Desiderata for an Every Citizen Interface to the National Information Infrastructure: Challenges for NLP

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Abstract

In this paper, I provide desiderata for an interface that would enable ordinary people to properly access the capabilities of the NII. I identify some of the technologies that will be needed to achieve these desiderata, and discuss current and future research directions that could lead to the development of such technologies. In particular, I focus on the ways in which theory and techniques from natural language processing could contribute to future interfaces to the NII.

Introduction

The evolving national information infrastructure (NII) has made available a vast array of on-line services and networked information resources in a variety of forms (text, speech, graphics, images, video). At the same time, advances in computing and telecommunications technology have made it possible for an increasing number of households to own (or lease or use) powerful personal computers that are connected to this resource. Accompanying this progress is the expectation that people will be able to more effectively solve problems because of this vast information resource. Unfortunately, development of interfaces that help users identify the information that is relevant to their current needs and present this information in ways that are most appropriate given the information content and the needs of particular users lags far behind development of the infrastructure for storing, transferring, and displaying information. As Grosz and Davis (1994) put it, "The good news is that all of the world's electronic libraries are now at your disposal; the bad news is that you're on your own–there's no one at the information desk." In this paper, I provide desiderata for an interface that would enable ordinary people to properly access the capabilities of the NII. I identify some of the technologies that will be needed to achieve these desiderata, and discuss current and future research directions that could lead to the development of such technologies. In particular, I focus on ideas related to agents and system intelligence and the role that theory and techniques from natural language processing could play in the realization of future interfaces to the NII.

Desiderata for an Every Citizen Interface to the NII

As I envision it, an every citizen interface would consist of intelligent information agents (IIAs) that can:

- work with users to determine their information needs;
- navigate the NII to identify and locate appropriate data sources from which to extract relevant information;
- present information in ways that are most appropriate to the type of information being conveyed, as well as the user's goals, time constraints, and current context (i.e., what other information resources are they currently accessing);
- adapt to changes in users' needs and abilities as well as changes in information resources.

Intelligent Interactive Query Specification

Database query languages allow users to form complex queries that request information involving data entities and relations among them. Using a database system, users can typically find the information they require or determine that the database does not contain such information. However, to use a database system, users must know which data resource(s) to access and be able to specify a query in the appropriate language. That is, the user must essentially form a plan to identify and access the information they require to achieve their information-seeking goal. In contrast, keyword-based search engines for the WWW allow users to search many information resources at once by specifying their queries using combinations of keywords (and indications of whether or not the keywords are required to occur in the document, whether they must occur in sequence, etc.). Such search engines do not require the user to form a detailed plan, but they often turn up many irrelevant documents and users typically do not know what data resources have been examined. Moreover, keyword-based search engines provide users with a very crude language for expressing their information-seeking goals.

To provide the kind of interface I envision, IIAs must be able to work with users to help them express their information-seeking goals in terms that the system understands and can act on. The IIA should then form a plan to find information that may help the user achieve those goals. That is, we would like to provide technology that would allow users to tell the system what information-related tasks they wish to perform, not exactly what information they need, and where and how to find it. For example, as an associate editor for a journal, I often need to find reviewers for papers on topics outside my area of expertise. I know that information is out there in the NII that could help me identify appropriate reviewers, but finding it is a difficult task. What I'd like is an IIA that could accept a goal such as "Find me highly-qualified, reliable reviewers for a paper on parsing using information compression and word alignment techniques." And perhaps a preference on the ranking of solutions such as: "And disprefer reviewers that have recently written a review for me." An interactive agent that did not know how to determine whether a researcher is "highly qualified" could engage in a dialogue with its user to determine how to assess this. For example, the user may tell the agent to assess this by counting articles in well-respected journals, or by counting citations in the citation index. Again, if the agent did not know how to determine what the user considered well-respected journals for this particular situation, it would work with the user to define this term, and so on.

As a more "every citizen" example, imagine a patient who has just been prescribed a drug and then catches the tail end of a news story suggesting that several people have become critically ill after taking the drug. This user would likely have a goal such as: "Tell me about side effects of Wonderdrug" and "Show me the serious side effects first." If no information on "serious side effects" were found, the agent should work with the user to define this term more precisely. For example, the agent could provide the user with a list of the types of side effects it encountered and ask the user which type(s) she considers serious.

