INTRODUCTION

The use of computers for teaching has enormous potential to serve not only as learning devices for students, but also as teaching supplements for instructors. Plant sciences have already utilized computer technology for dichotomous keys and plant identification programs available on compact discs or the World Wide Web. The full potential of computer assisted learning includes a capacity to store and easily access large amounts of textual, graphic, and audio information in a way that is efficient and user-friendly.

As shown below few, if any, currently available programs reach their full potential. Urban Trees of North Carolina (Russell, 1996), for example, is a slide show placed on compact disc, complete with audio and visual information of plant nomenclature and basic plant morphology. This program has numerous quality images and descriptive audio throughout, but no mechanism to locate information quickly. Users basically turn “electronic pages” and have limited control in the information delivery. Although useful for the identification of urban trees, this program lacks information on natural forest ecosystems and naturally-occurring species. Thus it has limited usefulness for foresters, wildlife biologists, and other natural scientists.

Woody Plant ID (Seiler, 1997) is an interactive identification tutorial covering 129 woody plants species found throughout the eastern United States. Contained on compact discs, this program contains many images of trees and morphological characteristics as well as user-friendly pathways of accessing and comparing information. However, this program is not information-rich; morphological descriptions lack detail. Habitat
descriptions do not include climate variations, soil ranges, or detailed geographic range information. Expansive natural history information, such as human and animal uses are lacking. Audio files are also absent, making learning the pronunciation of scientific and vernacular names difficult.

Trees of the Pacific Northwest (Littlefield and Jensen, 1997) is a World Wide Web tree identification program which assists users in identifying common conifers of the northwestern states. Complete with images of leaves, reproductive structures, and range maps, these Web pages contain information about nomenclature, morphology, and distribution. Although user-friendly, this program (1) covers only trees native to northwestern North America, (2) has small images which are difficult to see, and (3) lacks silvics information such as soil and climatic conditions. This tree identification program does not take full advantage of the capacity of computers.

Other existing programs are too general and too elementary for advanced study. Tree of Life (Maddison and Maddison, 1997), an on-going Internet project, contains information about phylogeny and biodiversity of all living organisms. Presumably, when all the information is linked, users will navigate through a phylogenetic tree to find specific information. This Web site currently contains no information or multiple images of pines, and access to a general information page on conifers is cumbersome due to the small print and confusing layout. With no audio, images, and text, this program is of little use to advanced study.

Furthermore, these programs contain no search engines, computer mechanisms for locating information, that allow users to compare graphical and textual data. Since some
species closely resemble other species, side-by-side pictures and information would assist users in differentiating between them. Search engines should provide information on morphological characteristics and allow users to choose the comparison.

Currently no user-friendly, information-rich program exists for naturally occurring trees of southeastern North America, one of the most species-rich temperate areas. Given the enormous information contained in the literature, as well as the laborious task of finding it, the time has come to consolidate this information into a computer database. With the rapid innovations in computer technology, creating an efficient and user-friendly information database is possible. The database should include: (1) large amounts of textual information, (2) numerous images, (3) audio of correctly pronounced common and scientific names and terms, and (4) mechanisms to locate information quickly.

This program would be useful to: (1) high school and college students enrolled in plant science courses, (2) high school and college instructors who need supplemental information, (3) foresters who use silvics information for land management, (4) arborists, landscapers, and nurserymen who grow and maintain urban trees, and (5) the general public who may want to learn more about southeastern trees. Furthermore, the information should be available anywhere in the world where access to computers exists.
PROJECT GOAL

This project has one goal, to make finding information about southeastern pines easier.

PROJECT OBJECTIVES

This project had two objectives:

(1) to develop an information-rich computer database for southeastern pines, and
(2) to develop user-friendly pathways to access this information.

METHODS AND MATERIALS

To make information easily available, the database was programmed to distribute information via the World Wide Web (WWW) using Netscape 3.0. The word “database” refers to all information available to users. Hyper-text markup language (HTML), a programming language for WWW pages, allows linkage between different information pages. The graphical user interface (GUI) was created on Macintosh and UNIX computer platforms, and the database information was placed in computer project lockers maintained by the NCSU Computing Center.

For database content, key botanical components of eleven southeastern pine species were included: (1) gross morphology of each species, including bark, buds, leaves, and reproductive structures; (2) habitat, including geographic range, climate, and soils; and (3) natural history, including common names, human commercial uses, wildlife uses.
Data on morphological characteristics were researched from Burns and Honkala (1990), Harlow et al. (1996), Krussman (1985), Kurz and Godfrey (1962), Lakela and Wunderlin (1980), Radford et al. (1968), and Vidakovic (1991). Habitat descriptions were compiled from Burns and Honkala (1990), Dorman (1976), and McWilliams, et al. (1986). Range maps from non-copyrighted government publications, (Burns and Honkala, 1990; Little, 1971) were directly scanned into the database using a La Cie Silverscan II flatbed scanner. Natural history information was gathered from Burns and Honkala (1990), Kurz and Godfrey (1962), Ledig and Little (1979), Lewis (1973), McWilliams et al. (1986), Mollenhauer (1939), Peterson (1980), Wacker (1979), Wahlenberg (1946), and Zobel (1969). Sources for the glossary included Harlow et al. (1996), Harris and Harris (1994), Little and Jones (1980), and Radford et al. (1968).

