

"Humane" Interfaces to Improve the Usability of Data Clearinghouses

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Abstract. Web-based metadata clearinghouses and catalogs are intended to help users locate and access geospatial data that may be spread across many physical locations. Their specialized thesauri and query interfaces can be a significant help to users who are already familiar with the subject area and know specifically what they are seeking. At the same time, they can be very confusing for users who are unfamiliar with metadata and the FGDC metadata standard. Researchers at Oregon State University are developing a more “humane” approach to metadata searches, one that does not assume users know in advance how to exploit metadata in their quest to find geospatial data. One of their first projects was to review usability aspects of several large clearinghouses. Three well-known usability assessment methods were applied: predictive evaluation, a user expectations survey, and user testing. This paper describes the procedures that were used and presents the findings. It identifies several barriers that must be overcome in order to make geospatial clearinghouses useful to key target audiences.

1 Introduction

The nation’s expanding network infrastructure is now providing the connectivity necessary to support large-scale data access by a wide variety of users, including not just researchers, but also policy-makers, educators, students, and the general public. However, connectivity alone cannot ensure usability (Pittman et al. 1998, Fraser and Gluck 1999). The people who need scientific information must be provided with sufficient information to locate relevant data and evaluate their likely usefulness before initiating time- and disk-consuming download operations (Flewelling and Egenhofer 1999). This is particularly true for repositories as broad and as rich as the National Geospatial Data Clearinghouse (NGDC), which encompasses sources from local, state, and federal governments as well as research institutions and private organizations. As with other point-of-entry systems, the NGDC user interfaces provide the only introduction to these data sources that most users will ever see. It will be from these interfaces that a broad user community shapes its understanding of what geospatial data are available, how they can be obtained, and how they should be interpreted or applied.

Given the importance of the NGDC to national awareness of geospatial information, it is essential that the interfaces reflect high standards of usability.

Because different cognitive processes are involved in conceptualizing geography, the users of geospatial data require new approaches to interface design (Downs and Stea 1977, Kuipers 1978, Moran 1981, Egenhofer 1988, Mark 1992, Montello 1993, Wang 1994, and Egenhofer and Mark 1995). Geospatial data systems are heterogeneous collections of spatial and non-spatial data. Most user-interface design tools, on the other hand, deal with uniform representations (predominantly lexical) and typically have focused on popular design components such as menus, panels, and mouse-based manipulation. Geospatial information is comprised of both lexical and graphical information that are closely interrelated. A successful user interface must be able not just to deal with two information modalities, but to provide mechanisms for integrating them into a coherent whole.

How to do this in a general way remains an open research question that cannot be addressed by a single project. But based on previous experience in usability engineering and interface design, a promising approach is to develop a series of related interfaces targeted at distinct user communities. This multi-level interface approach has been applied successfully to other types of scientific databases, and was found to expand data access to a much broader audience. We also suggest that it will be important to add a much higher degree of interactivity to the interfaces, similar to what Berry (1995) describes in his discussion of "humane GIS", hence the name of our project, the Metadata Humane Society (MHS). Users will need the ability to adjust their searches or requests while they are being carried out; this is particularly important for users who are not themselves specialists in geospatial data, and who could therefore quickly feel out of control in the face of very lengthy or complex retrievals.

By adjusting the nature and structure of the interfaces to the different user groups, we believe that it will be possible to make the NGDC responsive to a broader spectrum of user needs. To this end, researchers at Oregon State University affiliated with the Northwest Alliance for Computational Science and Engineering (NACSE) and the Department of Geosciences were contracted by the Federal Geographic Data Committee (FGDC) to assess the effectiveness of the NGDC's user interfaces for geographic data access and discovery, from the perspective of several target user communities.

2 Characterization of Target Audiences

The potential users of geospatial information typically have been characterized as falling into the following groups: geographers, cartographers, public utilities agencies, governmental and agencies involved with natural resource management, non-governmental organizations engaged in tracking biological populations or natural resource issues, ecologically oriented scientists, national defense agencies, and policy makers. We propose that science educators and students are also important potential users, and that the general public is likely to be increasingly interested in geospatial information.

