The Smart Internet: Transforming the Web for the User

Joanna W. Ng
IBM Canada Laboratory
Toronto, Ontario

Mark Chignell
University of Toronto
Toronto, Ontario

James R. Cordy
Queen's University
Kingston, Ontario

Abstract

Key architectural elements of the web, namely, HTTP, URL and HTML enable a very simple *user model of the web* based on hyperlinks. While this model allows browser-based access to a wide array of online content and resources, the limitations in user experience provided in this interaction model are increasingly apparent. Two decades after the birth of the web, new technologies such as Rich Internet Application, AJAX, and Web 2.0 seek to improve web user interfaces, but in general their main benefit is to individual server sites. Little advancement has been made to advance the *user model of the web* at a macro level where the interaction is driven not by the server but by the user. This paper proposes a novel approach to scientific study of the Web (Web science) where the traditional relationship between users and servers is inverted, so that web services are configured and integrated across multiple servers/sites in order to address the needs of users. The resulting interaction paradigm is referred to here as *smart interaction.* The Smart interaction approach is quite different from the current hyperlink-oriented user model driven from the perspective of the server side. *Smart interactions* require new web infrastructure (e.g., runtime components) and new patterns of services and resource interactions and compositions. A Complementary area of research is *smart services;* where the focus is on abstracting these web infrastructures and service interaction patterns into appropriate *web models* and algorithms. The combination of *smart interaction* and *smart services* will then result in a *smart internet* where user experience is enhanced, and user productivity unleashed, by passing control back to users.

1 A Copernican Transformation

The notion of a smart internet requires a transformation in our understanding of the web and its architecture – a complete change of perspective, from a server-centric understanding to a user-centric one. This change will be much like the Copernican revolution, where the presumed structure of the solar system changed from an Earth-centric one to a Sol-centric one. The smart internet revolution is likely to be just as controversial, and just as important as the Copernican revolution.

Three major extensions are called for in this transformation. First, a new "Copernican" *user model for the web* is needed that is centered on the users' concerns and cognition. Second, a new kind of *session concept* is required that centers on the user's perspective and her situation rather than the server's perspective of user interactions. Thirdly, the *concept of dynamic social binding of web interactions*, to turn what is currently a single user web interaction model into multi-users' collaborative web interactions under the user's control, is also needed.

In essence, the *smart internet* supports an instinctive *user model of the web*, one in which the discovery, aggregation and delivery of services and resources results in rendered content that is optimal for each user or group's situation.

2 Background

In 1989, Tim Berners-Lee invented the web and began the modern internet era. The internet is viewed as an 'irreversible innovation' of enhanced digital connectivity [11]. From its inception to the present, the Uniform Resource Locator (URL) has been used as the address of the specific web server from which users obtain resources and content. In this now classic model, the browser on the client device first makes a *connection* with the corresponding web server. The corresponding web server then processes the *request* sent in HTTP transfer protocol from the browser of the client. The web server directs and/or performs the requested units of functions or fetches the requested resources and sends the *response* back to the browser of the client also in *HTTP* transfer protocol as an *HTML* format response page. When the connection between the user's browser and the corresponding web server is no longer needed, the connection is *closed*. These connect-request-response-close interactions between a user's browser and a web server provide a simple usage model for the web. In spite of its simplicity, users have benefited greatly from having ready access to this massive, distributed, and loosely coupled network of information.

Advancement in the first decade of the Web era (the 1990s) focused on overcoming practical issues of web application development and deployment imposed by the web architecture. These issues included: security; scalability; performance; transactions and others. In the second decade of the Web (around 2000) technologies related to improvement of web user experience began to emerge. For example, Rich Internet Applications (RIA) aimed at "combining the media-rich power of the traditional desktop with the deployment and content rich nature of web applications" [1] in order to provide better user experience. The Web 2.0 initiative sought to enhance user experience by adding social computing tools, and by allowing users and other less technical participants to publish, as well as consume, content through lightweight programming models [21] and tools such as blogging. AJAX combined asynchronous data retrieval using the XMLHttpRequest object and data interchange in XML, with DOM and other standards-based presentation like XHTML and cascade style sheets (CSS) all bound together in JavaScript. The intent was to offer a web application user experience comparable to the desktop, but through the browser [9]. While each of these technologies has enhanced the user experience for individual server sites, the problem of how to move Web interaction to a user-centric approach, where services and content are aggregated across multiple sites according to user needs, has yet to be addressed.

