web application can represent such a model with its implementation of logical structure. By integrating and encapsulating relevant data into machine-understandable sections, they can be handled differently according to their meaning, but dependent on their context. These differentiated parts of a system enable a division of labour, since functionalities can be specific and respective to the parts they handle. Another aspect of the genetic social level and also semantic web application is a collaboration, in the meaning of a community, which needs to be active in order to

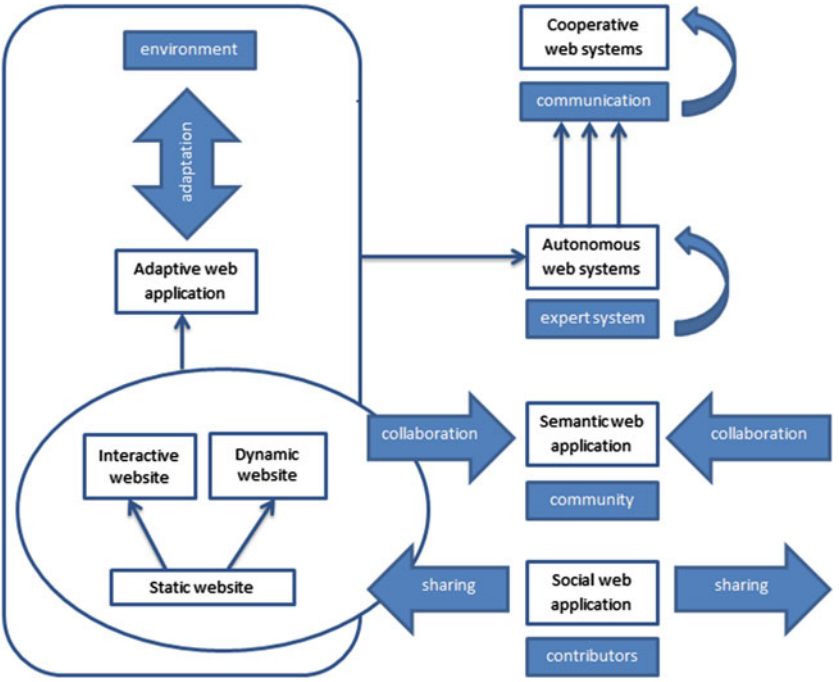

Fig. 1. Basic principles and interrelations of stages of web applications

implement linguistic and structural concepts on the web. A collaboration here represents a more elaborate social aspect with established terms and structure (Fig. 1).

(6) The sixth level as the animal level is characterized by an increased mobility, teleological behaviour, self-awareness and specialized information-receptors. Adaptive web applications correspond with this stage, as context-aware systems, with context represented by ontologies [20] from the fifth level. Mobility of a web application can be understood as an ability to function properly in different browsers, in various devices and with different screen sizes. Teleological behaviour ensures providing of different functionalities according to capabilities of chosen device. E.g. certain functionality associated with location and movement has use only for mobile devices. An adaptive web application is aware of itself, as of its capabilities, and aware of the relevant environment, which determines use of these capabilities. Web application then needs to correctly interpret information from sensors as specialized information-receptors.

According to the author, the current state of web applications can be placed past levels 1–3, in level 4 and in the beginning of both levels 5 and 6. The Boulding's hierarchy has three more levels, 7. The human level, 8. Human society and 9. The transcendental level. According to their features and a position in the hierarchy, we can roughly predict associated future stages of web applications. The seventh level as the autonomous web systems, which encapsulate wide range of functionality and are capable of complex decisions according to their implemented expert systems. The

eighth level can be predicted as the cooperative web systems, capable of communication among autonomous applications and delivering desirable performance without any human intervention. Of course, throughout the evolvement of web applications, implementation of necessary hardware and infrastructure had to precede certain software development.

5 Conclusions

This article discussed web applications in relation to the evolutionary approach of general systems theory. The suggested evolutional stages of web applications were presented, according to their complexity, usage and historical appearance. The author believes that this classification approached an evolvement from simple static websites to complex web applications and clarified the framework for this evolvement. The current state of web applications was suggested in the following way: (1) Fully using qualities of the first three technological levels, with an emphasis on dynamic and interactive features, (2) in the fourth stage of social web applications, which have already changed our social behaviour, (3) progressing in the both fifth and sixth levels, with continuing efforts for semantic web and emerging requirements for adaptive web applications. Future development has been briefly suggested in a correspondence with the seventh and eighth level in the Boulding's hierarchy.

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