A Framework for the Unified Presentation of Environmental Risk Information

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Abstract

As the world struggles with the Kyoto Accord and countries debate its ratification, it is individuals who will be asked to take more responsibility for their actions and the impact of those actions on their environment. In this context, "environmental risk" is used rather broadly to include not only overt risks, but also small and subtle ones encountered in daily life, the severity of which individuals may argue. Although the separate impacts of these everyday risks might be small, taken together they become much more significant. Risk factors include the energy needed to transport food and the environmental impacts of cleaning products.

Consumers and organizations dealing with procurement need to evaluate the environmental risks associated with their choices. This evaluation is presently very difficult since one needs to independently assess and integrate possibly incomplete and conflicting information from a wide variety of sources. This paper describes a solution to this evaluation problem through an open and extensible framework.

The core areas of concern addressed by this framework include the collection and synthesis of disparate data; access to this data; and presentation of the complex and potentially conflicting information. Development of a specialized XML (eXtensible Markup Language), through an open and collaborative process, would address the need for the description of sustainable life-cycle concerns. A web-based interface to this heterogeneous collection of data would provide the most universal access. An existing access technology, called *cogito*, is expected to provide benefits in terms of exploration and evaluation of alternatives. Information visualization techniques will be adapted and developed to allow the user to make sense of this conflicting information. Although the software components of the framework exist, present efforts are focused on the development of the appropriate markup language and the evaluation of how existing environmental risk information is made available to consumers.

1. INTRODUCTION

A recent OECD (Organization for Economic Cooperation and Development) report (OECD, 2002) entitled *Towards Sustainable Household Consumption?: Trends and Policies in OECD Countries* describes the consumers in OECD countries as generally having a high level of activism with respect to green issues, but a relatively low willingness to pay. The report indicates this may be due to a general "fatigue" amongst consumers with respect to green products. There seems to be a decline in trust of nearly all sources of environmental information and an increase in confusion about prioritization of environmental goals and which actions can be most beneficial. Although this is the age of the information superhighway, many consumers find it difficult to access information that will help them to make decisions that consider the environment.

As an example, consumers may fail to consider that a large amount of household GHG emissions are related to direct energy consumption for food preparation, conservation, and transport. Diet choices impact production, processing and distribution patterns. Recent work using Lifecycle Analysis (LCA) provides additional information on the choice of diets and related impacts on global warming, and provides a means to compare the GHG impact of one food product over another, by considering both production processes and transport distances.

Sustainable consumption, according to a definition proposed at the 1994 Oslo Rountable on Sustainable Production and Consumption (Oslo, 1994) is "an umbrella term that brings together a number of key issues, such as meeting needs, enhancing quality of life, improving resource efficiency, minimising waste, taking a life-cycle perspective and taking into account the equity dimension; integrating these component parts in the central question of how to provide the same or better services to meet the basic requirements of life and the aspiration for improvement, for both current and future generations, while continually reducing environmental damage and risks to human health."

The UN report, entitled *Sustainable Consumption: A Global Status Report* (Ryan, 2002) identified six strategic areas to address current problems: clarifying the various meanings of consumption; developing better feedback through indices to measure consumption pressure and quality of life; finding a more appropriate conceptual schema for describing systems of production and consumption; supporting and enhancing localised campaigns of action; focusing production and consumption-oriented action on the transformation of products and services; and developing and promoting the idea of 'leap-frog' change as a radical shift.

Consumers need a means to better connect cause and effect when considering the implications of their buying decisions. Consumers, both individual and institutional, must be able to routinely perform environmental risk assessment and understand the impacts of their decisions. These consumers must be able to assess impact not only in terms of GHG emissions, but in terms of water consumption and others factors. A framework for the unified presentation of environmental risk information is a first step in raising the awareness of environmental risks that are present within daily life and which are very subtle and easy to ignore or discount entirely. Although some may discount the need for action because uncertainty remains about climate change, evidence is much clearer about the impact of vehicle emissions on air quality and health (Blake et al., 2004). Ordinary citizens need to have this information, and have it presented in ways that allow them to make connections to their daily lives. In considering a tool that will provide access to this information, three separate but related issues are clear: how individuals will interact with and gain access to the information; what information will be presented; and how that information will be presented. Therefore, the framework will focus on the strategic areas by improving the computer-based tools and the interface that they provide to the data; the breadth of data available, its combination, and its organization; and the presentation of the data. It will enable the development of better feedback, it will seek to provide an access to information that will be simple enough to assist analysis and intervention, it can support and enhance local action campaigns (dealing with water use and reuse, for example), and it will help to bring consumption-oriented action to the transformation of products and services.

