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ABSTRACT

Many students find climate classification laborious and time-consuming, and through their lack of repetition fail to grasp the details of classification. This paper describes an expert system for climate classification that is being developed at Middle Tennessee State University. Topics include: (1) an introduction to the nature of classification, Koppen's classification system, and climographs; (2) the advantages and disadvantages of computer-based classification; (3) the rationale for using the C programming language and a DOS-based program; (4) the program design, the modules of software development, and future interface and graphics enhancements; (5) the use of the expert system in both classroom and independent instruction and the project evaluation. Three figures depict: flowcharts for Koppen classification system; a summary of climate subcategories and climate codes within the Koppen system; and a sample climograph. (AEF)

# Prototype Expert System for Climate Classification

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**Abstract**

Many students find climate classification laborious and time-consuming, and so fail to grasp the details of classification due to lack of repetition. The author is developing software for climate classification in the C programming language. Using an expert system, students can more easily classify large numbers of data sets and so learn both the logic and method of Koppen's climate classification system through repetition. Custom-designed software can also help students learn other classifications and similar activities. Reluctant students may overcome computer "phobias" while using this simple program and be coaxed into using computers for other activities as well.

## Introduction

An expert system is a rule-based software program that can be used for decision making. Scientific classifications are typically rule based and so are appropriate for use in expert systems. Several expert systems for mineral classification are available for use on personal computers (e.g., Diemer, et al., 1989; Donahoe, et al., 1989; Hart and Newmarch, 1988). This paper describes the characteristics of an expert system for climate classification that is currently being developed.

Nature of classification: The expert system described herein is based on an empiric classification. Empiric classification uses physical traits of the subject rather than information about its origins; it is a "what" classification rather than a "why." Empiric classifications are particularly appropriate for use in an expert system because they usually are based on presence or absence of characteristics, or abundance of components. This makes them easy to convert to a computer program.

Climate, Koppen's classification system, and climographs: Climates and climate classification are an integral part of meteorology, the study of weather. One of the earliest climate classifications, developed by the ancient Greeks, was based on temperature. This system divided the Earth into just three climate zones: torrid, temperate, and frigid. Modern empiric climate classifications take into account both temperature and precipitation patterns and so recognize many more climate categories. Numerous climate classification systems have been developed; however, the most widely used system was developed by Vladimir Koppen during the first half of this century.

In the Koppen system (Fig. 1a-b), geographic localities are assigned climate sub-categories (for example, humid subtropical, Cfa; Fig. 2) based on their monthly and annual precipitation and temperature averages. The boundaries between the individual climate categories loosely correspond to global vegetation distribution. For example, the division between polar (E) and microthermal (D) climates is a mean monthly temperature of 10°C or 50°F (Fig.1a), the temperature below which trees do not flourish. Koppen's classification is a useful tool for learning about the nature of climates and climate distribution, as well as climate classification. Both the process and the product of classification are important. That is why methodical, repetitious use of the classification is crucial. Climographs (Fig. 3), standard-format graphs of precipitation and temperature data, also help students visualize the general trends and relationships in the climatic data they classify.

## Computer-based classification

Advantages of computer classification: A computer program designed specifically for climate classification should prove very helpful for learning the Koppen classification system. As students use the program, the methodology of classification will be presented and subsequently reinforced. Having the computer ask the user a series of questions relieves the tedium of

