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Discovering the Future of the Web

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2014 brought the 25th anniversary of the World Wide Web. There is general agreement that it represents one of the most influential software applications in history and has transformed many diverse elements of human interaction. The global impact of the Web would naturally lead to speculation about the future of the technology and attempts to understand what has driven its evolution in the past and what will do so in the future. The definition of Web Science and its implementation in Web Observatories provide a viable mechanism for a more complete understanding of the technology and a paradigm for directing its future. Web Science also provides a powerful multi-disciplinary framework and compelling research opportunities.

Keywords: Future Web, Web Science, Web Observatory, Social Web, Data Web, Web Engineering

1. Introduction

In 2014 the World Wide Web celebrated its 25th anniversary amidst the fanfare befitting a technology that has, quite literally, changed the course of human communication, social interaction, commerce, entertainment, education and more. As the pundits analyzed the lessons learned in the Web's first quarter century, it was quite natural to ask the question, "What's next?" If the Web were a twenty-five year old human, it would be in the young adulthood and would rightfully be asking questions such as (1) What will I do with my future? (2) How can I contribute to the future of my family and those who depend upon me? The answers are not exclusively (or even largely) about technology any more than, for a young adult, they are exclusively about biology. The Web, like humans, is a part of a larger ecosystem that is affected by it and that it affects.

Obviously, the Web cannot ask itself such questions, but the stakeholders in the future of Web technology can and should. All too frequently buzzwords and catch phrases such as "Web 3.0," "Web 4.0," "The Smart Web," and "The Web of Things" (a subset of "The Internet of Things") are bandied about, but in reality no one can predict the future of the Web if it is "left to its own devices" (no double entendre intended). Wendy Hall and Mark Schueler (University of Southampton) have compiled an outstanding graphic shown in Figure 1. (`http://growthchart.weebly.com`) illustrating the history of the Web in the context of other technological advancements and the exponential growth of Internet users.

Hall and Schueler also identify the dominant areas of focus (e.g., "read only," "read/write," "social") that the Web has experienced since its inception. Their graphic, while beautiful in its execution, provides no clue as to the future of the Web except that it will most certainly involve more data, more users, and more devices utilizing new technologies. For example, where might the "Web of Things" (a subset of "The Internet of Things") fit? Some Web futurists have suggested that its future is invisibility or pervasiveness where it "dissolves into the background" or integration such as Ray Kurzweil's drive towards "singularity". In both cases, that future Web would not fit in the scheme of Hall and Schueler's Web evolution model. Some others see the Web as a platform for increased social colonization (expanding Figure 1's Social Web) driven and monetized by the service providers. Were this to happen, Web inventor Sir Tim Berners-Lee might likely disown it in the same way that Gutenberg might have reacted had he seen pornographic publishing, or the Greek philosophers if given the opportunity to comment on MOOCs (Massive Online

