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TOWARDS A SYSTEMATIC APPROACH FOR THE CREDIBILITY OF HUMAN-CENTRIC WEB APPLICATIONS

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The apparent "socialization" of the Web brings new prospects as well as challenges. In this paper, the issue of credibility of Web Applications in the light of increased human participation and collaboration is considered. The stakeholder types to which credibility of Web Applications is relevant are identified. Based on a taxonomy of credibility, the origins of the issue of credibility specific to human-centric Web Applications are explored and examples in support are presented. The role of addressing credibility within the auspices of flexible and iterative development processes is emphasized. A framework for understanding and addressing the credibility of human-centric Web Applications in a methodical manner is proposed. This framework includes quality attributes of concern to stakeholders and process- and product-oriented means for addressing them in a feasible manner. Finally, extensions of the framework, including implications towards the Semantic Web, are briefly outlined.

Key words: Agile Development, Credibility, Feasibility, Pattern, Quality Model, Semiotics
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1 Introduction

The Internet, particularly the Web, has opened new vistas for many sectors of society including education, business, and government. Indeed, Web Applications are playing an ever more integral role in our daily activities of communication, information, and entertainment.

Since the beginning of this century, there has been a notable transformation in way the Web Applications are developed, perceived, and used. There has been a steady shift in the *nature* of Web Applications: from passive to interactive, from read (only) to read-and-write, and from information push to information pull.

The catalyst of this transition of Web Applications is *us*, the people. Indeed, the TIME Magazine's naming the Person of the Year for 2006 to be "You" is a sign of this paradigmatic change. The pseudonym Web 2.0 (O'Reilly, 2005) has been used to describe the apparent "humanization" and even "socialization" of the Web as it moves towards becoming a means of participation and collaboration.

In spite of the significant prospects offered by human-centric Web Applications, there are certain caveats. The mere fact that virtually *anyone* can set up such applications claiming to offer definitive information on a topic or sell products and services, raises the issue of credibility from a consumers' viewpoint. If not addressed, there is a potential for lost consumer confidence, thereby compromising the benefits and opportunities the Web as a medium offers. Establishing credibility by appropriately engineering Web Applications is essential for an organization's reputation (Resnick et al., 2000; Gibson, 2002) and for building consumers' trust (Kamthan, 1999; Schneiderman, 2000; Jordan, Hauser, & Foster, 2003).

An emphasis on systematically understanding and addressing quality is central to all engineering. The view of this paper is that the same holds for the credibility of Web Applications.

The rest of the paper is organized as follows. We first provide the background and motivation necessary for later discussion, and state our position with respect to previous work. This is followed by identification of stakeholder types of Web Applications and their relationship to credibility, an examination of the origins of the issue of credibility specific to Web Applications, and discussion of credibility within of Web Application development processes. We then introduce a framework by which different types of credibility concerns in the context of human-centric Web Applications can be understood, systematically addressed, and thereby improved. Next, challenges and directions for future research are outlined. Finally, concluding remarks are given.

2 Background and Related Work

In this section, we present the fundamental concepts underlying credibility and present the motivation and related work for addressing credibility within the context of Web Applications.

2.1 The Nature of a Web Application

There are several possible views of a Web Application. For the sake of this paper, we view a *Web Application* to be a special class of information system in a distributed client-server environment. A Web Application is different from a Web Site in the sense that behaves more like an interactive software system specific to a domain rather than a catalog. Although a Web Application shares some common characteristics with other traditional software, it is distinctive in many ways in which it is developed, used, and perceived by its stakeholders.

We label a Web Application that actively involves people in its development or espouses to fundamentally impact people in their daily lives in its operation as "human-centric." We note that interactivity does not automatically imply "human-centricity" of a Web Application.

Based on the architectural principles of the Web (Jacobs & Walsh, 2004), we consider a Web Application to be a collection of information resources. A *resource* is anything that is identifiable by a Uniform Resource Identifier (URI) or an Internationalized Resource Identifier (IRI) reference, and can have one or more representations.

2.2 Basic Concepts of Credibility of Human-Centric Web Applications

For the purposes of this paper, we will consider credibility to be synonymous to (and therefore interchangeable with) believability (Fogg & Tseng, 1999). Since trust indicates a *positive* belief about a person, object, or process, we do not consider credibility and trust to be synonymous but we do consider credibility to be a necessary condition for establishing trust.

From Trustworthiness and Expertise to Credibility

The two primary dimensions of credibility (Fogg, 2003; Metzger, 2005) are *trustworthiness* and (demonstration of) *expertise*. Trustworthiness is defined by the terms such as well-intentioned, truthful, unbiased, and so on. The trustworthiness dimension of credibility captures the perceived goodness or morality of the source. Expertise is defined by terms such as knowledgeable, experienced, competent, and so on. The expertise dimension of credibility captures the perceived knowledge and skill of the source. Together, they suggest that "highly credible" Web Applications will be perceived to have high levels of *both* trustworthiness and expertise.

We note that neither implies the other. For example, a Web Application that suffers from serious usability issues would lack expertise but could be deemed trustworthy by the consumer on the grounds

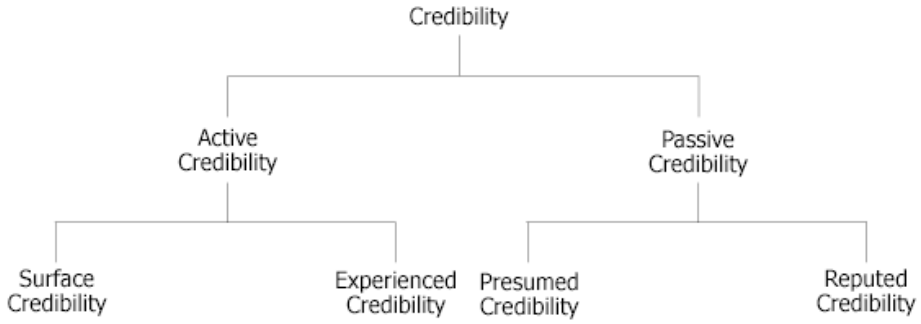
that the producer is a sibling or esteemed friend of the consumer. On the other hand, there are many examples of Web Applications that demonstrate technical expertise but simply cannot be trusted. For example, a Web Application may demonstrate "high" quality and provide the most comprehensive medical information available anywhere. However, if it becomes known that it is owned or sponsored by a single drug company (and this fact is not made explicit anywhere on the Web Application), there would be an indication of bias, and therefore its trustworthiness would come into question.

We note that trustworthiness and expertise are defined at such a high-level of abstraction that direct treatment is difficult. To do that, we must granularize them further to a level that can be addressed in a concrete manner. For that, the instrument we use in this paper is the existing knowledge base on quality.

A Taxonomy of Credibility

The concept of credibility can be classified based upon the types of user interactions with a Web Application. Figure 1 summarizes the classification.

Figure 1. A hierarchical view of a taxonomy of credibility in the context of Web Applications.



A user could consider a Web Application to be credible based upon direct interaction with the application (*Active Credibility*), or consider it to be credible in absence of any direct interaction but based on certain pre-determined notions (*Passive Credibility*).

We can decompose these further by using the classification of credibility in computer use (Fogg & Tseng, 1999) and adapting it to Web Applications. There can be two types of *Active Credibility*, namely *Surface Credibility*, which describes how much the user believes the Web Application based on simple inspection, and *Experienced Credibility*, which describes how much the user believes the Web Application based on first-hand experience in the past.

There can be two types of *Passive Credibility*, namely *Presumed Credibility*, which describes how much the user believes the Web Application because of general assumptions that the user holds, and *Reputed Credibility*, which describes how much the user believes the Web Application because of a reference from a third party.

Characteristics and Scope of Credibility

We note that credibility is not a "universal" concern that would automatically apply to all consumers with respect to all Web Applications in all circumstances at all times. There are certain unique characteristics of credibility that reflect its scope and can be highlighted as follows:

* Credibility and the Consumer. The credibility of a Web Application is a concern to a user if there is an associated cost (say, in terms of lost time, effort, or money) that is outright unacceptable to the user. In general, the higher the loss to the user, the more urgent the need there is for establishing credibility with the user. Also, that the Active Credibility of a Web Application is a concern may depend on the interaction options originating from task properties (significance, frequency, and so on), the intent of the user, and the role played by the user. For example, the credibility of a stock market application may be lesser concern to a user who is casually browsing and has no stake in the stock market, than to a user who is carefully monitoring the stock market indices in which (s)he has invested. This is in agreement with the dynamics of cognition and affect, and the interplay between them (Sillence et al., 2006).