Not all of these audiences are of equal importance in the design of the NGDC interfaces. The MHS project identified and prioritized the target user constituencies who use the Clearinghouse interface for geospatial resource discovery and access,

characterized the primary targets, and demonstrated how representatives from those groups could be incorporated into user testing activities.

Historically, the top priority for NGDC interfaces has been GIS specialists and government agencies. Scientific researchers, educators, and students have constituted a second-level priority. Business and industry, the general public, commercial data providers, and non-commercial data providers were grouped as a third. Although these priorities represent historical trends in the usage of the NGDC Clearinghouse, they may not reflect the audiences that should actually be supported by the FGDC. One could argue that because the clearinghouse provides a key public information resource, the general public may in fact be the FGDC's most important clientele.

For the purposes of this paper – and the user testing included in the project – we grouped the constituencies in the first and second tier into four target audiences:

- GIS specialists
- Members of government agencies
- Scientific researchers
- Educators and students

2.1 Characteristics of Primary Audiences: Expertise

Each of the four target audiences encompassed a range of individuals with varying levels of expertise. For the purposes of the NGDC interface, users are likely to differ in terms of six dimensions of background skills: web familiarity, catalog familiarity, map familiarity, metadata familiarity, domain familiarity, and GIS familiarity. Metadata familiarity refers to the degree to which users understand the purpose of metadata, its relationship to data, and standard formats for metadata. Domain familiarity is the degree of knowledge users possess within a disciplinary domain, such as ecology or geology. While it is possible to have various mixes of exposure and experience in all these dimensions, they are not completely independent. It is unlikely, for example, that someone with good GIS familiarity would not also be highly familiar with maps.

In terms of potential NGDC users, we assumed as a baseline that they would be comfortable with the Web in general and at least one Web browser in particular. We also expected at least some understanding of what catalogs and gateways do, since search engines are a common experience of most Web users. Most would also possess a reasonable level of skill with basic map navigation, including zooming, panning, and use of rubber-banding to select map regions, since these are also common features of many Web sites.

The ranges of expertise that we thought likely to occur in each of the target audiences, in terms of which are particularly likely to indicate the degree of success a user will have in approaching the site were summarized as follows:

1. GIS specialists are most likely to differ in terms of familiarity with the FGDC standard. While some will be comfortable with it, others will be accustomed to different standards, and a smaller proportion will be unfamiliar with any metadata standards at all.
2. In addition to individuals who are GIS specialists, many members of government agencies will be uncomfortable with the general concept of metadata. Some will

- also be unfamiliar with the concept of clearinghouses, but it is assumed that all are aware of portals/gateways. Those who are familiar with metadata standards may have no direct experience using the FGDC (or perhaps any) standard.
3. Some scientific researchers may have knowledge of metadata and perhaps even clearinghouses, but the majority of these users will be unfamiliar with even their basic concepts. Further, some will be unfamiliar with the notion of gateways.
 4. Although many educators and students will be comfortable with the use of gateways, it is unlikely that many will have significant understanding of how research data is organized and managed. Also, they will be unfamiliar with the metadata and metadata standards used in describing research data.

2.2 Characteristics of Primary Targets: User Goals

Each user will approach the NGDC site with particular goals in mind. The ease with which those goals can be met will largely determine the user's overall satisfaction with the NGDC interfaces. While the following descriptions are not exhaustive, they prove a representative sampling of the types of goals likely to be important to each target audience.

GIS specialists are most likely to be seeking data corresponding to some particular need (theme, location, time period). At times, however, the most important consideration is to locate data conforming to a particular format or projection, that are suitable for a particular software package, or that contain information/code that might be useful in performing some ancillary function. Different groups of users will be familiar with different sets of terminology, so synonym support will be important.

Government agency employees might share those goals, but also have some that are directly related to the role of their agencies.

Scientific researchers typically seek data that will complement their own research data, that can help to validate their models or hypotheses, or that indicate the usefulness of some method for analysis, interpolation, measurement, etc. They may also be conducting a more general search to learn what kinds of information are available via the Web, and where.

