PROBE: A PROGRAM TO FACILITATE USER-FRIENDLY GAMING WITH FORCYTE.

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The computer code for FORCYTE-11, a large ecosystem simulation model which was developed for a mainframe computing environment, has been successfully installed on a personal computer employing 32-bit coprocessor technology. A supervisory software package, PROBE, was developed to exploit the user-friendly nature of the PC environment.

Le code machine pour FORCYTE-11, modèle de simulation des écosystèmes élaboré pour un gros ordinateur, a pu être exécuté sur un ordinateur personnel utilisant une technologie de cotraitement de 32 bits. Un logiciel superviseur, PROBE, a été mis au point pour exploiter la facilité d'utilisation de l'ordinateur personnel.

INTRODUCTION

Sensitivity analysis and management gaming with computer simulation models both require large numbers of runs, often with only small changes being made to the input data sets between runs. Making repeated runs can be tedious, and is usually costly if the simulation model is run on a mainframe computer. Recent developments in micro-computer hardware and software offer a solution to these problems by making possible the transfer of large simulation models to specially configured personal computers.

There are many advantages provided by the micro-computer environment. For example, negligble costs of computer use remove an important financial barrier for users of large simulation models once the initial investment has been made. Widely available PC software, (such as excellent interactive graphics and data manipulation programs) is often superior to that available for mainframe computers. The availability of micro-computers renders large computer models more accessible to potential users. The development opportunities available in such an environment can therefore greatly enhance the accessibilty and usabilty of simulation models.

This paper describes the transfer of FORCYTE-11, a large ecosystem-level computer simulation model (Kimmins and Scoullar, 1987a,b) to a personal computer equipped with a special coprocessor board. A user-friendly software package (PROBE), designed to facilitate the execution and analysis of large numbers of simulation runs, is described. Although developed for use with FORCYTE-11, PROBE consists of several programs which can be easily adapted to other computer simulation models which run in the PC or coprocessor environment.

IMPLEMENTING FORCYTE ON A MICRO-COMPUTER

The ecosystem simulation framework FORCYTE-11 consists of several program modules, each of which performs a different task. The modules are written in FORTRAN-77 and some contain over 6000 lines of program code.

Current personal computer (PC) disk operating system (DOS) limitations on memory addressability have, until recently, necessitated major source code modifications before large mainframe FORTRAN programs could be downloaded to a micro-computer. Recently, 32 bit coprocessor boards have been introduced which remove these limitations and provide "personal mainframe" capabilities with speeds and features approaching those of the VAX-780. The coprocessor board is a self-contained mini computer, complete with its own RAM memory (1-8 Mbytes or more), and occupies a single slot in the host PC (IBM PC/XT/AT or compatible). It uses the I/O and disk filing facilities of the PC, but provides a separate and powerful computing environment which can be operated concurrently or interactively with the PC DOS environment.

The specific system used in the current work is a DEFINICON DSI-32 coprocessor (with 8 Mbytes of RAM) installed in an IBM PC/AT. A fully implemented FORTRAN-77 compiler is available for the DSI system. Using this compiler, only minor changes to the filename declarations were required for error-free compilation of FORCYTE-11

source code downloaded from UBC's AMDAHL 580.

With this configuration, the DSI board provides the computational power needed for running FORCYTE-11, while the PC DOS system is used to handle the user oriented tasks, including interactive graphics, statistical analysis, and data manipulation using spreadsheet programs.

PROBE: A USER-FRIENDLY SOFTWARE PACKAGE

PROBE was originally developed to exploit the user-friendly nature of the DOS environment and to assist in the sensitivity analysis of FORCYTE-11. The first objective was to decrease the time requirements of data entry, and to reduce the risk of data entry errors when changes were made to the FORCYTE input parameters. The second objective was to develop supervisory software which facilitates the setting up, running and interpretation of multiple runs of the model. Such multiple runs are essential both for sensitivity analysis and for management gaming where the predicted results of alternative silvicultural practices and management conditions must be compared and contrasted.

A standardized protocol for the execution of multiple runs and tabulation of their output was incorporated in PROBE to coordinate the comparison of results between several scientists using the same simulation model in different locations.