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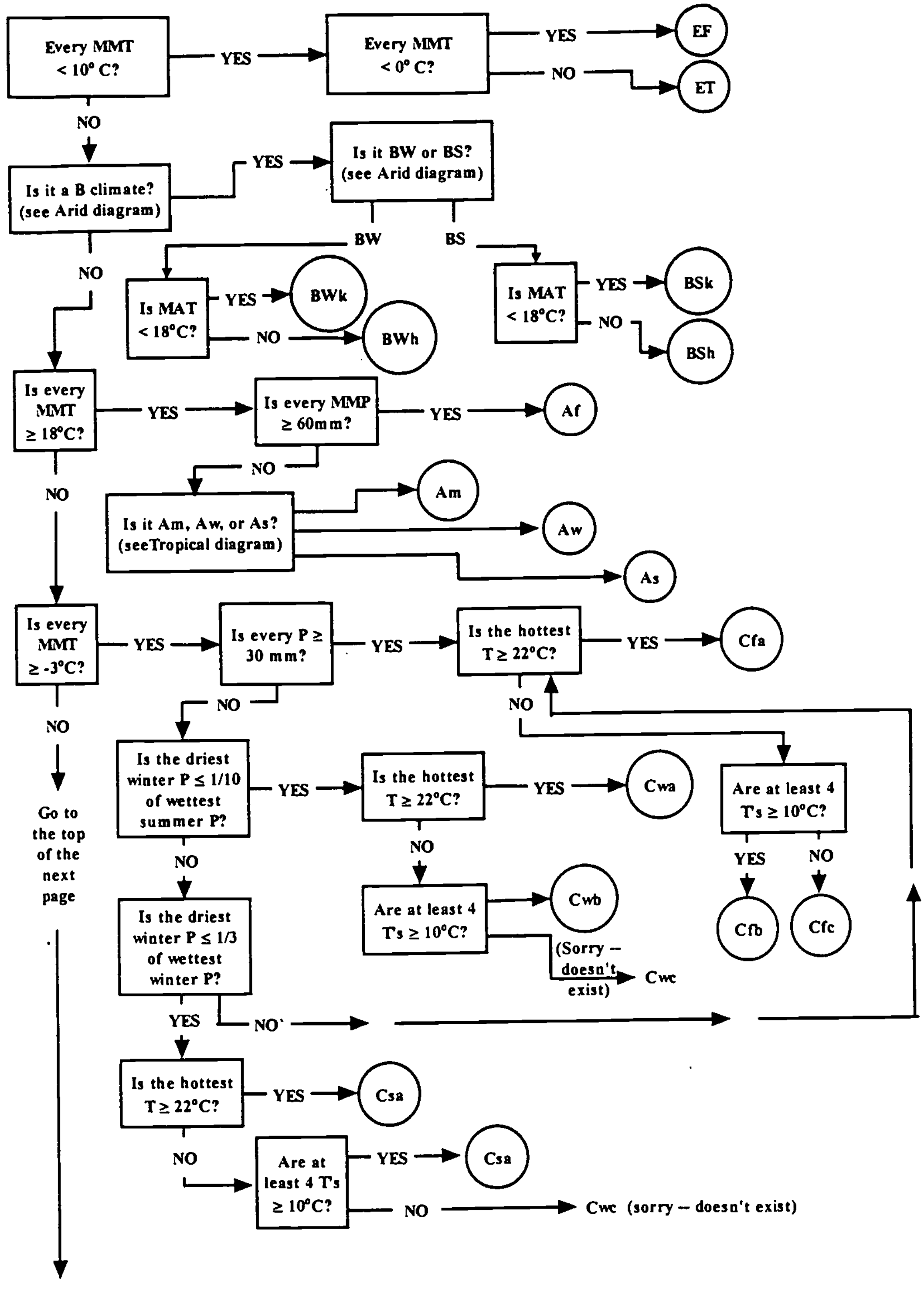


Figure 1a. Flowchart for Koppen climate classification system, climates A, B, C and E. T = temperature, P = precipitation, MMT = mean monthly temp., MAT = mean annual temp., MAP = mean annual precipitation, MMP = mean monthly precipitation. See Figure 2 for other codes. (Modified from Suckling and Doyon, 1991, p. 148)

