Volume 13 (1) March 2004

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LIMNOLOGY AND OCEANOGRAPHY
BULLETIN

Published by the American Society of Limnology and Oceanography

A VIRTUAL INSTRUMENT METAPHOR FOR OBJECT IDENTIFICATION: AN EXAMPLE APPLICATION USING TOXIC DIATOMS

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We have developed a teaching tool based on a virtual instrument metaphor. This software compiles information and assists in reaching a conclusion by the process of logical deduction. Human short-term memory can normally identify and sort between 5 and 9 items simultaneously (Evans 1987). Since the combination of characteristics in our relatively simple example already exceeds this capacity, a program such as presented here can provide significant external assistance in performing such tasks. The conceptual ground for the virtual instrument presented here is a dynamic truth table that responds to input provided by the student about their unknown specimen. Software tools, such as the specific example described here, simplify tasks relying on manipulation of multiple sets of data prior to making a decision or diagnosis.

Identification of any unfamiliar object can be a challenging exercise. In ecology, this difficulty is largely due to the ever-present variability and diversity that is the foundation of evolution. The process of identification through morphology is frequently made even more difficult by multilingual classical literature and identification keys. This is particularly frustrating for students working on projects where taxonomy is not the primary focus, but nevertheless an essential step in the research process. Professionals have written this large body of knowledge primarily with the intended audience being peers with equal proficiency in the subject. Overly expert terminology and inclusion of non-quantifiable, descriptive characteristics can be a significant stumbling block to less experienced practitioners. It is difficult for a student to proceed with confidence through such keys and mistakes made at one point can lead to blind alleys that are difficult to backtrack through once the error is discovered. Key characteristics needed to make correct decisions at many important junctures often are not included in the same source. It should not therefore be surprising that university students quickly lose interest in pursuing identification tasks (e.g., species, minerals, symptoms) by using traditional methods. All these factors undoubtedly contribute to the ever-declining use of previously accumulated knowledge, even when there is an urgent need and a practical application for this knowledge by a broader audience.

In our teaching experience, we have repeatedly seen that the current generation of students feels more comfortable using an instrument than navigating through a variety of printed sources. Therefore, we constructed a "virtual instrument" called *Pseudo-nitzschia-lator* that explores the applicability of this concept as a teaching tool to identify objects with quantifiable characteristics. We chose a well-circumscribed group of diatoms from the genus *Pseudo-nitzschia* that are of economic significance (some produce toxins), to build a prototype instrument using scanning electron microscope (SEM)-based characters available for direct observation and quantification. We used this data set because it was readily available to us and routinely used in our marine biology classes, but the concept demonstrated here would apply to any set of quantifiable characteristics in fields such as pathology, biostratigraphy and mineralogy. In these cases as well, all that is required is the collection of features (or extraction of these features from the classical literature) that unambiguously partition the range of variation present in the set of objects requiring identification.

The partitioned data set is integrated into a dynamic truth table that the student can manipulate as a virtual instrument. The software automatically updates the table as characteristics are entered for the unknown. In our specific example, when the unknown characteristics fall within the bounds for a particular species, the likelihood of a correct identification is indicated by a color change in the name of that species. The student is thus

The Limnology and Oceanography
Bulletin

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The *L&O Bulletin* is published quarterly by the American Society of Limnology and Oceanography, 5400 Bosque Blvd., Suite 680, Waco, TX 76710 USA. Postage paid at Waco, Texas. POSTMASTER: Send address changes to ASLO Business Office, 5400 Bosque Blvd., Suite 680, Waco, TX 76710 USA.

Subscription price to regular members is included in annual dues. Information on institutional subscriptions is available upon request from the ASLO Business Office.

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freed from manually or mentally keeping these taxonomic characteristics updated while engaging in deductive elimination leading to identification.

The logic of this program is relatively straightforward; in fact, prototype versions were implemented in a spreadsheet. We found through informal testing, however, that a visually interactive application can be more intuitively manipulated, less intimidating and more comprehensible to the current generation of students. The advent of fourth-generation software development tools and visual component libraries makes construction of such virtual instruments a rapid process with very little "real" programming involved. Despite our initial perception that similar tool development is ubiquitous, we were surprised by their scarcity.