The remainder of the paper is as follows. Section 2 deals with some background for this project. Section 3 deals with the design of the framework in terms of interface, data, and presentation. Section 4 discusses some preliminary test results and further planned tests. Section 5 presents conclusions and directions for future work.

2. BACKGROUND

According to its website, INFOTERRA (2000) is the global environmental information exchange network of the United Nations Environment Programme. The network operates through a system of national focal points, each of which is essentially a national environmental information centre. usually located in the ministry or agency responsible for environmental protection. The primary function of each centre is to provide a national environmental information service. INFOTERRA received its mandate at the 1972 Stockholm Conference on the Human Environment which recommended the establishment of a mechanism for the exchange of environmental information and experiences among countries. The 1992 Rio Conference on Environment and Development (UNCED) reiterated the importance of information for decision-making and requested the strengthening of the INFOTERRA network to improve information availability pursuant to Agenda 21, Chapter 40. The URLs for the national focal points of the United States and Canada were not operational at the time of this writing, but a consolidated form of information does not exist.

From evidence gained in studies of multi-family dwellings where utilities are sub-metered, consumers are likely to conserve when they are given appropriate information in an appropriate form and the responsibility for action. The Office of Energy Efficiency within Natural Resources Canada provides a CO_2 calculator on its website (NRCAN, 2003) to allow people to understand the harmful effects of idling vehicle engines. However, the results are available only for whole communities and only in terms tonnes of carbon dioxide emitted and dollars saved by conserving fuel. An individual consumer using this calculator can only guess at his or her own impact and may be even be disempowered to act alone. Although dollar savings are readily understood, carbon dioxide is expressed in tonnes and equivalently in gymnasiums. A more meaningful expression of carbon dioxide emissions might be in terms of the number of trees required to sequester them. After some searching on the web, one might be able to locate a resource to accomplish this translation from tonnes to trees needed (Roulet and Freeman, 1999). However, requiring the user to do this extra work of conversion is at odds with making the information accessible, and is in violation of Raskin's Second Law of Interface Design (Raskin, 2000): "the computer shall not make the user do more work than is absolutely necessary."

Donald Norman (1988) described the twin gulfs of execution and evaluation with respect to users dealing with computer interfaces. The gulf of execution is the distance that a user must cross in order to express his or her goal in terms of system commands. Similarly, the gulf of evaluation is the cognitive distance between the current system state and the one that would reflect accomplishment of the goal. With respect to the website carbon dioxide calculator, the goal of assessing one's individual impact on emissions is completely thwarted.

One might first seek environmental information about a product on the web through google, or a similar search engine. Table 1 lists the top five results from a "cleaning products environmental information" query in google. Of the information available through these URLs, much is inappropriate for direct application to the task of choosing amongst several cleaning products. The main exception is the Cleaning Products Pilot Project of the EPA (# 3 in Table 1). Although the Centre for a New American Dream (#4 in Table 1) did provide a list of approved cleaning products, there was no data to permit a comparison amongst products.

1. EPP Cleaning Products, Environmentally Preferable Product Information: the Commonwealth of Massachusetts environmentally preferable products procurement program with information about environmentally preferable cleaning products (http://www.state.ma.us/osd/enviro/products/cleaning.htm).
2. Sources of Indoor Air Pollution – Organic Gases (Volatile Organic Compounds): indoor air quality information from the United States Environmental Protection Agency (http://www.epa.gov/iaq/voc.html).
3. Environmentally Preferable Purchasing – Cleaning Products Pilot Project – Using the Environmental Attribute Matrix: cleaning products pilot project from the United States Environmental Protection Agency (http://www.epa.gov/oppintr/epp/cleaners/select/using.htm).
4. Procurement Strategies Program – Cleaning Products: Cleaning products and services information from the Center for a New American Dream (http://www.newdream.org/procure/products/cleanresources.html).
5. Procurement Strategies Program – Cleaning Products Work Group: Updated information from the cleaning products work group at the Center for a New American Dream (http://www.newdream.org/procure/products/cleaners.html).

Table 1: Top 5 search results for "cleaning products environmental information" query in google.

