Explaining the Evolutionary Development of the Web

Web 2.0 or Web 3.0, the semantic web

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ABSTRACT

Purpose – The Web has evolved from the rudimentary, hyperlinked collection of read-only and static information resources to a ubiquitous participative network computation platform, Web 2.0. Different conjectures have also been put forth as to what the future generations of the Web would entail. The purpose of this paper is to outline a developmental framework that would provide a descriptive macro-level account on the development of the Web to date and a justified conjecture of its future generations.

Methodology/approach – We leverage Complex Adaptive Systems (CAS) approach to model the Web as a service system comprising of agents with varying degrees of autonomy; employ a metatheoretical approach to elucidate our developmental model through different perspectives; and tentatively test our approach by contextualizing the theoretical conjectures drawn with a descriptive account of how the Web has evolved to date.

Findings – As the Web is a fractal system and thereby self-similar at all scales, we view that the understanding of service systems at the micro-level helps understanding the nature of the Web as a whole, and, accordingly, the evolutionary development of service systems helps explaining the punctuated evolution of the Web through different generations.

Research implications – Our research implies that different Web generations manifest the evolving systemic properties of the Web's constituent agents.

Originality/value – To date, no explanatory meta-level accounts exist to provide insights into the underlying principles and properties of the evolving Web. We aim at providing such an explanation, while also applying CAS approach in the novel context of service systems.

Key words – The Web, Web 2.0, Web 3.0, Service System, Complex Adaptive Systems (CAS), Panarchy

Paper type – Conceptual paper

1. Introduction

> I have a dream for the Web [in which machines] become capable of analyzing all the data on the Web – the content, links, and transactions between people and computers. A 'Semantic Web', which should make this possible, has yet to emerge, but when it does, the day-to-day mechanisms of trade, bureaucracy and our daily lives will be handled by machines talking to machines, leaving humans to provide the inspiration and intuition. The 'intelligent agents' people have touted for ages will finally materialize.
> – Tim Berners-Lee (1999)

The World-Wide Web (WWW), or the Web, was contrived to provide easy access to online information in documents that are linked to each other (Berners-Lee, 1989, 1992) per *hypertext* model (Nelson, 1965).The first generation of the Web comprised of fairly static information, mostly of impersonal and professional kind, with little interaction between sites.

O'Reilly (2007) coined the term Web 2.0 and operationalized the concept by looking at both design patterns and business models that set it apart from the first generation of the Web. He argues that value has moved from the commoditized web browsers and web servers up to services delivered over the Web platform, spanning all connected devices. Web 2.0 services such as Amazon, Wikipedia, or Flickr harness the "wisdom of the crowds" (Surowiecki, 2004), leverage "architecture of participation" (O'Reilly, 2004) and employ algorithmic data management to reach out to the entire web, including its "long tail" (Anderson 2006), not just the head. These services go beyond the page metaphor of Web 1.0 to deliver rich user experiences with PC-equivalent interactivity, while letting them to be syndicated and remixed with "mashup" services. In the world of Web 2.0, "we the media" (Gillmor, 2004) decide what is important. Top-down mainstream media are challenged by phenomena such as blogging, micro-blogging (e.g. Twitter) and social networking (e.g. Facebook). Taxonomic directories that characterized the Web 1.0 era have been replaced by "folksonomy" (Pink, 2005; Vander Wal, 2007) through tagging.

Different conjectures have been put forth as to what the next generations of the Web – Web 3.0, Web 4.0 – and so forth would entail. The most prevalent scenario of Web 3.0 is akin to *Semantic Web* (Berners-Lee, Hendler and Lassila, 2001): the machines would be able to read Web pages and make logical inferences based on the semantically annotated linked data (Heath and Bizer, 2011). Web 4.0 would hypothetically further increase the Web's autonomy and reasoning capability. There are yet few authoritative sources on what Web 4.0 would look like, but a renowned "blogosphere" citizen suggests that it builds on the tenets of ubiquity, identity and connection (Godin, 2007). Also, in Web 4.0, the network takes the initiative (ibid.): "I'm late for a dinner. My GPS phone knows this (because it has my calendar, my location, and the traffic status). So, it tells me, and then it alerts the people who are waiting for me."

