ORiON, Vol. 2, No. 1, pp. 1-14

MICRO-COMPUTER SIMULATION SOFTWARE : A REVIEW

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ABSTRACT

Simulation modelling has proved to be one of the most powerful tools available to the Operations Research Analyst. The development of micro-computer technology has reached a state of maturity where the micro-computer can provide the necessary computing power and consequently various powerful and inexpensive simulation languages for micro-computers have became available. This paper will attempt to provide an introduction to the general philosophy and characteristics of some of the available micro-computer simulation languages. The emphasis will be on the characteristics of the specific micro-computer implementation rather than on a comparison of the modelling features of the various languages. Such comparisons may be found elsewhere [1,2].

1. INTRODUCTION

High level special purpose simulation languages such as GPSS, SIMSCRIPT and DYNAMO have been available on main frame computers for a number of years and have been used extensively for the development of simulation models of real world systems. More recent advances led to the development of languages such as GASP and Q-GERT which provided the basis for state of the art languages such as SLAM and SIMAN. These languages provide extensive modelling capabilities and features such as high transportability between different computer systems and a choice of "world views" for modelling purposes. With the ever increasing availability and capability of micro-computers, special purpose simulation languages and support software specifically designed for micro-computers became available over the last two years. The micro-computer "revolution" also played a major role in the shift in emphasis from simulation languages with an ever increasing number of modelling features towards the development of integrated simulation system support software. Furthermore, micro-computer versions of most of the simulation languages that were originally developed for main frame machines have recently appeared on the market. Table 1 provides some information on some of the micro-computer simulation languages currently available [3,5,7,8,10].

When using the simulation technique and a simulation language there is very often a real user need for various kinds of support software. The special characteristics of a micro-computer, for example the availability of low cost graphic facilities, make it possible, not only to provide such support software, but to provide software with capabilities not often found in mainframe software. Table 2 provides some information on some of the simulation support software currently available.

2. MICRO-COMPUTER SIMULATION LANGUAGES

In general there exists a marked difference between software developed or adapted specifically for micro-computers and mainframe software which has merely been transported to micro-computers. The software developed specifically for micro-computers tend to be more user friendly and interactive, provide a relatively stand alone simulation system which does not require additional support software and requires very little or no special computer knowledge or skills from the user. The modelling capabilities of some of these micro-computer software may be somewhat limited when compared with main frame languages and in some cases recent advances in micro-computer technology are not fully exploited.

The capabilities of the main frame software running on micro-computers are very extensive but the effective use of some of these languages often require additional computer and programming skills from the user as well as the availability of additional support software such as compilers, text editors and file utilities. These languages may also provide access to additional simulation support software as well as interfacing to other available utility software. In adapting a main frame language for use on a micro-computer an effort is usually made to enhance the user friendliness of the software but at the same time to retain compatibility with the main frame version of the language.

The limitations of a specific micro-computer in terms of random access memory and disk storage space may present problems when handling very large scale simulation models. The availability of inexpensive random access memory for micro-computers and the advances in hard disk technology make it possible to handle most medium to large simulation models.

NAME OF SOFTWARE	WORLDVIEWS SUPPORTED	TYPICAL HARDWARE & OPERATING SYSTEM	ESTIMATED PRICE
ACES	Continuous difference equations	APPLE II DOS 3.3	$200
GPSS/PC *	Process interaction	IBM-PC MS-DOS	$900
ISIM	Continuous difference equations	IBM-PC MS-DOS	$300 to $600
Micro-DYNAMO *	Continuous system dynamics approach	IBM-PC MS-DOS	$245
Micro-NET *	Network discrete event	IBM-PC MS-DOS	$950
Micro-PASSIM *	Process interaction and event scheduling	IBM-PC MS-DOS	$125
PC-MODEL *	Next event Character screen animation	IBM-PC MS-DOS	$450
SIMAN PC *	Process, event and continuous orientations	IBM-PC MS-DOS	$1500
SIMSCRIPT PC *	Event scheduling and process approaches	IBM-XT MS-DOS	$5500
SLAM PC *	Process interaction, event scheduling and activity scanning	IBM-PC MS-DOS	$975
TurboSim *	Next event (Based on Turbo-PASCAL)	IBM-PC MS-DOS	$50
TUTSIM	Continuous difference equations	IBM-PC MS-DOS	$200 to $300

TABLE 1 Some available micro-computer simulation languages

Running a simulation model on a micro-computer may require computing times which are several orders of magnitude larger than what would be the case if the model is run on a main frame computer. However, the time required for development, debugging and even validation of a simulation model, may be very much the same whether a micro-computer or a main frame computer is used. The problem of long running times when using a micro-computer may be alleviated by using a numeric co-processor.