The Environmentally Preferable Purchasing (EPP) Cleaning Products Pilot Project provides three different attribute ranking tools (single, multiple, and weighted) to organize and evaluate a set of 29 industrial cleaning products. For each cleaning product, information with respect to the following eight environmental attributes is provided: skin irritation, food chain exposure (bioconcentration factor), air pollution potential (percentage of volatile organic compounds), contains fragrance, contains dye, product is a concentrate (reduced packaging), packaging is made of recyclable paper, and product minimizes exposure to concentrate. The presentation of this information is in tabular format. The difference between the three tools is in how they allow the user to organize and filter the products based on the attributes.

The Single Attribute Ranking Tool allows the user to organize the table of data based on one attribute at a time. Initially, the list of products is presented in alphabetical order. The user is able to sort the list according to any one of the environmental attributes. Since this tool only allows the sorting by one attribute at a time, it directly supports the task of selecting a product based on one attribute (i.e., which product has the lowest food chain exposure?). However, it does not support tasks involving more than one attribute (i.e., Which product has the lowest air pollution potential and the lowest skin irritation?). In these situations, the user must sort the list according to one attribute, and then scan for the other attribute values. The selection of the attribute to sort by determines precedence in sorting, which may not be apparent to the user.

The Multiple Attribute Ranking Tool allows the user to organize the table of data based as many as four attributes at a time, as well as filter the table based on the selection of a minimum acceptable level for each attribute. If the user selects only one attribute to sort by, and no filtering, the result is identical to the Single Attribute Ranking Tool. Selecting multiple attributes when ranking, and entering filtering information allows the user to answer complex questions such as "which products cause minimal air pollution and produce a small amount of air pollution or less?" However, since the sorting of the data and the filtering of the data are done separately, users may have difficulty converting their goals into commands to be executed.

The Weighted Attribute Ranking Tool allows the user to select filters for each of the attributes, and enter weights for the ranking of the data. A higher value supplied for the weight of an attribute will result in that attribute having a bigger impact on the sorting of the data. If the user enters equal values for the weights, the result is identical to the Multiple Attribute Ranking Tool. By allowing users to enter different weight values, they have the ability to indicate that one attribute is more important than another when organizing the data. While the sorting and filtering are provided together in this tool, users who are not familiar with weighted averages may have some difficulty in deciding an appropriate weight to enter.

3. FRAMEWORK DESIGN

The framework is intended as a means for consumers, both individual and institutional, to gain access to all the pertinent information relating to a particular product and service. Furthermore, the type of corporate citizenship demonstrated by the manufacturer, the use of animal testing, sources for ingredients, may all play important roles in some instances of this problem. Beyond the scope of the attributes presented are additional attributes related to performance and price which would add practical information about the product's use in actual situations. This is the type of information with which a service like epinions.com (2003) currently excels. Similarly, this web-based initiative will allow consumers to both access existing data and contribute new information. It will be designed and administered using open source principles, to ensure that the information remains open and accessible by adapting strategies to allow community-based scrutiny and review of the data sources. However, the available data will decide what is possible.

Ultimately, the system should provide the means to evaluate different alternatives according to the relevant criteria as a decision-support system but with the possibility for more. Patterns may emerge from analysis of data between databases. Of particular anticipated interest is the analysis of consumers' interactions to inform public policy and private investment: public policy can direct educational campaigns to increase awareness of factors not highly-rated by consumers and private investment can finance development of products where pronounced interest exists without any means of fulfillment.

Environmental risk information of the sort envisioned by this tool may only be available by combining many diverse data collections. For example, only in the context of local information do some choices that are not local begin to have a higher risk in terms of the GHG emissions associated with travel. To facilitate the combination of information from a variety of heterogeneous sources, XML (Bray et al., 2000) is considered key.

XML facilitates gathering of data by providing a medium for sharing relevant information, and supports the job of portraying data in a meaningful fashion. The use of XML also satisfies the need to properly document great quantities of data, a problem relevant to this endeavour. It can represent data of any kind, store it in an organized structure, and present a uniformity of data expression with which a community can converse and share. de Vos, Widergren, and Zhu (2001) further explain that "XML is accompanied by extensive technology infrastructure covering functions such as transformation, presentation, query, schema and exchange protocols. However, common adoption of XML has other benefits. It reduces the time and effort required to learn different systems. It imparts a degree of compatibility to different industry standards against the day when they come into contact with each other in the enterprise or on the public Internet." The data that will be presented by this system on the public Internet will need a means for unification of data expression. Using XML opens the door to information sharing among all interested parties, including government, industry, community organizations, and the general population.