The server-centric *(users for the web)* model of Web interaction has prevailed over the last two decades. While powerful, it is in need of replacement as its shortcomings become increasingly clear. The server-centric model is onerous for users, forcing them to access information from various sites; and then manually customize the information acquired from these sites in order to accomplish a particular task or purpose. User patience with such inconvenience is starting to wear thin [23]. The inconvenience of the current model for users stems from five major shortcomings.

1. The lack of *integration from the user's perspective,* to aggregate resources and content from multiple web servers centering on the user, her tasks and the context. Technologies like *portals* and *mashups* provide partial solutions to this problem, but both lack an aggregation model and framework to drive service composition from the user's perspective that can be handled and controlled by users themselves.

2. The lack of *individualization* is increasingly becoming an issue as users push for a user model for the web that is aware and adaptive to the user's real time context and situation. Today's personalization technologies use approaches like user categorization, configura–tion and customization but do not fully support real time, individualized requirements.

3. The absence of *server-initiated connections* such as asynchronous connections and service level batch processing is another handicap in today's primitive user model of the web. The user has to initiate and track tasks, and is provided with little to zero cognitive support both in terms of aiding prospective memory (remember what has to be done in the future) and in terms of carrying out complex tasks.

4. The lack of any notion of *service level collaboration*, the idea that multiple users may collaborate on a service instance, is another limitation that makes it difficult for people to work collaboratively when interacting with the Web.

5. Finally, *user control* over web pages is very limited and is primarily controlled by server side software programmers.

Research work in context-aware computing [5] the Semantic Web [33] and personalization [34] has made advances with respect to some of these shortcomings. However, without a cohesive and advanced *user model of the working* at a macro level (not just at the individual site level), and without a *web model* to capture the conceptual structure of Web content and services, these types of incremental advances will not lead to significant change.

This paper proposes an extension to the web, called *smart internet,* which includes a new user model of the web, *smart interactions*, that is centered on the perspective of the user instead of the server. This advanced user model is enabled by a new web model, referred to as *smart services*, that provides the integrated web infrastructure necessary to support the technical requirements of the smart interaction user model.

The remainder of this paper presents our vision for the *smart internet,* and outlines some of the research challenges posed by the two complementary aspects, *smart interactions* and *smart services*. The making of this vision into a reality will require many kinds of expertise and technical solutions. It is our hope that we can inspire others to join us in making of this important new vision a reality by contributing to solving these challenges.

3 The Smart Internet Vision

In this section highlights the three distinct principles of smart internet that set it apart from the internet today: an *instinctive user model, sessions for users and their matter of concerns,* and *collective and collaborative web interactions.* Each of these principles is described below.

3.1 Conceptual Overview

The smart internet will be an evolving extension of the internet in which online services and resources are discovered, aggregated and delivered dynamically, automatically and interactively in response to user or group's evolving concerns and situations, which may involve real time or proactive performance of tasks that address users' goals. All aspects must be conducted with awareness of, and adaptation to, the user's personal and group context, task requirements and characteristics. The resulting aggregation of resources and content will be delivered in a manner appropriate to the user's current concerns or situation, and as a unified entity abstracting relevant content and services from a single site, or from multiple sites and organizations.

To be practical, the smart internet must be an evolution and extension of the current internet, building on the existing basic architectural elements of HTML, URLs and HTTP, while hiding these techno-centric elements behind objects and interactions that are more appropriate and intuitive, tailored to the end user's current domain, goals and concerns. Rather than the user initiating interactions to accomplish tasks themselves, the smart internet should allow the user's current concerns to drive the implicit discovery and aggregation of services and resources to serve the user and support the user's cognition and action.

3.2 Principle 1: A User-Centric Model for Instinctive Interaction

The term "user model" has been used in a number of different ways in the literature on human-computer interaction [4]. Norman [19] distinguished between three different conceptual models relating to use of interactive systems: the user model; the design model; the system image. While the latter terms represent the designer's model of the system and how the system presents itself to the user, the term "user model" can refer not only to the user's model, but also to a model of the user (closer to Norman's concept of design model). In the present discussion, user model refers to the model of the user and her tasks that is assumed in designing systems, methods of interaction, and in guiding specific interactions.

