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Evolutionary Approach of General System Theory Applied on Web Applications Analysis

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ABSTRACT

This paper reviews evolution stages of websites and presents framework for websites analysis, based on the evolutionary approach of general systems theory. Development of websites and web-based applications is discussed, according to their historical emergence, usage, increasing complexity and integration of new aspects and principles. Resulting individual stages of this development are suggested in accordance with the evolutionary approach. Framework for websites analysis and evaluation is then presented in a form of criteria list for each defined stage. Website's maturity (in the meaning of internet's evolution) can be then determined by confronting these criteria

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INTRODUCTION

The internet belongs to major providers of information and has a significant impact on our lifestyle. It functions also as a platform for communication, used by a wide range of users (Shneiderman, 2000; Weinreich, 2008). Considering an important role and rapid evolution of the internet, it is useful to organize our knowledge of this evolution. By identifying individual stages of complexity in the field of website development, we can evaluate any website or web-based application according to their evolution or maturity. Framework for such evaluation, presented in this paper, is based on the evolutionary approach of general systems theory. Use of these principles for websites is justified by Yourdon's application of general systems theory to the information technology and systems (Yourdon, 1989).

General systems theory was invented by biologist Ludwig von Bertalanffy, who identified similar principles across many fields of knowledge, such as biology, social sciences, engineering or management (Hofkirchner, 2010). Purpose of his theory was identification of laws pertaining these many branches and creation of suitable conditions for their collective development (Hofkirchner, 2005). One of the key aspects of this approach is investigating systems as organizational units. Boulding defined two possible approaches to general systems theory, which are more complementary than competitive (Boulding, 2004). First approach relies on picking out general phenomena across various disciplines and create theoretical models. 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. The second approach will be used in this study and used for defining a hierarchy of evolution stages of websites and web-based applications.

1. The Evolutionary Approach of General Systems Theory:

The 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 increasingly complex, marking the evolution of knowledge (Rapoport, 1968). 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 (Bertalanffy, 1950; Gillies, 1982). The input means 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 output 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].

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Table 2: The maximum current distribution (A/m) at the active region.

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

2. The Evolution of Websites - Review of Stages:

We can distinguish individual stages of development in the field of websites and web-based applications. The stages were identified by authors in accordance with the evolutionary approach and appropriately to their complexity, usage and historical appearance. Numbering of stages follows complexity of web development and comply with an arrangement of levels in general systems theory by Boulding and Rapaport (Boulding, 2004; Rapoport, 1968). Individual stages will be reviewed in this section as a basis for next research part of the paper. Descriptive figures are appended to illustrate processing of the website on particular levels of complexity.

2.1 Static website:

The internet had started its existence with basic functionality - requesting and displaying HTML files. Its proper functioning was ensured as a collaboration of three fundamental technologies, specified by Tim Berners-Lee [5]. These are: HTML, URI and HTTP. A markup language, such as HTML or XML, forms a structure of a web document. Such website is considered static from a view of a user, as it does not change once loaded, until a user clicks on a next hypertext link.

The first of evolutionary levels is defined by Boulding as a static structure, also a framework or an arrangement. Static website fulfils this concept and therefore it was identified as the first evolutionary level of websites.

2.2 Interactive website:

We consider an interactive website as a static website with capability of client-side interaction. It is usually powered by a combination of HTML, CSS and JavaScript. CSS is primarily used for styling HTML documents, but it can also convey interaction like a hover effect. The latest specification of CSS - CSS3 - also brought a wide range of interactive features. It is essential that this interaction does not change the website as it does not involve communication with server. Temporary change of appearance as a result of user interaction is only visible on this particular user's browser.

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. Interaction here proceeds as a reaction of a website to a predetermined event on the client side, followed by predetermined effect.