* Installed at the University of Pretoria.

PLAYBACK (SIMAN Based) *   PLAYBACK provides a means of graphically animating simulation results through the use of thermometer-like bars that move up and down and boxes that change colours.
BLOCKS *   BLOCKS is an interactive graphic model builder for creating, editing and viewing SIMAN model files. BLOCKS allows the user to construct and edit a model in block diagram form directly on the screen and also automatically prepares the model input statements.
CODER **   CODER is an interactive, menu driven, code generator for creating and viewing SLAM network model files and will automatically prepares the model input statements.
DISFIT ***   DISFIT is an interactive, menu driven, support system that will perform basic statistical analysis on a set of data, draw histograms, fit anyone of a number of well known distribution functions to the data and report on the statistical significance of the fit.

TABLE 2 Some available micro-computer simulation support software

During the development phase of a simulation model using a single user micro-computer, the central processing unit is usually under utilized. This under utilization may be effectively used in the specific implimentation to provide a powerful user interface and other enhancements which are usually not available on mainframe computers.

The availability of micro-computer simulation languages has made an important contribution to the simulation modelling environment in the sense that it provides a variety of potential users with an inexpensive introduction to the use of a simulation language and therefore simulation modelling.

Tables 3 and 4 [4,5,6,7,8,10] provide summaries of some of the characteristics of SLAM II PC, SIMAN PC, GPSS/PC and PC SIMSCRIPT II.5 being representative of the most powerful and/or well known micro-computer system simulation software presently available.

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* Installed at the University of Pretoria.
** Available from the University of Pretoria.
*** Under development at the University of Pretoria.

	SLAM II PC	SIMAN PC	GPSS/PC	PC SIMSCRIPT
WORLD-VIEWS SUPPORTED	Process interaction, Event scheduling and Activity scanning	Process, Event and Continuous orientations	Process-oriented	Event scheduling and Process approaches
RELEASED	June 1984	February 1984	June 1984	September 1984
VERSION	Version 3.0	Version 3.0	Version 1.1	Version 2
SUCCESSFUL COMPUTER IMPLEMENTATIONS	IBM PC, IBM XT IBM AT, COMPAQ COMPAQ DESK PRO ZENITH 100 TI PROF OLIVETTI M24	IBM PC, IBM XT IBM AT, TI PROF ZENITH 100 HP 150 OLIVETTI M24	IBM PC, IBM XT IBM AT, COMPAQ AT&T, HYPERION SEEQUA OLIVETTI M24	IBM XT IBM AT IBM PC and OLIVETTI M24 with hard disk
REQUIREMENTS HARDWARE SUPPORT SOFTWARE	320K RAM MS-DOS, Editor MS-FORTRAN	320K RAM MS-DOS, Editor MS-FORTRAN	256K RAM MS-DOS	320K RAM 8087/80287 MS-DOS
RELATED SOFTWARE	Micro-NET, MAP/1 TESS, Mainframe version	BLOCKS, PLAYBACK CINEMA, Mainframe version	Mainframe version	SimVision Mainframe version
OUTSTANDING AND SPECIAL CHARACTERISTICS	DIF interface to LOTUS etc. Mixed discrete and continuous modelling	DIF interface to LOTUS etc. Mixed discrete and continuous modelling. Tektronix graphics	DIF interface Interactive Integrated environment Screen plots On-line help	SIMLAB, SIMEDIT, Virtual memory, Multi-tasking with windows, On-line debugging

Table 3 Some characteristics of SLAM II PC, SIMAN PC, GPSS/PC and PC SIMSCRIPT II.5

SLAM II PC and SIMAN PC may be considered to be the more advanced simulation languages from a modelling and historic point of view, while GPSS/PC and PC SIMSCRIPT II.5 belongs, to some extent, to a previous generation of simulation languages. However, the implementation of GPSS/PC and PC SIMSCRIPT II.5 on the micro-computer is at present without doubt better than the implementation of SLAM II PC and SIMAN PC. The PC SIMSCRIPT II.5 implementation makes effective use of the under utilization of the central processing unit to provide a powerful user interface and simulation environment. The GPSS/PC implementation uses, in a similar way, the under utilization of the central processing unit to provide such features as interactive operation, on-line help and error checking.