PROGRAM CONSTRUCTION AND OPERATION

The Microsoft® Windows®-based program was constructed using Borland Delphi Studio version 11 (Borland Software Corp., Scotts Valley, CA) and the Abakus Visual Component Library (VCL) version 2.5 (Baecker Software, Goldbach, Germany). The Abakus VCL provided knobs, switches, numeric indicators, light emitting diode (LED) indicators and meters that make up the bulk of the user interface (Figure 1). These object-oriented components are ready to use and can be easily interconnected so that, for example, a certain range of values entered by the user through manipulation of a knob or switch causes an LED to change color or a meter to indicate the entered value (Figure 1).

The first step in constructing a specific application involved a search of the literature and compilation of reported diagnostic features from voluminous classical taxonomic literature. We rejected descriptive properties in favor of unambiguous characters that can be reliably measured, counted, or determined to be present or absent. Boundary testing was conducted by pairwise object (here species) comparisons of minima and maxima for a given feature to eliminate those that were not useful in the process of discrimination. We concluded that seven features were the minimum necessary to reliably partition the eight species in all but a few pathological cases.

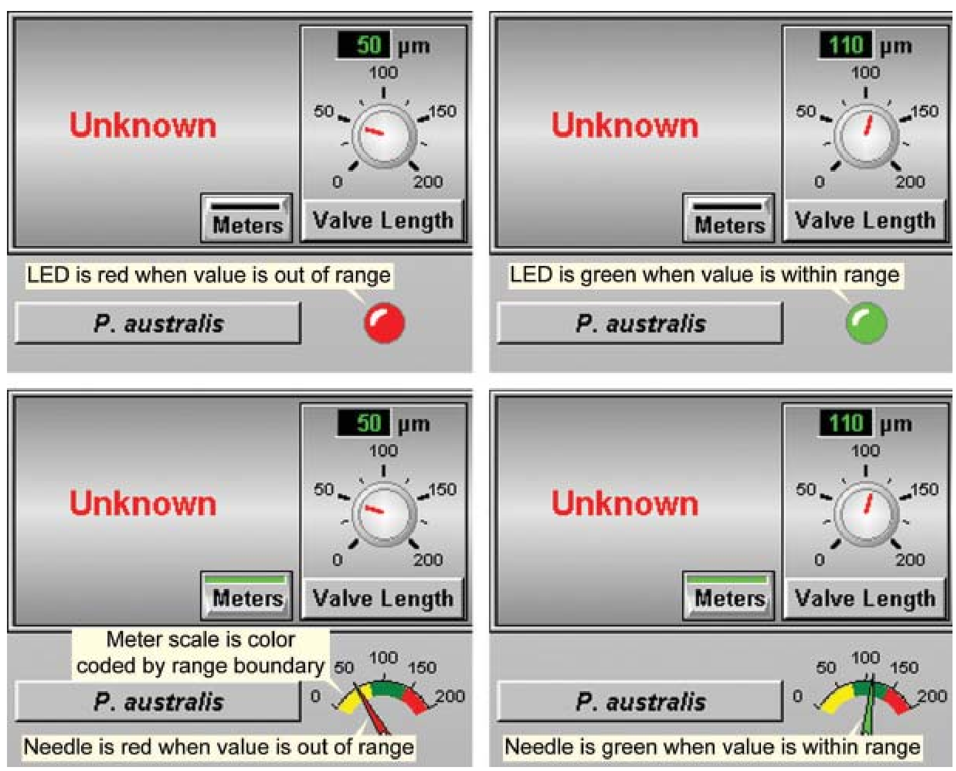

Figure 1. LED Mode (top) provides a Yes/No indication of a match between the unknown and a candidate species. Meter Mode (bottom) provides more information when necessary.

Values for characteristics of the unknown are entered by manipulation of the knobs and switches at the top of the application window. When the value for a characteristic falls within the bounds specified for a particular species, the corresponding indicator is automatically updated to indicate this condition. In LED Mode (Figure 1, Top), the student is provided with an uncluttered Yes/No or True/False indication of matches. The selection of Meter Mode (Figure 1, Bottom) gives more exact information for numeric measurements by providing a virtual analog meter that indicates where the entered value falls within the bounds for that particular species and characteristic. The Meter Mode is particularly useful when examining the goodness-of-fit for borderline or atypical cases. When the student has entered all of the characteristics for the unknown, and the values fall within the limits and conditions that satisfy a particular candidate species, that species name changes color to indicate a possible match (Figure 2).