Planning for Information Access

Once the agent has worked with the user to identify her goals, it must be able to form a plan to acquire the information that will aid the user in achieving those goals. IIAs must be equipped with strategies that tell them how to form such plans, and must also be able to trade off the urgency of the request against the cost of accessing different information sources and the likelihood that a particular plan will be successful. In the journal editor example, the agent may need to be capable of determining which information sources would be most likely to help find an appropriate reviewer before the end of the day. In the drug example, the agent may need to take into account the cost of accessing databases put out by pharamaceutical companies. Agents must also reason about how much advance planning to do before beginning to act, and how much information they should acquire before planning or acting in order to reduce uncertainty.

Making progress on these issues will require integrating several ideas coming out of the planning community, including: planning under uncertainty e.g. (Kushmerick, Hanks, & Weld 1995), reasoning about the tradeoff between reactive and deliberative behavior e.g., (Bratman, Israel, & Pollack 1988; Boddy & Dean 1994), planning for contingencies e.g., (Pryor & Collins 1996), and techniques that integrate planning, information gathering, execution, and plan revision (Draper, Hanks, & Weld 1994; Zilberstein & Russell 1993).

However, building agents that can form plans to find information will require that the agents have a model of the content of information resources. This poses several challenges to the natural language community. To form information access plans, agents must be able to efficiently and effectively assess the relevance of information resources to a given situation. This is just a case of the information retrieval (IR) problem, which is to maximize both *precision* (the proportion of retrieved documents that are relevant to a given query) and *recall* (the proportion of relevant documents that are found). The challenge is to represent the content of information resources so that the relevance decision may be made efficiently, without degradation in precision or recall. In IR systems, documents are typically represented as a collection of *index terms*, single words or (less typically) phrases that are either created by humans when the documents are put into the information base or produced automatically by systems for extracting such terms. Clearly, the sheer volume of information in the NII and the rapid rate at which it changes will require indexing to be done automatically.

Indeed, a simple form of automatic indexing is already being used to support Letizia (Lieberman 1995), an agent that recommends web pages as a user is browsing the web. Letizia uses a well-known keyword frequency measure that is based on the assumption that keywords that are relatively common in the document, but relatively rare in general, are good indicators of the content of the document (Salton 1989). As Lieberman (1996) points out, this heuristic is not very reliable, but it is easy to compute and "serves as a placeholder for more sophisticated techniques." These more sophisticated approaches will require identifying more structure in the text than keyword-based approaches can extract. Ideally, the extracted structure should encode linguistic or (even better) conceptual relations among terms or the concepts the terms represent. As in IR, automatic techniques for finding relevant information in the WWW must be able to process large amounts of unrestricted text (and eventually other media), but complete understanding of the documents is not necessary, so shallow or partial parsing techniques may suffice. Promising techniques are already emerging. For example, researchers have developed robust and efficient schemes for extracting and analyzing noun phrases from unrestricted text, e.g., (Evans & Zhai 1996). Other research focuses on inducing conceptual definitions, which describe the local syntactic and semantic context in which relevant concepts are likely to be found (Soderland *et al.* 1995).

To meet the challenges of the NII, new types of automatic indexing schemes will need to be devised. A major challenge for representing the contents of documents in terms of underlying concepts (as opposed to terms) is co-reference resolution, that is knowing when different descriptions refer to the same underlying concept. The most important entities in a document may be mentioned many times, using many different noun phrases and including anaphoric references. Considerable research in NLP has been focused on this problem, e.g, (Fox 1987; Grosz, Joshi, & Weinstein 1995; Hobbs 1979; Passonneau 1995; Sidner 1979), and projects that attempt to apply the theoretical results to WWW applications are needed. Research suggests that co-reference resolution is intimately related to discourse structure (Grosz & Sidner 1986; Passonneau 1997) and therefore techniques for automatically segmenting discourse will aid further progress on this problem (Passonneau & Litman to appear).