While there seems to be a clear tendency to label different Web generations, the underlying principles, properties and dynamics of the evolving Web have received little attention. In this paper, we aim at providing an explanatory meta-level account to provide insights into the developmental underpinnings of the Web.

1.1. Approaches to Modeling Social Systems

We concur with Fuchs (2005) that the Internet should not be considered as a mere technological system, but as a socio-technological system. Since the different Web generations are largely determined by how technology is used, we view that the concepts of social systems are of particular importance. We surmise that the increasingly intelligent web generations emerge from the evolving systemic qualities and structures enacted by the Web's constituent agents.

Until the 1990s, social systems were primarily modeled and simulated using Equation-Based Modeling (EBM; Sawyer, 2003). In EBM, the model consists of a set of equations, such as differential or difference equations, that are evaluated in the execution of simulation. One example of EBM is system dynamics – the de-facto modeling approach in industry and for social systems for decades (Sterman, 2002).

Another approach available for social simulations today is Agent-Based Modeling (ABM), or Multi-Agent Systems (MAS), that became more widely available during the 1990s (Sawyer, 2003; Gilbert, 2008). In MAS, the model consists of a set of agents that simulate the behaviors of various entities at the micro level of the social system (Sawyer, 2003). In EBM, one focuses on modeling the macro level, whereas in ABM/MAS the focus is on modeling the behavior at the micro level while letting the macro level behavior emerge (Van Dyke Parunak et al., 1998).

During the last decade, the ABM/MAS has been further developed into Complex Adaptive Systems (CAS) approach (for example, see Miller and Page, 2007). Complex Adaptive Systems (Holland, 1992) are self-similar: both the agents and the emergent systems are adaptive. They simplify the complex by focusing on the schemata of individual agents and showing how complex outcomes evolve from the interdependencies and nonlinear interactions between the agents. Agents are partially connected to one another and observe and act on their local neighborhood only. They co-evolve with each other so that each agent strives to increase its fitness function vis-à-vis other agents. As a result, the collective behavior of the system emerges through self-organization.

Spohrer et al. (2008) propose “service system” as an abstraction that will help understanding the nature of “service” and the respective Service-Dominant Logic (e.g. Vargo and Lusch 2004, 2008; Lusch and Vargo 2006). A service system is conceptualized as a configuration of resources partaking in reciprocal value co-creation with other service systems. The broad notion of service system applies to a wide variety of entities at different levels of scale, ranging from individual people to work systems, human organizations, industrial systems, and nations. As pointed out by Maglio et al. (2006), modeling of such systems is inherently complex.

1.2. Research Approach

The Web, as a whole, can arguably be seen as a large, in fact global, service system that serves (i.e. improves the state of) other service systems (e.g. the global economic system) through sharing its resources (information and services on the Web). Its constituent subsystems, such as web sites, services and infrastructure faculties (e.g. web search), can also be conceptualized as service systems that in turn may recursively consist of service systems. In short, the Web is a complex meshwork of heterogeneous, interdependent and co-adaptive service systems at different levels of scale.

Hence, we view that CAS is an applicable approach to study service systems, in general, and the Web, in particular.

The paper consists of two main sections. In Section 2, we elucidate our CAS-based approach by:

- Reviewing Verhagen’s (2000) typology of agents, to reflect the multilevel nature of stage-based development with increasing autonomy at each stage, central within the approach.
- Reviewing the Adaptive Cycle framework by Gunderson and Holling (2002) to describe the transition process between various points of stability within complex adaptive systems.
- Subscribing to the notion of panarchy (Gunderson and Holling, 2002) – a transitory hierarchy of adaptive cycles at different levels of scale to describe the multilevel, nested ecologies of complex adaptive systems.

In Section 3, we provide an account of the evolution of the Web to date. Our analysis covers three levels of scale: the services, the service provider/consumer organizations, and the Web at large, and proceeds through all the four Web generations identified.

2. Perspectives to Complex Adaptive Systems Approach

2.1. Classification of Agents

The Web is a fractal system (Eichmann 1999) and thereby self-similar at all scales: system characteristics at one scale are similar, at least in a statistical sense, to the characteristics at other scales. Hence, to understand the nature of the Web as a whole, we will turn to its constituent systems, i.e. agents, at the micro-level.

