A Framework for Web Science

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A Framework for Web Science

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Abstract

This text sets out a series of approaches to the analysis and synthesis of the World Wide Web, and other web-like information structures. A comprehensive set of research questions is outlined, together with a sub-disciplinary breakdown, emphasising the multi-faceted nature of the Web, and the multi-disciplinary nature of its study and development. These questions and approaches together set out an agenda for *Web Science*, the science of decentralised information systems. Web Science is required both as a way to understand the Web, and as a way to focus its development on key communicational and representational requirements. The text surveys central engineering issues, such as the development of the Semantic Web, Web services and P2P. Analytic approaches to discover the Web's topology, or its graph-like structures, are examined. Finally, the Web as a technology is essentially socially embedded; therefore various issues and requirements for Web use and governance are also reviewed.

Contents

1

Introduction

The World Wide Web is a technology that is only a few years old, yet its growth, and its effect on the society within which it is embedded, have been astonishing. Its inception was in support of the information requirements of research into high energy physics. It has spread inexorably into other scientific disciplines, academe in general, commerce, entertainment, politics and almost anywhere where communication serves a purpose [142, 143]. Freed from the constraints of printing and physical distribution, the results of scientific research, and the data upon which that research is carried out, can be shared quickly. Linking allows the work to be situated within rich contexts. Meanwhile, innovation has widened the possibilities for communication. Weblogs and wikis allow the immediacy of conversation, while the potential of multimedia and interactivity is vast.

But neither the Web nor the world is static. The Web evolves in response to various pressures from science, commerce, the public and politics. For instance, the growth of e-science has created a need to integrate large quantities of diverse and heterogeneous data; e-government and e-commerce also demand more effective use of information [34]. We need to understand these evolutionary and developmental forces.

Without such an appreciation opportunities for adding value to the Web by facilitating more communicative and representational possibilities may be missed. But development is not the whole of the story. Though multi-faceted and extensible, the Web is based on a set of architectural principles which need to be respected. Furthermore, the Web is a social technology that thrives on growth and therefore needs to be trusted by an expanding user base – trustworthiness, personal control over information, and respect for the rights and preferences of others are all important aspects of the Web. These aspects also need to be understood and maintained as the Web changes.

A research agenda that can help identify what needs to stay fixed and where change can be profitable is imperative. This is the aim of *Web Science*, which aims to map how decentralised information structures can serve these scientific, representational and communicational requirements, and to produce designs and design principles governing such structures [34]. We contend that this science of decentralised information structures is essential for understanding how informal and unplanned informational links between people, agents, databases, organisations and other actors and resources can meet the informational needs of important drivers such as e-science and e-government. How an essentially decentralised system can have such performance designed into it is the key question of Web Science [34].

'Web Science' is a deliberately ambiguous phrase. Physical science is an analytic discipline that aims to find laws that generate or explain observed phenomena; computer science is predominantly (though not exclusively) synthetic, in that formalisms and algorithms are created in order to support particular desired behaviour. Web science has to be a merging of these two paradigms; the Web needs to be *studied* and understood, and it needs to be *engineered*. At the micro scale, the Web is an infrastructure of artificial languages and protocols; it is a piece of engineering. But the linking philosophy that governs the Web, and its use in communication, result in emergent properties at the macro scale (some of which are desirable, and therefore to be engineered in, others undesirable, and if possible to be engineered out). And of course the Web's use in communication is part of a wider system of human interaction governed by conventions and laws. The various levels at which Web technology interacts with human society mean that interdisciplinarity is a firm requirement of Web Science.

Such an interdisciplinary research agenda, able to drive Web development in socially and scientifically useful ways, is not yet visible and needs to be created. To that end, in September 2005 a Web Science Workshop was convened in London, UK (details of the contributors to the Workshop are given in the Acknowledgements). The workshop examined a number of issues, including:

- Emerging trends on the Web.
- Challenges to understanding and guiding the development of the Web.
- Structuring research to support the exploitation of opportunities created by (*inter alia*) ubiquity, mobility, new media and the increasing amount of data available online.
- Ensuring important social properties such as privacy are respected.
- Identifying and preserving the essential invariants of the Web experience.

