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USING SIMULATION TO SOLVE PROBLEMS: A TUTORIAL ON THE ANALYSIS OF SIMULATION OUTPUT

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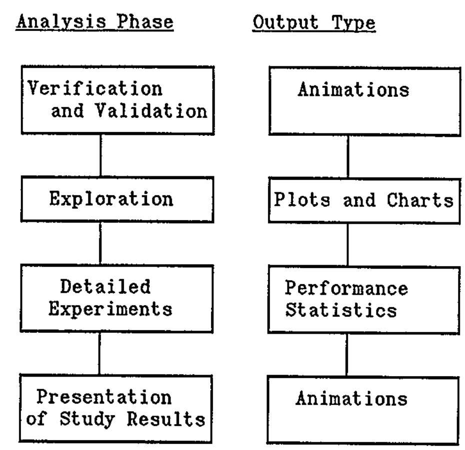
ABSTRACT

In this paper I will assume that a simulation model has been developed and the study team is faced with the question, "now that we have built a simulation model, what do we do with it?" The theme is that the three common modes of simulation output, animations, plots, and numbers compliment one another and are all important; however, they are often used in an inappropriate manner. Matching the type of output to the objectives of the analysis is critical. This paper discusses this theme and gives the major references for the tutorial to be presented at the conference. Most technical details will be given during the presentation. All comments presented here are my opinions and I welcome debate.

1. ANIMATIONS, PLOTS, AND NUMBERS:

Broadly speaking, a simulation can produce three categories of output. These are animations, plots, and numbers. It is sometimes argued that one mode of presentation is superior to the others; however, in this tutorial we will demonstrate how each has its place. The theme of this talk is that all three modes of output are necessary for a proper analysis of the simulation and the successful implementation of the results. When one chooses a simulation language, support for model analysis should be given at least as much weight as that given to support for model building, probably more weight. Unfortunately, the aid that most simulation languages offer in experimentation and output analysis is typically dismal. During experimentation, when problems are being solved and the simulation model has its only real utility, most languages abandon the user.

I have observed that during the life of a successful simulation project the predominant mode of output changes. Depending on where one is in the study, different types of outputs are the most useful. In general, as the study matures the desired output will tend to be more and more quantitative. However, once the study yields specific recommendations then the predominant mode of output reverts (like a second childhood) to animations. This is illustrated in the figure below.



Of course, few people are so fortunate as to have their study proceed in a linear fashion through the above steps; likewise, there are usually several types of output generated during each simulation run. The figure merely illustrates the type of output that the user seems to spend the most time studying at a particular phase of the study.

1.1 Animations:

Probably the most talked about feature of a simulation language and one of its major selling points is the sophistication of the possible animations that can be created. While animations are very important in model development and perhaps vital in selling the results of a study, it should be emphasized that under no circumstances should animations be used in solving problems. I base this overstatement primarily on two observed behaviors.

First, runs with animations are just too short to permit a proper system evaluation. Most analysts get bored watching an animation after a few hours. One of the real values of simulation is the ability to compress time; one can observe several years of simulated system behavior in seconds. Animation fails to fully exploit this time compression although some speed-up (or dilation) of time is typically accomplished.

The second major problem with using animations for problem solving is that the observer tends to focus only on unusual behavior. This may cause an overemphasis of some rare event with no real economic consequence that just happens to catch the eye. Designs may be ruled out before they are fully developed because of apparently poor performance at one stage in a single run animation. It may be that by changing a few parameter values the design would have been viable.

To reiterate: animation is most useful in the early stages of a simulation project to verify a model and at the end to sell the solution. The comments in the paper by Kevin Healy should be read by everyone using a simulation language that supports animation [1]. He points out the animation can be harmful when simulations are made unnecessarily detailed simply to support the animation. In is believable that more time might be spent developing animation graphics than on the simulation model itself.

Animation, done tastefully and correctly, is clearly the most powerful way to sell a solution to management. This is particularly the case with a manager that has no technical training beyond long division and deducts his subscription to FORTUNE as a professional journal. However, fancy animations (say, with "happy-face" figures) can an should arouse the skepticism of sophisticated managers.

1.2 Plots and Charts;

Plots and charts convey quantitative information pictorially; as such they are a bridge between the cold numbers of performance statistics and the lively cartoons of a full animation. Creative plots and charts can convey considerable information quickly [2], [3]. Such charts can involve the use of perspective, color, motion, and sound. Motion as in a 3-dimensional scatter plot with a moving "camera" or in the dynamic queue "thermometers" of G.E.'s ModelMaster [4] simulator is an area with a great deal of potential. Contrasting of histograms is an effective way of evaluating relative merits of systems that does not suffer from the two problems with animations cited earlier. Plots of data and charts are good ways of high-level analysis.

For detailed design work, graphical display of information is simply not feasible. Looking at histograms is not an effective way to select values for hundreds of parameters in a system design. The data needs to be condensed; there are numerical statistical techniques designed for just this purpose in mind.

1.3. Statistics:

When one gets to to bottom line: "will the proposed system pay?," the most effect tool is statistical analysis. With properly designed experiments and statistical analysis not only can system performance be measured but the precision of the measurements can also be assessed. You can quantify what is know and what is not known. Simulation is an ideal environment for statistical experimentation. Data is relatively inexpensive so asymptotic theories are more meaningful than in real-time experiments. Also, non-parametric methods, which are safer but less efficient than parametric methods are useful when data is cheap. I see a real need for tools that help in designing and analyzing simulation experiments. This area grossly lags the development of software for modeling.

2. Factor Screening:

A problem with all of the quantitative techniques is that there many be too many potentially important input variables in the model. The identification of the important factors in system performance should be the first (and often repeated) step in a simulation experiment. This is the area of factor screening. There are several useful statistical techniques that can help here [5]. A recent factor screening method based on frequency domain methods that is effective in simulations is presented in reference [6].

3. SUMMARY:

The appropriate mode of simulation output will change over the life of the simulation project. Selecting a simulation language and supporting software should recognize the different roles played by animation, plots, and statistics. A successful project will probably rely to some extent on several forms of output analysis.

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