Another issue relates to the fact that documents often cover several major topics, and only parts of a lengthy document may be relevant in any particular situation. Techniques that automatically subdivide texts into topical units that are semantically meaningful units are therefore necessary, and there is already promising work in this area, e.g., (Hearst 1994; Morris & Hirst 1991).

In addition, to aid information seeking agents, data may need to be indexed in multiple ways, e.g., reflecting different purposes the data may serve or different levels of detail. In the WWW, links going into and out of a document characterize that document, and may be useful in forming indexes to it (as is done in citation search systems). Finally, automatic indexing schemes that work across modalities are needed.

Intelligent Multimedia Presentation of Information

IIAs will be able to acquire information from many different information sources in a variety of media. These systems will need to be able to plan multimedia presentations that most effectively communicate this information in ways that support users in achieving their goals and performing their tasks. For example, an IIA helping a visitor to the Washington DC area identify good Thai restaurants may provide a Consumer-reports like chart rating the 10 best restaurants on a variety of features, a city map showing where the restaurants are located relative to the user's hotel, and spoken excerpts from restaurant reviews that are coordinated with highlighting of the row in the chart and dots on the map that correspond to the restaurants being described. We would also like such multimedia presentations to be tailored to the user's background and preferences, the task at hand, and prior information displays the user has viewed. In the restaurant example, if the system can determine that the user is not familiar with the DC area, specific directions to the various restaurants may be given, whereas for a DC native an address may be sufficient. If the user has previously requested detailed directions to one restaurant, and then requests directions to another restaurant nearby, the system may describe the location of the second restaurant relative to the location of the first.

Due to the vast information resources that are now available, improved networking infra-structure for high-speed information transfer, and higher quality audio, video and graphics display capabilities, intelligent multimedia presentation is an active area of research. As Roth and Hefley define them, intelligent multimedia presentation systems (IMMPS) take as input a collection of information to be communicated and a set of communicative goals (i.e., purposes for communicating information or the tasks to be performed by the user requesting the information). An IMMPS typically has a knowledge base of communicative strategies that enable it to design a presentation that expresses the information using a combination of the available media and presentation techniques in a way that achieves the communicative purposes and supports users in performing their tasks. They argue that IMMPSs will be most effective in situations where it is not possible for system developers to design presentation software because they cannot anticipate all possible combinations of information that will be requested for display. This is clearly the case for an every citizen interface to the NII.

Until recently, work on automatic graphics design has emphasized the need to model the perceptual and logical tasks that users need to perform to understand a graphic, and they have built computational systems that design presentations to support a given set of tasks (Beshers & Feiner 1993; Casner 1991). However, several researchers have demonstrated that promising approaches to automatic design of multimedia presentations can be developed by applying or extending theories and techniques that have proven useful for natural language processing. For example, researchers have successfully operationalized Grice's (1975) notion of conversational implicature to build systems that avoid false implicatures in both text and graphics (Marks & Reiter 1990; Oberlander to appear). In other work, Andre and Rist (1994) have generalized the linguistic notion of a referring expression to multimedia references.

Fully operational IMMPSs must perform several complex tasks. They typically consist of a presentation planner, a number of media generators, and a media coordinator. The presentation planner uses presentation design knowledge to select content to be included in a display intended to achieve a set of goals for a particular user in a given context. It uses its knowledge of techniques available to the various media generators to apportion content to media and generate a sequence of directives for individual media generators. Media generators (e.g., for natural language text, speech, and graphics) must determine how to convey the content given the directives they receive from the planner, and report back their results to the presentation planner and media coordinator. The coordinator must manage interactions among individual media generators, and resolving conflicts and maintaining presentation consistency.