Educators and students (here we focused on undergraduate and graduate use, rather than lower levels) are likely to be most interested in identifying sites whose research data is appropriate for use in coursework or student research projects. In some cases, the object may be simply to identify if such sites exist, rather than to actually access the data. Some of the questions will be similar to those delineated for researchers.

Finally, for all types of users there will be the need to re-find data or metadata that were located during some previous session.

These example goals were used in structuring the user tasks for the testing activities conducted as part of this project. They also served as the basis for application of the cognitive walkthrough method for usability evaluation, which was applied at multiple points as revised interfaces were designed and tested.

3 Identification of Barriers to Usability

Three types of usability evaluations were performed:

1. Initial *predictive evaluation* of existing sites: The usability engineering team identified those classes of usability problems that are known to be singled out most effectively by usability specialists.
2. *User testing* of existing NGDC interface: Through verbal protocol exercises, users identified specific usage problems.
3. *User expectations survey*: An electronic survey instrument was distributed to potential users to identify their expectations.

3.1 Initial Predictive Evaluation of Existing Sites

An evaluation procedure was used to arrive at an understanding of the current state of usability among typical Web sites devoted to access of GIS metadata, to establish what the primary barriers to usability are, and to identify any existing approaches that seem promising for improving the usability of the NGDC. Project researchers evaluated the interfaces that had been identified as target sites for this project. In doing so, they assumed various “user roles” and carried out pre-defined tasks associated with each role.

Metadata familiarity can be further broken down into: (1) an understanding of what metadata is and how it relates to data, what metadata standards are and how they are used, and how metadata clearinghouses can be used (e.g., Wright et al., 2000); (2) the user's familiarity with metadata standards in general, such as the FGDC standard. This will have impact on how efficiently and effectively user interactions with the NGDC site are.

Each team member took one or more of the following target user roles in performing the evaluations:

- GIS specialist familiar with the FGDC standard
- GIS specialist familiar with the standards, but not FGDC
- Agency staff experienced with another standard
- Agency staff unfamiliar with the clearinghouse concept
- Agency staff unfamiliar with metadata standards
- Scientific researchers unfamiliar with metadata
- Scientific researchers unfamiliar with the gateway concept

The results of the individual evaluations were combined and analyzed collectively in order to determine the strengths, weaknesses, trends, and recommendations discussed in this paper.

3.1.1 Criteria Used in Evaluations

Several traditional measures of usability were evaluated in the context of a particular role at a particular site:

- **Explicitness** is the degree to which it is clear how the site should be used.
- **Compatibility** offers a measure of the degree to which operations fit in with expectations based on the user's real-world experiences.

- The **effectiveness** of an interface demonstrates the extent to which the user's task can be achieved.
- The site's **efficiency** is the amount of time and/or effort to achieve the user's goal or task.
- **Consistency** measures the degree to which similar tasks are performed in similar ways.
- The site's **learnability** refers to the capability of an interface to help a novice user learn about its features and usage.
- **Feedback** is the criteria that measures the degree to which user actions are acknowledged with some meaningful response.
- **Error prevention** measures the degree to which possibilities for error are minimized.
- **Error recovery** measures the degree to which a user can recover quickly and easily from errors.
- The **legibility** of an interface is the ease with which text and other elements can be discerned and comprehended.
- The **visual clarity** criteria rates the degree to which information is organized so that the user knows quickly, and without confusion, how he/she should use it.
- **Prioritization** is the degree to which the most important functionality and information are also the ones most easily accessible to users.

3.1.2 Individual Site Evaluations

The search interfaces of the target sites were tested by a total of five project researchers. Two browsers (Netscape, Internet Explorer) were used on a total of five operating systems (MS Windows/98, MS Windows/95, MS Windows/NT, Solaris, IRIX), and several machine/monitor combinations. All trials were conducted using direct network connections to the Internet, with good connectivity, so reports on efficiency indicate the best that a user might expect to see.

3.1.3 Findings

In general, visual clarity characteristics tended to be rated highest for the sites evaluated. That is, information was typically displayed in a manner that made it quick for the user to understand how to proceed. Many sites also were helpful in visually attracting the user's attention directly to the fields that were needed in order to get results.