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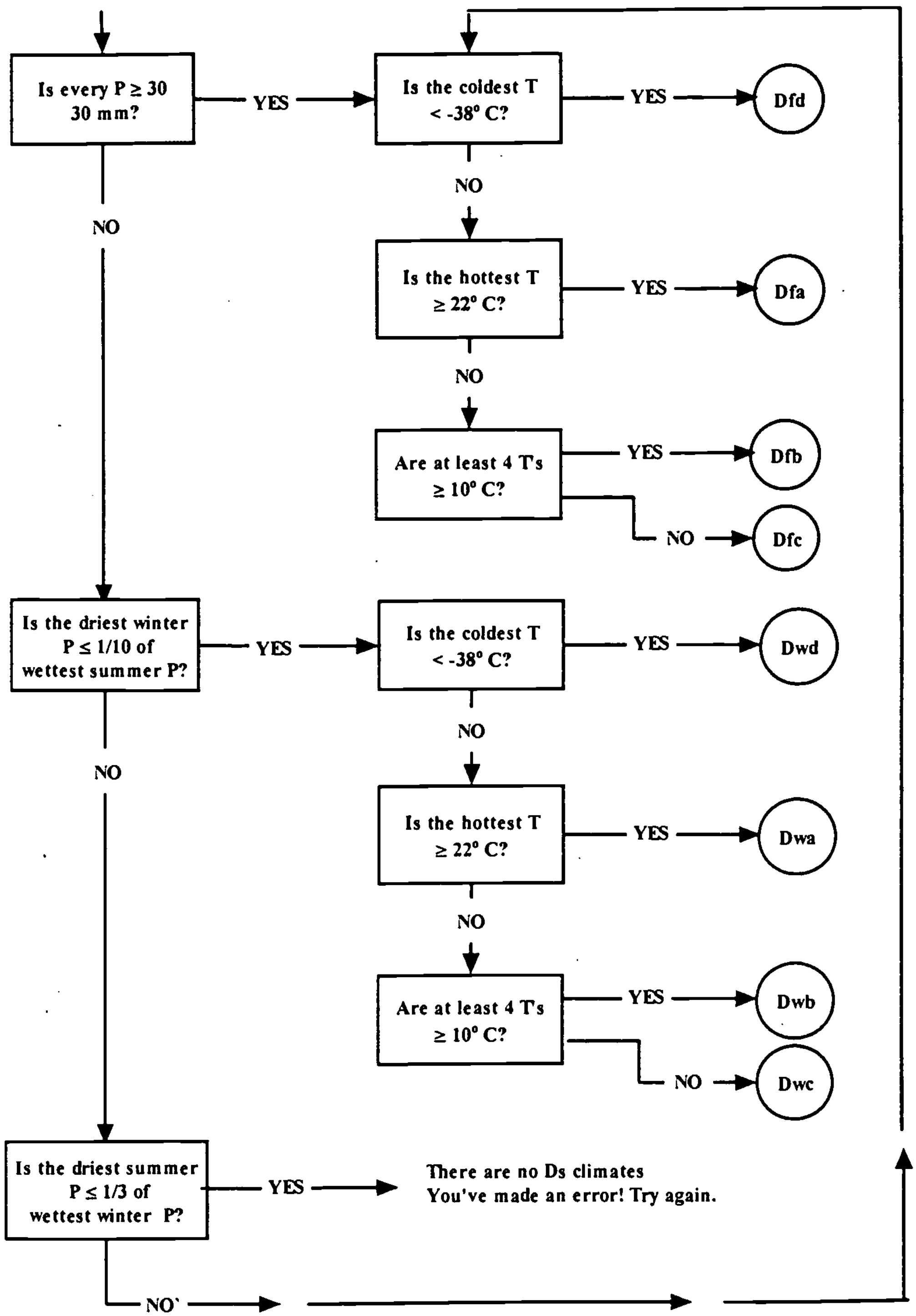
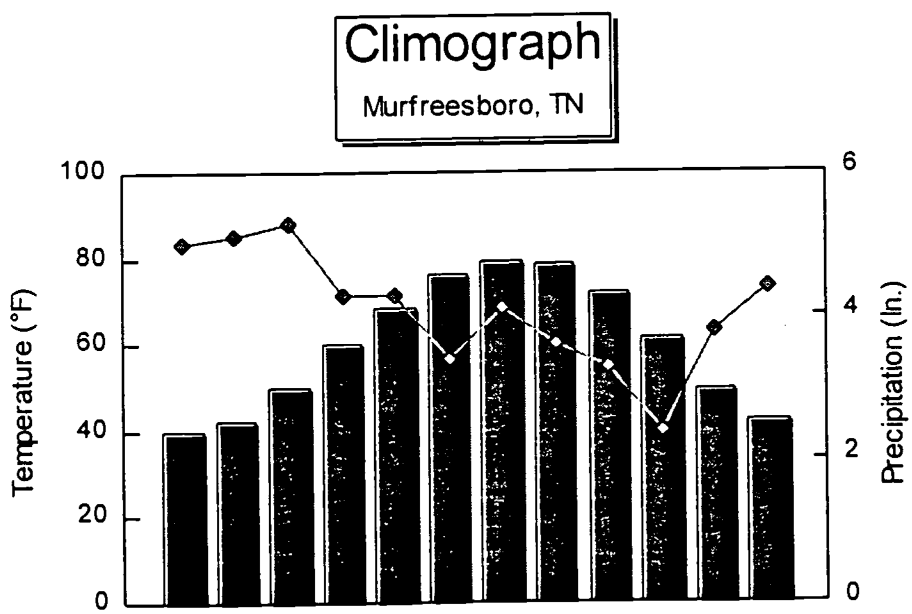