Verhagen (2000) suggests a typology of agents based on the degree of freedom they have with respect to their plans, goals, and norms. Each successive level in this typology is increasingly sophisticated in terms of the agent's behavioral characteristics:

- **Reactive Agents** do not have internal states, but only associate the response with the stimulus. A reactive agent lacks deliberation and has no means of influencing the environment in a preconceived way.
- **Plan-Autonomous Agents** have more autonomy than reactive agents, since they may choose how to achieve the goal state that, however, the agent itself cannot change. Goals are not distinguished from interests, but whenever another agent of the state of the environment triggers the agent to pursue a goal, the goal becomes an interest. The agents have a repertoire of actions that they can aggregate to a plan to achieve the given objective.
- **Goal-Autonomous Agents** have the autonomy to determine their "prevailing interests" by evaluating what the world provides in terms of goal satisfaction and goal priority. The goals are linked to a goal that the agent already has. Verhagen (2000) calls this reasoning capability of goal-autonomous agents strategic reasoning.
- **Norm-Autonomous Agents** have the autonomy of generating their own goals and to choose which one they are going to pursue, based on a given system of norms. The agent is able to judge the legitimacy of its own goals and those of other agents. In the case of a goal conflict, the agent may change its norm system and respective goals. The generated norms can be used to evaluate states of the world in terms of whether or not they could be legitimate interests. Legitimacy is determined socially by the norms of the agent with respect to the agent society it is a part of. Verhagen (2000) calls this reasoning capability of norm-autonomous agents normative reasoning.

2.2. The Adaptive Cycle and Panarchy

The Adaptive Cycle framework by Gunderson and Holling (2002) is a metaphor that attempts to provide a general account of the organization and dynamics of complex adaptive systems. Originating from experience with productive biotic ecosystems, the concept has tentatively been considered also in other contexts, such as human organizations (Gunderson et al., 1995), business systems (Hurst, 1995) and social and political systems (Holling and Sanderson, 1996).

The Adaptive Cycle circles in three dimensions: the potential available for change, the degree of connectedness, and the resilience of the system. The first two of these dimensions are depicted in Figure 1. In addition to the two traditional ecosystem functions of exploitation and conservation, constituting the "front loop" of the cycle, Holling and Gunderson (2002) propose two additional functions of the "back loop": release and reorganization. These four functions are described below.