The team found that efficiency was not a problem in most cases. The exception to this was in cases where there was little or no feedback indicating that work was being performed. Users tend to tolerate a waiting period better when they are being informed

that progress is happening towards their desired goals. When no feedback is forthcoming, they lose confidence, often suspecting that the server has gone off-line, that the browser has stalled, etc. It should be noted that we used high-speed network connections in performing the tests; it is to be expected that many users would experience significantly slower access times than we did. In cases where we explicitly called out problems with efficiency, we had trouble with the browser reaching its time-out limit before the server responded, even with a fast network connection.

Overall, we found that the most consistent problem areas were feedback, error recovery, and error prevention, and to a somewhat lesser extent, prioritization. In the area of feedback, as noted above, when the user's actions are not acknowledged with a reasonable response period, he/she becomes impatient or concerned. Therefore, proper feedback is critical for any operation, which is liable to require more than about 10-20 seconds to complete. Feedback, however, was neglected entirely at many of the sites evaluated.

Both error recovery and error prevention are important helping the user apply his/her time effectively. Failure to prevent errors – and to provide simple mechanisms for undoing the effects of errors – not only slows down the user's progress, but quickly becomes frustrating. For example, if the user can recover quickly from an improper choice of keywords (or if that error can be prevented entirely), he/she can readily move forward to accomplish the intended actions.

In the area of prioritization, it is critical that the most important functionality and associated information be available to the user in a straightforward manner, since users typically respond to what has been presented, rather than searching through a site to determine if other functions are available. Very few of the sites appear to recognize this concept and present the most commonly needed and most useful functions early in the screen traversal process. A significant number of the sites require that the user perform several actions in order to arrive at the screen that offers key functionality.

3.1.4 Recommendations

This section summarizes our recommendations for the NGDC interfaces, based on the approaches, features, and barriers we identified during the predictive evaluations. The evaluation team met as a group to discuss not just the ratings, but also their recommendations for which existing interfaces offered the best foundation for the NGDC. By consensus, the following sites were identified as the “top contenders”. (Note that the sites may have been altered since the studies were carried out.)

- CEONet (<http://ceonet.ccrs.nrcan.gc.ca/cs/en/index.html>): The prime discovery and access component of Canada's national spatial data infrastructure initiative.
- SEDAC (<http://sedac.ciesin.org>): The Socioeconomic Data and Applications Center is one of the Distributed Active Archive Centers in NASA's Earth Observing System Data and Information System (EOSDIS).

- MEL (http://mel.dmso.mil/mel-bin/java_query): The Master Environmental Library is a one-stop site for ordering environmental information sponsored by the Defense Modeling and Simulation Office.
- ASDD (http://www.auslig.gov.au/servlet/asdd_power): The Australian Spatial Data Directory is the component of the Australian Spatial Data Infrastructure that provides search interfaces to geospatial dataset descriptions (metadata).
- DAACGD (<http://www-eosdis.ornl.gov>): The Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center for Biogeochemical Dynamics is operated by the ORNL Environmental Sciences Division.

Number and type of interfaces needed: Given that different levels of user expertise require distinct subsets of the usability criteria, we recommend that there be at least two interfaces available for the NGDC, addressing different target audiences: (1) users unfamiliar with GIS and spatially-based searches; and (2) users already comfortable with searches based on location and geographically-related keywords

We do not think it will be necessary to add additional interfaces to reflect users' familiarity with clearinghouses. In fact, our testing experiences indicate that it will be important to draw clear distinctions between *data* and *metadata* for all levels of users, in order to avoid unpleasant surprises. Similarly, we believe that the availability of higher-level summary metadata will be key for all users, even those familiar with the FGDC standard. Therefore we do not recommend separate interfaces based on users' familiarity with the standard.

Key characteristics for NGDC interfaces: While the relative priorities of features or user support vary from one user class to another, there are certain criteria will be essential for all interfaces and all users. Explicitness, effectiveness, and feedback fall into this category. Assuming that there are two interfaces, as outlined above, we further note that non-geospatial users will also require particular support for learnability, error prevention, and prioritization of functionality. The interface for more advanced users should focus instead on efficiency and error recovery as secondary goals.