Considerable progress has been made toward systems that perform these tasks for limited domains, user tasks, data and presentation types. For example, extant prototype systems can coordinate text and graphical depictions of devices for generating instructions about their repair or proper use, e.g., Comet (Feiner & McKeown 1991) and WIP (Wahlster *et al.* 1993). These systems generate multimedia presentations from a representation of intended presentation content, and represent progress towards some of the functionality we would like in an every citizen interface. For example, these systems can effectively coordinate media when generating references to objects (e.g., "the highlighted knob") (McKeown *et al.* 1992), and can tailor their presentations to the target audience and situation, e.g., (McKeown 1993; Wahlster *et al.* 1993). In addition, WIP generates its presentation in an incremental fashion. This allows WIP to begin producing the presentation before all of the input is received, and to react more promptly if the goals or inputs to the generator are changed. These are important features for an IMMPS that will be used in an interface that is presenting information from the NII. Another important area of recent research is in coordinating *temporal media*, e.g., speech and animation, where information is presented over time and may need to be synchronized with other portions of the presentation in other media, see e.g., (Dalal *et al.* 1996; Feiner *et al.* 1993; André & Rist 1996).

Ideally, we would like an IMMPS to have the capability to flexibly construct presentations that honor constraints imposed by media techniques, and that are sensitive not only to characteristics of the information being presented, but also to user preferences and goals, and the context created by prior presentations. Researchers working in text generation have developed systems capable of using information in a discourse history to point out similarities and differences between material currently being described and material presented in earlier explanation(s), omit previously explained material, explicitly mark repeated material to distinguish it from new material (e.g., "As I said before, ..."), and use alternative strategies to elaborate or clarify previously explained material (Carenini & Moore 1993; Moore 1995; Moore, Lemaire, & Rosenblum 1996).

This prior research requires rich representations of the information that is presented, as well as models of the users goals, tasks and preferences. Extending this work for an interface to the NII will require research on standardized data modeling languages and/or translation kits, and reusable models of common tasks. Researchers working on the knowledge-based approach to machine translation are developing large reusable ontologies that are both language and domain independent, e.g., (Mahesh & Nirenburg 1995; 1996), and efforts to construct such resources semi-automatically are underway (Knight & 1994 1994). We must explore the usefulness of these ontologies in systems the automatically generate multimedia presentations. Initial work is promising. We are currently designing a system that integrates the notion of communicative planning with task based graphics design (Kerpedjiev *et al.* 1997). We have developed a stratified archictecture and are attempting to define a domain and media independent language for specifying presentations in order to make it easier to develop IMMPS for new application domains. This work makes use the work on reusable ontologies. Approaches aimed at developing IMMPSs capable of operating with shallower representations should also be explored.

Finally, we cannot expect and may not even want IMMPSs to be monolithic systems that completely design presentations according to their own criteria. Thus, we must devise systems that can provide many levels of assistance to users in the presentation design process. We cannot expect users to fully specify presentation design choices; it is more natural for them to learn a language for expressing their tasks and goals than it is for them to learn a language for describing presentation techniques. In some cases, users will have preferences about presentation design in advance of display generation. In other cases, they will want the ability to alter the way information is presented once they have seen an initial presentation. Research is needed to develop natural, flexible interfaces to support interactive design, such as those described in (Roth *et al.* 1994; 1995).

User Interface Environments for Information Exploration

Even if we can provide IIAs that accept the type of queries I envision, users will want the capability to browse or explore the NII. This may be because they could not articulate a query (even interactively) until they saw some of what was available, or because the information they received led them to want further information. In addition, users may want to see some of the information in more detail or see it presented in a different manner. For example, a user who is relocating to a new area may have requested a visualization that shows several attributes of a set of available houses and relationships between them, e.g., the number of rooms, the lot size, the neighborhood, and the asking price. Once this display is presented, the user may then want to select some subset of the particular houses contained in the original display, pick up this set and drag-and-drop it on a map tool to see more precisely where the houses in the set are located.

To provide these kinds of capabilities, we will need to develop software environments for exploring and visualizing large amounts of diverse information. As Lucas et al. (1996) argue, this requires moving from an *application-centric* architecture to an *information-centric* approach. The distinction hinges on differences in the basic currency through which users interact with the system. In application-centric architectures, the basic currency is the file and users must rely on applications to fetch and display the information from files. Each application has its own user interface which defines the types of files people can manipulate and what they can do with them. With the introduction of graphical user interfaces and the desktop metaphor, files became concrete visual objects, directly manipulable by the user, storable on the desktop or in folders, and, to a limited extent, arrangable by users and software in semantically meaningful ways. But the contents of those files was still out of direct reach of the user.