One of the assumptions of the Smart Internet approach is that identifying and applying appropriate user models is essential, in keeping with the requirements of user-centered design (e.g., Norman [19]). Instead of being user-centered, the user model of the internet today is by and large techno-centric, exposing the fundamental components of the web architecture, resulting in a "one HTML page at a time" interactive model convenient for the server. The widespread use of the Internet should not be taken to indicate that the techno-centric user model is sufficient. Users adapt to fit what the web has to offer, and in order to use valued content and services, they are willing to connect to myriad web sites, filtering the relevant information for their own context in order to address the task at hand. But this causes a great deal of inconvenience and wasted effect. What we seek instead is an alternative user-centric model that leads to interactions that are instinctive for the user, rather than being fitted to the server and awkward for the user.

There are three critical implications of the principle of instinctive user model for the web.

1. *Metaphors as Cues for Instinctive Response*

The system image of the smart internet should use metaphors based on objects and operations from real world analogies that are familiar and appropriate to users and map well to the user's current domain of concern. Well chosen metaphors hide the techno-centric elements of the system, while promoting a good mapping between the concerns of the user and the functionality of the system.

Meaningful user interactions are driven by goals that are then reflected in the things that matter to the user when interacting with the system. These "matters of concern" ("*moc*") should drive the design of interactions, so that users no longer deal directly with URLs and logon forms for secured sites, not because they are not needed but because they are handled for them behind the scenes, just as people can drive cars without having to worry about all the details of how the engine is working.

Google maps "points of interest" are an example that illustrates the type of interaction envisaged, where the prime metaphor for user interaction is based on objects and operations like "Interest Category" and "Find Direction" that are in the user's domain.

2. *Web Page Content and Control by and for Users.*

Another implication of instinctive interaction is the transfer of control of the rendered HTML page to end users so that individualized content is dynamically and adaptively aggregated for effective interaction with the user's *mocs*. Content and services could then be placed in individualized contexts based on the current collection of *mocs* applicable to the current persona (e.g., a user may have different personas depending on whether she is at home, at work, or mobile).

a. *Aggregative Content.*

Currently online users have to deal with the one page per response per domain server request-response model of web interaction. The principle of instinctive interaction requires a completely different method of interaction.

In the smart internet, the rendered response is *aggregated for the purpose of the user* as a whole person with multiple current matters of concern. Transforming from *the users for the web* to *the web for the users* means providing *moc*-relevant resources and content extracted and abstracted from one or more servers and tailored to the concerns of the individual.

b. Adaptive to system of interactions

Instinctive interaction should be tailored not to a device for situation, but to a lifestyle and *the user's systems of interaction and other elements of context that are part of that lifestyle*. Adaptation to user's multiple systems of interaction is not just in form factor (e.g., different devices) but also in function. Traditionally, mobile devices provide a squeezed miniature of their desktop counterpart, resulting in inferior user interfaces. Instinctive interaction requires a different approach where subset units of functions that are optimal for the device of interaction; persona in context and other factors of context are adapted for the user's *moc.*

3. *Control.*

The control of the HTML page as rendered response is transferred from the server to the user. Web application development for the smart internet enables users to control the form and content of web pages so as to suit their own purposes and context. For example, users can specify different preferences, rules and policies for aggregation for their various personas (personal, professional etc.) and *mocs*. These pre-set user rules and conditions then control how pages are put together.

4. *Calm, Instinctive, Cognitively Compatible.*

Not only should the metaphors and entities of smart internet interactions match key features in the user's problem domain, but the methods and style of interaction should be compatible with *the user's cognition.* This is in sharp contrast to existing internet interaction, which requires its users to initiate and drive interactions with the web to accomplish their tasks. Such interactions are synchronous in nature, and users bear all the cognitive burden of initiating actions and remembering where related information is located.

In contrast, smart interaction, while still leveraging the web as a platform, provides better support for the user's cognition, reducing the amount of information that has to be held in prospective memory, reducing the complexity of tasks to be performed by the user, and so on.