* Credibility and the Web Application. We also note that credibility can be associated with the whole or a part of a Web Application. A part could be a single resource (for example, a standalone animation or a graphic embedded in a "Web Page") or a subset of resources in a sub-system (for example, a payment system of a shopping application). For example, credibility can be associated with a single resource (for example, a standalone animation or a graphic embedded in a Web Page) or with multiple resources (for example, a Web Page with several embedded resources or a payment sub-system of a shopping application).

* Credibility Assessment. The assessment of whether a Web Application is credible is not Boolean but rather (similar to other external quality attributes like usability) varies over a spectrum. Furthermore, like trust (Riegelsberger, Sasse, & McCarthy, 2005) an assessment of whether a Web Application is credible may not be reached instantaneously by a user but vary over the time over this spectrum. This spectrum is likely to be intrinsically dependent on several quality attributes that are weighted according to a set of criteria that would include the nature of the domain, services rendered by the Web Application, and preferences of a user. It is beyond the scope of this paper to suggest values for this spectrum or set predetermined acceptability criteria.

2.3 Related Work on the Quality-Oriented View of Credibility of Human-Centric Web Applications

In this section, we outline and assess past initiatives towards understanding and addressing credibility of Web Applications.

Relationship of Credibility to Other Quality Attributes and to Quality Models for Web Applications

In some ways, credibility overlaps with other quality attributes such as dependability, accessibility, and usability. Indeed, dependability (Avizienis, Laprie, & Randell, 2000) is defined as the trustworthiness of a computing system that allows reliance to be justifiably placed on the services it delivers. For the sake of understanding and for improvement, dependability is expressed as a combination of widely recognized quality attributes (McGregor, 2007). As an example, for e-commerce applications these attributes are found to be availability, reliability, and security. However, as discussed later, these attributes alone are not sufficient for characterizing credibility. The relation of credibility to other quality attributes such as accessibility and usability has been pointed out elsewhere (Wathen & Burkell, 2002; Lazar, 2005) but few details are given.

There have been various initiatives in the past for understanding and addressing the quality of Web Applications: some of them list, organize, and discuss relevant quality attributes (Brajnik, 2001; Dustin, Rashka, & McDiarmid, 2001; Offutt, 2002; Ross, 2002; Mendes & Mosley, 2006; Hasan & Abuelrub, 2006), while others provide a means for evaluation (Olsina & Rossi, 2002; Mich, Franch, & Gaio, 2003). However, these efforts are restricted by one or more of the following aspects: credibility concerns are not discussed directly or indirectly within the context of quality; the precise relationship between the representation of a resource in a Web Application and the named quality attributes is not always clear; it appears that the concerns related to quality have not necessarily been approached from a stakeholder's viewpoint; there is no apparent rationale for decomposition of quality and/or

organization of quality attributes; although quality attributes relevant to Web Applications are given, the means of addressing them are either suggested informally or not at all; the focus in addressing quality is less on assurance (prevention) and more on evaluation (cure); and the discussion on quality is predisposed towards a specific implementation language or a rendering tool. Therefore, the option of simply adding credibility to the list of quality attributes in one of the existing quality models for Web Applications is not considered in this paper.

The issue of the credibility of Web Applications has garnered attention over the last decade from diverse viewpoints, including communication, cognitive psychology, ethics, human-computer interaction (HCI), information technology, library science, and philosophy. This has lead to some notable theoretical (Rieh & Belkin, 1998; Bruce, 2001; Fogg, 2003; Metzger, 2005; Danielson, 2006) and empirical (Eysenbach et al., 2002; Fogg et al., 2003; Walther, Wang, & Loh, 2004; Consumer Reports WebWatch, 2005; Sillence et al., 2006) studies (or a combination thereof) pertaining to the credibility of both commercial and non-commercial Web Applications for various domains of interest.

Specifically, previous efforts have proposed different but semantically overlapping sets of factors that affect credibility of Web Applications. In one case of analyzing the credibility of Web Applications essentially independent of any domain (Rieh & Belkin, 1998), the factors of *source*, *content*, *format*, *presentation*, *currency*, *accuracy*, and *[performance]* are given. In another case (Fogg, 2003), it is concluded that the factors of *real-world feel*, *ease of use*, *expertise*, *trustworthiness*, and *[message] tailoring* positively impact credibility, while *commercial implications* and *amateurism* negatively affect credibility. In context of Web Applications providing health-related advice (Sillence et al., 2006), several factors aggregated within the categories of *heuristic*, *content evaluation*, and *longer-term engagement through source integration and self-disclosure processes* are highlighted as part of a model for trust. However, the relationship of these works to established standards and studies on software quality in general (Fenton & Pfleeger, 1997; Dromey, 2003), and to the known theoretical frameworks on (information) quality (Eppler, 2001) in particular, are apparently nonexistent.

Improvement of Credibility of Web Applications

There have been some partial efforts towards addressing the credibility of Web Applications. A set of guidelines for improving the credibility of general and domain-specific Web Applications have been presented (Fogg, 2003; Sillence et al., 2006). However, these guidelines are stated in such a fashion that they can be open to broad interpretation (for example, due to the use of terms such as 'boring', 'clear', 'good', 'moderate', 'poor', 'rapid', and so on); they do not explicitly consider their realization within any development process; are stated at such a high-level that they may not always be practical to apply, thereby may be difficult to use by a novice engineer; they do not always provide a theoretical basis for their inclusion; and they do not take the organizational or technical trade-offs into consideration (for example, they are not prioritized).

In general, the initiatives towards addressing the credibility of Web Applications are limited by one or more of the following issues: the approach towards ensuring and/or evaluating credibility is not systematic, the discussion on credibility is not within the context of any known Web Application development process, the proposed means for ensuring credibility is singular (for example, only guidelines), and the issue of feasibility of the means is not addressed.

3 Prospects and Concerns in Understanding and Addressing the Credibility of Human-Centric Web Applications

In this section, we consider approaches for understanding and addressing Active and Passive Credibility.

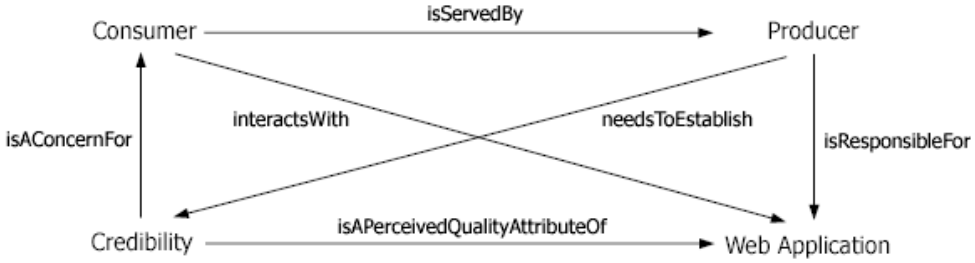
3.1 Stakeholders and Credibility of Human-Centric Web Applications

We identify two broad classes of stakeholders with respect to their *roles* in relationship to a Web Application: a *producer* (such as an owner, manager, engineer or maintainer) is the one who owns, finances, develops, deploys, or maintains the Web Application, and a *consumer* (such as a novice or expert user) is the one who uses the Web Application for some purpose.

A precise formulation of a stakeholder model is beyond the scope of this paper. We, however, note that the stakeholders are usually geographically dispersed, culturally diverse, and may communicate using different natural languages. They vary with respect to a Web Application in their cognitive or physiological abilities, personal preferences, and level of education and skills. From a Viewpoint-Oriented Requirements Definition (VORD) (Kotonya & Sommerville, 1998) perspective, the owner and the manager are indirect viewpoints, while the engineer and the maintainer are direct viewpoints in their relationship to the Web Application.

The credibility is a *perceived* quality attribute with respect to the stakeholders of a Web Application. We view credibility as a *contract* between a producer and a consumer as shown in Figure 2.

Figure 2. A high-level view of the interrelationships between credibility and stakeholders of a Web Application.



Furthermore, we note that the goals of consumer and the producer with respect to the credibility of a Web Application are different. A consumer would like to assess if a Web Application as a whole including the functionality and information in it is credible while a producer aims to engineer "highly credible" Web Applications in the hope of establishing credibility with the consumer.

3.2 A Quality-Oriented View of the Origins of the Issue of Credibility of Human-Centric Web Applications

The credibility of software systems is a critical issue in its own right (Fogg & Tseng, 1999). However, the credibility of Web Applications deserves special attention for several, non-mutually exclusive, factors that we now briefly discuss.

Maturity of the Web

The attainment of maturity is a crucial step towards addressing Presumed Credibility.

The Web is a bit more than a decade old during which it has notably matured. In spite of the exponential growth in its world-wide availability and use, and the rapid ascent in technologies related to it, this time period is seen as "young" by many. This is particularly the case when compared to other public services (such as banking, medical, or postal service) that are tried-and-tested, have been around for several decades, and are expected by us to be credible.