In their Visage system, Lucas et al. (1996) take an information-centric approach in which the basic currency is the data element. Rather than limiting the user to files (or documents) as targets of direct manipulation, Visage permits direct drag-and-drop manipulation of data at any level of granularity. A numeric entry in a table, selected bars from a bar chart, and a complex presentation graphic are all first-class candidates for user manipulations, and all follow the same "physics" of the interface. Users can merge individual data items into aggregates and summarize their attributes, or break down aggregated data along different dimensions to create a larger number of smaller aggregates. These capabilities form the foundation for a powerful interface for data navigation and visualization.

A challenge for NLP researchers is to provide tools that can be used in an environment such as Visage. For example, we could imagine a tool that extracted data from a textual description in a document and encoded the data in the format required by Visage. We could also imagine explanation tools, in which a user would select a chart, or a region of a chart, and drop the selected item on an "Explain" tool that would then produce a natural language description of the chart. Some initial steps in this direction have been made. We (Mittal *et al.* 1995) have recently built a system that can automatically generate "explanatory captions" for information graphics which have been generated by the Sage system either completely automatically (Roth & Mattis 1990; 1991) or interactively with the user (Roth *et al.* 1994).

Adaptive Interfaces

Although the Visage approach has proven successful for the simple graphics implemented in the Visage prototype (i.e., text in tables, bars in charts, and symbols in maps), continued research is needed to handle the wide range of data and presentation types that populate the NII. In particular, new approaches that allow richer analysis of the information contained in hypertext documents are needed. One area that is developing technology relevant to this need is research on adaptive hypertext and hypermedia systems, which exploit information about a particular user (typically represented in the user model) to adapt both the hypermedia displays and the links presented to the user (Brusilovsky 1996). Adaptive hypermedia is useful in situations where the hyperspace is large or the system is expected to be used by people with different knowledge and goals. This is clearly the case for the NII.

Researchers in text generation, e.g., (Moore & Mittal 1996), are working on interfaces in which system-generated texts are structured objects. During the generation process, the system applies abstract rules to determine which text objects should be selectable in the final presentation, i.e., which text objects will have "hyperlinks" associated with them. To pose questions, the user moves the mouse over the generated text, and those portions that can be asked about become highlighted. When the user selects a text object, a menu of questions that may be asked about this text appears. Question menus are generated on the fly using a set of rules that reason about the underlying concepts and relations mentioned in the selected text (as represented in a knowledge base). Because the system has a record of the plan that produced the text, as well as a user model, the system can reason about the context in which the selected text occurs, and provide a menu of follow up questions that are sensitive to both the discourse context and the individual user. In this system, texts are synthesized from underlying knowledge sources by the system in response to the user's question or the system's need to communicate with the user. Because the text is generated dynamically, the system cannot in advance identify the particular text objects that should have associated links, nor the links to other texts. Indeed, in this framework, traversing a link corresponds to asking the system to generate another text. Moreover, the follow-up questions, which correspond to the links in traditional hypertext systems, cannot be pre-coded and fixed in advance, but are generated dynamically using heuristics that are sensitive to domain knowledge, the user model, and the discourse context. A more detailed description of the implementation of this technique and examples from two prototypes systems are given in (Moore & Swartout 1990; Moore & Mittal 1996).

As with many other AI approaches, this technology depends on the system having a rich underlying representation of the domain content described in the generated text, as well as a model of the textual structure. But we can easily imagine adapting this technology for use with the NII. As noted above, techniques for automatically generating indexes from unrestricted text for information retrieval exist, so we can expect that such indexes will (or could) be available for many, if not all, documents on the NII. In addition, parsers and part-of-speech taggers can robustly identify the constituents of sentences, e.g., (Brill 1993). Building on these existing technologies would allow an interface in which, say, all noun phrases in a document become mouse-sensitive, and the hyperlinks to other documents are determined on demand by using the noun-phrase (synonyms, etc) as an index to find related documents. Techniques developed in the area of adaptive hypermedia may also be employed to allow the selection of links to be sensitive to the user's knowledge and goals.

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