The concept of *calmness* has emerged as a key aspect of ubiquitous computing which relates to how users' attention is engaged. Human attention has a number of key properties (e.g., Wickens and Hollands [30]), including limited capacity, and differences in types of attentional resource (with a key distinction being between verbal and visuo-spatial attentional resources). In order to be calm, interactions should engage both the center and the periphery of the user's attention moving back and forth between the two. Peripheral attention does not require the executive processing of focal attention but allows a person to maintain awareness of information in the environment. The periphery at a given moment may be the center of attention in the next and smart interaction should exploit the properties of cognition to provide information and options in a way that it easy for people to perceive and assimilate while going about other activities. By loading more processing in to the periphery, smart interaction informs without overburdening, freeing users' cognitive capacity to handle more things [28] while making tasks calmer and less disruptive.

Calmness in the smart internet may be achieved in many different ways, such as by adding asynchronous interfaces to allow *mocs to move* back and forth between the periphery and the center of attention depending on user specified rules, and aggregating and adapting based on the user's changing personas and context.

3.3 Principle 2: Session for Users and their Matters of Concern

Today, the notion of session keeps track of the user and their interactions from the perspective of the server. The session ends when the user stops interacting with the site. Traditionally, a user session is defined as "a series of requests issued by a user to a web site in a single visit to the site" [15]. Technically, user sessions are HTTP sessions used to preserve the conversational state between a given server site and connection with a browser instance of a client device. Important session information such as user account and password are preserved and associated with the corresponding client, avoiding the need to ask for the same required information in a given request-response dialogue, resulting in better user experience. The existing concept of session, (i) is associated with one particular server, and (ii) is bounded by user's real time synchronous interactions.

When the web's center of gravity is refocused on the user, the concept of session must be extended beyond the server site view of user initiated real time synchronous interaction. In the smart internet, sessions are oriented to the perspective of users and their matters of concern, rather than simply being states that the server site wants to keep track of. Two major implications follow from this shift of emphasis.

1. *Interactions need not be synchronous.*

   Sessions centered on the user and her matters of concern should not be exclusively real time synchronous interactions initiated by the user. To sufficiently support the user's matter of concerns, smart interaction needs to add, (i) asynchronous interaction patterns, such as events and asynchronous conversations. Examples might include setting up of monitors; reminders or alerts based on certain conditions (triggers) or the setting up of prospective memory related tasks of *mocs* such as scheduled tasks, and (ii) batch processing where sequences of service interactions within or across several server sites are remembered and repeated automatically.

2. *Session as a Cohesive Continuum across multiple systems of interaction.*

   Web applications in the smart internet see users, their concerns and tasks as a continuum of ubiquitous access across one or more systems of interaction. This revised concept of session has the following implications: (i) Smart internet sessions maintain *mocs* as persistent states in order to keep track of progress towards the user's goals and sub-goals and the need for user's attention for each *moc.* Smart internet sessions will involve semantic integration of a relevant set of composite services and server site sessions to deduce and maintain (persist) overall state and progress of *mocs.* (ii) This persistence means that users will not lose or change their state or the state of their matters of concern when switching system of interactions. Thus users will always be able to continue where they last left off. (iii) This means that switching personas or context does not throw the user into a new logon session. When re-authentication is required, it will be done on the user's behalf (without requiring the user's involvement). This also means that the user's multiple systems of interaction can function as a cohesive unit, forming a continuum for the users and their *mocs*. This is very different from today, when each change of system of interaction leads to a new session that is treated as if unrelated to previous sessions.

3.4 Principle 3: Collaborative & Collective Web Interactions

The third principle of the smart internet that distinguishes it from the current internet is that it explicitly supports close collaborate between users to resolve shared matters of concern. This principle has the following implications.

1. *Dynamic Social Binding.*

   Dynamic social binding is defined as the capability to select other users dynamically to share interaction elements for different levels of interactions associated with *mocs*. Shared interactions will occur at different levels of intensity, ranging from sharing of views as read-only, to co-execution or delegation of tasks and subtasks of mocs, thereby turning web interactions from solitary undertakings to multi-user collaboration. Online shopping can be used to demonstrate the application of this principle. Suppose a user, A, has started a matter of concern relating to online Christmas shopping for his children. He places multiple items from the catalog into the shopping cart. Using dynamic social binding, user A selects his wife, user B, to co-execute different elements of interaction for the online Christmas shopping task as a moc. Now user B is enabled to participate and collaborate in operations of user A's *moc* such as adding items to the shopping cart. Once the collaborative work has been completed, User A can transfer the session to user B or end the dynamic social binding session and continue to checkout himself.