XML provides an aid in the portrayal of the data. The leverage of XML resides in the rich description it provides the data, transforming data into information that is organized and ready for consumption. The system can interface more directly with the data due to the expressiveness inherent in the XML. The key to exploiting this advantage lies in providing the appropriate XML schema or DTD. An open and collaborative approach, allowing input from the community to improve the schema, is the direction of this project. The United Nations Environment Programme (INFOTERRA, 2003), has the mission "to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations." For example, UNEP in partnership with other stakeholder organizations developed the Global Reporting Initiative (GRI), a process to develop Sustainability Reporting Guidelines, for voluntary use by organizations reporting on the economic, environmental, and social dimensions of their activities, products and services. It is hoped that this project can contribute to these UN efforts (UNEPTIE 2001, GRI 2004) with the development of a markup language to encapsulate sustainable consumption and lifecycle concerns and connect many disparate data sources.

As information is collected from different sources, the XML framework brings it together in an organized fashion. It essentially provides documentation of the data, maintaining its integrity regardless of the volume. Data-mining can then be carried out to discover useful patterns. As the collection of data increases in size the system continues to supply useful human-oriented information from that data. The mapping of user concepts to the data may not be precise, and the framework as described would include some flexibility in creating these associations which may extend beyond a single database related to food in order to incorporate transportation emissions in assessing the GHG impact of a particular food choice.

The data available to be queried determines what types of questions can be answered by the system. Some effort must be made to advertise the data is available, so the user can understand the range of questions that he or she may ask. The data with which to assess environmental risk is not readily available for the layperson, so connections between the user's questions and the data must be made. If the environmental attributes of products and services are correctly specified so that they match the user conception of the problem and the different sources of data are correctly linked so that the complete life cycle information is available, then we must make those choices accessible to the user. Each attribute has two or more values. If a product or service is identified as a collection of attributes, it is possible then to think of each product as being addressable in these terms. These addresses are part of the space of all available addresses, in the following form. For N atttributes, each N-tuple of values is a distinct point in the product address space, as follows:

$$<v_1, v_2, ..., v_N> \in A_1 \times A_2 \times ... \times A_N$$

Different products will likely have different addresses within this space (to differentiate themselves), but certainly some addresses will be very close together. Considering the EPA CPPP attribute matrix, there are already over 10,000 possible addresses in this space, illustrating the problem of "combinatorial explosion." Without going too far beyond the 29 products in the EPA example, an exhaustive search would be impractical (considering the environmentally less-preferable alternatives would no doubt add substantially to this total). It is also fruitful to consider this product space as a solution space (Simon, 1977), since the expectation exists that a solution to the current problem can be found amongst the combinations of attribute values. The notion of the product space is useful as a means to examine similar products whose addresses are close to one another. It is also useful to consider the opportunities for new products or the reasons why a portion of the product space contains no entries. If, for example, within this framework consumers could indicate their willingness to pay a premimium for a product that provided a heretofore missing combination of attribute values, this would provide incentive to manufacturers to provide that option. This information, or the opportunity to consider it, would be much more unlikely to exist with the means to easily consider alternatives within the product space.

The computer has the promise to democratize exploration of these parameter spaces, as suggested by Jessup (1992), for example. The promise, however, will not be fully realized until software addresses the issue of access. In general, the relationship between humans and computers can be viewed as either automatic, manual, or augmented (Kochhar et al., 1991). Automatic systems are generally prescriptive and work with very little input from the user to determine a solution for the user. Manual systems provide the building blocks but require the user to take responsibility to assemble them. Augmented systems encompass a wide range of designs are intended to allow the computer to support the user's activities by working with the user. Although many, including Foley and Ribarsky (1994) consider that automatic systems are the only feasible solution to the curse of dimensionality, these systems presuppose a complete, or at least adequate, articulation of the problem. Winograd and Flores (1985), however, contend that such a definitive articulation is not possible but it is rather an ongoing process. This paper describes the adaptation of an augmented system, called *cogito*, to this decision-support application to allow for an initially incomplete articulation of the problem to be refined as the interaction progresses.

