ABSTRACT

The SIMSCRIPT II.5 programming language is described. SIMSCRIPT II.5 with its integrated graphical interface, SIMGRAPHICS, substantially reduces time and effort in simulation model development. Its English-like syntax improves readability of the code and substantially reduces the need for documentation.

1. INTRODUCTION

SIMSCRIPT II.5 is a well established, standardized, and widely used language with proven software support. Experience has shown that SIMSCRIPT II.5 reduces simulation programming time and cost several fold when compared to FORTRAN. It assists the analyst greatly in the formulation and design of simulation models and gives the programmer and analyst a common language for describing the model. The benefits of using SIMSCRIPT II.5 can be felt at all stages in the development of a model, including:

1.1 Design

The powerful "world-view" consisting of Entities, Attributes, and Sets provides a natural conceptual framework in which to relate real objects to the model.

1.2 Programming

The modern, free-form language contains structured programming constructs and all the built-in facilities needed for model development. Model components can be programmed so as to clearly reflect the organization and logic of the modelled system.

1.3 Testing

A well-designed package of program testing facilities is provided. Tools are available to detect errors in a complex computer program without resorting to memory dumps and other archaic means.

1.4 Evolution

The SIMSCRIPT program structure allows the model to evolve easily and naturally from simple to detailed formulation as more information becomes available. Many modifications, such as changes in the discipline of performance measurements or changes in ordering, can be made without program modification.

1.5 Documentation

The powerful English-like language allows for modular implementation. Because each model component is readable and self-contained, the model listing can be understood by the end-user who may not be at all familiar with programming. Because the detailed model documentation is the program listing, it is never obsolete or inaccurate.

2. OVERVIEW

2.1 Purpose of simulation

The purpose of a simulation must be clearly articulated before embarking on model development. Many modelling efforts have been doomed to failure, because a clear goal was never determined. The natural tendency is to model in great detail that part of the system which is well understood and "sweep under the rug" or over-simplify those parts which are not understood. The detailed model of the well understood parts yields many lines of model code and gives the illusion of great progress, when in fact, a much smaller model of the entire system may actually be of much greater value.

In general, a model is an abstraction of the real system under study. It is not necessary or even desirable to include all of the details of the actual system. Deciding which details are essential and which may be omitted for the purposes of the study is perhaps the most difficult task which the modeler faces.

2.2 Concept of a World-View

Without its world-view, SIMSCRIPT II.5 would be just another programming language, albeit a very powerful one. But with its world-view, the modeler is guided in the formulation of a complete specification of the problem. The objects in the real world map very naturally into the SIMSCRIPT II.5 objects, which break down into classes termed TEMPORARY ENTITIES, PROCESSES, and RESOURCES. (All capitalized words are part of the SIMSCRIPT II.5 vocabulary.) Any entity may have ATTRIBUTES which give it individual characteristic values. While all instances of a particular entity class have the same named attributes, each instance has its own values for the attributes. In addition, entities may be organized into SETS in order to represent any type of ordered list with various ordering disciplines (FIFO, LIPO, or RANKED by any combination of attribute values).

After the static structure of the model has been described, the dynamic aspects are described in terms of process routines. Each process routine corresponds to a declared process entity. Very natural commands are employed for manipulating objects within the process routines. Processes may WORK or WAIT for a period of simulated time. They may be FILED in sets or REMOVED from them. They may ACTIVATE, INTERRUPT or RESUME one another. Processes may REQUEST or RELINQUISH resources, automatically waiting for those which are unavailable when requested and automatically starting other processes when relinquishing unneeded resources.

Animation in SIMSCRIPT II.5 is a very natural extension of the established world-view. Entities may be declared to be GRAPHIC in order to participate in animated displays. The actual form of the display (the so-called "icon") is described through the use of an editor and may be changed independently of the model.

2.3 Self-Documenting Code

Over the years, we have observed numerous unsuccessful simulation projects that had no documentation except for a FORTRAN listing. Many of these listings contained few explanatory comments. Even a thoroughly commented FORTRAN listing is difficult to decipher for anyone other than the person who wrote it. Often, even the original author has difficulty understanding it after a short time.

We have also seen great amounts of money wasted on manuals
and flowcharts intended to make it easier to develop, maintain, modify, and enhance the model. This waste is a consequence of the realities of model development. Most models evolve over a long period of time because of new and increased understanding of the system, changing goals and availability of new data. Because of the evolutionary changes, flowcharts, prose documentation, detailed descriptions of routines and variables, and program comments often become obsolete, incomplete, or incorrect shortly after they are written. The longer the model is around—and many models in use today were developed five or more years ago—the more this type of documentation deteriorates.

For the purposes of computer program development, modification, and enhancements, the only dependable documentation in a changing environment is the source program listing. The quality and usefulness of this documentation is determined by the model design and the choice of simulation language. SIMSCRIPT II.5 has been shown to reduce the amount of code required when compared to FORTRAN by at least 75%, a four to one reduction!