Figure 1b. Flowchart for Koppen climate classification system, D climates. (Modified from Suckling and Doyon, 1991, p. 149)

| Climate categories | Codes and sub-categories | Climate categories | Codes and sub-categories |
|---|---|---|---|
| Tropical (A) | Af - Tropical rain forest | Mesothermal (C) | Csa, Csb - Mediterranean |
| | Am - Tropical monsoon | | Cwa, Cwb - Subtropical monsoon |
| | Aw - Tropical savanna | | Cfa - Humid, subtropical |
| Arid/Semi-arid (B) | BW - Desert | | Cfb, Cfc - Marine West Coast |
| | BS - Steppe | Microthermal (D) | Dfa, Dfb, Dwa, Dwb - Humid continental |
| Polar (E) | EF - Ice cap | | Dfc, Dfd, Dwc, Dwd - Subarctic |
| | ET - Tundra | | |

Figure 2. Summary of climate subcategories and climate codes within the Koppen classification system.




| X-Axis | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ■ Temp (°F) | 40 | 43 | 50 | 60 | 69 | 76 | 80 | 79 | 72 | 62 | 50 | 42 |
| ◆ Prcp. (In.) | 5.0 | 5.1 | 5.3 | 4.3 | 4.3 | 3.4 | 4.1 | 3.6 | 3.3 | 2.4 | 3.8 | 4.4 |

Figure 3. Sample climograph based on temperature and precipitation data from Murfreesboro, Tennessee.

classification -- for some it may even be enjoyable -- while allowing the user to better understand the significance of each of the steps required for climate classification. Although the individual steps are rather simple, classification with the Koppen system can appear involved (Figure 1a-b) and the logic of the system often escapes students when they are asked to manually classify sets of climate data. Repetitively classifying climates helps students to better understand the controls on climate and climate distribution as well as the strengths and weaknesses of the Koppen classification system.

With the software providing data handling support, students can focus on the systematics of classification, rather than on logistics such as numerical calculations and formulas. Relieved of this burden, students are more likely to remain attentive and to perform multiple repetitions. Using a computer for classification also allows students to recognize that computers are useful for repetitive tasks, and are an especially powerful tool when used as an expert system. Providing screen and printed output in the form of climographs should help students to visualize climate data and climatic relationships.

For some students this may be their first exposure to computers. Computer-illiterate students will use the computer in a very controlled environment, helping to minimize the potential for intimidation. This program may allow reluctant students to overcome their computer-related anxieties and coax them into the use of computers for other types of projects. The computer illiterate student is one of my main motivations for developing this software. College students who choose to remain computer-illiterate are, I believe, doing themselves a grave disservice. I consider my classes an opportunity to expose computer- illiterate students to computers in a low stress setting with minimal demands. Use of a software program in a general studies science course may be a computer-illiterate student's last opportunity for exposure to computers before entering the job market.

Pitfalls of computer classification: The major shortcoming of computer-assisted classification is really no different than that for manual classification: an unmotivated student can easily work through the program, ignoring the information presented, and quickly finish the assignment. However, due to the ease of use of the software as compared to manual classification, the student is perhaps more likely to perform the assignment and learn about the methodology involved.

Another possible problem is that of "computer-phobic" students refusing to use the software. The instructor can avoid this problem in two ways. First, either develop or obtain software that is very easy to use. As discussed below, that is one of the main reasons I choose to develop my own software using the C programming language. By doing so, I gain control over the nature and operation of the user interface. Second, provide students with ample instruction in the use of the program and opportunities to explore it in your presence. These two steps should alleviate most, if not all, of the difficulty in getting "computer-phobic" students to participate in computer-assisted assignments.

Rationale for the C programming language and a DOS-based program: The expert system discussed here is being developed using the C programming language. In addition, I am using a C function library of user-interface tools that aid in development of a "windowed" user interface with pull-down menus, pop-up help screens, data entry windows, etc.

Using the C programming language to develop this software rather than a programmable database or spreadsheet program, can be justified in several ways. These include:

- substantially less computer knowledge required on the part of students
- minimal system requirements -- runs on virtually any PC-compatible computer
- requires no other software packages for operation -- no risk of violating software licenses, or problems with students being dependent on software availability in campus computer labs
- easily converted to other computer platforms (e.g. UNIX) due to the popularity of the C programming language

The software will be appropriate for use on virtually any PC-compatible computer with a 5-1/4" or 3-1/2" disk drive, 640K of memory and graphics capability. Although it might be easier to program for the Microsoft® Windows™ operating system/graphical user interface, I am intentionally avoiding Windows because of its less widespread presence in the computing world and its more complex operating environment. While arguments can be made concerning the ease of use of Windows, DOS-based programs are easier to set up so that the user has no interaction with the operating system. In the case of MS-Windows, it is difficult, if not impossible, to eliminate the need for knowledge concerning how to open and close windows, start up programs, choose drives, etc.