This perception of "youthfulness" of the Web gets reinforced when the users come across "unprofessional" writing or "amateurish" designs, often originating from the misuse or overuse of the technologies for purposes other than intended rather than a profound understanding of the nature of

business, intricacies of the information architecture, or the needs of the user. Examples of these ranges from the placement of "Under Construction" banner to the trap of recursive frames to the inclusion of blinking text without any apparent rationale.

Delivery of Web Applications and User Experience

The dynamics of delivery of Web Applications to the consumers and their past and present experience with it are related to Active Credibility.

The delivery context in a decentralized and varying environment of user agents and devices is non-trivial. Web Applications are only delivered on-request; they are not acquired and installed like desktop software. An engineer has no control over the end-user device or the user agent deployed by a user for accessing a Web Application. Apart from some rudimentary data on the client-side (such as the knowledge of device, operating system, and user agent), there is little knowledge that an engineer has of the user preferences, particularly on a first-time use.

On the other hand, the users usually have little or no control over the behavior or rendering of information, although some of this can be circumvented via personalization of the Web Application and by configuration of the user agent. For example, the information in a Web Application may render only partially or not at all in the user agent. A resource at the end of a link may change at any time without any intimation: the information in it may change to what may not be conducive to the intent of the Web Application, the conditions of access (such as UNIX-style file permissions) to it may change, or it may simply be removed (cease to exist).

The lack of control and non-proximity although may not in itself instill doubt, the absence of a human component raises and exacerbates a variety of emotions (uncertainty, perplexity, or anxiety), particularly in the time of crisis such as unavailability or denial-of-service. The situation only gets exacerbated when a user is continually asked to install certain components (fonts or ancillary software say plug-ins or ActiveX controls) in order to view a specific Web Application.

It has been the conclusion of a survey (Fogg et al., 2003) that people use the same types of criteria for assessing information on the Web as they use for traditional media and indeed they seek out familiarity in the former with respect to the latter. However, there is currently no "standard" for user interfaces of Web Applications: this provides freedom to the producer to be "uniquely artistic" but evidently at the risk of violating the basic principle of consistency (Scapin et al., 2000) in user interface design. As a user moves from one application to another, this leads to a non-transferable knowledge and thus puts a significant burden on the "learning curve."

Users expect that a Web Application will be available when they need it and be accommodating with respect to the errors on their behalf or otherwise. However, experiences of users with technologies of the Web have not always been positive. The instability of the user agents and their extensions or errors in client-side scripts has, at times, unfavorably impacted the user's system. This has shaken customer confidence and created negative perceptions about the Web.

Legality, Ethics, and Privacy of Information

The distributed environment of the Web can lead to a variety of legal and ethical issues. A Web Application could be geographically located anywhere in the world. The stakeholders of a Web Application need not be co-located. For example, they may be in different jurisdictions in the same country or in different countries. So, the laws that govern the provider and the user of that Web Application may be different.

The possibilities of personal harm such as theft of computer domain name ("pharming") or theft of user identity ("phishing") remains high in a networked environment. Misuse of information provided by users with proportionally little legal repercussions for the perpetrators is, as surveys have

shown (Consumer Reports WebWatch, 2005), a matter of grave user concern. News of mishaps only worsens Presumed Credibility, particularly if the user is not aware of the provider.

One particular ethical (and sometimes legal) issue that commonly arises is due to reuse. Although the request for a resource may have been made to a single specific address, not all parts of that resource that are delivered may originate from the same address. Indeed, some of the parts of the resource may be hosted on external servers whose bandwidth is used without request. For example, this is possible via "inlining" images, "deep linking," or "framing," all of which may be transparent to a novice user. This often seamless integration of external resources in a Web Application when combined with means to "persuade" consumers (such as advertisements) raises the issue of credibility (Choi & Rifon, 2002).

As recent surveys (Paine et al., 2007) have shown, privacy continues to be a critical concern to many users. There are Web Applications particularly the Web Portals that require a user to submit personal information, at times, in the name of personalization. However, the provision for personalization in the light of respecting privacy leads to both an ethical (Johnson, 1997) and a legal issue. For businesses (Kasanoff, 2002), managing this dichotomy is a constant struggle as the benefits of respecting one can adversely affect the other, thereby impacting the credibility of the application in the view of their customers. This is particularly critical when the electronic medium is the only "face" of a business that a customer has ever been exposed to.

Security of Web Applications

Security is a classical issue for most computer systems. However, there are a variety of security-related vulnerabilities that get amplified in a networked environment and can lead to uncertainty and fear among users. The Web brings unique security-related challenges that can impact client- or the server-side (Stein, 1998). Indeed, laxness in security has been identified as one of the major causes of failures in Web Applications (Pertet & Narasimhan, 2005).

For example, a consumer could inadvertently enter degenerate characters (like shell metacharacters) in a fill-out-form that may compromise the security of the system on which the Web Application is residing, and therefore a producer must take steps for protection against such vulnerabilities. (In retrospect, these extra security measures that a producer must take can adversely impact the usability of the Web Application.)

On the other hand, a consumer could download a program/script (upon persuasion of the producer or inadvertently) as part of its interaction with the Web Application that would automatically install and run on his/her system to provide unauthorized access to others.

Integrity of Information

The Internet and the Web offer the freedom to virtually anybody to become a contributor. The document-centric nature of Web Applications allows space for not only interchanging but *publishing* hypermedia information.

However, in this "citizen journalism," there are no universal standards for posting information that in absence of suitable measures, may be easily altered, plagiarized, misrepresented, or created anonymously under false pretenses. The news industry where print medium is competing with the electronic medium has felt this impact (Nagura, 2006; Cassidy, 2007). The recent trend in the use of "blogs" to express personal opinions (that, at times, are incidentally or deliberately, masqueraded as "facts") has only compounded the problem. Instead, users are very much on their own and must depend upon their own skill (that they may not possess) in sorting out truth from falsehood, accuracy from inaccuracy, and honesty from charlatanism (Curzon, 2005). This particularly has had an acute impact on the user perception of health-related Web Applications (Eysenbach et al., 2002; Walther,

Wang, & Loh, 2004) due to the potential for the distribution of inaccurate medical information from unqualified sources and the presence of implicit advertising of drugs.

In recent years, publishing and sharing information such as photographs, audio, or video files is becoming a routine part of the participatory nature of the Web. Indeed, Web Applications such as Flickr, Napster, and YouTube are exemplars of this phenomenon. However, checking the integrity and sanctity of data gets increasingly challenging particularly as *binary* data is uploaded by the consumers in order to be shared by others.

In fact, this issue spans across the boundaries of privacy, security, legality, and ethics. For example, (false) information defaming a person or information revealing unauthorized personal details along with photographs could be anonymously posted on social networks such as Facebook or MySpace, or (simply by using a certain file name) a music snippet violating the copyright or a virus camouflaged as a movie clip could be readily uploaded. These go beyond technical inconveniences or public embarrassment, and have beginning to enter the legal realm. The cases of misrepresented identity on for instance MySpace have led to defamation charges and litigation.

3.3 Integration of Credibility in Web Application Development Process

The need to manage the size, complexity, and growth of Web Applications has led to the discipline of Web Engineering (Kappel et al., 2006; Mendes & Mosley, 2006; Rossi et al., 2008). A systematic process leading to the realization of the product (namely, the Web Application) is integral to Web Engineering.

In the past few years, it has been emphasized that humans be an important consideration in the development of Web Applications: for instance, the development is "user-centered" (Lazar, 2001; Constantine & Lockwood, 2002) or "audience-driven" (De Troyer, 2001).

Furthermore, due to the unique nature of Web Applications, their production is prone to various factors including volatile requirements, consumer expectations, burgeoning competition, pressures due to time-to-market, and fluctuations in underlying technologies. This calls for adoption of a development process that is sufficiently agile (Highsmith, 2002).

If credibility is important to an organization, it needs to be considered as a first-class concern *throughout* the Web Application development process. For that, incorporating credibility as a mandatory non-functional quality concern during early planning stages and subsequently in requirements specifications would be essential. We note, however, that the level of organizational process maturity (Paulk et al., 1995) may inhibit the extent (if at all) of such an adoption.

Indeed, we suggest that any initiative towards addressing the quality of Web Applications should take place within the auspices of a development process that is user-centered, flexible, iterative, mature, and has a broad community and tool support. To that regard, we recommend the use of Extreme Programming (XP) (Beck & Andres, 2005) for small-to-medium size projects and the Rational Unified Process (RUP) (Kruchten, 2004) for large projects. Both XP and RUP have been adapted to Web Applications (Wallace, Raggett, & Aufgang, 2002; Kappel et al., 2006).

