Community Science For Biodiversity Monitoring

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Summary

Increasing the spatial scales and temporal frequencies at which species occurrences and locations are recorded is central to biodiversity informatics. There are not nearly enough trained scientists to do the job and remote sensing methods have severe limitations for most taxa. This project is trying to rapidly build communities of people (academic taxonomists, amateur natural historians, environmental educators, concerned citizens and students) and institutions (universities, environmental NGOs, governmental agencies and schools) to produce important scientific data about biodiversity. We are recording information about phenology to examine climate change, invasive species to document habitat disturbance and occurrences of common species such as ants for which there are no field guides. Building monitoring communities is made possible by digital technologies that permit four key advances: 1) high quality yet relatively inexpensive mini color field guides, 2) GPS spatial coordinates of individuals or populations, 3) electronic vouchers using digital cameras and 4) public digital libraries available over the Internet. This project has several strong benefits for the K-16 community. They will be gathering data in an authentic way for the entire scientific community, they will be directly involved in the scientific process as now required by many state and federal educational standards, and because of the direct contact with other species they are like to develop stronger appreciation of our essential dependence on Nature's goods and services.

Background

Preventing biodiversity loss is one of the important environmental challenges that society faces (PCAST 1998, NRC 2001). There is also a clear understanding that environmental problems, such as global climate change, fresh water availability, agricultural production and biodiversity loss are interconnected (Luchencho 1998 and NRC 2001). A significant step towards reversing environmental degradation entails documenting and sharing environmental data, especially biodiversity data.

While very significant progress has been made in developing biodiversity information infrastructure at the national, continental and global scales (for instance ABI 2001, GBIF 2000, ITIS 1999, NBII 2001), there are still great strides to be made as recently described in Science (Sugen and Pennisi 2000). Authors noted the importance of digitizing data from natural history collections, the ability to share information across databases, the delivery of data to the desktop, and the continued monitoring of biodiversity by conservation biologists in collaboration with the taxonomic specialists usually located in natural history museums.

Advantages of Citizen Science Partnerships for Biodiversity Monitoring

A missing element in the Science articles was the role that citizen-scientist partnerships play in monitoring biodiversity (Christmas Bird Count, Mussel Watch, the Fourth of July Butterfly Count, the USGS's amphibian monitoring, Reef Environmental Education Foundation, Texas Nature Tracker's Office; see Stevenson et al 2001 for web addresses). In the United States, the citizen or community science approach was pioneered by Cornell's Laboratory of Ornithology (Cornell Citizen Science 2001) and has expanded rapidly with the wide adoption of the World Wide Web (WWW). The Laboratory for Ornithology supports about a dozen projects that include traditional birding activities such as the Christmas Bird Count and new forums such as the Great Backyard Bird Count (GBBC). There are also several community-based projects that focus broadly on biodiversity (BioBlitz, Chicago Wilderness, Discover Life, Massachusetts Biodiversity Days; see Stevenson et al 2001 for web addresses).

These citizen-scientist partnerships share two characteristics that make them central to developing biodiversity infrastructure. They provide data on spatial and temporal scales that are impossible to document using other methods - there are not nearly enough trained scientists to do the job and remote sensing methods have severe limitations for most taxa. Second they involve the public and school children in local efforts that build community understanding and support for biodiversity issues.

This present project, based on a community science approach, examines ways to greatly expand the taxa that non-professionals can monitor. It also proposes ways to garner the help of citizens and school children in documenting invasive species and in recording phenological data that will address climate change issues. These ideas arise out of our Electronic Field Guide Project (EFG).

The Electronic Field Guide Project

The Environmental Informatics and Visualization Laboratory at UMass Boston, with support from NSF, is developing Electronic Field Guides (EFGs)(http://www.cs.umb.edu/efg/) to provide a web-accessible distributed database that will greatly help amateur observers with identifying species and recording ecological observations. EFGs are built on the approach of paper Field Guides (FG) that make the identification of species easier than using dichotomous keys produced by taxonomists (Stevenson et al. 2001). In addition, EFGs free the designer from the inherent restrictions of production and traditional publishing, including long time lags in preparation, expense of production and broad geographic coverage necessitated by economic considerations. A fundamental goal of the EFG project is to produce software for biologists that allows them to easily make their own EFGs and eliminates the need for software engineers.

We have a working model of an EFG (http://alpaca.cs.umb.edu:8080/efg/index.html). It is based on an object-oriented software design that (1) is extensible (2) strictly separates the data from the user view, (3) is scaleable and (4) has an open interface so the information can be exchanged with other databases. The software follows the model/view/controller paradigm in which data are stored in an object-oriented database called "Object Store", the view is presented in XML that is translated into HTML and JAVA is used as the controller. A challenging part of the work has been developing software while at the same time showing progress from a biologist's perspective. Our solution has been for our field biologist, William Haber, to develop a website using conventional software tools (http://www.cs.umb.edu/~whaber/Monte/MV/MV-3.html). This has had the beneficial effect of demonstrating progress with the biological data and providing user views to help the software engineers.

The work described here is targeted at expanding the impact of our NSF sponsored research on databases and digital technologies for EFGs. Our original vision was to develop technologies and test them out on small groups of users, which we are doing. However, rather than waiting until EFG technologies are mature, (a truly field portable EFG requires high resolution color display technologies that are 4 to 7 years away,) we want to work on the community-building aspects to see what approaches are needed to scale up the EFG concept.