In the mainframe version of FORCYTE, the preparation of input data files for multiple runs is a very tedious and error prone task. Extensive experience has shown that a frequent source of problems in running the model was accidental deletion or insertion of a character or line in the input data file. Such errors are very hard to detect because input data files may contain several hundred lines of information. PROBE minimizes these errors by acting as a buffer between the user and the input file.

THE STRUCTURE OF PROBE

PROBE is composed of three separate activities: setup, run and analysis.

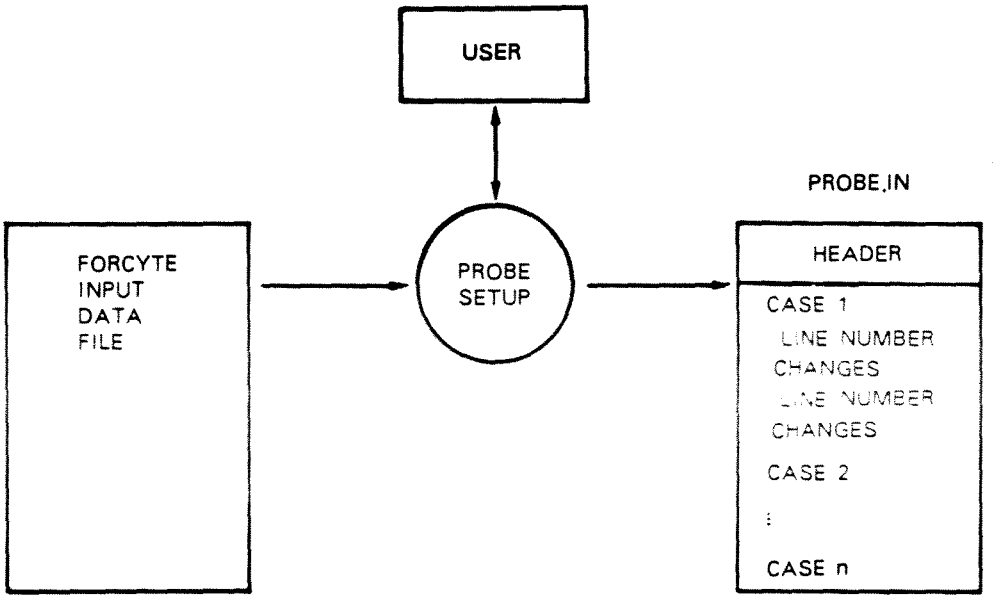

FIGURE 1. The SETUP activity is illustrated. The user employs the interactive program PROBE SETUP to prepare the data file PROBE.IN. This file contains the information required to execute multiple runs of FORCYTE.

The SETUP activity

The user employs an interactive Turbo Pascal program (SETUP, see Figure 1) to prepare the control data file (PROBE.IN). This file contains descriptive header information (which will label the subsequent simulation runs) and the changes which will be made to the FORCYTE input parameters for those runs. Identical in form, separate files can be created for FORECYTE-11's FORSOILS, TREEGROW and FORCAST data modules. After identifying the FORCYTE input data file in which changes are to be made the user selects the lines which will be edited.

A special line editor (which prevents user errors of the type mentioned above) was developed for this program. No changes are made to the original FORCYTE data files during the SETUP process. The assembled PROBE.IN files contain only the instructions for the changes, not multiple copies of the entire input data files.

The run time activity

After completing the SETUP procedure, the user executes the desired set of simulation runs by entering a single DOS command: "PROBE". This invokes a DOS batch file which automatically performs the multiple runs of the FORCYTE modules. PROBE manages a large number of input and output files, executes several programs which operate in both the PC and coprocessor environments, and conducts limited error checking. A diagram of the program flow is shown in Figure 2.

The batch supervisor first calls the Pascal program OVERLAY which transfers the header information to the output file (PROBE.OUT). OVERLAY then retrieves from PROBE.IN the commands and data lines with which to modify the specified FORCYTE input data file for the first case. Appropriate FORCYTE program modules are invoked sequentially on the DSI board, and selected output is transferred to PROBE.OUT. The batch supervisor then returns to OVERLAY to prepare the data input files for the next case. This sequence is repeated until all cases have been run.