XP practices such as OnSite Customer, The Planning Process, and Pair Programming take human-centered issues into consideration. Specifically, the user stories that are fed into The Planning Process for requirements elicitation could serve as placeholders for raising and manifesting credibility-specific issues. However, the development of Web Applications in a distributed (say, outsourced) setting can pose obstacles towards the realization of certain XP practices. In RUP, the credibility-related concerns could be a part of the business modeling and requirements workflows. However, RUP deploys use cases for requirements elicitation and the precise relationship of use cases to certain quality requirements (such as performance) is yet unclear.

3.4 A Framework for Addressing Active Credibility of Human-Centric Web Applications

We adopt semiotics (Stamper, 1992) as the theoretical basis for communication of information. There are different views of quality (Wong, 2006). We view Active Credibility of Web Applications as a qualitative aspect and address it indirectly from the perspective of semiotics as illustrated in Table 1.

The aforementioned framework for Active Credibility could be expressed in a compact form as $\mathbf{F_{AC}} \equiv (W, R_W, Q_{S(T)}, M; D)$, where R_W is a representation of a resource in a Web Application W, $Q_{S(T)}$ denotes a quality attribute at tier T of a semiotic level S, M denotes a means for either assurance or evaluation of $Q_{S(T)}$, and D denotes a technique for decision support.

We now discuss each of the components of the proposed framework in detail.

Identification of Semiotic Levels

The first column of Table 1 addresses semiotic levels. We are particularly interested in the communicative properties of the representations of resources in a Web Application.

From a semiotics perspective, we can view a representation on six interrelated levels (Shanks, 1999): physical, empirical, syntactic, semantic, pragmatic, and social, each depending on the previous level in that order.

We focus only on the quality-related concerns at the last five levels as they directly involve a Web Application and/or its stakeholders. At the *empirical level* the interest is in the characters used in a representation, at the *syntactic level* the interest is in language (or notational system) to which a representation corresponds to, at the *semantic level* the interest is the meaning of information in the representation, at the *pragmatic level* the interest is in the utility of a representation to its stakeholder(s), and at the *social level* the interest is in the manifestations of social interaction among stakeholders with respect to a representation.

Decomposition of Semiotic Levels and Assignment of Quality Attributes

The second column of Table 1 draws the relationship between semiotic levels and corresponding quality attributes.

Table 1. A semiotic framework for Active Credibility of Web Applications.

Semiotic Level	**Quality Attributes**	**Means for Assurance and Evaluation**		**Decision Support**
Social	**Credibility**	Process-Oriented: Inspections, Testing Product-Oriented: Training, Guidance Metrics	Tools	Feasibility
	Aesthetics, Legality, Privacy, Security, Transparency			
Pragmatic	Accessibility, Usability			
	Comprehensibility, Navigability, Interoperability, Performance, Readability, Reliability, Robustness			
Semantic	Completeness, Validity			
Syntactic	Correctness			
Empirical	Expressivity			

Construction: Quality Attributes and their Relationships

Since each semiotic level is rather high to be tackled directly, we decompose it (Fenton & Pfleeger, 1997) further into relevant quality attributes that are widely-known, and inspired by factors discussed in the previous section and by empirical studies conducted elsewhere (Fogg et al., 2003). We contend that the quality attributes included are necessary but make no claim of their sufficiency.

Since not all attributes corresponding to a semiotic level are on the same echelon, they are placed at different tiers. Specifically, credibility belongs to the social level and depends on the layers beneath it. The quality attributes *aesthetics (presentation)*, *legality*, *privacy*, *security*, and *transparency (of the producer)* also at the social level depend upon the quality attributes *accessibility* and *usability* at the pragmatic level, which in turn depend upon the quality attributes *comprehensibility*, *interoperability*, *navigability*, *performance*, *readability*, *reliability*, and *robustness* also at the pragmatic level. As the meaning of these quality attributes can vary in the literature, it is important that they be adopted and followed consistently. If necessary, we could resort to the IEEE Standard 1061-1998, the ISO 9241-11:1998 Standard, and the ISO/IEC 9126-1: 2001 Standard, for the definitions of the quality attributes.

The quality attributes at the pragmatic level depend upon two complementary quality attributes at the semantic level, namely *completeness* (relevant knowledge of the domain is captured in the representation) and *validity* (the representation conforms to the knowledge of the domain). We note that the quality attributes of accuracy (Rieh & Belkin, 1998; Eysenbach et al., 2002) and currency (Rieh & Belkin, 1998) suggested in previous works on credibility are subsumed by semantic validity. It is obvious that a representation must be correct with respect to the language (or notational system) it claims to be an instance of. Finally, a representation is necessarily constrained by the characters in some encoding from some character set such as the Universal Multiple-Octet Coded Character Set (UCS) defined by ISO/IEC 10646-1:1993 Standard or the Unicode used to express it.

Analysis: Characteristics of Quality Attributes and their Relevancy

We note several characteristics of the quality attributes in Table 1. While some quality attributes are objective, others are subjective. In particular, we view the achievement of credibility as a soft goal that cannot be completely satisfied; it can only be satisfied to a certain degree, that is, *satisficed* (Simon, 1996). This is because while some quality attributes that are deemed necessary (like legality and performance) can be completely satisfied, others can not and can only be satisficed.

The quality attributes are not necessarily mutually exclusive, and this dependency can be either favorable or unfavorable (Wiegers, 2003).

The quality attributes are also not absolute from both stakeholder and technical perspectives. For example, novice and expert users may associate different degrees of significance to quality attributes (Stanford et al., 2002). Some of the quality attributes are classical and relevant in a desktop environment but they get amplified, and in certain cases exacerbated, in a networked environment. Furthermore, while legality is a concern for any product and usability is always a concern for interactive systems, privacy or security may not necessarily be a relevant concern for *all* Web Applications.

We discuss only the entries in the social level in some detail. The sensitivity part of visual perception is strongly related to aesthetics as it is close to human senses. The artistic expression plays an important role (Tractinsky et al., 2006) in making a Web Application "attractive" to its customers beyond simply the functionality it provides. It has been pointed out in a large survey on credibility (Fogg et al., 2003) that the aesthetics of a Web Application that is appropriately presented gives the perception of "professionalism" and is essential for establishing the expertise dimension of credibility. It is critical that the Web Application be legal (for example, is legal in the jurisdiction it operates and

all components it makes use of are legal); takes steps to respect user's privacy (for example, does not abuse or share user-supplied information without permission); takes steps to secure itself (for example, in situations where financial transactions are made). The provider must take all steps to be transparent with respect to the user (for example, not include misleading information such as the features of products or services offered, clearly label promotional content, make available their contact information including physical address, policies regarding returning/exchanging products, and so on).

Next, we separate the semiotic quality attributes and the means for addressing them. We note that the mapping between the attributes and the means is many-to-many.

Means for Active Credibility Assurance and Evaluation

The third column of Table 1 lists the means for assuring and evaluating Active Credibility. The adoption of any means in a development process would usually depend on a high-level of organizational process maturity (Paulk et al., 1995) for which is no a priori guarantee.

The means can be classified in different ways. For example, they can be placed in process-oriented and product-oriented tiers where the former can make use of the latter. Alternatively, these means could also be viewed as those that are preventative (provide assurance) and those that are curative (focus on evaluation). Since it is important to address Active Credibility as early in the Web Application development process as possible, we contend that the focus on assurance should be at least as much as it is on evaluation.

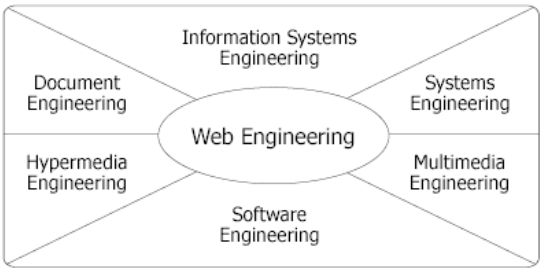
We now briefly discuss two product-oriented means, namely training and guidance for assuring the Active Credibility of a Web Application.

Training in Requisite Knowledge and Skills

The desirable knowledge and skills (Hansen, Deshpande, & Murugesan, 2001; Hadjerrouit, 2005) for a systematic development of a Web Application go beyond what is part of conventional training of a typical software engineer.

Indeed, Web Engineering depends upon other disciplines for its existence (Figure 3), namely document engineering, information systems engineering, systems engineering, multimedia engineering, software engineering, and hypermedia engineering.

Figure 3. The engineering universe of Web Applications.