2.3 Dynamic website:

Dynamic website is defined by server-side scripting, which is often accompanied by a database system. Server-side scripting requires server-side language, such as PHP, ASP, Java or Perl. As a database system is usually used relational database MySQL or MSSQL. Additional value of dynamic websites is possibility to use the same page structure and design for dynamically loaded content, and also to use different parts of structure and functionality depending on the request. This made possible content management, search engines and variety of applications with preserving and maintaining user data like webmail or online stores (Doyle, 2010).

The third evolutionary level is defined as the control mechanism, with a purpose of transmission and interpretation of information. The dynamic website corresponds with this description, as it enables inserting, updating and a retrieval of information. It dynamically delivers information and it also provides mechanisms for data validation. Content management system is a great example of a control mechanism, which is a principal description of the third evolutionary level in the Boulding's hierarchy.

2.4 Social web application:

In this stage, internet has evolved from provider of information to a socialization platform, where every user can be a contributor to its content. Socialization of the internet is covered by term Web 2.0. It is technologically associated with AJAX, enabling rich functionality. Other feature are mash-ups, joining multiple data sources or services to create a new service. Core aspects of Web 2.0 are then data (mash-ups), functionality (AJAX) and socialization (community) (Vossen, 2007; Ankolekar, 2007). This approach leads to a functionality dependence and information redundancy, as the same data occur in many variations across the web, with little or none unified content organization.

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 is maintained without central interventions. Social networks and wiki sites are great examples on self-maintenance. Activity of sharing, a social aspect with none or loose terms, is typical for this stage. Self-reproduction can be viewed e.g. in the form of mash-ups. Boulding also defined this stage as a level at which life begins to differentiate itself from not-life (Boulding, 2004). In accordance with this, social networks create living systems, which are changing our social behaviour (Vossen, 2007).

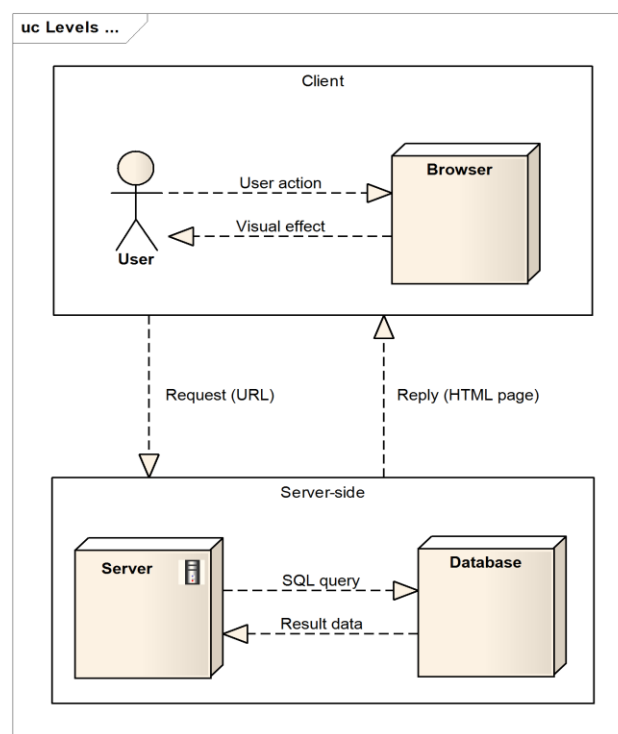


Fig. 1: Schema of first three levels of website development.

2.5 Semantic web application:

Fifth level of websites can be represented by an aspiration for semantic web, which 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 architectures (Wahlster, 2006). Embedding web content in a logical structure enables not only machine-readable data, but also machine-understandable data (Berners-Lee, 2001). Semantic web aspires for providing information models and languages that embed semantic contexts and metadata to enable automated processing of data (Vossen, 2007).

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. By integrating and encapsulating data, they can be handled differently and these differentiated parts of a system enable a division of labour. Another aspect of the genetic social level and also semantic web is a collaboration, as of a community, which needs to be active in order to implement linguistic and structural concepts on the web. A collaboration here represents a more elaborate social aspect with established terms and structure.