The resulting output file, PROBE.OUT has a predetermined structure. It contains both general and run-specific header information, as well as the following output for each FORCYTE module and case:

- selected information about the input data file
- changes made to the input data
- selected FORCYTE dynamic output variables (multiple time steps)
- selected FORCYTE end-of-run output variables (run summaries).

Because only a subset of the standard FORCYTE output is retained in PROBE.OUT, care has been taken to ensure that sufficient information is recorded to completely reproduce the runs. This includes the version and release numbers for each FORCYTE module being used, labels which identify the input data set, and the modifications to the input data. PROBE also archives each PROBE.OUT file and assigns a unique index number to it.

The analysis activity

Two types of output variables are associated with each run of the FORCYTE modules: end-of-run variables (eg. total biomass production, stemwood mean annual increment, financial benefit-cost ratio, etc.) and dynamic variables for which the development over time is of interest (e.g. foliage biomass, nutrient demand and uptake, stand density, etc.). As shown in Figure 2, a single output data file is assembled by PROBE for each collection of runs comprising a simulation experiment. This output file contains selected sets of both types of variable from the standard FORCYTE output, and is organized to provide a quick summary and comparison of the multiple run results. To achieve this, the PROBE.OUT data file is imported directly into a SYMPHONY (LOTUS Develpment Corp.) spreadsheet specially configured for the purpose. With the present protocol, using the IBM PC/AT with 2 Mbytes of RAM, more than 60 runs of FORCYTE-11 can be imported directly into a single SYMPHONY spreadsheet.

The spreadsheet program, performs several tasks which assist in the analysis of the series of runs and users can easily define and establish many more tasks to meet their specific needs. For example, the spreadsheet used in this project is configured to automatically:

- display tables comparing selected end-of-run variables for the different runs,
- construct bar charts to facilitate visual comparison of the ranking and the absolute values of different runs,
- draw X-Y line plots to provide a graphical display of the time trends of dynamic variables produced by the different runs,
- perform predetermined manipulations and calculations (including some statistical analyses) of the raw output using the computational facilities of the spreadsheet program,
- print selected data ranges, tables and graphs.