As reflected from surveys (Krunić et al., 2006), the courses related to the Web offered at institutions often tend to focus primarily on the manipulations of the "popular" (and moving target) client- and/or server-side technologies-of-the-day. The result is that the students tend to learn more about "technology hacks" rather than the lasting and time-invariant knowledge of the fundamentals of analysis and design necessary towards a *systematic* approach to the development of large-scale Web Applications.

We recommend that, apart from a comprehensive technical background in Web Engineering and perhaps that of other means of addressing credibility, the learning "toolkit" of a prospective professional Web Engineer should be encouraged to include at least the following six aspects listed below (in no particular order of significance):

* Communication. This could include training in (not just syntax but) the style of information description languages such as the (Extensible) HyperText Markup Language ((X)HTML), the Extensible Markup Language (XML), the Cascading Style Sheets (CSS), and so on. This also could include ability of journalistic writing, including the ability of balancing information with other types of media (related to marketing such as advertisements).

* Decision Making. This could include training in informed and balanced decision making in order to analyze the trade-offs and decide amongst different design approaches, or between the use of early and established technologies.

* Domain Understanding. This could include basic knowledge of domains that are common to many Web Applications: issues related to legal issues such as those related to intellectual property rights (IPR) and licensing; basic knowledge of financial issues (such as those related to merchant accounts and payment systems) in the lieu of support for commercial transactions; and training in cultural-sensitivity for internationalized and/or localized application contexts.

* Quality Engineering. This could include understanding of quality attributes specific to the domain of the Web Application, their social manifestations, and means to prioritize those (Berander & Andrews, 2005).

* Standards. This could include appropriate use of standards such as those from Institute of Electrical and Electronics Engineers (IEEE) and International Organization for Standardization/International Electrotechnical Commission (ISO/IEC) for both the process and the product.

* User Modeling. This could include means of precisely identifying user classes, user preferences and their needs (that could be carried out during the development of use cases and/or personas).

Guidance

We consider guidelines and patterns as two "bodies of knowledge" based on past experience and expertise that can serve as aids for structured guidance. They are both preventative rather than curative (Dromey, 2003) in their approach towards quality improvement.

Guidelines. The guidelines encourage the use of conventions and good practice. They could serve as a checklist with respect to which an application could be heuristically and, to certain extent, automatically evaluated. There are specific guidelines available for addressing accessibility (Chisholm, Vanderheiden, & Jacobs, 1999) and usability (Nielsen, 2000) of Web Applications.

However, guidelines suffer from certain limitations that place obstacles in their widespread use. The shortcomings and difficulties in the application of guidelines for accessibility and usability have been exposed (Vanderdonckt, 1999; Ivory, 2001). Specifically, they may seem rather general, vague, or contradictory at times; they often do not discuss trade-offs as a consequence of their application or relationships among them; and they tend to be assume a certain level of knowledge of the domain and therefore are more suitable for an expert than for a novice.

Patterns. The reliance of past knowledge and experience aggregated by experts in form of "best practices" can be useful for any development. A pattern provides a conceptually reusable and proven solution to a recurring problem in a given context (Appleton, 1997). A opposed to guidelines, patterns are more structured and describe the reasoning behind and scope within which the solution works. In recent years, patterns for Web Applications have begun to appear (Graham, 2003; Van Duyne, Landay, & Hong, 2003; Tidwell, 2005). There is some provision of the use of patterns during design in both XP

and RUP. Although details are not given, it has been pointed out (Friedman, 2005) that identifying patterns for the design of Web Applications could be useful towards addressing the credibility of these applications. Indeed, with a judicious use of patterns it is possible to tackle many of the pragmatic and social quality attributes in Table 1.

However, there are certain caveats in the adoption of patterns: there is an evident cost involved in adaptation of patterns to new contexts; even though the mapping between patterns and quality attributes is many-to-many, currently most patterns are not classified by quality attributes that they address; the selection of suitable patterns may not be trivial (Segerståhl & Jokela, 2006); and there is always a distinct possibility that for a given problem, there simply may not be any suitable pattern available.

We now briefly discuss two process-oriented means, namely inspections and testing for evaluating the Active Credibility of a Web Application.

Inspections

Inspections (Wiegers, 2002) are a rigorous form of auditing based upon peer review that, when practiced well, can help evaluating some of the quality attributes at each of the semiotic level in Web Applications. These are aesthetics, correctness, completeness, comprehensibility, legality, privacy, readability, transparency, and validity.

Inspections could, for example, assess if the presentation of information appears "professional", check if the syntax of an (X)HTML document is correct, check if the information that claims to be from the financial domain is valid, determine "sufficiency" of contact information, decide what information is and is not considered "promotional", help improve the natural language-based labels used (say, in a navigation system), or assess the readability of documents or images.

Since inspections is a means for *static* verification, it can evaluate in rather limited form (if at all) the quality attributes that by necessity require some form of "dynamism" or real-world use via execution. These include accessibility, interoperability, navigability, performance, reliability, robustness, security, and usability.

In spite of the usefulness of inspections in early defect detection, there are certain caveats: their effectiveness lies strongly on the reading technique deployed (Conte, 2005) and they entail an initial cost overhead of training each participant in the structured review process followed by the logistics of checklists, forms, and reports involved.

Testing

Testing is a means for *dynamic* verification and is usually supported by most Web Application development processes (Nguyen, Johnson, & Hackett, 2003). The attributes of accessibility, correctness, interoperability, navigability, performance, reliability, robustness, security, and usability can to a large extent be tested (semi-)automatically using tools or with the help of actual users.

However, a full-scale accessibility or usability testing requires setting up an environment (hiring users, acquiring infrastructure for video monitoring, and analysis of data) can prove to be prohibitive for small-to-medium size enterprises. Furthermore, not all quality attributes at either pragmatic or social levels in a Web Application can be tested automatically. For example, it is not possible to completely test a Web Application for aesthetics, comprehensibility, legality, privacy, readability, or transparency (like producer's intent) using tools; human inspection would be necessary for checking and determining the level of support of these quality attributes. Thus, inspections and testing can *complement* each other.

Metrics

Metrics can provide a quantitative measure for quality improvement quality concerns at pragmatic and social levels. Indeed, in recent years, there has been an increasing interest (Ivory, 2001; Arrue, Vigo, & Abascal, 2005; Mendes & Mosley, 2006) in suggesting metrics for different aspects of analysis and synthesis in the development of Web Applications. These metrics could be used for multiple purposes, for example, during inspections or otherwise to evaluate design artifacts or the final product for some of the quality attributes in Table 1, or to compare effectiveness of guidelines for accessibility or for usability (Ivory, 2001).

There are currently certain obstacles in the widespread use of metrics. A support for metrics begins with their acknowledgment in a software process model, which in XP or RUP is yet to be seen. Most of the metrics have been introduced and used on empirical grounds, and are not formally validated against the representational theory of measurement (Fenton & Pfleeger, 1997). The currently available metrics do not cover all the quality attributes in Table 1. The currently available metrics (Ivory, 2001) also appear to have been derived with a HTML-specific view of the implementation of a Web Application: there is a lack of metrics for say resources expressed and delivered in the XML. A large-scale measurement effort would typically require automation, but support for it in form of metrics databases with processing capabilities are at present scarce.

Tools

There are various tools that can assist semiotic quality improvement by directly or indirectly supporting other means. In doing so, they can help improve quality concerns at technical and social levels, manually, semi-automatically, or automatically (Ivory, 2001). For example, they can help us detect security breaches, inform us of absence of privacy metadata, report violations of accessibility guidelines, or suggest image sizes favorable to the performance on the Web.

However, acquisition of state-of-the-art tools can be expensive for educational institutions and for small-to-medium size businesses, although this situation is changing with the rise of Open Source Software (OSS). In certain cases, the use of tools may be prohibitive. These include automatic identification and/or correction of violations of attributes like completeness or validity, or evaluation of subjective and difficult to measurably quantify attributes like aesthetics.

Decision Support

The last column of Table 1 acknowledges that the activities of assurance and/or evaluation must be realizable in practice.

The providers of Web Applications take into account organizational constraints of time and resources (personnel, infrastructure, budget, and so on) and external forces (market value, competitors, and so on), which compels them to make quality related decisions that, apart from being sensitive to credibility, must also be feasible.

For example, an a priori guarantee that a Web Application will be accessible or usable to *all* users at *all* times in *all* task-specific or computing environment-specific situations that the users can find themselves in, is simply unrealistic.

The feasibility analysis is evidently related to decision making (Clemen, 1996) and could be a part of the overall Web Application project planning activity. There are well-known techniques such as Analytical Hierarchy Process (AHP) and Quality Function Deployment (QFD) for carrying out feasibility analysis, and further discussion of this aspect is beyond the scope of this paper.

