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Abstract

In this paper, we review, synthesize and extend the World Wide Web (WWW) models for collaboration into a meta-framework. We start with a set of requirements for a framework for collaborative systems and describe a specific architectural implementation of the suggested framework for Internet based collaboration building upon current research efforts worldwide. Areas that need further research and our future plans are described.

Introduction

The traditional view of information processing is largely static --input, processing, output. Real systems, however, change. They have histories within their various contexts or perspectives, and possible futures. This aspect of 'evolution' is explicitly applicable in the context of collaborative systems.

The present information system protocols are constructed by application of legacy protocols in a fractal hierarchy leading to systems that become brittle and highly inefficient over time due to 'patchwork' building of system upon system and the movement of objects. The WWW unifies prevalent Internet protocols via simple hypertext to provide a means of collaboration on the Internet [Berners-Lee 91] and indeed holds vast potential for collaboration.

To date, however, inspite of an explosion of data, the Web generally lacks useful semantic structure and contains mostly information of unknown value, quality, or accuracy. To fully realize the Web's potential for collaboration, the evolutionary model has to support what we call "a sea of objects [Czech 1996] in the state of becoming" as a general principle. Evolution is not limited to the internal growth of the system alone, but to a constant stream of seamless interactions with varied (often unknown or unpredictable) other systems. In evolutionary systems we don't know the future data flow up front. In network systems minor changes in location of objects can radically change communication requirements and network data flow. In collaborative systems, user or group perspectives on objects can supplement the basic object behavior.

Prior investigation [Turoff 1990] and the nature of Internets suggest that in order to design internet based collaborative systems that can evolve gracefully, each system component has to be thought of as an evolutionary framework that allows a variety of implementations and yet effectively interacts with other components and meets the requirements outlined in Table 1.

A Quick Review of Existing Models

Memex [Bush 45] envisioned a desktop knowledge base empowering individuals. This vision must be extended to the Internet and collaborative groups. "As we may think" is more difficult than Bush imagined. Developing a "Society of Mind" [Minsky 88] may involve building a collaborative network,"the mind of society" as a prerequisite.

Table 1 Requirements for Evolutionary Collaborative Systems

Component Framework	Requirements

1. Socio-psychological framework for collaboration	• Universal Access • Privacy, Ownership, Security, and Reliability • Simple, transparent, safe sharing of information • Time and place independence
1. A framework to support individual and group organization, communication, information handling and task support	• A group communication model • An event handling, change control, and task support model • A general structured communications capability with unified individual and group organizational tools and event processing • Dynamic behavior of network objects based on individual and group classifications
1. User Interface Framework	• Intuitive and consistent paradigm for information and communications access and organization from a user perspective through orthogonality • Flexibility in access devices and environments • Tailorability, extensibility
1. A framework for global network object infrastructure	• Streaming multi-mode multimedia object support • Addressability of all network objects • Distributed and decentralized architecture
1. A framework for network-independent and perspective-independent evolutionary meta-tools	• Support for integration of available meta-information sources • I*nteractability* (vs. intero*per*ability) of independently evolving frameworks and objects (interactability implies dynamic, conversing / negotiating, self-aware, self-modifiable / growing behavior for the objects)

The Electronic Information Exchange System (EIES) defined a tailorable group environment [Turoff 90] and a distributed architecture which includes self-organizing principles [Whitescarver 87]. The need for thinking of any Hypertext system as a collaborative system is clear [Rao 90], [Bieber 97]. Effective collaborative Hypertext systems must impose general-purpose semantic structures upon Hypertext databases that allow a wide variety of applications and thought processes to be represented [Balasubramanian 94]. These structures need to constantly evolve to operate seamlessly with the current uncontrolled explosion of Internet resources. Specifically, (a) extension and application of techniques such as the Meta Content Format [Guha 96] an Resource Description Messages [Hardy 96]for the individual / group authoring and query processes and (b) abstracting, adapting and integrating the frameworks and principles underlying the multi-user internet games and virtual reality into the context of collaborative systems [Bhamidipati 97].