## Program design, development and capabilities

Program design: This software is designed to perform the following tasks:

- accept climatic data input by the user;
- classify climates based on data input;
- interactively indicate procedures used for classification;
- output tabular data summaries and climographs to the screen;
- save data sets to disk for later use;
- print out data, graphs, and climatic summaries for each data set.

The user interface is "window" based. Error-checking routines test for invalid data and key strokes and advise the user accordingly. Help screens are available throughout.

Software development: Anyone who has undertaken a large computer programming project recognizes that it is time-consuming. Thorough planning is the key to success. Time spent in the planning stages will pay off later with time savings by avoiding pitfalls and false starts. The program should be developed as a series of independent modules. A modular approach makes software development and debugging more manageable. A modular approach also makes later additions of program enhancements easier, and less "buggy."

The modules should closely correspond to the program's main facilities and functions. The modules are as follows:

- user interface
- climate classification algorithms
- data input
- tabular output
- graphic output
- interactive input/output
- disk input/output
- printer output

The initial stages of program development involve either writing "pseudocode" -- a simplified, English-language version of the actual C code -- or constructing flow charts of the program logic. This allows rapid development of the basic organization and logic of the overall program. Figures 1a and 1b represent at least part of logic necessary for development of the climate classification algorithms.

After developing the program's logic and structure, the programmer writes and debugs the actual C language routines for the individual modules. Next, the modules must be integrated, and debugged again. Finally, the program is extensively tested for any memory conflicts, hidden bugs, or other problems. Depending on the skill level of the programmer, development time per module may be ten to twenty hours or more. If the developer uses one of the more recently developed MicroSoft Windows™-based development packages (e.g. Microsoft's Visual Basic™), development times should be somewhat shorter, but there is a corresponding loss of control over the user interface and operating environment.

Future enhancements: After the program is fully functional and has been used enough by students to work out any hidden bugs, I hope to add a mouse-driven interface. The use of a mouse in the data entry portion of the program is superfluous as the key strokes are simple and consist mostly of typing data with a few simple menu choices. However, a mouse-driven interface will enable me to add another, very significant enhancement to the program: a world map illustrating climate distribution. After clicking on a particular climatic region, the user will be shown a descriptive summary of the region's climate and a synopsis of the mechanisms responsible for its existence.

## Pedagogic approach

Classroom and independent instruction: I envision this expert system being used by both the instructor and students. Using the software in a computer laboratory on campus, the instructor could present the concepts of climate classification and climographs, and explain the Koppen classification system in detail. Students would then be shown how to use the Koppen system to classify a variety of world climates. While in class, the instructor could assign each student two or three data sets for in-class, manual classification. After students complete this task, the instructor might review the mechanics of climate classification by manually classifying the assigned data sets.

After students begin to grasp the nature of classification with the Koppen system, they could receive a copy of the software as well as instruction in its use. The instructor would then assign about twenty data sets for classification, either in class or at home, using the expert system.

Before performing each step in the classification, the user can receive instructions concerning either software operation or the logistic of the current classification step using the integrated help screens. After completing a step, students can either proceed to the next step, or review the completed step. With this approach, the novice user can receive interactive help at anytime; however, once proficient, s/he can quickly navigate through the classification procedure.

Project evaluation: After students classify a number of data sets manually and using the expert system, they should be given a written survey to complete. The survey might ask students to discuss how well the software aided their understanding of the classification system, and to rate the ease of use and speed of software-aided classification as compared to manual classification. Students might also be asked to write a short narrative expressing their overall opinion of the software, for example, whether they enjoyed using it, what they would do differently, whether it was fun, easy, visually interesting, etc. Feedback from the students could be used to make improvements to the program, if necessary, as well as to isolate and correct any software "bugs."

## Conclusions

Using this software, all students should experience an increase in their understanding of climates and climate classification. Software-driven classification provides multi-media instruction when combined with lecture, visual aids, assigned readings, and manual classification. A multi-media approach should better serve the range of student needs in terms of learning strategies, and reduce the likelihood of students becoming bored or failing to grasp the methodology of climate classification.

Software development with the C programming language provides programmers with both flexibility and control in developing the user interface, and with great potential for portability to other computer platforms.

Based on the author's experiences using other types of software in the classroom, instructors should anticipate a range of responses from students using this expert system. Nearly all computer-literate students should find it easy to use and helpful in learning the Koppen climate classification system. Initially, students who are not familiar with computers may be somewhat intimidated by the software. Instructors should offer "computer-phobic" students ample opportunity to become comfortable with the computer and the software program before students begin the computer-aided part of the assignment on their own.

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