The limited amount of specialized terminology used in the application (striae, fibulae, poroids, interspace) is defined and exemplified visually. The student receives help with recognizing and determining the values of characteristics by clicking the button bearing the characteristic label below each virtual control (Figure 3). Similarly, buttons bearing species names access reference images for further verification.

ASSESSMENT

Our feedback from trial use of *Pseudo-nitzschia-lator* by both novices and experts in the field indicates that such applications provide the user with a more straightforward decision making process when compared to traditional methods. In the teaching laboratory it frees the instructor from hours spent individually tutoring students on how to navigate a dichotomous key. Current students quickly grasp the use of this "virtual instrument". We discovered that a brief presentation of generic diagnostic characteristics (size,

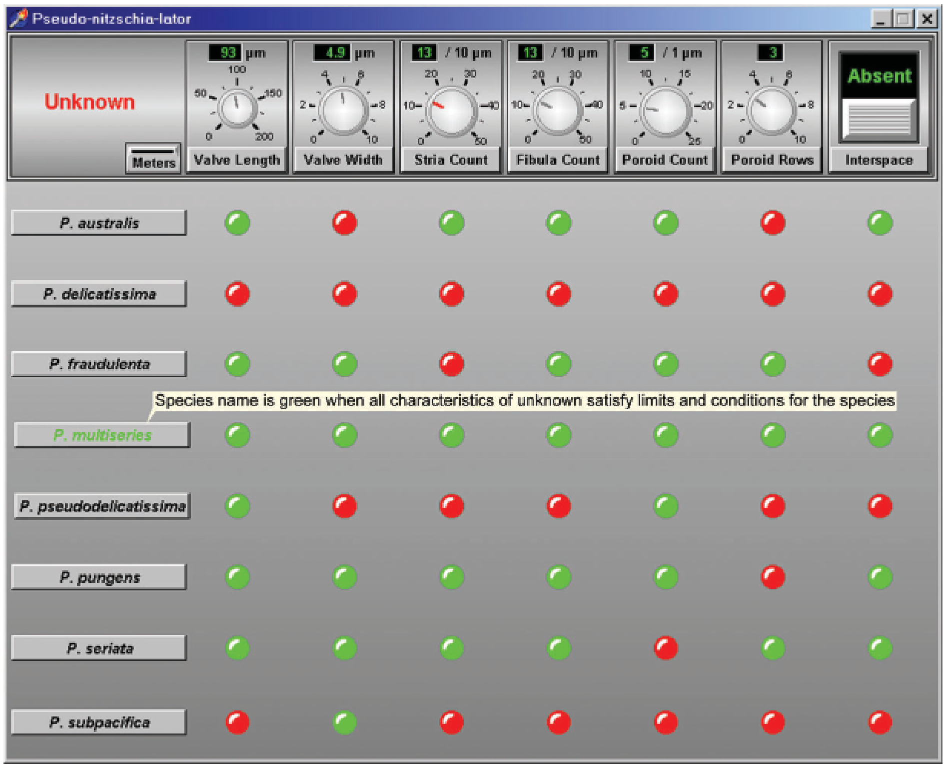

Figure 2. When values entered for an unknown satisfy the limits and conditions for a candidate species, that species name turns green to indicate a possible match.