2.4 Large model development

SIMSCRIPT II.5 has traditionally been the language of choice for very large models. There are no inherent limits to this size of either SIMSCRIPT II.5 programs or their data structures. The dynamic storage allocation of SIMSCRIPT II.5 frees the modeller from concerns about the size of data elements and all the error-checking code necessary to enforce array limits. The modularity of the language structure permits large teams of developers to work on independent segments of the model without needing to know all of the details of other elements of the model.

2.5 Portability

SIMSCRIPT II.5 is a truly portable language. It was originally developed for large mainframe computers, but it has evolved with the necessity to implement on minicomputers and microcomputers. The IBM Personal Computer implementation of SIMSCRIPT II.5 is one of the most advanced software packages available on that computer architecture. The modelling language has been designed and maintained to be compatible across all the implementations. These include: CDC, Cray, Datageneral, ETA, Gould, Honeywell, IBM, Prime, Sun, UNISYS, VAX (both VMS and Unix).

3. SIMSCRIPT II.5 LANGUAGE FEATURES

SIMSCRIPT II.5 is a complete programming language. In addition to its simulation modelling capabilities, it has a full range of input/output capabilities including the ability to specify either formatted or freeform input, screen-oriented output (including cursor placement), generalized reports which may expand to multi-page width as well as length. The TEXT mode of variable declaration permits very general text manipulation of character strings of arbitrary length, including operations such as concatenation, substring search and replace, case change, etc.

The entity/attribute/set structure mentioned above is an extension of a very powerful underlying data structure. Arrays in SIMSCRIPT II.5 may be of any dimension whatever, without limit. The allocation of storage for the arrays occurs during execution and arrays may be deallocated and reallocated with different dimensions. (If there were a need for much reallocation, the temporary entity concept would more likely be used.)

SIMSCRIPT II.5 contains all of the constructs of modern structured programming. Search commands relate to the data structures to be scanned. Program segments may be modularized along functional lines as routines, functions, monitoring routines (to be called implicitly when the monitored variable is either accessed or modified or both), as well as the process and event routines of simulation. Routines may also be executed recursively.

The support of the representation of statistical phenomena is extensive. Generators exist for random numbers distributed according to uniform, integer uniform, normal, logarithmic, exponential, beta, gamma, Erlang, Poisson, binomial, triangular, and Weibull distributions. If these are not sufficient, an arbitrary numerical distribution is available to describe any distribution as a

1. Table of values versus probability (individual or cumulative).

The collection of data in the form of statistical performance measures is supported by three very powerful statements: ACCUMULATE, TALLY, and COMPUTE. ACCUMULATE and TALLY update statistical counters as the variable of observation changes values. Then only when the results are needed are the final statistical calculations performed. The measures available include number of samples, sum, average, maximum, minimum, standard deviation, variance, sum of squares and mean square. ACCUMULATE performs these calculations on a time-dependent basis, while TALLY performs them on a sample-basis.

SIMSCRIPT II.5 has recently been enhanced to enable the user to develop models which include processes which change continuously with simulation time. This enables models to be built for those systems which are described in terms of differential equations with superimposed discrete events. The combined capabilities enable the user to define models where dependent variables may change discretely, continuously, or continuously with discrete jumps superimposed.

Part of the ongoing development effort of SIMSCRIPT II.5 is to make the interface between user and model easier to understand. Traditionally, the output of a simulation run was collated tables of data which required extensive analytical capability on the part of the user in order to understand the underlying interactions between various parts of the system under investigation. Much progress has been made in providing facilities within the language whereby these interactions may be represented graphically. This enables models to be developed in which the parameters can be easily represented as presentation graphics such as pie charts, strip charts, duals level meters, bar graphs, etc. These so-called smart icons are updated on the screen as the simulation proceeds. In addition, animation capabilities have been developed to display moving objects against a static background in order to give further insight into the complex interactions which take place within a system.

The preparation of the presentation graphics as well as the icons for animation is accomplished through the use of editors. The icons are stored with the program but may be modified without having to modify the program or clutter it with non-system related code.

4. THE PC SIMLAB ENVIRONMENT

Many of the capabilities of PC SIMSCRIPT II.5 are made possible because of SIMLAB. SIMLAB is an operating environment for the SIMSCRIPT II.5 compiler, editors, and runtime. SIMLAB supports a multitasking environment in which it is possible to perform several tasks simultaneously. During program development, it is possible to edit several portions of the program simultaneously (in different windows). During execution, it is possible to open debug windows, set break points, and track the execution of the program through its source code. It is also possible to have multiple, concurrent output streams to different windows. SIMLAB also makes it possible to write, maintain, and execute programs which are much larger than the actual memory of a PC can contain. Through its virtual addressing mechanism, programs which would normally require main frame capacity are being developed on PCs.

5. EXAMPLE CODE

Simulation involves the passage of time in the life of some object. For example, passengers arrive at an airport, wait for a passenger agent, get a boarding pass and leave. General purpose programming languages, such as Pascal, C and FORTRAN, lack the constructs to make time pass in a simulation. The programmer has to write these constructs before he or she can get on to writing the simulation.