This text grew out of the Web Science Workshop, and it attempts to summarise, expand and comment on the debates. That an interdisciplinary approach was required was agreed by all, encompassing computer science and engineering, the physical and mathematical sciences, social science and policymaking. Web Science, therefore, is not just about methods for modelling, analysing and understanding the Web at the various micro- and macroscopic levels. It is also about engineering protocols and providing infrastructure, and ensuring that there is fit between the infrastructure and the society that hosts it. Web Science must coordinate engineering with a social agenda, policy with technical constraints and possibilities, analysis with synthesis – it is inherently interdisciplinary, and this text is structured to reflect that.

Developing the Web also involves determining what factors influence the Web experience, and ensuring that they remain in place. Examples of basic architectural decisions that underpin the Web include: the 404 error, which means that failure to link to a resource doesn't cause catastrophic failure; the use of the Uniform Resource Indicator (URI); and the full exploitation of the pre-existing Internet infrastructure (such as the Domain Name System) as the platform on which the Web was built. Standards are also crucial, and the World Wide Web Consortium's (W3C) work of creating and recommending standards while maintaining stakeholder consensus shows that engineering needs to go hand in hand with a social process of negotiation.

Section 2 reviews these basic scientific and architectural principles in more detail. Exploring the metaphor of 'evolution' may help us to envisage the Web as a populated ecology, and as a society with the usual social requirements of policies and rules. Connecting relevant approaches, covering variant methodologies, varying spatiotemporal grain sizes and modelling across a wide range of domains, will be challenging.

Section 3 looks at some of the issues to do with engineering the Web, and how to promote, and be promoted by, new technologies such as grids or services. Perhaps one of the most important potential developments to be discussed in this section is the Semantic Web. The Web is usually characterised as a network of linked documents many of which are designed to be read by humans, so that machine-readability requires the heuristics of natural language processing. However, the Semantic Web, a vision of extending and adding value to the Web, is intended to exploit the possibilities of logical assertion over linked relational data to allow the automation of much information processing. Research and development has been underway for some time now on developing the languages and formalisms that will support querying, inference, aligning data models, visualisation and modelling.

To flourish, the Semantic Web needs the same decentralising philosophy as the World Wide Web. One challenge is to ensure that various individual data systems can be amalgamated with local consistency without attempting the impossible task of trying to enforce consistency globally. Furthermore, the basic use of a common set of symbols – URIs – by a number of formalisms with contrasting properties, such as rules and logic, without assuming any kind of centralised or 'basic' formalism for describing the Web is also non-trivial. A third issue is to do with bringing data together to leverage the power of amalgamation and serendipitous reuse; most data currently sit in standalone repositories and are not published (in contrast to the WWW, where documents are routinely made available to a wider audience).

Section 4 looks at attempts to analyse the Web in ways that can feed back into the engineering effort. For instance, modelling the Web mathematically will enable search and information retrieval to keep pace with its growth, especially if linked to important fields such as natural language processing, network analysis and process modelling. Understanding emergent structures and macroscopic topology will help to generate the laws of connectivity and scaling to which the Web conforms.

As noted, the Web's value depends on its use by and in society, and its ability to serve communication needs without destroying other valuable types of interaction. This means understanding those needs, their relation to other social structures, and the two-way interaction with technological development. Social issues such as these are discussed in Section 5, and include philosophical issues to do with the meaning of symbols, logical problems such as methods of reasoning, and social issues including the creation and maintenance of trust, and the mapping of social communities via their activities on the Web.

Some of the interactions between society and Web technology are current and require policies for regulation and expressing preferences. For instance, the Semantic Web clearly motivates a corporate and individual cultural imperative to publish and share data resources, which in turn will require policies dealing with access control, privacy, identity and intellectual property (as well as interfaces and systems that can express policy rules to a heterogeneous user base). Policy, governance and political issues such as these are discussed in Section 6.

Section 7 provides a brief conclusion, summarising the case for a Science of the Web, and encapsulating the vision that this text, in an extended form, has presented.

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