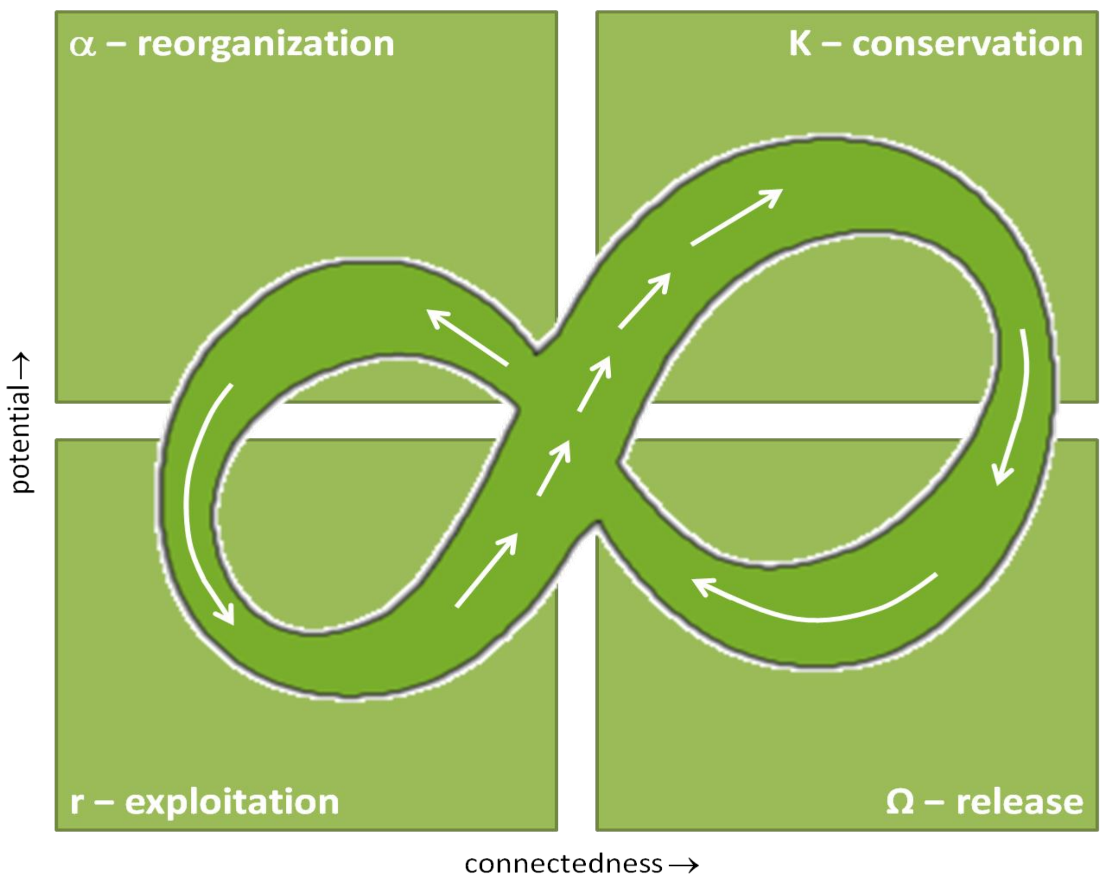

Figure 1. The adaptive cycle of renewal (Gunderson and Holling, 2002).

Reorganization. Holling and Gunderson (2002) equate the reorganization phase (α) of the adaptive cycle to the phase of innovation and restructuring in an industry or in society. At this phase, the system's connectedness is low and potential and resilience are high. This allows reassembling previously tightly connected elements and creates auspicious conditions for creative experimentation: a favorable substrate for the appearance and initial establishment of entities that otherwise would be out-competed. Random new constellations of elements can generate unexpected processes of growth, but the α phase is also vulnerable to unexpected crises.

Exploitation. The exploitation, or r phase, represents a period of competition among pioneers, such as start-up organizations, and survivors from previous cycles. Stable configurations are retained, while unstable ones are eliminated. Once the system has found its new structure, it starts a progression from r to K, exploiting stable configurations and sustaining autocatalytic growth. Connectedness between interrelated entities increases and potential accumulates, while resilience of the system decreases (Holling and Gunderson, 2002).

Conservation. At the conservation (K) phase, markets for products saturate, profit margins decrease, technologies diffuse, and organizations become bureaucratized and rigid. The system reaches a critical threshold, where the contracting stability domain makes the structure vulnerable to crisis and subject to transformation. The competitive advantage shifts from adaptiveness to control of variability. (Holling and Gunderson, 2002).

Release. The release (Ω) phase denotes a sudden increase in uncertainty. After a long period of somewhat predictable behavior, chaotic behavior ensues. This phase starts the rapid back-loop from Ω to α, the outcomes of which can be highly unpredictable and uncertain.

The adaptive cycles constitute dynamic, stratified structures – panarchies – in which complex adaptive systems nest in one another in a transitory hierarchy maintained by the interactions across scales (Holling et al., 2002). Each level operates at its own pace, embedded in slower, larger levels and invigorated by faster, smaller cycles (Folke, 2006). The slower and larger scales set the conditions for smaller and faster ones, but become sensitive to change from the lower scale at the Ω and α phases. Holling, Gunderson and Peterson (2002) identify two panarchical connections across scales, as depicted in Figure 2:

Remember connection that draws from the accumulated experience and history of the higher scale. The slower and larger scale facilitates change, renewal and re-organization in the lower scale, which is starting its adaptive cycle at α.

Revolt connection that may create new opportunities that are absorbed and diffused across the larger scales, but it may also cause a collapse up to the higher level cycle in the panarchy, especially if that cycle is at the K phase, where resilience is low. This collapse may be rapidly cascaded across larger scales.