2.6 Adaptive web application:

Adaptive web applications are suggested as the sixth level. Considering expansion of mobile devices with internet access, an adaptation of web is necessary. This can be relevant to visual appearance, since desktops, notebooks, tablets, mobile phones etc. have different range of screen dimensions and control possibilities (Frain, 2012). Adaptation is also providing different functionalities according to capabilities of chosen device or personalized content. New techniques are emerging to deal with these requirements, such as HTML5 API. Evolution of websites is connected to a development in ambient intelligence, ubiquitous computing and intelligent user interfaces (Marzano, 2003). Web applications are becoming context-aware systems with three basic functionalities - sensing, thinking and acting (Loke, 2007). A research on sensors is also closely connected with this stage, e.g. sensing movement, light, location, proximity or biological signals (Schmidt, 2002).

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 (Loke, 2007). Mobility can be understood as an ability to function appropriately in different environments. Teleological behaviour ensures different functionalities according to capabilities of chosen device. Adaptive web application is aware of its capabilities, and of the relevant environment, which determines use of these capabilities.

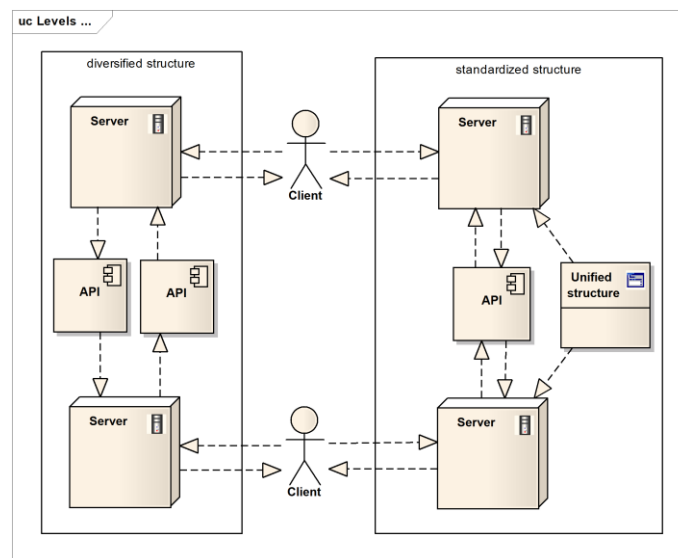


Fig. 2: Schema of the fourth level (on the left) and the fifth level (on the right).

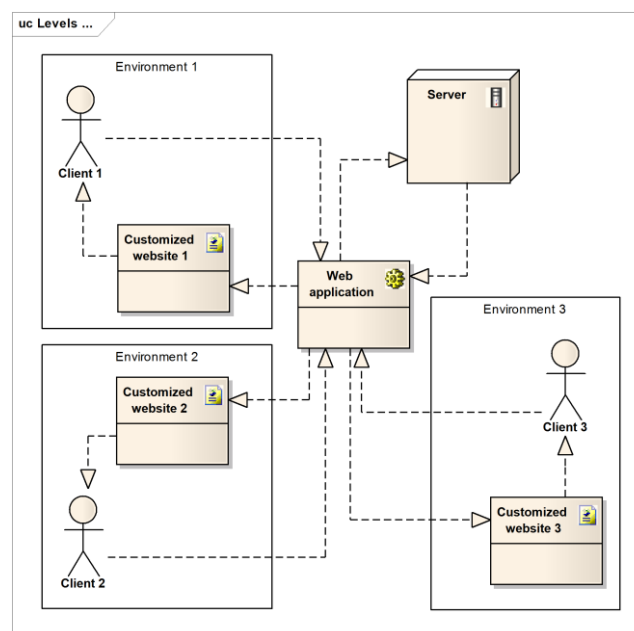


Fig.3: Schema of the sixth level of website development.