3.2 User Expectations Survey

A user expectations survey was implemented in order to understand what potential users expect to be able to accomplish using the NGDC interfaces, and to identify the models and task structures they are likely to bear. The survey was distributed at the 2000 Summer Assembly of the University Consortium for Geographic Information Science (UCGIS). Fourteen UCGIS participants responded. Given the fact that over 100 people were registered and received the questionnaire, this response was very disappointing. Questions to a few individuals indicated that they were not responding because they did not know why they would want to use a clearinghouse; it is not known whether this was a general attitude among the non-respondents.

3.2.1 Findings

A sub-population analysis, which identifies sub-populations of respondents and seeks trends in those results, was performed. This portion of the analysis grouped respondents into two subpopulations, based on whether or not they have visited the NGDC clearinghouse site. Due to the small number of responses, we did not break out individuals who had visited other sites versus those with no experience.

Respondents unfamiliar with the NGDC site indicated that they would likely search on the basis of all three criteria (place, time, and keyword). Those familiar with the site, on the other hand, were more likely to search on the basis of just one criterion, typically keyword. This may reflect what kinds of searches they found effective in the past when using the site.

Across the board, users from both subpopulations indicated that they were more likely to search on the basis of a region at the county level or more specific, rather than a country, state, or other broad geographic area. The most common response, from both subpopulations, was that the target would be selected by rubber-banding an area on a map. Typing in a place name was the second choice; again, this was fairly consistent across subpopulations. It is interesting to note that specification via latitude/longitude was indicated as an important mechanism by every respondent in the second subpopulation, but that only a third of the NGDC-familiar users thought they would specify geographic targets in this way.

Persons unfamiliar with the NGDC site indicated that they would most likely be searching for data from a "recent" time period (i.e., from some past date up to the present time). Those experienced with the NGDC site indicated that the ability to specify a particular time or to request data from recurring time periods would be equally important.

Respondents from both subpopulations agreed that complete metadata was not as important as the ability to see a list of data sites, ranked by the amount of data present, and a summary of key metadata fields. The list was ranked as most important by users familiar with the NGDC site, while unfamiliar users indicated summaries of metadata fields as their first choice. Members of both subpopulations thought it was more important to see summaries of metadata fields and ranked lists of datasets than complete sets of metadata. Thumbnail sketches of the data were ranked slightly higher by the NGDC-familiar users, perhaps because other users have not seen these and are uncertain of their purpose/value.

NGDC-familiar respondents were clear that they access the clearinghouse primarily when they need to locate new data sites, whereas users without NGDC experience thought they would visit it whenever they wanted new data. This may reflect the fact that NGDC clearinghouse searches are currently much slower than node-based searches – something that unfamiliar users would not know. The NGDC-familiar users added comments like “less and less often does it take me to the data I need” and “only when all my other sources fail.”

Users ranked the importance of efficiency, completeness, feedback (“informative messages that tell you what to try if something goes wrong”), performance (“speed of metadata retrieval”), and comprehensiveness (“how many GIS data sites are covered by the clearinghouse”).

Respondents familiar with the NGDC clearinghouse tended to rank comprehensiveness and search-specification efficiency as the most important, with metadata completeness and feedback as least important. The inexperienced users, on the

other hand, often cited metadata completeness as tops, followed by search-specification efficiency, perhaps because they are not really aware of what NGDC metadata includes.

3.3 User Testing of Existing NGDC Interface

User testing of the existing NGDC interface was carried out to arrive at an understanding of how users access and apply the existing NGDC interfaces and to identify specific usage problems that should be addressed during interface improvement. All tests were in the form of head-on comparisons of two sites, and performed by undergraduate and graduate students in an upper division, introductory GIS class at Oregon State. Thus, the subjects can be characterized as those already familiar with GIS principles and techniques, and with the FGDC standard for metadata. Students were assigned to particular pairs of sites to ensure full coverage. A total of 26 tests were performed, covering 5 of the sites that previous evaluations had identified as “top contenders” as design sources (for purposes of task performance comparison, we only considered sites that included the West Coast of the US).