In all cases when a user of computer software wants to find a solution, either he or she knows what is needed or wants to explore what is available. If the user is familiar with computers in general and the software specifically, then it may be an easy matter specify a particular solution.

One may be able to articulate the attribute values for an ideal product, but such an alternative may not exist within the system. Therefore the system should present the alternatives that best meet the present needs of the user, and allow the system to notify the user when better alternatives come along. However, this user may also be unaware of better solutions that exist outside of his or her experience, content with a local rather than global maximum. When exploration is indicated, it may involve considerable work even for an expert user. In the domain of data plotting, Bertin (1983) rightly indicated that it would take "more patience than imagination to generate 100 DIFFERENT FIGURES from the same data." That patience may give out before the best solution may be found is a serious issue.

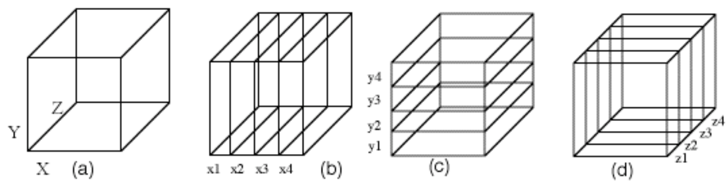

Figure 1: Consider a three-dimensional parameter space, depicted in (a), with parameters X, Y, and Z (each with 4 values). Organizing the space in terms of any of those 3 axes leads to other states shown (b-d). For example, as in (b), if space is partitioned according to values in X, those 4 can be shown sequentially while values from Y and Z can be chosen pseudo-randomly.

For users who do not have sufficient expertise to operate the particular software, the translation between the semantics of the problem and the syntax of the software can become more onerous. From the perspective of solution spaces, Perkins (1995) classifies spaces depending on the amount of clues available: Klondike spaces are clue-poor and homing spaces are clue-rich. Ideally, tools would enable users to transform a Klondike space into a homing space for themselves. In the case of data, it can be a test to say how well people relate to the labels and structure of the data.

Although it is difficult for a user to generate hundreds of alternatives, it is not so for the computer. If it is possible to parameterize the form of the solution, all available solutions that fit that model can be computed automatically. Instead of quickly returning to the problem of the combinatorial explosion, a different approach is used. The parametric representation of the solution makes it well-suited to a genetic algorithm (Goldberg, 1989), but the standard implementations may be too automatic. An augmented ones (Design Galleries – Marks et al. 1997) also automates this initial review by having the computer first evaluate each solution. Such a specification can unwittingly eliminate desirable alteratives. Even though Design Galleries presents the user with a sampling of the full range of solutions, based on the results of the initial evaluation, specification of the metric *a priori* may represent a significant hurdle especially when the requirements are hard to specify, or even articulate.

The involvement of users is important from the perspective of personalization. Therefore, the design of *cogito* relies on the user beginning with the whole space and making decisions at the time of inspection instead of beforehand. Rather than attempt an exhaustive search for the optimal solution, the focus is to find satisficing solutions instead (Simon, 1977). Yet, if not all solutions are likely to be directly evaluated, the system must provide an effective means to choose the combinations that will be reviewed, since all will be available. This is done by allowing the sapce to be partitioned and having each partition sampled.

The paradigm of interactive evolution is well-suited to a system that is designed to encourage individual involvement. The user is be able to see alternatives without having the burden of directly specifying them and see what range of options are available. This sort of approach, which has the benefit of a low syntactic burden for the user by virtue of its direct manipulation style, has been used to great effect by Sims (1991), for example.

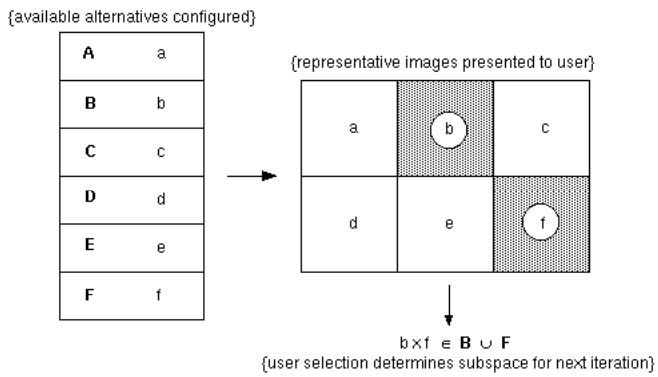

Figure 2: Schematic view of the interface: the space of available alternatives is grouped according to user-specified criteria (see Figure 1). Each group (A-F) has a representative element (a-f) that is displayed to the user. The subspace for the next iteration is based on the user selection (b and f).