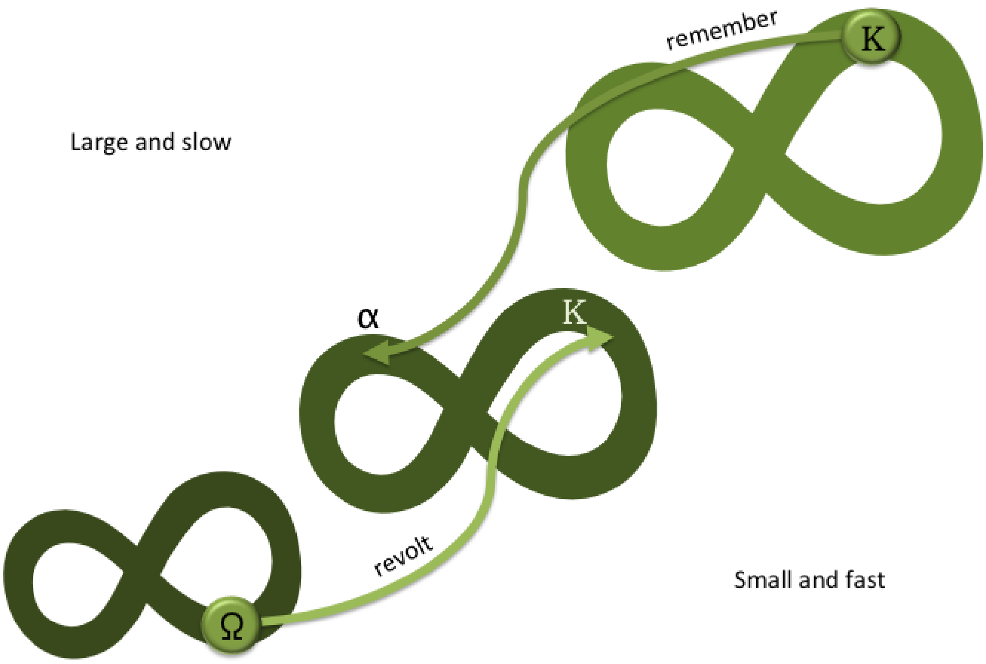

Figure 2. Panarchy (Gunderson and Holling, 2002).

3. The Evolution of the Web – Explained

In this section, we utilize the different perspectives presented in the previous section to explain the evolutionary development of the web. Specifically, we conceive the different levels of service systems in the Web as panarchic scales (Holling et al., 2002), leverage Verhagen's (2000) classification of agents to outline the characteristic nature of each identified Web generation, and conceptualize these Web generations as adaptive cycles (Holling and Gunderson, 2002).

3.1. Scales of the Web

Holling et al. (2002) identify three scales in analyzing ecosystems: small and fast, intermediate size and speed, and large and slow. In the context of the Web, we map these three scales to individual services, service organizations, and the Web at large, respectively. We surmise that, due to the fractal nature of the Web, systems at all levels of observation co-evolve coterminously in statistical sense. The increasing sophistication of service systems is co-causal with the new Web generations embracing and transcending the previous ones.

The largest scale represents the entire Web. Our estimation of the timescale of Web generations ranges in about 10–15 years. The middle scale is represented by organization-level service systems, e.g. Amazon, Google. The cycle at this scale is faster; companies continuously introduce new services and reorganize old offerings. The smallest scale is at the level of individual services. New services come and go frequently.

According to the CAS principles, developments and behavior at the micro level may beget unforeseen new types of behavior to emerge at the macro level. For instance, an individual service may cause a "revolt" and be advanced to the next scale. A case in point would be the micro-blogging service Twitter that rapidly diffused as a pervasive phenomenon of large consequence.

3.2. Service Systems as Increasingly Autonomous Agents

Hypothesizing that each successive Web generation would represent an increase in the autonomy of its constituent service systems, we conjecture that the different Web generations from 1.0 to 4.0 would pertain to Verhagen's (2000) classification respectively.

Service systems in Web 1.0 are rather static and predictable. The Web services are simple "reactive agents", where the response is directly coupled with the response. The service consumer is in full control of service interactions, as the used services behave deterministically. As an example, we can think of a simple Web site of a company or early online booking systems of online travel agencies.

Service systems in Web 2.0 represent a more sophisticated degree of autonomy. They can be abstracted as "plan-autonomous agents" that entail a degree of deliberation in achieving the goals imposed by the service consumers. These service systems usually involve human interaction, value co-creation and use of social media and technologies. Service interactions are still rather predictable, yet not entirely deterministic. As an example, we can think of Amazon bookstore and its sophisticated social recommendation engine that suggests, upon purchase, similar items that others have bought and provides pertinent lists of books recommended by other users.

As discussed in the introduction section, the Web is currently on the verge of its 3rd generation. The emerging Web 3.0 is generally seen as extending the socially constituted Web 2.0 with machine interpretable Semantic Web technologies and inference mechanisms. We view that Web 3.0 will comprise of "goal-autonomous" service systems, capable of setting their own goals within the context of service user fulfillment.