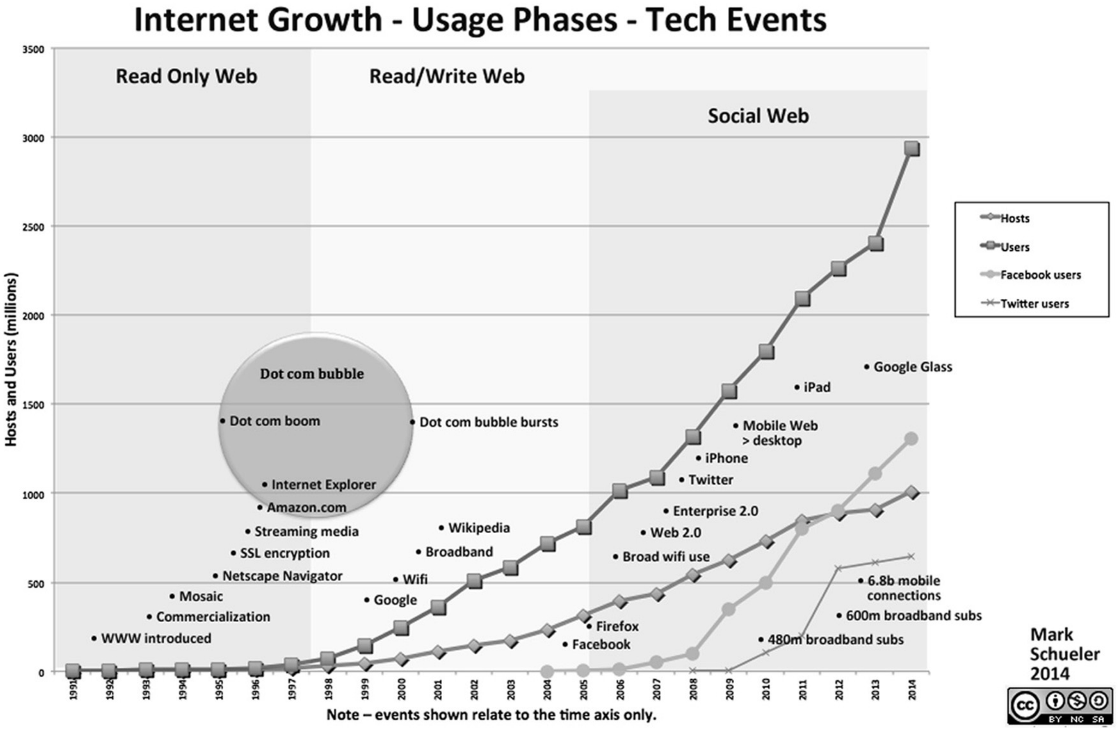


Figure 1.

Open Courses) and their impact on teaching and learning.

2. Understanding Web Technology Drivers

But perhaps Figure 1 does provide a clue to understanding the Web's future in the way that it portrays the "dot com bubble". This phenomenon is depicted as an "outlier," something not predicted and indicative of unknown forces at work. It suggests that Web behavior is not strictly driven by its underlying technologies. This possibility will be discussed further later in this paper.

In all of the 25th birthday celebratory discussions, it was largely ignored that despite the Web's far-reaching impact, we are still observing a "dumbed-down" version of the Berners-Lee vision. In his keynote address at the 1996 World Wide Web conference, Ted Nelson, responsible for the term hypertext, asserted "your future is my past" when comparing current and future Web features to those already defined (though not implemented) in his Xanadu system. Figure 2 shows the configuration of the

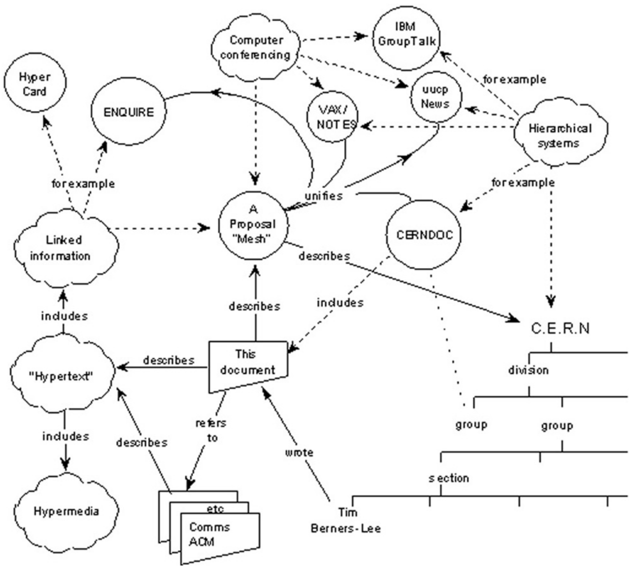


Figure 2.

Web in the original 1989 proposal (`http://www.w3.org/History/1989/proposal.html`).

The elements described in Figure 2 show that the Web contains social, authoring, editing, multimedia, and semantic components. It could therefore be asserted that during the past 25 years when terms such as Web 2.0, "The Semantic Web," and "The Social Web" have been used, that they are not examples of new technologies or applications, but rather new, previously hidden, components of the original Web revealing themselves at the appropriate time. So like explorers of natural systems, the future of the Web might already be hidden in its original design.