The Framework for Active Credibility in Perspective

In this section, we briefly discuss the scope and limitations of the proposed semiotic quality framework for Active Credibility.

Firstly, it appears that a complete formalization of the framework particularly that of certain quality attributes may not be possible. Although, this makes the discussion accessible to non-technical stakeholders, however, it can make the realization of certain means, and quantification and automatic verification of credibility improvement, difficult.

Secondly, the framework is intended to be general: it is independent of any specific domain and any specific set of consumers. However, in the real-world situation there is always an underlying domain to which a Web Application corresponds to and there is often a dedicated user community, both of which are not accounted for.

Thirdly, the framework does not take legacy support into consideration. Specifically, it does not take into account *existing* Web Applications with credibility-related issues or means for refactoring them.

3.5 Addressing Passive Credibility of Human-Centric Web Applications

In this section, we briefly look into the case of Passive Credibility, specifically Reputed Credibility.

We acknowledge that the perceptions related to Presumed Credibility may be one of the most difficult to tackle. There are no absolute guarantees for Presumed Credibility assurance but a combination of the following techniques could help: personalizing the application to user context; providing an informative frequently asked questions (FAQ); providing an explicit privacy policy, for example, based on the Platform for Privacy Preferences Project (P3P) and A P3P Preference Exchange Language (APPEL) that ensure that users are informed about privacy policies before they release personal information (Kamthan & Pai, 2007); and appropriately labeling the nature of content of a Web Application as per the Platform for Internet Content Selection (PICS)/Resource Description Framework (RDF) while conforming to the requirements of the Internet Content Rating Association (ICRA).

In the real-world, the assurance for credibility is often provided by a third party such as approval of a drug by the national medical association or certification of degree granting programs by a recognized body. WebTrust and TRUSTe are two relevant initiatives in the direction of addressing Reputed Credibility, which we now briefly discuss.

In response to the concerns related to for business-to-consumer e-commerce and to increase consumer confidence, the public accounting profession has developed WebTrust Principles and Criteria and a WebTrust seal of assurance. Independent and objective certified public or chartered accountants, who are specifically licensed by the American Institute of Certified Public Accountants (AICPA) or Canadian Institute of Chartered Accountants (CICA), can provide assurance services to evaluate and test whether a particular Web Application meets these principles and criteria. The WebTrust seal of assurance is a symbolic representation of a practitioner's objective report. The VeriSign encryption and authentication technology and practices help assure the consumer that the seal on a Web Application is authentic and that the provider is entitled to display it.

The TRUSTe program enables companies to develop privacy statements that reflect the information gathering and dissemination practices of their Web Applications. The program is equipped with the TRUSTe "trustmark" seal that is awarded only to those that adhere to TRUSTe's established privacy principles and agree to comply with ongoing TRUSTe oversight and resolution process. The privacy principles embody fair information practices approved by the U.S. Department of Commerce, Federal Trade Commission, and prominent industry-represented organizations and associations.

Finally, we note that although the inclusion of trustmarks such as those from WebTrust and TRUSTe may have merit (Wang, & Emurian, 2005) and several commercial enterprises have adopted them, they are neither a guarantee, nor a substitute for other means that lead to Presumed Credibility.

They are only third-party-based proxy indicators of quality and may not match consumer expectations as is the case in other contexts such as health-related information (Burkell, 2004).

4 Some Directions for Future Research

The work presented in this paper can be extended in a few different directions, which we now briefly discuss.

Table 1 provides a structured but informal way of expressing the relationships among quality attributes, and between quality attributes and means for addressing them. A formalization via an ontological approach of the framework for credibility could be useful. An ontology is an explicit formal specification of a conceptualization that consists of a set of concepts in a domain and relations among them (Gruber, 1993). We hope that further investigations into formalization of the concept of quality would lead to an upper-level ontology that will allow precise definition and organization of such relationships, and enable reasoning with them. The initial work on the ontology for software quality (Mendes & Abran, 2004; Abran et al., 2006) as defined in the Guide to the Software Engineering Body of Knowledge (SWEBOK) (Abran et al., 2001) and on the ontology for patterns for Web Applications (Kamthan & Pai, 2006a) could provide input in this direction.

As we have seen from the foregoing discussion, there is parity between credibility and ethical practices in Web Applications. This relationship would be worth exploring further, particularly in the light of the close association between ethics and quality (Reynolds, 2003; Tavani, 2004).

In affecting computing, affect is often considered as one of the types of information that can be modeled, measured, and evaluated (Albarracin & Kumkale, 2003; Boehner et al., 2007). In an affective approach to Web Applications, we could view Active Credibility as part of the following sequence: user interaction results in an affect (say, an emotional response) which in turn results in a judgment of credibility. An investigation into the interrelationship between the types of user affects and assessments of credibility would be of interest.

In spite of recent progress to explicitly support quality while preserving agility (Sampaio, Vasconcelos, & Sampaio, 2004) in process models, there is currently no explicit support for credibility in agile methodologies such as XP. In particular, the support for pragmatic and social quality attributes discussed in this paper could foster the adoption of agile methodologies in the development of human-centric Web Applications.

The framework for Active Credibility proposed above is theoretical and could benefit from practical empirical validation on a large-scale similar to other related contexts (Fogg et al., 2003; Sillence et al., 2006). However, this does not automatically imply that the results would be generalizable or transferable to arbitrary contexts as, for example, Web Applications and their stakeholder classes in different locale are usually not identical.

It is known (Schneidewind & Fenton, 1996) that, when applied judiciously, standards can contribute towards quality improvement. Indeed, credibility has recently (Carduci & Isaak, 2003) been a topic of interest in standards for Web Applications such as the IEEE Standard 2001-2002. However, awareness and broad use of these standards among providers remains a challenge.

The Semantic Web has recently emerged as an extension of the current Web that adds technological infrastructure for better knowledge representation, interpretation, and reasoning (Hendler, Lassila, & Berners-Lee, 2001). However, the "human" aspects of the Semantic Web remain largely unaddressed (Kamthan & Pai, 2006b; Vossen, Lytras, & Koudas, 2007). A natural extension of the discussion on credibility in this paper could be within the context of Semantic Web Applications. In particular, the quality attributes of Table 1 would apply to instances of an ontology that is represented in an ontology specification language that uses XML as its serialization syntax.

5 Conclusion

By moving from a collective of computers towards a community of people, the Internet along with the Web is metamorphosing itself into a (virtual) social network (Hoschka, 1998). This evolution will continue to harness the human information processing and the "collective intelligence" (Engelbart, 1995) of society at-large. The user concerns of credibility and the extent to which they are addressed will remain a key determinant towards the success of this paradigm.

One of the core themes of Web 2.0 is that *users add value*. However, in that endeavor, quality control cannot be an *afterthought*: a Web Application that is not sensitive to the pragmatic and social quality attributes discussed in this paper will not automatically become more "human-centric" merely by addition of more features or information. Indeed, as the line between the producers and the consumers gets blurred with the socialization of the Web, the assurance of credibility is increasingly becoming a *collective* and *symbiotic* responsibility of both the producers and the consumers.

Often, genuine progress is based upon the lessons learnt from the past. Although there have been many advances towards enabling the technological infrastructure of the Web in the last decade, there is much to be done in addressing the social challenges, including user perceptions and expectations. For a successful realization of the contract between producer and a consumer, the technical as well as social aspects of Web Applications need to be acknowledged, embraced, and acted upon.

In order to elevate, restore, or sustain consumer confidence, it is incumbent upon the producers to take steps to engineer a Web Application in a feasible manner so that it is perceived as credible. Understanding and addressing the credibility of Web Applications in a systematic manner is one step in that direction. Since credibility is a social concern, it is not always amenable to a purely technological treatment. Still, by decomposing it into quantifiable elements and approaching them in a feasible manner, we can make improvements towards its establishment.

In conclusion, credibility engineering of human-centric Web Applications is a new imperative, and is likely to remain so in the foreseeable future. Human-centric Web Applications belong to an ecosystem where *both* the people and the product play a role in its evolution. If the success of a Web Application is measured by use of its services, then establishing credibility with the users is critical for the providers. By making efforts to improve upon the criteria that affect credibility, the providers of Web Applications can change the user perception in their favor.

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References

[1] Abran, A., Cuadrado, J. J., García-Barriocanal, E., Mendes, O., Sánchez-Alonso, S., & Sicilia, M. A. (2006). Engineering the Ontology for the SWEBOK: Issues and Techniques. In: Ontologies for Software Engineering and Software Technology. C. Calero, F. Ruiz, & M. Piattini (Eds.). Springer-Verlag. 103-121.