The user-orientated, self-contained and integrated approach of the PC SIMSCRIPT II.5 implementation is an excellent example of the sophisticated user interface that may be obtained, and should be expected, from well-designed micro-computer software.

	SLAM II PC	SIMAN PC	GPSS/PC	PC SIMSCRIPT
OUTPUT PROCESSING AND REPORT GENERATION	Menu-driven output processor Preformatted summary report Print plots Histograms Output to disk	Command-driven output processor Preformatted summary report Screen/Print plots Histograms Conf. intervals Output to disk	Report formatter Preformatted standard report Screen plots Frequency distribution tables Output to disk	User written and formatted output reports Screen graphics Histograms Video screen control Output to disk Colour screen
INTERACTIVE CAPABILITIES	Very limited User programable	Very limited User programable Interactive debugger	Interruptable Modification/step/restart Manual simulation	Limited apart from built-in on-line debugging windows Programmable
DEBUGGING FACILITIES	System trace Translation and runtime error handling	System trace Translation and runtime error handling Debugger	Interactive query Trace block Runtime error handling	Compilation and runtime error handling and trace back
GRAPHICS CAPABILITIES	Only print plot graphics Print plots Histograms	Screen/Print plot graphics Tektronix interface Print plots Histograms	Dynamic screen graphics	Screen graphics Histograms Barcharts
RUNNING TIMES *	2.1	1.5	3.0	8.5
MODEL DOCUMENTATION	In-line and between line commenting	In-line and between line commenting	In-line and between line commenting	Self documenting Between line commenting
DOCUMENTATION	Adequate [4,5]	Adequate [6,7]	Extensive [8,9]	Extensive [10,11,12]
RELATED LITERATURE	Mainly one text and reference book. Growing application base	Mainly one reference book Growing application base	Extensive literature and application base	Extensive literature and application base
SPECIAL LANGUAGE FEATURES	Network approach and FORTRAN library Flexible and easy to learn basic concepts Special materials handling module	Block diagram approach and FORTRAN library Flexible and easy to learn Special materials handling and manufacturing features	Block statement approach Flexible but not so easy to learn basic concepts	Self contained General purpose programming language Extremely flexible but also complex

Table 4 Some characteristics of SLAM II PC, SIMAN PC, GPSS/PC and PC SIMSCRIPT II.5

* The execution times are based on running an equivalent simulation model of an M/M/1-queueing system on a Columbia Dataproducts microcomputer with 384 K RAM, 10 M Byte hard disk, 8088 processor and 8087 co-processor. Loading, translation, compilation and linking times are not included but times for printing and/or writing are included. The figures indicate the ratio to the execution time of an equivalent model coded in FORTRAN 77.

The modelling constructs, features and flexibility in terms of the different "world views" supported, incorporated in SLAM II PC and SIMAN PC provide a powerful language which at the same time is relatively easy to learn and to understand. It is also encouraging to note that further developments have taken place in the form of related and/or support software for example the development of TESS and CINEMA.

The general software organization, from a conceptual user point of view, of the relevant four simulation systems are shown in Figures 1 to 4 [4,5,6,7,8,10].

The software organization of SLAM II PC and SIMAN PC is very similar and consists of a translation/compilation phase followed by linking of routines, execution and output processing. The user friendliness is not very high necessitating at least some knowledge of the operating system, a FORTRAN 77 compiler and a general purpose text editor.

PC SIMSCRIPT II.5 provides a sophisticated, stand alone and self supporting simulation environment in the form of a simulation laboratory known as SimLab. SimLab provides easy access to the built in editor, the compiler, the on-line debugger and various file utilities.

The software organization of GPSS/PC is to some extent similar to that of PC SIMSCRIPT II.5 although it is somewhat less integrated. The outstanding feature of the GPSS/PC software is the interactive capabilities that are available.