In the mid-1990s, the discipline of Web Engineering was introduced (by the author with others). "Web Engineering actively promotes systematic, disciplined and quantifiable approaches towards successful development of high-quality, ubiquitously usable Web-based systems and applications." (Wikipedia). A goal of Web Engineering is to distinguish Web-based development from the traditional methods found in Software Engineering. It is also important to emphasize the importance of aesthetic and interaction components in the design of Web-based systems, not necessarily found in software applications. Web Engineering recognizes the multidisciplinary elements of Web technology and encourages the involvement of diverse skills (e.g., psychologists, educators, etc.) on Web design teams. Web Engineering foresees the use of engineering methods and tools to build the Web of the future.

There is, perhaps, one fundamental flaw in attempting to define Web Engineering. Traditional engineering is built upon science that defines the variables and sets the parameters controlling development. Therefore, if Web Engineering is truly an engineering discipline, then what is the science behind the Web? Is it Computer Science (questionably a science itself), or a new science?

It is amusing (and sometimes enlightening) to think of the Web like the cosmos or physical universe. The metaphor of "cyberspace" has become a part of the common vernacular. So, perhaps the science behind the Web looks something like cosmology. For example,

- Both the early universe and the early Web experienced a period of rapid, uncontrollable expansion;
- This expansion has led to both visible and invisible (dark) components;
- Expansion continues due to strong and poorly-understood forces;
- Web hyperlinks, like physical gravity, are capable of extending great, if not infinite, distances;
- The Web, like the physical universe, is comprised of diverse entities fueled by different forces and in constant interaction with one another and with unknown structures;
- These entities frequently "burn out," become irrelevant and lead to new entities;
- The goal of cosmology is to understand the entities, forces, and mechanisms/laws in order to determine whether in the future the universe will implode or continue expansion until it becomes a cold, distant, lonely place.

The analogy between cosmology and "the science of the Web" is not intended to be frivolous and will be revisited later in this paper.

3. The Emergence of Web Science

In 2006, Sir Tim Berners-Lee, Dame Wendy Hall, and others founded the "Web Science Research Initiative" (later changed to the "Web Science Trust"). The group called for a new, unique scientific discipline that focuses on "the analytical power of researchers from disciplines as diverse as mathematics, sociology, economics, psychology, law and computer science, to understand and explain the Web. It is necessarily interdisciplinary – as much about social and organizational behavior as about the underpinning technology." Like other "real" sciences, its goal is to understand the mechanisms behind the Web by incorporating all those disciplines that "are affected by Web technology" and/or "affect Web technology". An understanding of the science "behind the Web" could conceivably allow it to be truly engineered in a way for mutual benefit. For example, if Web Science could be quantified, it might have been possible to understand/predict the "dot com bubble" outlier in Figure 1 and prevent a similar situation from recurring in the future.

Effectively, Web Science asserts that the Web can be viewed as a new (and unique) technical and social phenomenon that cannot be generally described in the context of another natural, social, or man-made (i.e., technological) science. In addition, it can (and should) be studied as a single/growing entity ("in situ") rather than strictly in terms of its underlying parts (e.g., computer protocols). If successful in these endeavors, Web Science suggests that otherwise not understood or misunderstood behaviors of the Web could potentially be controlled, managed, and even engineered.

Specifically, the phenomena observed in Web Science are a result of scale, as illustrated in Figure 3 (from Tim Berners-Lee).