As the solution space is explored and landmarks are found, the user is able to develop a mental model of the solution space just as one develops a model of an application's interface (Rosson and Carroll, 2002). This process helps the user to gradually articulate his or her needs in a particular situation. Despite the fact that a complete articulation, especially before any exploration, is not possible (Winograd and Flores, 1985), Wegner (1997) asserts that this interactive approach is also much more powerful.

The final element in the framework will involve the presentation of information in such a way that it facilitates communication of the important features of a product and comparison of alternative products. At this point, it is unclear what sort of visual representation, if any, might be most useful. It is expected that the results of the current and planed studies will have an impact on the direction the final presentation step will take. Although it may be best to leave this decision to the user, requiring too many choices between the presentation of the information and selection of the data may be distracting for the users. One visual representation under consideration is the Nightingale Rose (Wainer 1997), or an adaptation, because of its better features for comparison. Like a pie chart it is circular, but whereas the pie chart varies the angle with the data but keeps radius constant, the Nightingale rose maintains the angle and varies the radius with the data.

4. EVALUATIONS AND DISCUSSION

In order to assess the utility of EPA CPPP (#3 in Table 1) purchasing decision tool interfaces (both in terms of commands and the naming of attributes), an experiment based on the EPA website[1]was designed to test users on each interface with three questions (involving one, two, and three attributes). The same questions were associated with each interface in all trials, but the order in which the interfaces were presented was varied. Each participant was given a pre-task questionnaire, a set of three tasks (each with three questions to be answered by one of the tools) whose order was varied, and a post-task questionnaire. Performance was measured by recording response times, errors with the software, and correctness of responses made. Qualitative data was also collected on a post-task questionnaire with Likert-scale questions about their use of the different tools, and some open-ended questions relating to their impressions of the tools. Although the results are not yet complete[2], a great many participants are experiencing difficulties with the tools and seem unable to use them to their full capacity. These tool interface issues seem to have superceded concerns about the presentation of the product information in terms of the eight attributes.

The experience with the testing of the EPP CPPP tools indicates that considerably more effort must be devoted to the development of satisfying activities around the discovery of product information. The tasks in the study are somewhat artificial because they are meant to test the participants' use of the tools more than have them conduct a common query. Although relatively little comment has been made about the appropriateness of the different labels, it may still be a real issue that was merely obscured by the structure of the experiment. The issue of labeling of attributes will be explored in further planned studies.

Specifically, a usability study with the present EPA CPPP data accessed through the *cogito* interface will be conducted. The promise of the *cogito* approach is the ability for the user to partition search results based on different choices for an attribute, allowing the user to quickly see the range of his or her choices.

The choice and naming of attributes will be explored in different ways. Participants in the first study will articulate the names they use to distinguish between cleaning products through the techniques of Kelly's Personal Construct Psychology (Kelly, 1955). Participants will see sets of three cleaning product descriptions then be asked to distinguish the one that is most different and why. These responses will be used to determine the attributes that people use to distinguish between products, and what they are called. To this collection of names, the result of a search for all names of all attributes used with respect to cleaning products will be added and participants will be asked to perform a card-sorting task with these names. The resulting grouping of names will help to adapt the means by which information is provided to consumers attempting to choose between competing products. Once attributes and names have been decided, a final phase of the investigation will use conjoint analysis to ascertain the relative importance of the attributes.

With a new understanding of attributes and names, participants will be once again asked to work with the EPA CPPP tools and with *cogito,* except for this trial, the data will be presented using the newly derived attributes and names.

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[1] the multiple and weighted attribute ranking tools were not functional on the EPA website, though their interfaces inspired the functionality of new versions of tools that were used in the study.
[2] the study should be complete in time for the final version of this paper.

5. CONCLUSIONS

There is great incentive to act in dealing with climate change and other impacts now being felt. Dissemination of information about environmental risks along with opportunities for action will be an area of increasing importance. It is clear from the study conducted here that the functionality of the software and the organization of the underlying information may need further development. The *cogito* model has shown great potential in other application areas and its study in this context will be beneficial.

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7. REFERENCES

Bertin, J. 1983. Semiology of graphics: diagrams, networks, maps. University of Wisconsin Press.