3. FUTURE DEVELOPMENTS

The companies responsible for the development of the relevant four simulation systems are involved in a continuous process of extending and enhancing the specific simulation language. For example, the most recent version of SLAM II provides an add-on module developed especially for modelling complex material handling systems. In a similar way the most recent version of SIMAN provides an interactive debugger, additional facilities for exploiting the bit-mapped graphics capabilities of the micro-computer and new modelling constructs for simulating manufacturing systems. This process of extending the capabilities of an existing language will undoubtedly continue in the future.

A second observable trend in the development of simulation software consists of providing the user not only with a simulation language but with an integrated simulation environment. Probably the best example of such a simulation system presently available is the SLAM-based system known as TESS (The Extended Simulation System). Apart from the SLAM II modelling capabilities TESS provides such features as a high level query language, an integrated data base, extensive statistical data analysis, report generation and scenario animation.

FIGURE 1 SLAM II PC SOFTWARE ORGANIZATION

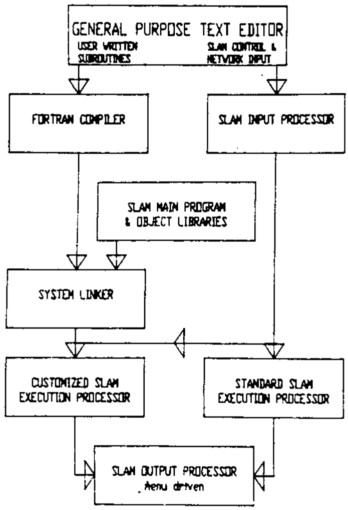


FIGURE 2 SIMAN PC SOFTWARE ORGANIZATION

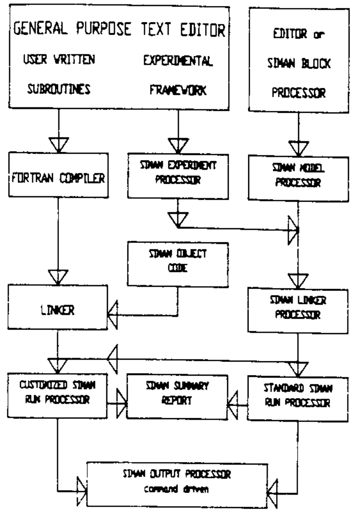


FIGURE 3 PC SIMSCRIPT II.5 SOFTWARE ORGANIZATION

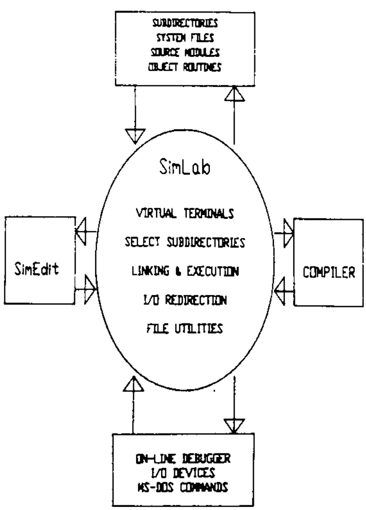
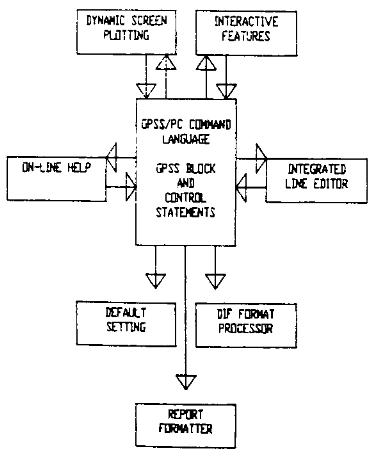


FIGURE 4 GPSS/PC SOFTWARE ORGANIZATION



The third and most recent trend in the development of simulation software consists of the capability to display the output from a simulation model by means of animation and dynamic graphics. The main purpose of this development is to enhance the user interface to such an extent that the non-simulation-expert may interact with the simulation model and the modelling process. Typical examples of available simulation systems providing some form of animation are PCMODEL, CINEMA, TESS and SEE WHY.

The last development worth mentioning is the availability of very specialized simulation systems dedicated to the modelling of specific kinds of systems. Typical examples are MAP/1 (Manufacturing System Simulator) and Robot-SIM (Robotics Simulator).

Table 5 provides some information regarding recently developed advanced simulation systems.