In a similar vein, we can make a sophisticated conjecture that Web 4.0 would manifest the qualities and structures of "norm-autonomous agents". The service systems will have full autonomy to choose their goals and take sovereign action vis-à-vis other agents. The very notion of service consumer becomes blurred, as the service systems will increasingly take on purposeful "prosumer" characteristics. The web services may evolve to independent and intentional agents that not only work on behalf of the user but also become their users, correspondingly.

3.3. Web Generations as Adaptive Cycles

We view that each Web generation can be conceived as an adaptive cycle that undergoes the phases of growth, conservation, release and finally reorganization leading to the next generation in the evolution. Holling and Gunderson (2002) associate the phases of the adaptive cycle with three different properties: potential (i.e. accumulated resources), connectedness (i.e. controllability or increased rigidity) and resilience of the system. As examples of potential accumulating in economic or social system, Gunderson and Holling list skills, networks of human relationships, and mutual trust. In the context of the Web, we can consider potential as pertaining to the amount of users, web pages, data, bandwidth and other similar resources that enable alternative options for the future of the Web. Connectedness refers to the degree of internal control that a system can exert over external variability (Holling and Gunderson, 2002). The increasing connectedness within a given Web generation can thereby be understood as the rigidities that appear in the phase of growth and when facing the varying needs of its users. The third property, ecosystem resilience, represents the capacity of a system to experience disturbance and still maintain its ongoing functions and controls (ibid.). As the adaptive cycle of a Web generation moves toward K, resilience shrinks and makes it vulnerable to external variability that exceeds its controllability and triggers the next cycle.

To test this idea, we will next review how each Web generation has developed and accumulated potential and resources in its adaptive cycle and identify the rigidities that have triggered the transition to the next generation. We have collected the characteristics of each Web generation in Table 1. outlining:

- a short description of the *Essence* of the generation
- the *Accumulating resources* in the generation (i.e. potential)
- the *Rigidities* associated with the generation (i.e. connectedness)
- *Producers* typical to the generation, and
- *New consumers* that have emerged in the generation (or will emerge in the future).

Table 1. Characteristics of each Web generation seen as an adaptive cycle.

	Web 1.0	**Web 2.0**	**Web 3.0**	**Web 4.0**
Essence	Static information online	Dynamic co-creation	Semantic web	Automatic reasoning
Accumulating resources	Linked pages, amount of users	Linked people, amount of data	Linked data, advances in AI	Linked agents
Rigidity	Cumbersome and restricted way of producing content.	Difficult to find relevant information from the massive amount of unstructured data produced by the people	A mismatch between the limited information processing resources and capabilities of humans and the vast amount of machine-readable data.	
Typical producer	Experts	People	Services and sensors	Agents
New consumers	People	Services	Agents	

Web 1.0 consisted of static information on pages hyperlinked to each other. In the beginning, the content was predominantly produced by experts, who published factual information and had the skills or access to skills to create web pages. As the amount of content consumers – the ordinary people using the Web – grew, the cumbersome way of publishing web pages became a restriction to the Web's further growth.

Technologies such as Wiki and blogging enabled Web 2.0, in which people turned from content consumers to co-creators of content. In addition to linking web pages, "we the media" (Gillmor, 2004) started linking to each other on social networking platforms such as Facebook. As the number of content producers increased, so did the amount and variety of data. This was further enabled by the increase in available bandwidth and a multitude of new devices, such as mobile phones with embedded cameras, to access and produce content on the Web.

Due to the vast amount of unstructured data that people, and increasingly also services and sensors, are producing, it has become difficult to find relevant information on the Web. As depicted in Figure 3, we are currently at the verge of the Web 3.0, in which data, in addition to pages and people, will be structured and linked. A new publishing paradigm is emerging for producing “linked data” on the Web (Heath and Bizer, 2011). Already in Web 2.0, the mashup services may act as “consumers”. We surmise that in Web 3.0 services will become increasingly intelligent agents that have some degree of autonomy in their behavior.