Four Technologies to Implement the EFG Vision Now

Most people need a field guide to identify species. They do not have the patience or technical background to use keys. **Rapid Color Guides** (Foster 2000) are laminated 8.5 x 11 pages with 20 to 25 color pictures per side, labeled with species names, which can be produced on inkjet plotters. These pages yield high quality yet relatively cheap, mini field guides for local species. We believe that this technology can be used to greatly expand the taxa that are currently identified by amateurs in biodiversity surveys.

Central to documenting biodiversity is placing species occurrences in a geographic reference system. Traditionally biologists simply noted the town and/or county where the collection was made. However, now we have GPS (Global Positioning System) that is going to revolutionize the way we collect biodiversity data. **GPS units** are inexpensive, easy to use and field portable. When GPS Selective Availability was turned off on 1 May 2000, very high quality spatial data (with a 5m diameter) could be collected using field portable instruments that cost less than $150. The implementation of WAAS (Wide Area Augmentation system) technology in the newest models can reduce that diameter to 3m. (Additional WAAS satellites will increase the availability of this more accurate technology).

The third important technology is a way for people to document what they have seen. Historically biologists have collected specimens to deposit in natural history museums as mandated by the scientific method. For citizen scientists and even professional biologists collecting is not possible or often desirable for a variety of ethical and financial reasons (NWS 1994). However, a photograph can provide a long-lasting record of observations. Today's **digital cameras** offer an ideal way to collect an electronic record or **e-voucher** (Monk and Baker 2000) of what was seen in the field. Rapid advancements in digital photography are making it competitive with film methods at greatly reduced costs. Once transferred to a computer, digital images can be quickly posted in digital libraries and shared over the Internet. Within the birding and butterfly worlds, photographs are growing as a way for naturalists to document their observations. Just like a physical specimen, an image provides a record for the community to view, discuss and come to a consensus about the name of the species.

We believe that these technologies, in conjunction with public databases built on **Digital Library technologies** with open source software (http://www.w3c.org) to share information over the WWW, can rapidly and significantly enhance biodiversity infrastructure.

Progress in Building Environmental Informatics Communities

Building communities to monitor biodiversity. The most important perspective to emerge is that field naturalists (academic taxonomists and ecologists, amateur natural historians, environmental educators) regularly monitor biodiversity because of their great love of the environmental but have no venue in which to share their knowledge or expertise. The WWW and good database technology could provide a platform to share digital imagery, maintain local species lists, facilitate the production of local field guides by taxa, location and season. To engage this community, it would be necessary to provide high-end digital cameras and some training in software. It is also likely that to scale up the use of this community to answer questions about species citizens have found will require an insulating layer of naturalists such as college students to prevent the volume of questions from being overwhelming.

Prototyping of Monitoring Protocols. The second set of activities focuses on prototyping three biodiversity monitoring activities.

1. Global climate change is perhaps one of the most widely acknowledged environmental problems (IPCC 2001). We have initiated a project to monitor the phenology of dandelions (www.dandelionbiology.org). With the help of an elementary school teacher, a workshop for educators was presented at the Massachusetts Environmental Educators Society meeting this spring. About 30 teachers have signed up to participate in the project. Seminars are planned in Rhode Island and Maine. We plan to collect data on the web.

2. Biodiversity Days is an annual three-day statewide citizen-based effort already established in Massachusetts to monitor biodiversity (May 31 to June 2, 2002). Taxonomic specialists that we have contacted are in the process of making mini field guides (ants, common weeds, bumblebees, marine plants) to be used by citizens and school children during the survey process. We expect to answer the question "Will Biodiversity Day participants search for and report on taxonomic groups which have been outside the traditionally attractive groups such as birds, butterflies and wildflowers?"

3. Invasive species are now recognized as a major threat to biodiversity. Several teachers have agreed to use mini guides in conjunction with GPS units and digital cameras to have their classes locate and record invasive species. Most effort has been focused on Broadleaf Pepper Bush (*Lepidium latifolium*) in salt marshes. A mini guide will be made and distributed this spring to teachers that shows Japanese

Honeysuckle, Japanese Knotweed, Leafy Spurge, Multiflora Rose, Russian Olive, Tree-of-heaven, Purple Loosestrife, Phragmites, Norway Maple, Black Swallowwort, Black Locust, Common or Smooth Buckthorn, Asiatic Bittersweet, Japanese Barberry, and Garlic Mustard.

Computer Science Problems in Environmental Informatics

The thrust of this work is aimed at community-building and technology transfer, not fundamental challenges in computer science. Many of the developments we know of fall into the category of software engineering. For the most part, the development of technology is driven by the much larger economic forces of the commercial world so it is quicker to adapt these technologies than to develop them de novo. Nonetheless, there are important sets of informatics problems common to all levels and disciplines of biology including naming, identification, functional assessment, spatial mapping, evolutionary history, metadata definitions, model definitions and model testing. Associated with the biological issues are significant problems in computer science and software engineering such as access control, automated data collection, resource discovery, standard and distributed database design for heterogeneous data, user interfaces, data mining, software tool making, and modeling standards. We would love to be able to find species accounts on the web, distill information from each, reformat it and deliver it to a wide variety of audiences. In the future, people will develop Star Trek Tricoder devices to sample the environment and kids will be able to photograph and view a flower in three dimensions.

The WWW, digital libraries, and the XML related developments (http://www.w3c.org), as well as a host of hardware developments, hold the promise to open up the power of information to society as a whole. Technologies that help automate effective communication between the public (in our case kids, teachers, birders, gardeners, field naturalists) and information specialists (in our case taxonomists and ecologists) offer the most promise to engage society as a whole in the democratic process.

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