The Dexter model [Halasz 90] updated our view of hypertext, but limited the perspective to individual authors and hard links. We generalize the notion of hypermedia to encompass the both the physical and logical (abstract/rule based) mappings of selections of hypermedia by various relationships to other selections of hypermedia.

WWW extended hypertext to the global networks. W3C and NCSA (Habenaro[NCSA 96]/ISAAC[LaLiberte 96]) continue to supply extensions and frameworks applicable to parts of the collaboration problem.

Our objective is to synergize with current efforts while filling in the missing elements and obeying a methodology that allows our objects to collaborate so that we may collaborate.

Architectural Implementation

Our desire is to apply and integrate existing standards where desirable or dictated by market acceptance in order to maximize accessibility to relevant legacy or otherwise non-conforming network objects, i.e. IIOP (CORBA), SMTP, NNTP (Collabra), POP, IMAP, MIME, LDAP (X.500). Any "components" we develop should function at least with Netscape Navigator / Communicator and Microsoft Explorer in addition to any customized container(s) we build, or, in cases where there is no browser support, standard electronic mail asynchronously using RFC822/MIME extensions and semi-structured messages [Malone 87].

A1 Architecture for the Social framework for Collaboration. People are generally quite willing to share information as long as their privacy and ownership is honored and the pace of change imposed on them is comfortable. Although decision quality generally tends to decrease as group size increases, noncompetitive groups with clear goals and schedules can be highly effective, and develop group solutions which represent the collective intelligence of the group [Hiltz 88]. A collaborative system must address the needs of all collaborators including those participating through third parties. Groups can set their own rules for collaboration. The communication structures must be tailorable to the needs and norms of individuals and groups. Individuals will initiate group processes and control their membership in groups and dissemination. Modifications and deletions by authors will be propagated throughout the group environment. Strict communication structures such as Coordinator [Flores 88] are too confining generally (even though they might be quite effective in certain situations) and must be augmented with highly general open and free discussion structures.

A2 Architecture for the Individual and Group Framework. Information processing, in general, may be modeled as generating and organizing Collections (i.e. set theory). Group processes, utilizing a simple list paradigm, may model processes of any number of dimensions, while also providing a generic framework for activity support for group processes. Multi-mode objects as well as ordinary text can be expressed as or addressed and dealt with in various ways as individual or group Collections down to the bit level. Attributes, dependencies and discussions can be attached at any level of the hierarchy. Users can monitor any activities (a kind of Collection) they have access to, organized and summarized according to personal preferences or system/activity defaults. The behavior of network objects becomes a synthesis of protocols based on how the object has been classified by various users and groups, the rules (behaviors) defined for those classifications, the ambiguity resolution rules, and the particular user perspective and sharing rules. The whole system, from the member perspective, is the Collection of Collections that the member may access. Our design calls for *tickets* to be added if a user is extending privileges to other users / groups. These tickets may be either permanent or temporary in nature. Thus groups/users can be given selective and/or temporal permissions to participate in a collaborative space.

Members, their mailboxes, conferences, and other collaboration spaces require submission, delivery and update protocols along with relevant roles and permissions[Turoff 89]. The group environment will consist of servers on the Internet supporting user and group agents communicating as peers, user agents on the user's PC will be replicated on the network for redundancy and to allow the user to connect from anywhere or work off-line. The group environment demands concurrency control and coordination for shared objects as well as support for the various rules for generating group views from individual activities. The task support model includes (a) rule-based workflow support, (b) repetitive procedure automation, (c) general event processing and (d) information filtering.

A3 Architecture for the User Interface Framework. Our next generation communication space (container) shares the activities of the user with others based on the user's contextual sharing rules and displays activities of others based on contextual reception rules. It provides for navigation between individual and group views (orderings etc.). The interface will allow graphical alteration (customization) by the user and persistently evolves as the user opens or closes different windows/frames of various dimensions. At the same time, it will support a command line that supports ALL functionality. Users will see in the command line the equivalent command for each function that they perform graphically, and a full transcript will be maintained. Using the command line a mouse will not be required. Segments of the command history can be used as procedures to automate common functions by serving as actions associated with user defined rules.