Each student was assigned a series of tasks related to retrieving information associated with a target location. The targets were defined to be a small city in California, Oregon, or Washington, to minimize the effects of subjects' lack of familiarity with the basis for the search.

Subjects attempted to retrieve information on the basis of place name, mapping regions, and subject keywords. Each student repeated the same steps for both Web sites assigned to him/her. If the search was successful, the student was asked to describe the kinds of information retrieved. If unsuccessful, the reason was recorded. Subjects were also asked to indicate what kind of metadata had been retrieved and how readable it was, the ease with which they were able to learn and use the site, and their impressions on site performance.

After repeating the procedure with the second site, subjects were asked to indicate which of the two sites they preferred, and why.

3.3.1 Findings: User Preferences

Given the critical nature of some of the comments, and the fact that the sites may have altered considerably since our tests were performed, they are referred to here as “Site A,” “Site B,” etc. (The assignment of the letters reflects the order in which comments are made here, and should not be interpreted as corresponding to the list ordering in the last section.) In fact, the nature of the criticisms are more revealing about usability barriers than the specific sites which occasioned the comments.

Site A was the resounding favorite. This site was always preferred over the other, in each head-on comparison where it was included. It received high marks for both usability and metadata readability. Subjects' searches were almost always successful and search results were found to be richer in content than the other sites.

In contrast, Site B did very poorly in the overall rankings. Only once was it preferred over any other site; in that case, it was preferred over Site C because it was considered faster and easier to use. The poor overall rating was associated with complaints about the

site not working properly, the site being down, and searches not working. For those few searches that did work, subjects thought the Site B metadata was readable.

Site D was another poorly rated site. Again, it was preferred over another site on only one occasion, when it was being compared with Site E . A major factor was probably the fact that only one subject considered himself completely successful with a search. A couple of other subjects complained about the incomprehensibility of the metadata.

Both Site C and Site E received mixed ratings. They were preferred only approximately half of the time. The two sites got mixed reviews on site usability and metadata readability.

3.3.2 Findings: Subjects' Rationale

Subject responses were further analyzed to establish what general patterns determined why a particular site would be chosen over another. In the majority of the tests (approximately 70%), users preferred a site because they found it easier to use. In particular, they seemed pleased if it was easy to select the location they were interested in. Other reasons why a site was preferred were better (typically shorter) procedures for selection, and better (more complete) search results.

In general, subjects found few differences in the readability of metadata from different sites. In one instance, metadata returned by Site E was found to be too obscure to be useful. Overall, search speeds appear not to be an issue, at least in the sense that one site is significantly better or worse than the others.

It should be noted that both the place-name and map searches only worked approximately half the time. This fact definitely influenced what subjects thought about the sites, and is consistent with what we have observed in other types of usability tests. In particular, the place and map searches typically failed on Site C; on the rare occasion when searches did yield results, the user had good things to say about it. In two tests, Site B was down and could not be evaluated.

4 Conclusion

Usability encompasses a variety of factors, including how easy an interface is to learn, how easily it can be remembered by infrequent users, its efficiency in the hands of advanced users, its forgiveness of user errors, and how well it can be applied to new tasks or needs that evolve. These are human factors, requiring that the interface designer understand how the target users think about their tasks and respond to system capabilities. Historically, data access interfaces have been based on what data specialists understand about how the interface will be used. This is a poor foundation for usability, particularly in cases where users are likely to span a number of distinct communities. The interface features that a GIS specialist finds “instinctively right” may be incomprehensible to biological researchers, policy-makers, or students. Moreover, inconsistencies and omissions, which a specialist user automatically compensates for, can lead to confusion and misunderstanding when the interface is by used other audiences. Usability assessment identifies where these barriers occur and how they might be resolved.

Knowing more about the characteristics influencing the usability of geospatial metadata and search interfaces is a critical first step in developing interfaces that improve

the accessibility and usefulness of Web-based clearinghouses. As indicated by our findings, current clearinghouses have a number of characteristics that create barriers to usability for key target audiences. The usability attributes that were identified as most important to target user constituencies can be exploited to develop more “humane” interfaces that can truly will assist users in exploring the availability of geospatial data.

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