At the micro-level, the Web is best viewed as

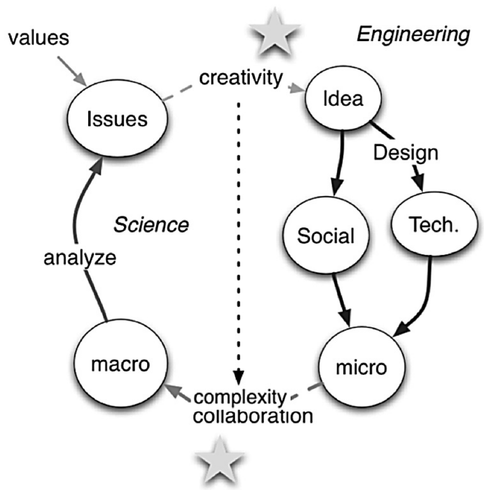


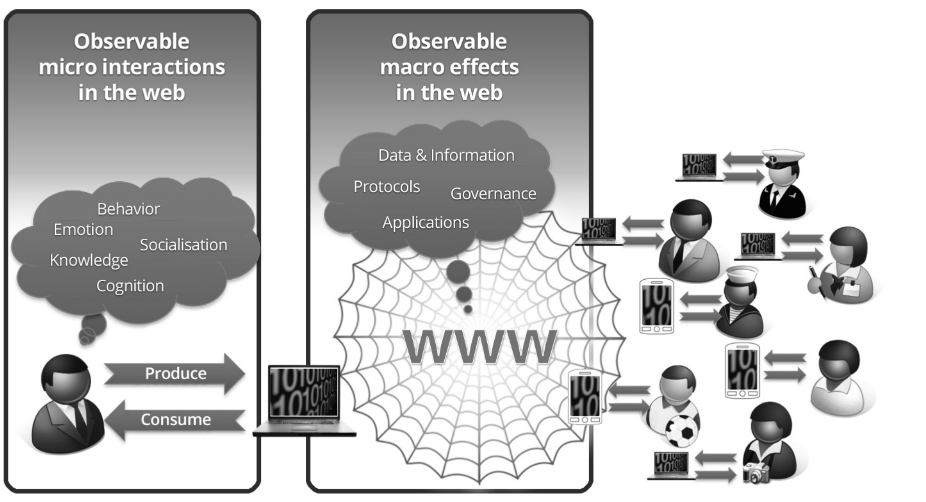
Figure 3.

an engineering artifact expressed in terms of standardized, collaborative tools and protocols (e.g., HTTP, HTML, etc.). A Web page standing alone is of little particular interest. The science begins to appear at the macro-level when complexity is introduced by linking and shared services. For example, there is no rule in Web page design restricting the number of outbound hyperlinks beyond one. (Without one, there would be no exit linking). Without such a rule it might be reasonable to expect the topology of a collection of Web pages/sites to be random. However, there is observable evidence that the topology more closely resembles a "scale-free graph". (Barabási). "Living organisms, when allowed to make freely willed decisions, seem to end up obeying some kind of mathematical law." (Gandhi Viswanathan, theoretical physicist, Federal University of Alagoas, Brazil).

Such observations might provide a clue as to what other insights might be extracted from the Web.

In Figure 4 (from the work of Steffen Staab), the interaction between these micro-environments and corresponding macro-environments are explored.

"The Web becomes a gigantic informational ecosystem that can be used to quantitatively measure and test theories of human behavior and social interaction." (Huberman, *The Laws*



(cc-attrib Steffen Staab. http://west.uni-koblenz.de)

Figure 4.

of the Web, 2001). "The Social Web" was the latest element in Wendy Hall's and Mark Schueler's Web evolution timeline (Figure 1). Is it reasonable to think that the future Web will only consist of refinements to the current "Social Web?" What disciplines other than those typically described as "the social sciences" are likely to contribute to the future Web? Will the "Web of Things" be similarly driven by social interactions between non-human participants?

The "Social Web" is currently very highly leveraged by Web-based E-Commerce and Web-based education. Capturing the experience from these two applications (and others) can likely provide a greater vision of the requirements facing the Web of the future and engineering solutions for maximizing benefit.

Figure 5 is often referred to as "the colliding disciplines" diagram. Its goal is to graphically represent the intersection of the diverse research disciplines found in Web Science and the degree to which they are actively involved.