3. Summary of the web evolutionary stages:

Evolutional stages of websites and web-based applications were reviewed in section 3. A summary of conclusions, completed with remaining stages of Boulding's hierarchy (but yet expected in web evolution) is presented in [Table 2].

Table 2: 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 Scripting client-side language, styling language (hover), creating simple dynamics
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

To the authors best knowledge, the current state of the internet 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 by their expert systems. The eighth level as the cooperative web systems, capable of communication among autonomous applications and delivering desirable performance without human intervention.

4. Framework proposal for websites analysis:

On the basis of reviewed evolutional stages, list of criteria can be defined, which are typical for particular stage. Some of the criteria are of course applicable also in earlier stages, but they have been deliberately allocated to the stages, where their effect is most pronounced or it can be completely performed by means available in this particular stage. By confronting these criteria with factual state of evaluated website, we can determine its maturity in the sense of the internet evolution.

These criteria should be in theory hierarchically based, with one level as necessary requirement for the next level. This is not usually true with real web applications, as there is no enforcement on the internet regarding quality of development and poorly designed sites get as much space as standards-complying websites. Also to a certain extent, it is possible to ignore possibilities of particular stage and target more recent and complex issues. Finally, requirements may differ for specific web projects.

Table 3: List of criteria, which apply to individual evolutional stages of websites

Level	Type of website / output	Essential feature / input
1	Static website (HTML, CSS)	structure (technical aspect) visual design content
2	Interactive website (CSS, JavaScript)	user-website interaction performance issues strategy of fallback
3	Dynamic website (PHP/ASP/..., MySQL/MSSQL)	content management navigation and usability search engine optimization
4	Social web application (social aspect - sharing)	customization communication rights and security issues
5	Semantic web application (social aspect - collaboration)	structure (logical semantic aspect) machine-understandable
6	Adaptive web application (HTML5 API, JavaScript)	responsiveness to device context-awareness (sensors)

At the first level of static website, three main components are responsible for result - structure, visual design and content. Structure is regarded here from pure technical aspect via HTML. Visual design considers layout, colors, fonts etc. ensured by CSS. Content has a quality perspective, especially its relevancy, correctness and amount. These three criteria remain essential throughout the whole hierarchy at every level.

The second level adds CSS effects and JavaScript to create interaction between a user and website. Additional criteria to consider in this stage are connected to this interaction.

The third stage, dynamic website, uses server-side scripting language and database primarily to ensure content (or functionality) management. With this approach comes increased need for viable navigation, usability and search engine optimization.

At the fourth level, the development is more of social nature than technological. Website complying with this evolutionary stage should facilitate customization i.e. support for personalization and user content, and some form of communication and feedback. Important back-end criteria are rights management and security issues, which were already important in the third stage, but reach increasing importance here, considering that users have much greater access to web application than before.

The fifth stage, semantic web application, is defined by more complex social aspect in the form of collaboration. This social aspect takes place on back-end part of the internet in order to create underlying structure and rules.

Adaptive web applications on the sixth stage are, in current state, enabled primarily by HTML5 API and JavaScript, along with infrastructure equipment as sensors. General criteria for this evolutionary stage are responsiveness to device parameters and capabilities and context-awareness (which is on client-side delivered by sensors).

Conclusions:

This paper reviewed evolution stages of websites and web-based applications according to their historical emergence, usage, complexity and integration of new aspects. The authors believe that this classification clarified the evolvement of internet from simple static websites to complex web applications. Individual stages of this development were discussed with connection to the evolutionary approach of general systems theory. Framework for websites analysis and evaluation was then proposed in a form of criteria list for each defined stage. By confronting these criteria with factual state of the evaluated website, we can define its maturity in the meaning of internet's evolution and available possibilities and necessities, which are connected with individual evolution stages. Elaboration of this framework along with concrete computation of websites evolution index is planned to be subject of further studies.

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