SIMULATION SYSTEM	CHARACTERISTICS AND FEATURES	TYPICAL HARDWARE	ESTIMATED PRICE
CINEMA	Based on SIMAN Extensive dynamic animation and graphics capabilities	IBM-AT with special additional graphics hardware	$28000 including hardware
SEE WHY and EXPRESS	Based on special graphics language Interactive Screen animation	IBM-AT Cromemco DEC VAX and Prime with Intecolor graphics	20000 to 40000 pounds sterling
TESS	Based on SLAM Query language Integrated database Statistical data analysis Scenario animation Network management Report and graphics generation	DEC VAX 11/700 series and Hewlett Packard or Tektronics graphics hardware	$25000

Table 5 Characteristics of some advanced simulation systems

The simulation systems mentioned in table 5 are relatively expensive and require specialized computing equipment. If the expected advances in micro-computer technology materialize, these systems or other systems with similar characteristics may become available on micro-computers in the near future.

4. CONCLUSIONS

The availability of a variety of system simulation software for micro-computers is without doubt a major advance in terms of the accessibility and potential usefulness of the simulation modelling approach. However, the relative long execution times that may be expected when using a micro-computer to conduct experiments with a relative large simulation model may still be a problem. Furthermore, the probable under utilization of the micro-computer central processing unit has in several instances not been fully exploited in order to provide a sophisticated and powerful user interface. The capability of the micro-computer to support truely interactive features has, in a similar manner, not been exploited apart from some notable exceptions like MicroNET and GPSS/PC. Possible future enhancements of the interactive capabilities as well as the interactive graphics and animation features of micro-computer simulation software will play a very important role, not only in making the modelling task easier, but also in improving the credibility, and therefore acceptability of simulation modelling results. The very important interface between the micro-computer simulation software and the rest of the software environment, for example an external database, is almost non-existent in the majority of instances.

A real user need does exist for an easy to use INTEGRATED SIMULATION SUPPORT SYSTEM which incorporates and integrates a powerful simulation language, a sophisticated user interface, user friendly support software and interactive capabilities. Some characteristics of an integrated simulation support system are already apparent in some micro-computer simulation languages. Unfortunately no single micro-computer simulation software package, presently available, may be considered to be superior in all relevant aspects. Further developments to enhance the capabilities of simulation languages will probably occur but the established trend towards a systems approach for the development of simulation software will prevail for the foreseeable future. Furthermore, the present trend of developing and adapting simulation software for use by a micro-computer will probably continue as micro-computers continue to become even more powerful.

Advances in the development of simulation software and in the technology of micro-computers have provided the Operations Research Analyst with an effective tool to increase the productivity with which the simulation modelling activity may be performed. Micro-computers, and especially the user oriented philosophy inherent in most micro-computer software, are playing an important part in introducing professional people, from diverse diciplines, to the general benefits of using computers and computer software. The use of micro-computers and simulation support software will, in a similar manner, be instrumental in introducing the "not so expert" to the concepts and potential benefits of simulation modelling and will enhance the capabilities of the expert simulationist.

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NAMES AND ADDRESSES OF SOFTWARE DISTRIBUTERS

SLAM, MicroNET, MAP/1
and TESS

Pritsker and Associates, Inc.
P O Box 2413
West Lafayette
Indiana
47906
United States of America

SIMAN, BLOCKS, PLAYBACK
and CINEMA

Systems Modeling Corporation
P O Box 10074
State College
Pennsylvania
16805
United States of America

TurboSim

Micro Simulation
37 William J Heights
Framingham
Massachusetts
01701
United States of America

GPSS

Minuteman Software
P O Box 171
Stow
Massachusetts
01775
United States of America

SIMSCRIPT and SimVision

C.A.C.I.
3344 North Torrey Pines Court
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California
92037
United States of America

ACES

Modulo 2 Company
P O Box 58781
Tukwila
Washington
98188
United States of Amnerica

ISIM

Crosbie, Hay and Associates
P O Box 943
Chico
California
95927
United States of America

Micro-DYNAMO

Software Sales
Addison-Wesley Publishing Co.
Jacob Way
Reading
Massachusetts
01867
United States of America

Micro-PASSIM

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TUTSIM

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United States of America

PC-MODEL

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United States of America

SEE WHY and EXPRESS

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P O Box 5
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