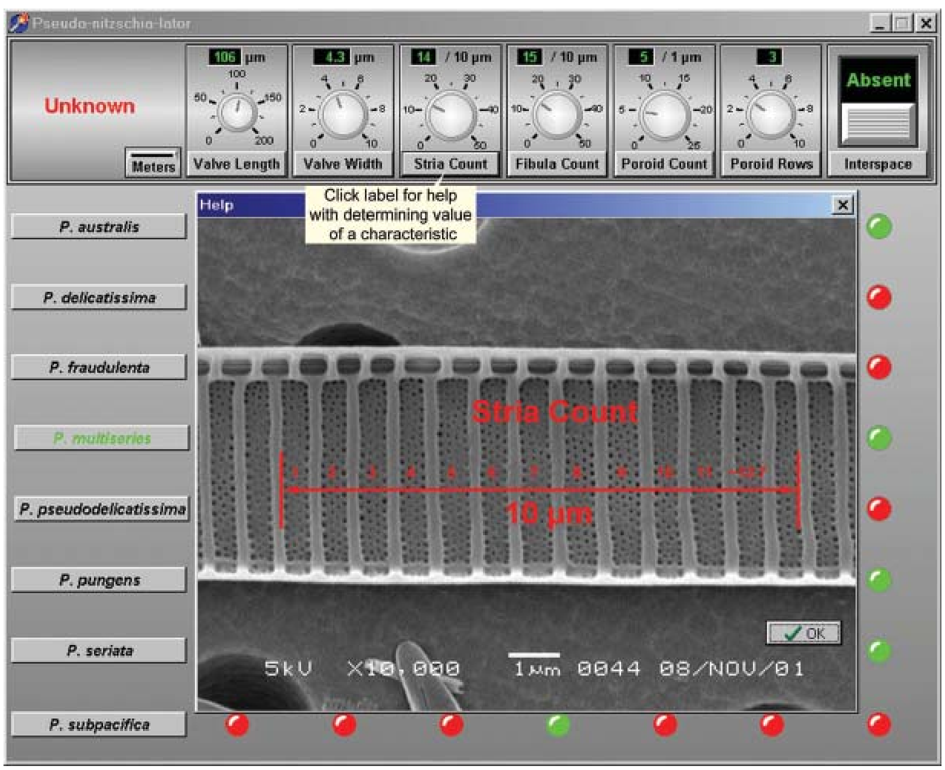

Figure 3. By clicking the button bearing the characteristic label, the user is presented with visual help on the characteristic and how it is measured or counted. Buttons bearing species names similarly present representative images for that species.

shape) in combination with *Pseudo-nitzschia-lator* allows a class of students to correctly identify these species faster and with less difficulty. It also facilitates excellent consistency between groups of students.

In our practice, this tool liberated laboratory time that we now use for teaching and practicing species based aspects of community ecology and for population biology studies in plankton rather than for plankton taxonomy. Autoecology and community studies carry a great attraction for students who seem to be forever interested in how other living beings function in their environment. However, this interest quickly evaporates if, before they can study the biota, they have to endure hours of training in taxonomy to ensure that they study the same entity. From the instructor's side of the classroom, this tool provides a refreshing alternative to student frustration with identification before getting to the interesting material on which these skills depend. We also hope that students exposed to taxonomy in this manner will develop a greater appreciation for the field and be more willing to deal with the intricacies of dichotomous keys when taxonomy is the primary focus of study.

While our application uses SEM-based morphometrics, the concept of a dynamically updated truth table could be adapted for virtually any classification context (environmental quality assessment, forensic diagnosis, laboratory protocol selection, etc.). Software tools such as described here can aid in de-mystifying expertise of object recognition, reduce time and effort spent on identifying objects, improve consistency of identification and limit the need for subjective individual judgments. A recent report by Culverhouse et al. (2003) brings attention to the need for practical, globally applicable tools that aid in maintaining long-term self- and mutually-consistent species identification in research and monitoring laboratories (e.g., invasive parasites, toxic forms), but other similar applications abound. However, skills need to be taught, first!

The use of fourth-generation computer software development packages and reusable visual component libraries makes construction of applications such as *Pseudo-nitzschia-lator* relatively easy for individuals with even rudimentary programming experience. Our goal is to make this process even easier and with broader application through the development of a general-purpose toolkit (i.e., software with user configurable rows and columns). The present demonstration of this concept, *Pseudo-nitzschia-lator*, is available as a free download at: http://www.mta.ca/dmf/psnul8r.htm.

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SOFTWARE INSTALLATION

Pseudo-nitzschia-lator will run on any PC-compatible computer with Windows 95 or above. A screen resolution of 1024 x 768 or higher is recommended so that the whole interface can be viewed without scrolling. A 16-bit (High Color) setting or higher is also recommended to prevent dithering of the user interface.

The program does not add or modify files anywhere except those in its own folder, and does not modify the Windows registry. To uninstall the program, simply delete the folder where it was installed.

The file "installpsn.exe" is available at http://www.mta.ca/dmf/psnul8r.htm. This is a self-extracting archive that will unpack all files necessary for *Pseudo-nitzschia-lator*. Installation is performed as outlined below:

1. Place the file in its own folder (folder name is unimportant). Double-click the file to launch the self-extracting utility.
2. A dialog box will appear giving the option of placing the extracted files into any folder, with the current directory as default. Accept the default directory or make changes as desired and click "Start". A message will be displayed when all files have been extracted. Click OK.
3. The file "installpsn.exe" can now be deleted if desired.
4. Double-click the file "psnul8rv5.exe" to run the program. A shortcut to the program can be created and placed on the desktop, Start Menu or elsewhere in the usual manner.