2. *Collective Intelligence.*

   In Smart interaction, matters of concern become the major drivers of activity, explicitly centering the processing on user needs and interests. In keeping with this focus on mocs, text and semantic search in the smart internet should return search results in units of *mocs* as a (pre-set; or ready-to-use as-is or with minor modification) purposeful composite collection of related services and resources instead of being simply a list of unrelated single hyperlinks as in today's internet. One would envision a new kind of search interface that enables users to locate, customize, consume, rate and review such type of interactions as matters of concern or users themselves author their own. Queries such as "what do people with similar profile as mine do in similar matter of concerns (*moc*)?" should also be answered by the collective intelligence to be offered as *moc*-advisor for user assistance. This functionality can be provided by harvesting statistical data of historical behavior, user ratings, user reviews and feedback presented to users. Proactive analysis on such collective intelligence can be done as batch processing.

4 Web Science of the Smart Internet

The three principles of *smart internet,* that set it apart from the current internet, were outlined in the preceding section. In this section a research agenda is outlined concerning the science of the *smart internet.*

Web science studies the web as an empirical science as well as a science of synthetic formalism and algorithms, with the goals being (i) to derive hypotheses that predict and explain the web and (ii) to formalize the engineering of the web. It is intended to be a multidisciplinary science of the web [2]. Research on the smart internet fits within the scope of web science. With respect to the Web science of *smart internet*, two major research activities are identified, namely: (i) formalizing an advanced ***user model*** of the web (for *smart interactions*) that centers around users and their matters of concern and (ii) formalizing a ***web model*** (for *smart services*) including formalizing the algorithms required to orchestrate the web as a cohesive platform that enables the advanced user models required for smart interaction.

4.1 Smart Interactions: The User Model for the Smart Internet

The smart internet needs to be much more user-centric and responsive to user needs for web interactions to address user's matters of concerns than is the current internet. The goal of the smart internet with respect to user modeling is not to have a deep psychological understanding of each user, but rather, to develop normative models that represent the broad characteristics and is optimal for the purpose of why user uses the web. At the same time, such model has to be flexible and adjustable (such as by filling in the details and parameterization of a normative user model) to suit particular context. In general, the user model will contain *metaphors*; *concepts; objects; operations and relationships among them* [14]. The baseline user model of the current web uses hypermedia as the uniform interface. It provides resource identification from the perspective of the server side with great simplicity [8]. In order to move from this baseline model to smart interactions, we propose a research agenda aimed at formulating this normative *user model of the web* that encapsulates the key elements of all three principles of smart internet, focusing on the user. One key assumption in this formation is that user modeling should occur at a macro level across the web instead of occurring only at a micro level, i.e. bringing improvement to individual server sites.

Empirical research is needed to determine how users would want to use the web at a macro level as a platform of services and resources to support them in achieving their goals and addressing their matters of concern. Research relating to *smart interactions* (that is the ***user model for the smart internet***) should address the following issues.

Metaphors that elicit instinctive response to goals and concerns

Appropriate metaphors allow people to more easily transfer existing knowledge and skills to new situations. Metaphors can exist at different levels of abstraction and detail. For example, bookmark is the most widely adopted metaphor of the current internet well chosen to hide the techno-centric architectural element of the web, namely the URL.

One key research issues in smart interactions is to identify metaphors for this new *user model of the web,* that are exemplars of all three smart internet principles, in order to best elicit instinctive user responses towards her goals and concerns, leveraging services and resources from the internet as her supporting platform.