[2] Abran, A., Moore, J. W., Bourque, P., & Dupuis, R. (2001). Guide to the Software Engineering Body of Knowledge - SWEBOK. IEEE Computer Society.

[3] Albarracin, D., & Kumkale, G. T. (2003). Affect as Information in Persuasion: A Model of Affect Identification and Discounting. J. Personality and Social Psychology, 84(3), 453-469.

[4] Appleton, B. A. (1997). Patterns and Software: Essential Concepts and Terminology. Object Magazine Online, 3(5), 20-25.

[5] Arrue, M., Vigo, M., & Abascal, J. (2005). Quantitative Metrics for Web Accessibility Evaluation. First Workshop on Web Measurement and Metrics (WMM 2005), Sydney, Australia, July 26, 2005.

[6] Avizienis, A., Laprie, J.-C., & Randell, B. (2000). Fundamental Concepts of Dependability. Third IEEE Information Survivability Workshop (ISW 2000), Boston, USA, October 24-26, 2000.

[7] Beck, K., & Andres, C. (2005). Extreme Programming Explained: Embrace Change (Second Edition). Addison-Wesley.

[8] Berander, P., & Andrews, A. (2005). Requirements Prioritization. In: A. Aurum & C. Wohlin (Eds.). Engineering and Managing Software Requirements. Springer-Verlag, 69-94.

[9] Boehner, K., DePaula, R., Dourish, P., & Sengers, P. (2007). How Emotion is Made and Measured. International J. Human-Computer Studies, 65, 275-291.

[10] Brajnik, G. (2001). Towards Valid Quality Models for Web Sites. The Seventh Conference on Human Factors and the Web (HFWeb 2001), Madison, USA, June 4-6, 2001.

[11] Bruce, B. C. (2001). Credibility of Web: Why We Need Dialectical Reading. J. of Philosophy of Education, 34(1), 97-109.

[12] Burkell, J. (2004). Health Information Seals of Approval: What Do They Signify? Information, Communication & Society, 7(4), 491-509.

[13] Carduci, M., & Isaak, J. (2003). Standards and Web Site Credibility. The Third IEEE Conference on Standardization and Innovation in Information Technology (SIIT2003), Delft, The Netherlands, October 22-24, 2003.

[14] Cassidy, W. P. (2007). Online News Credibility: An Examination of the Perceptions of Newspaper Journalists. J. Computer-Mediated Communication, 12(2).

[15] Chisholm, W., Vanderheiden, G., & Jacobs, I. (1999). Web Content Accessibility Guidelines 1.0. W3C Recommendation. World Wide Web Consortium (W3C).

[16] Choi, S. M., & Rifon, N. J. (2002). Antecedents and Consequences of Web Advertising Credibility: A Study of Consumer Response to Banner Advertisements. J. Interactive Advertising, 3(1).

[17] Clemen, R. T. (1996). Making Hard Decisions: An Introduction to Decision Analysis (Second Edition). Duxbury Press.

[18] Constantine, L. L., & Lockwood, L. A. D. (2002). Usage-Centered Engineering for Web Applications. IEEE Software, 19(2), 42-50.

[19] Consumer Reports WebWatch. (2005). Leap of Faith: Using the Internet Despite the Dangers. Results of a National Survey of Internet Users for Consumer Reports WebWatch. A Consumer Reports WebWatch Research Report, 2005.

[20] Conte, T. U., (2005). Reading Techniques for Web Application Design. The Nineteenth Brazilian Symposium on Software Engineering (SBES 2005), Uberlândia, Brazil, October 3-7, 2005.

[21] Curzon, S. (2005). Credibility: Seven Teaching Challenges. Internet Credibility and User Symposium, Seattle, USA, April 11-13, 2005.

[22] Danielson, D. R. (2006). Web Credibility. In: Encyclopedia of Human-Computer Interaction. C. Ghaoui (Ed.). Idea Group.

[23] De Troyer, O. (2001). Audience-Driven Web Design. In: Information Modeling in the New Millennium. M. Rossi & K. Siau (Eds.). Idea Group.

[24] Dromey, R. G. (2003). Software Quality - Prevention Versus Cure? Software Quality Journal, 11(3), 197-210.

[25] Dustin, E., Rashka, J., & McDiarmid, D. (2001). Quality Web Systems: Performance, Security, and Usability. Addison-Wesley.

[26] Engelbart, D. C. (1995). Toward Augmenting the Human Intellect and Boosting our Collective IQ. Comm. ACM, 38(8), 30-33.

[27] Eppler, M. J. (2001). The Concept of Information Quality: An Interdisciplinary Evaluation of Recent Information Quality Frameworks. Studies in Communication Sciences, 1(2), 167-182.

[28] Eysenbach, G., Powell, J., Kuss, O., Sa, E.-R. (2002). Empirical Studies Assessing the Quality of Health Information for Consumers on the World Wide Web: A Systematic Review. J. American Medical Association, 287(20), 2691-2700.

[29] Fenton, N. E., & Pfleeger, S. L. (1997). Software Metrics: A Rigorous & Practical Approach. International Thomson Computer Press.

[30] Fogg, B. J., Soohoo, C., Danielson, D., Marable, L., Stanford, J., & Tauber, E. R. (2002). How do Users Evaluate the Credibility of Web Sites?: A Study with Over 2,500 Participants. The 2003 Conference on Designing for User Experiences (DX 2003), San Francisco, USA, June 6-7, 2003.

[31] Fogg, B. J. (2003). Persuasive Technology: Using Computers to Change What We Think and Do. Morgan Kaufmann Publishers.

[32] Fogg, B. J., & Tseng, S. (1999). The Elements of Computer Credibility. The ACM CHI 99 Conference on Human Factors in Computing Systems, Pittsburgh, USA, May 15-20, 1999.

[33] Friedman, B. (2005). Credibility by Design. Internet Credibility and the User Symposium, Seattle, USA, April 11-13, 2005.

[34] Gibson, D. A. (2002). Communities and Reputation on the Web. Ph.D. Thesis, University of California, Berkeley, USA.

[35] Graham, I. (2003). A Pattern Language for Web Usability. Addison-Wesley.

[36] Gruber, T. R. (1993). Toward Principles for the Design of Ontologies Used for Knowledge Sharing. In: Formal Ontology in Conceptual Analysis and Knowledge Representation. Kluwer Academic Publishers.

[37] Hadjerrouit, S. (2005). Designing a Pedagogical Model for Web Engineering Education: An Evolutionary Perspective. J. Information Technology Education, 4, 115-140.

[38] Hansen, S., Deshpande, Y., & Murugesan, S. (2001). A Skills Hierarchy for Web Information System Development. In: Web Engineering: Managing Diversity and Complexity of Web Application Development. S. Murugesan & Y. Desphande (Eds.). Lecture Notes in Computer Science, 2016, Springer-Verlag, 223-236.

[39] Hasan, L. R., & Abuelrub, E. (2006). Criteria for Evaluating Quality of Websites. The Sixth IBIMA Conference on Managing Information in Digital Economy, Bonn, Germany, June 19-21, 2006.

[40] Hendler, J., Lassila, O., & Berners-Lee, T. (2001). The Semantic Web. Scientific American, 284(5), 34-43.

[41] Highsmith, J. (2002). Agile Software Development Ecosystems. Addison-Wesley.

[42] Hoschka, P. (1998). From Basic Groupware to the Social Web. ACM SIGGROUP Bulletin, 19(2), 5-9.

[43] Ivory, M. Y. (2001). An Empirical Foundation for Automated Web Interface Evaluation. Ph.D. Thesis, University of California, Berkeley, USA.

[44] Jacobs, I., & Walsh, N. (2004). Architecture of the World Wide Web, Volume One. W3C Recommendation. World Wide Web Consortium (W3C).

[45] Johnson, D. G. (1997). Ethics Online. Comm. ACM, 40(1), 60-65.

[46] Jordan, K., Hauser, J., & Foster, S. (2003). The Augmented Social Network: Building Identity and Trust into the Next-Generation Internet. First Monday, 8(8).

[47] Kamthan, P. (1999). E-Commerce on the WWW: A Matter of Trust. Internet Related Technologies (IRT.ORG).

[48] Kamthan, P., & Pai, H.-I. (2006a). Representation of Web Application Patterns in OWL. In: D. Taniar & J. W. Rahayu (Eds.). Web Semantics and Ontology. Idea Group, 41-67.

[49] Kamthan, P., & Pai, H.-I. (2006b). Human-Centric Challenges in Ontology Engineering for the Semantic Web: A Perspective from Patterns Ontology. The Seventeenth Annual Information Resources Management Association International Conference (IRMA 2006), Washington, D.C., USA. May 21-24, 2006.