Blake, R. B., Diaz, P., Piwowar, J., Polanyi, M., Robinson, R., Whyte, J. D., Wilson, M. 2004. Weathering the Political and Environmental Climate of the Kyoto Protocol. The Saskatchewan Institute of Public Policy, Public Policy Paper Series Number 22.

de Vos, A. Widergren, S.E. Zhu, J. 2001. XML for CIM model exchange. In Proceedings of Power Industry Computer Applications (PICA) 2001, pp. 31-37.

Epinions.com 2003. Epinions.com by Shopping.com. Accessed at http://www.epinions.com/ on 28 February 2004.

Foley, J., Ribarsky, W. 1994. Next-generation data visualization tools. In L. Rosenblum et al., editors, Scientific Visualization, Academic.

Goldberg, D. E. 1989. Genetic algorithms in search, optimization, and machine learning. Addison-Wesley, Reading, MA.

GRI 2004. Global Reporting Initiative: A Collaborating Centre of the United Nations Environment Programme. Accessed at http://www.globalreporting.org/ on 28 February 2004.

INFOTERRA 2000. UNEP-Infoterra: The Global Environmental Information Exchange Network. Accessed at http://www.unep.org/infoterra/ on 28 February 2004.

Jessup, M. E. 1992. Scientific visualization: Viewpoint on collaborations of art, science, and engineering. SIGBIO Newsletter, February, pages 1-9.

Kelly, G. 1955. The Psychology of Personal Constructs. Norton.

Kochhar, S. et al. 1991. Interaction paradigms for human-computer cooperation in graphical-object modelling. In S. MacKay and E. M. Kidd, editors, Proceedings of Graphics Interface '91.

Marks, J. et al. 1997. Design galleries: A general approach to setting parameters for computer graphics and animation. In *Computer Graphics: SIGGRAPH '97 Conference Proceedings*.

Norman, D.A. 1988. The psychology of everyday things. Basic Books, New York.

NRCAN 2003. Idle-free! Carbon dioxide calculator webpage from the Office of Energy Efficiency within Natural Resources Canada. Accessed from http://oee.nrcan.gc.ca/idling/calculator/CO2_calculator.cfm?PrintView=N&Text=N on 28 February 2004.

OECD 2002. Towards Sustainable Household Consumption?: Trends and Policies in OECD Countries, OECD E-Book.

Oslo 1994. Oslo Rountable on Sustainable Production and Consumption, Part 1 - THE IMPERATIVE OF SUSTAINABLE PRODUCTION AND CONSUMPTION, 1.2 Defining sustainable consumption. Accessed from Linkages: a multimedia resource for environment and development policy makers, http://www.iisd.ca/consume/oslo004.html, on 28 February 2004.

Perkins, D. N. 1995. Insight in minds and genes. In R. J. Sternberg and J. E. Davidson, editors, *The Nature of Insight*, pages 495-533. MIT Press, Cambridge, MA.

Raskin, J. 2000. The Humane Interface. Addison-Wesley.

Rosson, M. B., Carroll, J. M. 2002. Usability Engineering: Scenario-based development of human-computer interaction. Morgan-Kaufmann.

Ryan, C. 2002. Sustainable consumption - A global status report. UNEP Division of Technology, Industry and Economics, Paris.

Roulet, N. T., Freedman, B., 1999. What Trees Can Do to Reduce Atmospheric CO_2. Tree Canada Foundation.

Simon, H. 1977. Models of Discovery, Reidel, 1977.

Sims, K. 1991. Artificial evolution in computer graphics. In R. J. Beach, editor, Computer Graphics: SIGGRAPH '91 Conference Proceedings, pages 319-328. ACM Press.

UNEPTIE 2001. United Nations Environment Programme Sustainable Consumption - Division of Technology, Industry and Economics. Accessed from http://www.uneptie.org/pc/sustain/ on 28 February 2004.

Wainer, H. 1997. Visual Revelations. Copernicus (Springer-Verlag).

Wegner, P. 1997. Why Interaction Is More Powerful Than Algorithms, Communications of the ACM, 40(5), pages 80-91.

Winograd, T., Flores, C. F. 1985. Understanding Computers and Cognition. Ablex, Norwood, New Jersey, USA.

Bray T., Paoli J., Sperberg-McQueen C. M., Maler E. 2000. Extensible Markup Language (XML) 1.0, Second Edition, World Wide Web Consortium.