As an overall metaphor, we propose *"matters of concern" (moc)* as a way of connecting user needs and interests to content; resources and services of the web. The metaphor of matters of concern may entail concepts such as *to-do list* as a collection of all mental *tasks* related to resolve the concern of the matter. Such collection is structured as a flexible meta-model that is compatible with user's thinking and remembering things that have to be done. A person's matters of concerns may drift in an out of focus, and change in their priorities, depending on the context. One of the challenges for smart interactions is to translate metaphor of such intrinsic dynamics into cohesively integrated artifacts of user interfaces as *system images* [19]. Another challenge is to build, manage and maintain, for the user, appropriate process models, state-transition diagrams, and the like to support detailed task interactions and completion of a given *moc*. Areas for future research may include formulating the definition of additional objects and operations of the *moc* metaphor, and translating them into user interactions artifacts, that are optimal for the eliciting of user's response towards achieving goals or addressing concerns. For example, how to define these objects and operations, so that they can function as effective *perceptual substitution* (Walestein, 2002) such that the assessment of the states and progress of a *moc* (which can become very complex) will be transformed into fast operations for its user in order to elicit instinctive responses appropriate to the status of the *moc*.

Additional research in the web science of *smart interactions* may also lead to additional metaphors to be defined and identified towards the goals of the *smart internet.*

Another key research question is to find out what objects and operations in the current internet that users would rather not be made aware of (even though they are necessary or even critical to the web as a system) so that they can be better focused on objects and operations directly relevant to their goals; tasks and concerns. The follow on question is to ask how to make them invisible. Objects and operations such as logon on forms; input form data for personalized data that is constant may exist in many *to-dos* (which involved multiple secured server sites) of a given *moc.* These result in operations that are complex and cognitively challenging (e.g. remembering the multiple account numbers and passwords or having to look them up before keying in) operations, resulting in distraction of the user from her goal of resolving concern of the *moc*. A good metaphor for the normative user model of *smart interactions* will make these distracting operations invisible.

A Model that enables Task Simplification

The advanced user model required for smart interaction includes the aspect of transforming difficult tasks into simple ones. Tasks are simplified by making them more *narrow* and *shallow* in shape [19]. For instance, a given matter of concern (such as booking vacation) typically involves multiple bookmarks (such as car rental reservation link; hotel reservation link; air ticketing link; points of interest links etc.), each maps to different tasks related to booking vacation. Instead of the user mentally keeping track of all necessary to-dos regarding booking vacation by manually managing these hyperlinks for that concern, they can be collapsed into a *moc.* The user benefits not only by the cognitive offloading, but she can keep using this *moc* over again in the future; or share it with a friend, or have it rated or commented, and so on. In general, task simplification will lead to reduced cognitive effort and an increase in cognitive compatibility. Task simplification requires a re-engineering of the web, so that no compromises in efficiency or effectiveness are made in order to create a simpler view of the task for users.

Research is needed to determine when and how tasks may be simplified. Since this is an engineered solution that has to work across a wide range of Web interactions, user testing cannot be used to determine what works and what doesn't on an ad hoc basis. Instead, predictive models of task simplification, along with rules for linking simplified views of tasks in the user interface with more detailed views of the task at the back end. When this process works well the user becomes a *supervisory controller* (cf. Sheridan, 2002) specifying what needs to be achieved and monitoring the outcomes without worrying about the details. Task simplification for smart interaction is like the analogy of autopilot, but applied to the scope of the web: the plane is flown in autopilot mode (telling it where to go and making sure that it gets there) rather than the manual mode, with all the effort and expertise that requires. In the travel booking example, a supervisory control type of interaction would allow the user to simply activate the 'booking travel' *moc* whereupon all recommended transactions would be presented to the user for confirmation or modification, with the web working behind the scene to carry out the details implied by the user selections.

Service level batch processing, while still very new, will play a significant role in the engineering of the web to fulfill the *smart interactions* requirement of supervisory controller.

Possible future research may involve mapping task taxonomies identified in human factors and human-computer interaction research into patterns of smart interactions where users can exercise supervisory control over a simplified view of the task..

A Model that provides Cognitive Support

Cognitive support may be loosely defined as the *assistance offered by an artifact* for a user to think and solve problems of his concern. Cognitive support theory is about how and why some abstracted class of artifacts (and their uses) lead to more effective cognition [26, 27] and reduce or completely eliminate the possibility for error. User model of smart interactions exemplify the principle of: "knowledge in the world, not in the head" [19]. The less a person needs to know about a task she is concerned about, without compromising the system's (which is the web as a platform) ability to complete the task in a way the user would want, the better. A key strategy in smart interaction is to let the system keep track of how things stand with regard to ongoing mocs. If keeping track of the states of the matter of concerns is offloaded to the system, then the user may be informed about task status on a "need to know basis" through *alerts* or *reminders*. By moving *mocs* in and out of the user's awareness based on the user's need to know, the interface can be made more calm and the task memory load of the user can be reduced but with increased processing capacity for the user.