Some of the disciplines represented in Figure 5 are obvious (e.g., computer science, artificial intelligence), while some others are noticeably absent (law, economics). Possible strategies for addressing these disparities are discussed in the Conclusions section of this paper.

The Web Science Trust now supports a global network of laboratories (WSTNet) conducting research in various aspects of Web Science.

4. Web Observatories

The latest implementation of the Web Science concept is the establishment of The Web Observatory Project. It aims at developing a global data, analytics, and visualization environment for the advancement of Web Science research, and ultimately improving economic and social prosperity. Given the ever-increasing streams of Web data, the Web Observatory positions itself as a suitable environment to study the evolution and impact of the Web's ecosystem, which operates at massive scale and is dominated by unexpected, emergent phenomena and radical user-led innovations in technology and society.

Earlier, there was the analogy comparing the Web universe with the physical universe. Web observatories peer into the Web in the same way that astronomers and astrophysicists gaze at the skies, trying to understand the basic driving forces of astronomy and cosmology. Like the "dark energy and dark matter" driving the expansion of the physical universe, social forces

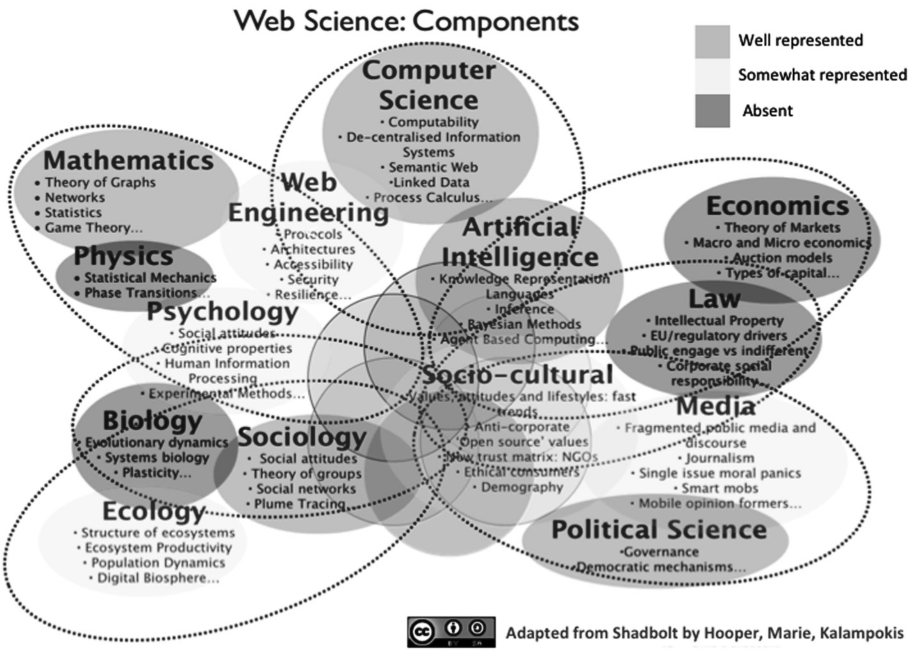


Figure 5.

are driving the expansion of the Web and providing its physics. It is the Web's social component at the beginning (Figure 2) that made it unique, useful, and personal. Technology, not a social component, was the basis for the Web's earlier competitors/peers (e.g., Gopher, WAIS, Hyper-G, etc.) and perhaps that is why those systems were not accepted as readily. The Web interaction model has now become an affordance for many software applications, even if that application is actually not Web-based.

Web observatories (like their astronomy counterparts) should practice "real science". In the WWW2014 (`http://www2014.kr`) workshop on Web observatory interoperability and standards organized by Dame Wendy Hall, David De Roure (Oxford University) posed the question, "How do we support research that is reproducible (and repeatable, replicable, referenceable, retrievable, reviewable, replayable, reinterpretable, reusable, reconstructable, repurposeable, remixable, reliable, respectful, reputable, revealable, refreshable, recoverable, and reparable)?"