[50] Kamthan, P., & Pai, H.-I. (2007). Personalizing Web Portals. In: Encyclopedia of Portal Technologies and Applications, Volume 2. A. Tatnall (Ed.). Idea Group, 699-704.

[51] Kappel, G., Pröll, B., Reich, S., & Retschitzegger, W. (2006). Web Engineering. John Wiley and Sons.

[52] Kasanoff, B. (2002). Making it Personal: How to Profit from Personalization without Invading Privacy. John Wiley and Sons.

[53] Kotonya, G., & Sommerville, I. (1998). Requirements Engineering: Processes and Techniques. John Wiley and Sons.

[54] Kruchten, P. (2004). The Rational Unified Process: An Introduction (Third Edition). Addison-Wesley.

[55] Krunić, T., Ružić-Dimitrijević, L., Petrović, B., & Farkaš, R. (2006). Web Design Curriculum and Syllabus Based on Web Design Practice and Students' Prior Knowledge. J. Information Technology Education, 5, 317-335.

[56] Lazar, J. (2001). User-Centered Web Development. Jones and Bartlett.

[57] Lazar, J. (2005). Tools and Technology for Web Credibility. Internet Credibility and the User Symposium, Seattle, USA, April 11-13, 2005.

[58] McGregor, J. D. (2007). Dependability. J. Object Technology, 6(3), 7-12.

[59] Mendes, E., & Mosley, N. (2006). Web Engineering. Springer-Verlag.

[60] Mendes, O., & Abran, A. (2004). Software Engineering Ontology: A Development Methodology. Metrics News, 9(1), 64-71.

[61] Metzger, M. (2005). Understanding How Internet Users Make Sense of Credibility: A Review of the State of Our Knowledge and Recommendations for Theory, Policy, and Practice. Internet Credibility and the User Symposium, Seattle, USA, April 11-13, 2005.

[62] Mich, L., Franch, M., & Gaio, L. (2003). Evaluating and Designing Web Site Quality. IEEE Multimedia, 10(1), 34-43.

[63] Nagura, R., Seki, Y., Kando, N., & Aono, M. (2006). A Method of Rating the Credibility of News Documents on the Web. The Twenty Ninth Annual International ACM SIGIR Conference on Research and Development on Information Retrieval (SIGIR 2006), Seattle, USA, August 6-11, 2006.

[64] Nguyen, H. Q., Johnson, R., & Hackett, M. (2003). Testing Applications on the Web: Test Planning for Mobile and Internet-Based Systems (Second Edition). John Wiley and Sons.

[65] Nielsen, J. (2000). Designing Web Usability: The Practice of Simplicity. New Riders Publishing.

[66] Offutt, J. (2002). Quality Attributes of Web Software Applications. IEEE Software, 19(2), 25-32.

[67] Olsina, L., & Rossi, G. (2002). Measuring Web Application Quality with WebQEM. IEEE Multimedia, 9(4), 20-29.

[68] O'Reilly, T. (2005). What Is Web 2.0: Design Patterns and Business Models for the Next Generation of Software. O'Reilly Network, September 30, 2005.

[69] Paine, C., Reips, U.-D., Stieger, S., Joinson, A., & Buchanan, T. (2007). Internet Users' Perceptions of 'Privacy Concerns' and 'Privacy Actions'. International J. Human-Computer Studies, 65, 526-536.

[70] Paulk, M. C., Weber, C. V., Curtis, B., & Chrissis, M. B. (1995). The Capability Maturity Model: Guidelines for Improving the Software Process. Addison-Wesley.

[71] Pertet, S. M., & Narasimhan, P. (2005). Causes of Failure in Web Applications. PDL Technical Report PDL-CMU-05-109. Carnegie Mellon University, USA.

[72] Resnick, P., Zeckhauser, R., Friedman, E., & Kuwabara, K. (2000). Reputation Systems. Comm. ACM, 43(12), 45-48.

[73] Reynolds, G. (2003). Ethics in Information Technology. Thompson Publishing Group.

[74] Riegelsberger, J., Sasse, M. A., & McCarthy, J. D. (2005). The Mechanics of Trust: A Framework for Research and Design. International J. Human-Computer Studies, 62(3), 381-422.

[75] Rieh, S. Y., & Belkin, N. J. (1998). Understanding Judgment of Information Quality and Cognitive Authority in the WWW. The Sixty First American Society for Information Science Annual Meeting (ASIS 1998), Pittsburgh, USA, October 24-29, 1998.

[76] Ross, M. (2002). Quality in Web Design for Visually Impaired Users. Software Quality J., 10(4), 285-298.

[77] Rossi, G., Pastor, O., Schwabe, D., & Olsina, L. (2008). Web Engineering: Modelling and Implementing Web Applications. Springer-Verlag.

[78] Scapin, D. L., Leulier, C., Bastien, J. M. C., Vanderdonckt, J., Mariage, C., Farenc, C. Palanque, P., & Bastide, R. (2000). Transferring Knowledge of User Interfaces Guidelines to the Web. Ergonomie et Interaction Homme-Machine (ErgoIHM 2000), Biarritz, France, October 7-8, 2000.

[79] Schneiderman, B. (2000). Designing Trust into Online Experiences. Comm. ACM, 43(12), 57-59.

[80] Schneidewind, N. F., & Fenton, N. E. (1996). Do Standards Improve Product Quality? IEEE Software, 13(1), 22-24.

[81] Segerståhl, K., & Jokela, T. (2006). Usability of Interaction Patterns. CHI 2006 Conference on Human Factors in Computing Systems, Montréal, Canada, April 22-27, 2006.

[82] Shanks, G. (1999). Semiotic Approach to Understanding Representation in Information Systems. Information Systems Foundations Workshop, Sydney, Australia, September 29, 1999.

[83] Sillence, E., Briggs, P., Harris, P, & Fishwick, L. (2006). A Framework for Understanding Trust Factors in Web-Based Health Advice. International J. Human-Computer Studies, 64(8), 697-713.

[84] Simon, H. (1996). The Sciences of the Artificial (Third Edition). The MIT Press.

[85] Stamper, R. (1992). Signs, Organizations, Norms and Information Systems. The Third Australian Conference on Information Systems, Wollongong, Australia, October 5-8, 1992.

[86] Stanford, J., Tauber, E., Fogg, B. J., Marable, L. (2002). Experts vs. Online Consumers: A Comparative Credibility Study of Health and Finance Web Sites. A Consumer Reports WebWatch Research Report, 2002.

[87] Stein, L. (1998). Web Security: A Step-by-Step Reference Guide. Addison-Wesley.

[88] Tavani, H. T. (2004). Ethics and Technology: Ethical Issues in an Age of Information and Communication Technology. John Wiley and Sons.

[89] Tidwell, J. (2005). Designing Interfaces: Patterns for Effective Interaction Design. O'Reilly Media.

[90] Tractinsky, N., Cokhavi, A., Kirschenbaum, M., & Sharfi, T. (2006). Evaluating the Consistency of Immediate Aesthetic Perceptions of Web Pages. International J. Human-Computer Studies, 64(11), 1071-1083.

[91] Van Duyne, D. K., Landay, J., & Hong, J. I. (2003). The Design of Sites: Patterns, Principles, and Processes for Crafting a Customer-Centered Web Experience. Addison-Wesley.

[92] Vanderdonckt, J. (1999). Development Milestones towards a Tool for Working with Guidelines, Interacting with Computers, 12(2), 81-118.

[93] Vossen, G., Lytras, M., & Koudas, N. (2007). Revisiting the (Machine) Semantic Web: The Missing Layers for the Human Semantic Web. IEEE Transactions on Knowledge and Data Engineering, 19(11), 145-148.

[94] Wallace, D., Raggett, I., & Aufgang, J. (2002). Extreme Programming for Web Projects. Addison-Wesley.

[95] Walther, J. B., Wang, Z., & Loh, T. (2004). The Effect of Top-Level Domains and Advertisements on Health Web Site Credibility. J. Medical Internet Research, 6(3), 2004.

[96] Wathen, C. N., & Burkell, J. (2002). Believe It or Not: Factors Influencing Credibility on the Web. J. American Society for Information Science and Technology, 53(2), 134-144.

[97] Wiegers, K. E. (2002). Peer Reviews in Software: A Practical Guide. Addison-Wesley.

[98] Wiegers, K. E. (2003). Software Requirements (Second Edition). Microsoft Press.

[99] Wang, Y. D., & Emurian, H. H. (2005). An Overview of Online Trust: Concepts, Elements and Implications. Computers in Human Behavior, 21, 105-125.

[100]Wong, B. (2006). Different Views of Software Quality. In: Measuring Information Systems Delivery Quality. E. Duggan & J. Reichgelt (Eds.), Idea Group, 55-88.