Such a metaphor with the dimension of providing good cognitive support to users will drive new definition of *session* that go beyond that of today's which is for the purpose of tracking only user initiated interactions and one server site at a time. Additional research is required to define sessions that support smart interactions requirements such as maintaining and managing states for *mocs* per user and often involve multiple server sites. One area of research in this regard is the role of personal agents as a means of creating persistent sessions that address matters of concern for users.

In addition, integrative research between human-computer interfaces and web architecture at a macro level for batch processing (in terms of task completion behind the scene without user involvement) and asynchronous services (in terms of system-initiated connections and interactions, only user-initiated) will be critical to enable real world implementation of an advanced user model that provides cognitive support to its users.

Relevant future research on cognitively compatible user models might include the integration of the various cognitive support methods that have been proposed into a system for reducing cognitive complexity in smart interaction. Another area of research would involve how interruptions should occur. An early example of this type of research is the work on attentional user interfaces by Horvitz et al. [12]. How errors are prevented is also another key research area.

A Model that enables Adaptive Aggregation:

The user model for smart interaction should adapt dynamically to the user's context. Context can be defined as any information that can be used to characterize the situation of an entity (a person, place or object) to bring the most relevant content to the user [5]. Adaptation can be applied to the presentation layer, and/or the service execution layer. The goal is to bring most relevant server side resources from multiple sources to the user as an individual. Relevant research on this topic would include what aspects of the user model to adapt and when to adapt them. One goal of such research might be to define a meta-model; rules and framework to guide aggregation of content enabled by technologies such as mash ups.

The Concept of Dynamic Collaboration

"Connect-request-response-close" is the basic interaction phases between a browser client with a given server site for a single user today. One dimension of the user model of smart internet is the capability for the user to dynamically bind to another user who can i) share view ii) share execution iii) transfer execution.

Dynamic binding for collaborative server side services is a fairly new research area. It sees collaboration not as an application in itself but as a service that can be integrated into a larger context of operations. Dynamic collaborative services (as in Service Oriented Architecture) will be a key research area for enabling this functionality. Possible research issues include adding objects and operations to start and stop dynamic collaborations within a *moc;* the design of appropriate collaborative interfaces for smart interaction; interruption patterns in dynamic collaboration; access control and policy enforcement; security and privacy control and others.

4.2 Smart Services: The Web Model for the Smart Internet

Smart interactions define new and advanced user models of the web at a macro level gravitating around the user by leveraging services and resources from multiple server sites. This will transform client and server interactions patterns. Today's client-server interactions, when abstracted as a web model, can be thought of as a *web-graph* with *nodes* being the web pages and *edges* as hypertext links [15]. Smart interactions add new dimensions to client-server interactions, specifically (i) server-initiated connections and interactions; (ii) batch-processing as in completing server side services without user's involvement (iii) dynamic-binding of multiple clients into the same connections for service level collaborative interactions and (iv) services flow such as sequential and parallel services; and likely others.

In a nutshell, smart services is to transfer the web services from the control of the web programmer to the hands of the end users. The research agenda of smart services includes the development of abstracted web models that capture the service interactions, and formalization of algorithms to engineer the necessary web infrastructures to support the discovery, aggregation and delivery of services and resources and delivery of services and resources from the web platform under user control. Research relating to *smart services* (the web model for the smart internet) should address the following issues.

Smart Services Web Models

Smart interactions impose new requirements on the web as a platform. The requirements of a high degree of personalization and dynamic adaptation (to real time situations and context) of web interactions for each individual user may give rise to new web models. Server side services needed for a given *moc* and its web interaction artifacts are distinctly separate and independent. For example, the subset of services of a given *moc* for a user's interactions with a mobile phone that has GPS will be different from the services of the same *moc* when the user interacts using a workstation. Which subset of services for a given *moc* is made accessible on each kind of interaction device is an important question. The combination of *mocs* needed for each context, such as persona and type of interaction device, that is optimal for the user's cognitive support is another important problem to solve. How to dynamically compute all of these based on a prescribed framework and rules is another key research question. More experiments and empirical studies will be required to derive and define efficient web models appropriate to the smart internet.