The "Social Web" has also introduced the notion of "social machines". They are defined as "Web-based socio-technical systems in which the human and technological elements play the role of participatory machinery with respect to the mechanistic realization of system-level processes" (Shadbolt & Smart). This definition focuses attention on the way in which Web-based technologies serve to control, constrain, coordinate or otherwise influence an increasing number of social processes (Shadbolt & Smart).

There is a strong correlation between Web Science/Social Machines/Web Observatories and projects on Data Science, Virtual Laboratories, and Linked Open Data. Work in these projects would certainly be supportive of De Roure's "19Rs". The sharing of diverse datasets (hopefully as linked open data) is encouraged and actively sought after. Like virtual laboratories, these datasets are made available to students and researchers in multiple disciplines around the world, for practical experiments, analysis, and integration ("mash-ups").

5. Conclusions

The title of this paper is "Discovering the Future of the Web". This title is couched in the belief that the future of the Web does not lie in technology, but rather in an exploration of the processes that have driven Web evolution. One of the dominant processes has proven to be the Web as a platform for social interaction. Continuing exploration can currently be found in the Web Science and Web Observatory initiatives. Instead of being dissected into individual artefacts, the Web should be viewed as a unique single entity constantly undergoing a metamorphosis. If these efforts prove successful, the components of the future Web "may reveal themselves".

Such revelations are likely to occur since the Web itself "is a laboratory". It is history's largest laboratory housing enormous, multi-disciplinary datasets and diverse effects. It provides a vast playground for researchers to test theories in the absence of other effects that can plague measurements or on previously impossible scales. Like the observable universe (which now includes the observable Web), everything is right in front of researchers. It is just a matter of looking in the right direction, at the right time, using the right tools. Web Science/Web Observatories can employ the traditional methods of classical experimental science.

Web Engineering needs to re-align itself with Web Science as opposed to Software Engineering. The validity of Web Science will need to be reflected in the methods of Web Engineering. Insights/data obtained from Web Science/Web Observatories could then be used in engineering the future Web.

One of the greatest challenges to Web Science (and its ability to define the future Web) depends upon its success in building a multi--disciplinary effort (Figure 5). Those disciplines under-represented need to be encouraged to build and share their datasets. An even greater challenge may come in the building of common, shared, multi-disciplinary vocabularies and ontologies. Researchers and practitioners from diverse disciplines (e.g., Computer Science and Law) must be able to communicate with each other without compromising the richness of their individual fields and without prejudice or preferential treatment.

Figure 2 illustrates the architecture of the Web proposed twenty-five years ago. Despite the efforts to predict its future, Sir Tim Berners-Lee still maintains, "the Web as I envisaged it, we have not seen it yet. The future is still so much bigger than the past" (`http://www.opening-governance.org/sir-tim-berners-lee/`). A stated goal of the World Wide Web Foundation (`http://webfoundation.org`) is to "lead the Web to its full potential". Achieving this goal in a future Web will be a major task involving the skills and talents of a wide variety of individuals and institutions. This task must be conducted methodically and scientifically. The Web cannot be allowed to shape its own future – there are lessons to be learned from incidents such as the "dot com bust" and the current debates on Web/Internet spying and governance. The emergence of Web Science and Web Observatories are a great step forward in the effort of "discovering the future of the Web".

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Upon his return he was part of the team that established the first non-European Web site at SLAC (the fifth site in the world). Ever since, his academic research interests have evolved in parallel with Web technology and he has become internationally recognized as a WWW pioneer and visionary. He is often considered to be the "first American Webmaster" and one of the founders of the discipline of Web Engineering.

In addition to his work at SLAC, Prof. White also holds faculty appointments at several other institutions, advisory positions on a variety of academic, government, and commercial committees, and is a member of the organizing committees of several major conferences series. He frequently lectures and speaks internationally to academic and commercial audiences. The Association for Computing Machinery (ACM) has selected him to be a part of their Distinguished Speaker Program.

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