Presumably, the amount of machine-processable data will substantially increase in the future, while Artificial Intelligence (AI) makes further advances. We extrapolate that there will eventually be a mismatch between the limited information processing capabilities and resources of humans and the voluminous amount of machine-readable data on the Web. We postulate that in Web 4.0, the agents will be linked to each other and increasingly become the producers of content. As suggested in Figure 3, Web 4.0 is projected to emerge towards the end of this decade.

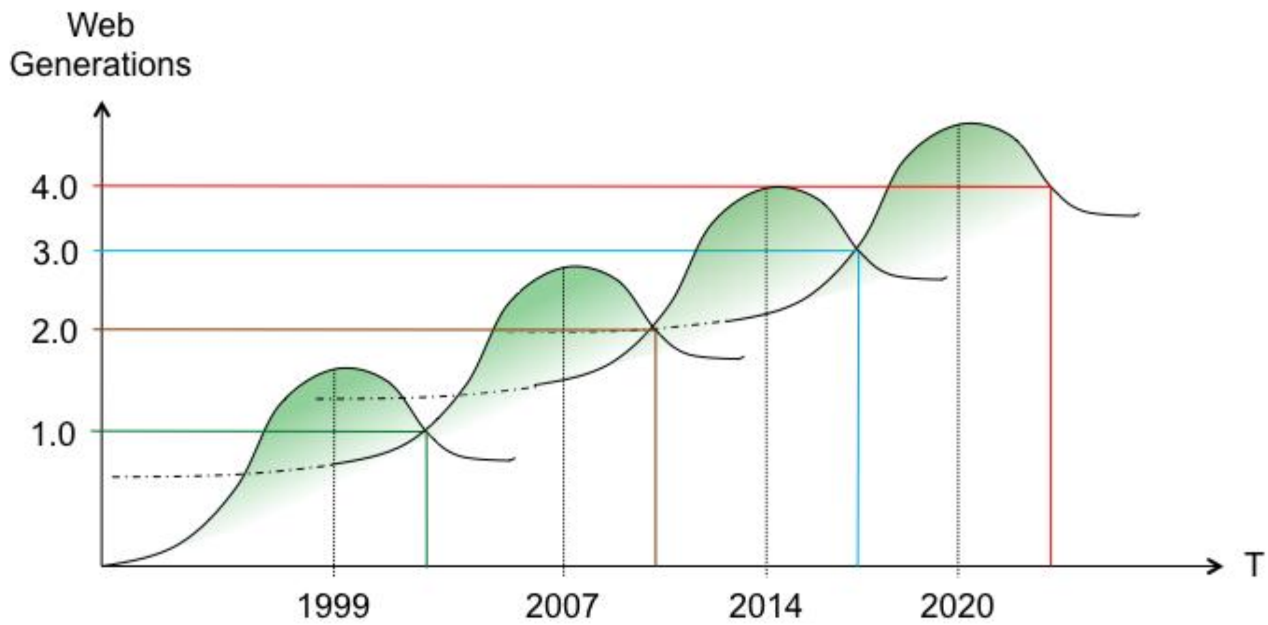

Figure 3. The development of the Web through identifiable generations.

4. Conclusions

In this paper, we have conceptualized the Web as a multi-scale service system and used Complex Adaptive Systems (CAS) approach to provide an explanatory account of how the systemic properties of different Web generations can be attributed to the increasing sophistication of its constituent agents. To this end, we have related the ecological notions of Adaptive Cycle and Panarchy (Gunderson and Holling, 2002) to Verhagen’s (2000) typology of agents.

The resulting model of the evolving Web comprises of three levels of scale and four waves of development. Each Web generation is seen as an adaptive cycle that undergoes the phases of growth, conservation, release and finally reorganization at the next generation.

As the key results of this study, we found that:

- As the service systems increase in autonomy in each successive Web generation, the control of service consumers over the service they are using progressively diminishes.

- For each Web generation, characteristic accumulating resources can be identified that cause such rigidity that it triggers an evolutionary leap to the next generation.
- The content consumers at each generation tend to become the content producers at the next generation.

Based on our analysis, the Panarchy model seems to fit well in explaining the development of the Web. We think that it could potentially be applied in other service system related contexts, as well.

The conceptual nature of this paper does not readily lend itself to traditional quantitative or qualitative research methods. However, one conceivable avenue for empirical research would be to gather and investigate publicly available quantitative data on the identified accumulating resources over time. In any event, the tentative conjectures presented herein invite further corroboration.

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