A4 Architecture for the global network object infrastructure Framework. The object infrastructure implied by the above frameworks includes:

- Generalized hierarchical naming from network, system, group and user views.
- Mapping to Internet object URLs/URNs and legacy systems.
- Clear simple protocols and role definitions for maintaining the object hierarchies.
- content addressability
- maintenance of cross-references and garbage collection
- handling exceptional /custom object behavior (such as when legacy objects need to operate in new contexts with a modified protocol)
- Streaming multi-mode multimedia object support.

Collection objects, described above are accessed via Perspective objects. They maintain the object hierarchy within the group environment. Perspective objects are proxies that act like smart pointers, which include rules that supplement or alter the behavior of a network information object. Each perspective may be thought of as a particular object level "use case" that defines a particular interface to a particular object.

Arbitrary data on the network identified by URLs on the Web might represent almost any class of object. To support this, where appropriate, each class implements a classify message which, based on the pattern in its value, calls the classify method in its applicable sub-classes or other related classes.

The model supports synchronous communications as a special case of asynchronous communications to make time coincidence transparent to the user. This implies streaming/buffering support in addition to simple store and forward. Transparent multi-mode delivers live media in the special case where the user has caught up to the present time in the process.

A5 Network-independent and perspective-independent meta-tools. In our model, individual and group activities and the commands corresponding to those activities become the templates for structuring future activities. The command language used should be user-friendly, have strong meta-language capabilities and enforce the object model (e.g. Smalltalk and Self). Users achieve reusability by reuse of their own activities or those that they have permission to access. Those aspects that change from one use to another, become the parameters and alternatives in the emerging abstraction.

In group systems organization of objects is ambiguous due to differing system, group, and user views. Additionally, the polymorphic nature of behaviors in object environments allows ambiguous protocols when untyped arguments, multiple inheritance, or proxy objects are employed. We are faced with either restricting utility and evolutionary behavior of group object systems, or managing the ambiguity. Ultimately we need a knowledge base, not a simple package to manage our protocols. Various meta-data formats support exchange and one supports a mediation framework [Sakata 97] A general model is the Stanford Knowledge Interchange Format (KIF) and Knowledge Query and Manipulation Language (KQML) [Finin 1995], provide a framework for representing, sharing and accessing knowledge bases. KIF is used with functions defined in object Lisp but can readily incorporate Smalltalk, Prolog and Java primitives in order to share behavior in addition to meaning

We have defined network objects with perspectives, including dynamic behavior in a knowledge base. These objects can become personalized intelligent agents that resolve ambiguity to provide the user with an expert system that "understands" user preferences for the interface --classifying and sharing objects, and acting on behalf of the user on the network.

Areas for Future Research

Our future research and implementation plans include:

1. Global optimization of *evolved* behavior.
2. Evolving the current model to a higher level to represent a meta-model of social frameworks
3. Integration and evolution of user and group agents with other intelligent agents to form higher levels of collective intelligence relevant to individual and group problems.
4. Embodiment of economic [Turoff 81] frameworks supporting simple scaleable defaults as well as complex trading rules. Who pays for the storage of shared objects? How do we share intellectual property? This framework needs to be ubiquitous for collaboration to thrive.

Conclusion

The pace of information explosion on the Internet combined with a lack of semantic richness in content presentation in this medium tremendously worsens 'user disorientation', 'user productivity loss' and other undesired effects. Yet, the ubiquitous nature of the Internet demands that effective systems be developed for this environment to maximize societal benefit. This paper makes a small beginning by offering an integrative framework and architecture for Internet-based collaborative systems that allow incremental layering of the complexity inherent in the design of evolutionary systems.

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