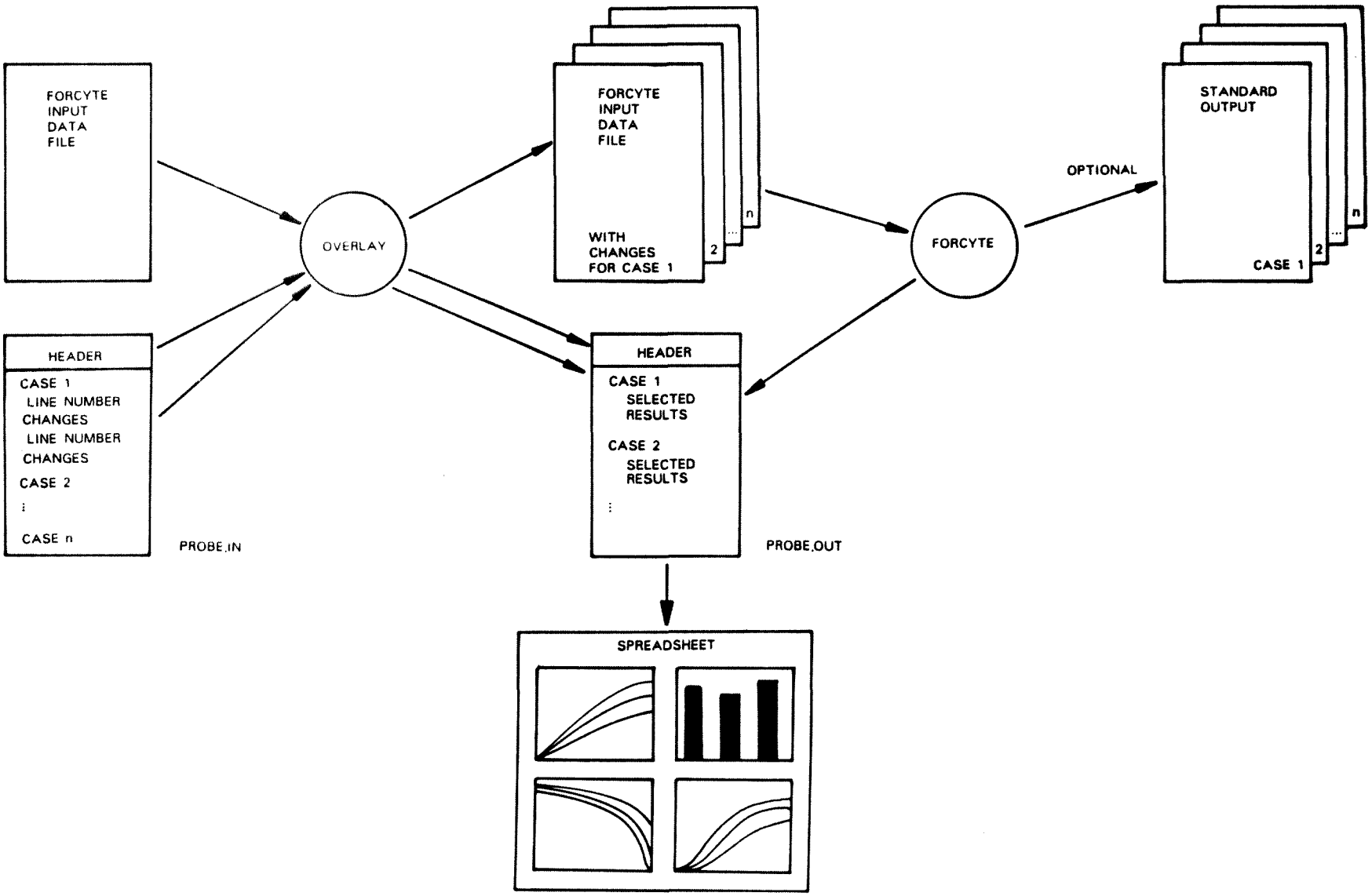

FIGURE 2. The activities involved in running PROBE are schematically presented. The supervisory program PROBE controls the repeated execution of the programs OVERLAY and FORCYTE. The accumulated results in PROBE.OUT are subsequently imported to a customized spreadsheet.

Of particular merit is the ability to preconstruct a set of interpretive and comparative graphs within the spreadsheet, a feature enhanced by the use of multiple graphics windows. When a new PROBE.OUT file is imported to the spreadsheet these preset windows provide an immediate preview of the experimental results.

There is insufficient space to summarize here all the benefits that the use of a powerful spreadsheet program such as SYMPHONY provides to the FORCYTE model user. Suffice it to say that with such highly developed PC programs, users have at their fingertips a set of extremely powerful tools with which to explore their understanding of ecosystem processes or attempts to model them.

CONCLUSION

The preparation of input data files and the execution of multiple runs of FORCYTE on a mainframe computer can be expensive, time consuming, tedious, and, because of the risk of data input errors, frustrating. These can be major impediments to user-acceptance and use of complex models like FORCYTE. A dedicated and experienced user requires one to two hours to prepare the input data files and execute 10 to 15 runs (at significant computing cost). Additional time is needed to assemble tables and graphs and to compare the results of these runs.

In contrast, using the PROBE protocol and programs in a PC environment as described above, a user can set up control files for 5 simple cases, execute the 5 simulation runs of FORCYTE-11, import the results into a SYMPHONY spreadsheet, and begin to print comparative, interpretive results in graphical form in about 20 minutes total elapsed time. For most of this time (while the simulations are running) the user need not even be present!

The transfer of FORCYTE-11 to the micro-computer environment has made new analytical tools available to the model user. Together with the time and cost savings, these tools make the construction of "what if" comparisons of different forest management practices a realistic task. It is hoped that PROBE will help FORCYTE to fullfill its potential in the evaluation of future forest ecosystem management strategies.

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