Information and images for pine trees were gathered and structured uniformly for five pages of cross-linked data including: (1) title page, (2) bark page, (3) buds and leaves page, (4) habitat and range page, and (5) reproductive structures page. Supplemental information pages such as a glossary and bibliography were cross-linked to relevant pages within the program. This structured format allows easy access to information as well as future additions of different tree species.

To explore the capabilities of hypermedia programming, several technical enhancements were incorporated into the database infrastructure. Using the programming language PERL, a random-access generator was created to randomly load one of 4 different images of longleaf pine each time this species was accessed. A search engine, programmed using PERL, served as a comparison tool for the database. This engine
worked by displaying an interface which allows users to compare and contrast information on 2 different tree species, choosing different characteristics including: (1) bark, (2) buds and leaves, and (3) reproductive structures. Results produced textual information and side-by-side images of both species. Each image was also linked to its respective title page so users can quickly access more detailed information.

Using a Canon EOS Rebel XS camera and Kodachrome 64 slide film, numerous color photographs of each pine tree, including bark, leaves, branches, and reproductive structures, were taken in either natural settings or arboreta. Selected objects were set against a black backdrop with a ruler for scale.

Images were digitally scanned into the computer, either in JPEG or GIF format using a Kodak RFS 2035 film scanner, then transferred to the database where each was linked to the appropriate Web page. Range maps and hand-drawn images were scanned using the flatbed scanner. All images were edited and enhanced using Photoshop 3.0 on Macintosh computers and transferred to the locker via Fetch, a Macintosh program for transferring files via File Transfer Protocol on networked computers. Using a computer sound recorder, the scientific name and the most common vernacular name of each tree were recorded and stored as computer sound files. These files were linked to names on each title page, and would be pronounced each time users clicked on the highlighted name.

Additional tree information pages were created and linked to different pages throughout the database. A glossary of botanical terms used in the program was created and linked to most database pages. Each title page contained a link to a bibliographic page. A general diagram of various pine tree characteristics was created and linked to the
starting page. Lastly, a naval stores page and a grass stage page were linked to pine species possessing these characteristics.

**RESULTS**

The resulting database is a World Wide Web computer linked database, structured in a taxonomic classification of the 11 pines native to southeastern North America. The first classification divides the trees into three sub-generic subsections recognized by Little and Critchfield (1969). Each subsection is subsequently linked to the appropriate pine species page.

The database used 24.8 MB of memory and contained 122 GIF and JPEG images. Table 1 provides an example of the HTML programming used for the shortleaf pine title Web page. Seventy-seven HTML pages similar to the one in Table 1 were created. At present, the Web site is located in computer project lockers maintained by the NCSU Computing Center and has the following Web site address or Uniform Resource Locator (URL): http://www2.ncsu.edu/unity/lockers/project/dendrology/
Table 1. HTML programming for shortleaf pine title page

```html
<html>
<head>
<title>Eastern White Pine</title>
</head>
<body>
<h1>Eastern White Pine</h1>
<h3>Pinus strobus</h3>
<body>
<h3>Tree Characteristics</h3>
<ul>
<li>Height at maturity: Typical: 25 to 33 m (80 to 100 ft) Maximum: 48.2 m (158 ft)</li>
<li>Diameter at breast height at maturity: Typical: 90 to 120 cm (36 to 48 in) Maximum: 170 cm (68 in)</li>
<li>Crown shape: Broadly conical with open spaces between branches, producing a layered appearance.</li>
<li>Stem form: Excurrent</li>
<li>Branching habit: Horizontally spreading; one tight spiral formed each year along the main bole (uninodal). Thus tree age may be estimated by counting the spirals.</li>
</ul>
Eastern white pine is the only naturally occurring white pine tree in eastern North America. Of the pines in the United States, this tree is second only in size to sugar pine (Pinus lambertiana) which occurs on the west coast. Considered a long lived tree, this pine commonly lives to 200 years of age, and selected individuals may live to 450 years.

Human uses: Furniture, interior trim, window framing, shelving, and Christmas trees. Also grown for landscaping and stabilization of strip-mine spoils.

Animal uses: Songbirds, such as the yellow-bellied sapsucker (Sphyrapicus varius), pine warbler (Dendroica pinus), and red crossbill (Loxia curvirostra), eat the seeds. A few mammals like the beaver (Castor canadensis), porcupine (Erethizon dorsatum), white-tailed deer (Odocoileus virginianus), and snowshoe hare (Lepus americanus) may also consume seeds, bark and foliage. Favorite tree for bald eagle (Haliaeetus leucocephalus) nests.

<table>
<thead>
<tr>
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<tbody>
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</tr>
<tr>
<td>&lt;TD&gt; &lt;A href=&quot;http://www.cgibin.ncsu.edu/dendrology-bin/compare.pl&quot;&gt;Interactive Comparison Tool&lt;/A&gt;&lt;/TD&gt;</td>
</tr>
</tbody>
</table>
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The following is a printout of the database Web pages, with the following exceptions. Highlighted links cannot be activated and shown on paper, and are therefore not included. Interactive comparison tool results are also not provided because the large number of possible comparisons made printing impractical.

All database pages have been printed in the order that they appear in the program, but the following concessions were necessary. Page numbers have been added to the hard copy to assist in locating material, but no page numbers appear in the computer program. Although a single information page may contain large amounts of data, in World Wide Web format it is treated as one page, and must be scrolled on the computer screen. Therefore, the printout may appear to have disjointed page breaks, which are not present in the actual database.