5.1 Processes

In general, SIMSCRIPT's simulation constructs are built around the concept of a process. This is a routine that describes what happens to the object as it moves through time. For example, here is the SIMSCRIPT code that processes a passenger in a terminal.
ARRIVAL. TIME

order. SIMSCRIPT 11.5, unlike many other languages, is not case

variable. variable used only once. This is part of SIMSCRIPT's

substantial error checking capability.

As a matter of style all SIMSCRIPT words are shown as
capitals and lower case; user defined words are all capitals. This

way the substance of the model is apparent as you scan the code.

The two apostrophes at the end of the process routine are the

beginning of a comment. The first statement declares

ARRIVAL. TIME to be a local, real variable.

The PASSENGER. AGENT is a resource. The PASSENGER

to have a PASSENGER. AGENT before he can get a boarding

pass. So he requests one, if one is available, the next line of code is

executed immediately.

If a PASSENGER. AGENT is not available, control passes to

the timing routine. The timing routine files this PASSENGER in

queue waiting for a PASSENGER. AGENT and starts execution

of the next process.

When a PASSENGER. AGENT becomes available and this

PASSENGER is first in the queue, the timing routine removes the

PASSENGER from the queue and schedules him to continue

execution. When this PASSENGER is the next process to be

executed, control returns to the process routine at the line after the

request statement.

The next statement calculates the amount of time the

PASSENGER had to wait for a PASSENGER. AGENT. Time.v is

the current simulated time.

The Wait statement represents the passage of time while the

PASSENGER gets his boarding pass. The amount of time is drawn

from an exponential distribution with a mean of

MEAN. SERVICE. TIME using a random number stream 1.

As with the resource, control passes back to the timing routine.

The timing routine files the PASSENGER in a queue of pending

events, called an event set. This queue is ranked by the time of

reactivation. Reactivation time for this PASSENGER is the current

simulated time plus the amount of time drawn from the exponential

distribution.

When this PASSENGER is next up for execution, control

returns to the statement after the wait statement. The PASSENGER

relinquishes the PASSENGER. AGENT so that someone else can use

it and disappears from the scene.

The great advantage of this construct is the modeler can write

the steps of the process in structured English. Having done this, he

or she only has to create passengers when they are needed, and

SIMSCRIPT will handle all details of scheduling and execution.

Notice that the process is clear about what is supposed to

happen. This reduces the chances of logical errors in coding. More

importantly, an airline employee can read the code and know

whether it represents what really happens.

5.2 Creating Instances of Processes

The process routine show what happens to one passenger. We need

to create many passengers to run a simulation. The general

technique involves creating a second process that functions as a

passenger generator.

Process PASSENGER

Define ARRIVAL. TIME as a real variable

Let ARRIVAL. TIME = time.v

Request 1 PASSENGER. AGENT(1)

Let WAITING. TIME = time.v - ARRIVAL. TIME

Wait exponential.f (MEAN. SERVICE. TIME, 1) minutes

Relinquish 1 PASSENGER. AGENT(1)

End ' 'PASSENGER

Process PASSENGER. GENERATOR

Define I as an integer variable

For I = 1 to 120 do

Activate a PASSENGER now

Wait exponential.f (MEAN. INTERARRIVAL. TIME, 2) minutes

Loop ' 'I = 1 to 120

End ' 'PASSENGER. GENERATOR

PASSENGERS are created one at a time with some time passing

between creation of each PASSENGER. In actuality, this is the wait

between arrivals that normally occur at an airport: generally

passengers do not all show up at once.

The PASSENGER. GENERATOR will create 120 passengers.

An alternative to the For statement is:

Until time.v >= RUN. TIME

In this case PASSENGERS would be created until some simulated

time had passed, say eight hours.

The Activate statement creates the process notice for this

instance of the passenger, sets the reactivation time, time.a to

time.v (i.e. now) and files it in the event set. The

PASSENGER. GENERATOR then waits some amount of simulated

time before looping and creating the next PASSENGER. It passes

control back to the timing routine. The timing routine sets the

PASSENGER. GENERATOR's reactivation time to the current time

plus the time drawn from this exponential distribution.

It then files the PASSENGER. GENERATOR in the event set,

gets the next process notice and starts executing it. When the

PASSENGER. GENERATOR is first in the event set, the timing

routine returns to the statement after the Wait statement, loops,

creates the next passenger and goes back to the event set.

5.3 Running the Simulation

All that remains is to start the simulation and build some I/O

structure to support the model. As in any full-featured language,

SIMSCRIPT supports formatted input and output of results.

More significantly, SIMSCRIPT's built-in graphics package,

SIMGRAPHICS, supports a wide range of presentation graphics

and animation. Well-designed animation greatly enhances the

effectiveness of the simulation, allowing you to better understand

what is happening in the model.

6. SIMSCRIPT 11.5 AVAILABILITY

SIMSCRIPT 11.5 is a proprietary product of CACI Products

Company. It is sold on a free-trial basis. A special university

program is supported by CACI in which SIMSCRIPT 11.5 is

supplied to educational institutions for the cost of distribution.

7. TRAINING

Week-long training courses are given by CACI on a regular

basis. These courses are held in their training facilities in La Jolla

and Washington, D.C., as well as at other locations throughout the

world. The same course is available for on-site training as well.

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