Base Web Infrastructure Extensions

What new requirements for web infrastructure will be required to realize smart interactions is a key research question. User-based ervice interaction patterns will require capabilities that the current standard web infrastructure simply does not support, and new facilities will need to be. An initial set can be identified as follows:

- Base web infrastructure **for *server-side initiated connections and services:*** This includes infrastructure for event processing, and asynchronous services such as reminders and scheduled tasks. The research agenda in this area includes methods and algorithms for efficient filtering and co-relations; models for client-side asynchronous interaction tailored to the user's cognitive support; performance requirements (e.g. critical medical events) and other issues.

- Other components that may need to be added to the base web infrastructure include ***collaborative services*** and ***data visualization.***

New Web Infrastructure for the Smart Internet

Apart from the base web infrastructure to support the supply of services from each server site, there is a need for a new kind of web infrastructure that manages services at the macro level. This new level must handle *mocs* in terms of their states and sessions, and the mapping of services from multiple server sites to the dynamic context of the user's device access at the time. The requirement is for a model of composed services that spans sites but is centrally managed for users as individuals. Some key ideas we can pursue in this direction are:

- Base web infrastructure for ***service level batch processing:*** Service level batch processing involves the execution of a series of services in a distributed fashion without human interaction, so that the selected services can be set up to run to completion without human involvement. This implies that all the parameters required for invocation of the series services can be pre-set and saved to be processed at service run time. This problem poses many research challenges, including invocation patterns for service level batches. For example, batch invocation could be schedule-based, event-based, or based on detection of other user interactions. A key challenge here is the design of a programming model for service batches, including capture and collection of input parameters for service invocations. Service-level batch processing is a critical element for user cognitive support.

- ***Infrastructure to Support Dynamic Adaptation***: Support of smart interactions will need a richer model for adapting services to context that supported by the current web infrastructure. The ability specify the adaptation of presentation to devices and context while retaining the user's *mocs* will be a major research challenge.

- ***Inference Engine:*** A web infrastructure component responsible for the processing of dynamic user context, using user rules and policies to infer the most appropriate aggregation of services for the purpose of dynamic personalization will be needed. Research challenges here include rule definition, validation, and interpretation. A model of life cycles of service use will be critical to the engineering of this component.

- ***Practical Ontology Infrastructure*:** If the smart internet is to be sensitive to the real-world problems and contexts of the user, support for semantic ontologies must be a key component of the new web infrastructure. A framework for ontology infrastructure that allows for dynamic inference and tagging of services and batches will be a key part of smart services.

- ***Flow Engine***: In order to orchestrate user-level services with minimal user intervention, we envisage the need for a service flow engine which can support and manage both direct user interactions and batch services in a consistent, efficient and secure way.

- ***Service Registry and Self-discovery Approach for Service Semantics:*** Automating the matching of end-user intentions with services, batches and previous interacitons will require a system that can automatically associate semantic tags with services (e.g., in WSDL) and components of services (such as the out message). Such a facility must work without involving the user directly, and might for example use reverse engineering techniques to infer and add tags.

There are many other key challenges, such as security models for the smart internet. It is not clear for example how to meet server side security requirements while relieving the user of her cognitive burdens. What is the security model for server-initiated services such as events or asynchronous service interfaces? What is the security model for service-level batch processing and collaborative services? How can we hide the diversity of security requirements across sites while simplifying the user's tasks?

Putting all these new web infrastructure components together into a consistent new web model and framework for web application development in the smart internet is itself an exciting research challenge.

5 Conclusion

This is just the beginning of the research agenda for this Copernican transformation to a *smart internet.* We position this as a research agenda within the scope of web science; extending the internet towards the goal of developing a new web model we call *smart services* that views web services at the macro level to support the user as an individual. We began by discussing the formulization of a user model of the web we call *smart interactions*. We outlined the three major principles that distinguish the smart internet from the web in its current form, namely: (i) an instinctive user model; (ii) a session model focusing on the user's concerns, not just a single server site; and (iii) collective and collaborative web interactions. It is our belief that the research agenda in the smart internet will take us on a journey of transformation in re-engineering the web to focus on the users rather than the servers.

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