Apr 21st, 2:00 PM

Paper Session I-B - GSIM: A Low Cost MBR Approach for KSC Design and Operations

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GSIM: A Low Cost MBR Approach for KSC Design and Operations

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ABSTRACT

NASA research, over the past 8 years, has developed Model Based Reasoning (MBR) technology to the point where it can now be applied to solve operational problems. GSIM is a tool developed jointly by NASA and LSOC that builds on this research, making MBR technology cost effective and readily available. Using GSIM, high fidelity MBR models can be developed on standard office computers and workstations. Using the intuitive GSIM model development environment, these models can be constructed at the rate of approximately 10x that required for development of lower fidelity math models, such as those used today for launch team training and application software validation. MBR models are not single use investments; but support diverse functions such as design assistance, traditional operations simulation, training, FMEA, real-time system monitoring/diagnosis and data fusion.

This paper presents findings/plans of the GSIM project and discusses long term benefits of wide spread life cycle oriented use of MBR technology at KSC.

DEFINITION

model 4: a miniature representation of something; also: a pattern of something to be made 5: an example for imitation or emulation 11: a description or analogy used to help visualize something...that cannot be directly observed 12: a system of postulates, data, or inferences presented as a mathematical description of an entity or state of affairs. [Webster87]

object 1a: something material that may be perceived by the senses. [Webster87]

class 3: a group, set, or kind sharing common attributes: as a: a major category in biological taxonomy ranking above or below the phylum or division. [Webster87]

INTRODUCTION

Model Based Reasoning, or MBR, is a unique and powerful approach for applying computers to solve real-world problems. Its most distinctive characteristic is its separation of data and program. For example, MBR could be applied by an auto manufacturer to provide services for all its makes of vehicles. A separate model could be constructed for each make of vehicle. Application programs could then be developed to perform each kind of service that was needed e.g. printing wiring diagrams or implementing a diagnostic service center to be placed in each dealer's shop. Each application program would work for all makes of vehicle, (past, present or future) for which a model was developed.

MBR Models capture how something works and what it is. This is done by defining its component parts and the interaction between those parts. MBR Engines are application programs that work on MBR Models. As shown in Figure 1, MBR Models are the fuel required to run any MBR Engine. Thus the maintenance cycles of both models and engines are separate. Both models and engines can be modified or added independently without affecting the other.

A secondary benefit of the use of MBR systems is a dramatic reduction in the quantity of software that must be developed or maintained. Figure 2 illustrates the effect of applying MBR technology to the Launch Processing System application software currently required for Shuttle processing and launch at KSC. In the MBR approach, the primary investment for developing new...
systems is the MBR Model which roughly equivalent to the schematics & specifications task today.

This leads to a top level organization for MBR systems such as that shown in Figure 3. This organization is in fact the one used by the GSIM (Graphics Based Simulation) project. It consists of MBR tools, engines, models, and classes. MBR engines apply model data to provide a direct service like simulation or diagnosis. MBR tools provide utility services such as import/export to commercial products, model library management and printing. Models are composed of objects and the inter-object connections which is equivalent to the data captured by a schematic. Each symbol on the schematic becomes an object. Example objects might be: a solenoid, a hydraulic pump, or a hydraulic line. Each object belongs to a particular class of objects. This is equivalent to a vendor part number for an object. This same class can be used many times on a single page of a schematic.

Classes let us define once how a class of objects works and reuse it many times.

MBR technology has been under investigation / development over the past 8 years at KSC. The driving force behind this MBR development has been diagnosis, however simulation is one of the natural spin-off benefits. The pilot system was LES (Lox Expert System). It was developed in 1984-85 by NASA/KSC, assisted by LSOC, to expedite problem diagnosis during Shuttle Lox loading operations.[Jamieson85] The follow on system was KATE (Knowledge-based Autonomous Test Engineer) which has been under development from 1986 to present.[New87] KATE adds the capability to control as well as diagnose. Both systems
have some simulation and dynamic schematic drawing capabilities as well. The third system was SCAN (Shuttle Connector Analysis Network) which was developed by LSOC (Lockheed Space Operations Company) and is the only one of the three to

An MBR view of the engineering task focuses first on capturing system knowledge in a standard and reusable form. This task is the creation of the MBR model. Once completed, MBR engines are used to accomplish or assist in many of the other activities. The MBR model becomes the primary focal point for changes in the vehicle or GSE. MBR engines become the focal point for changes in process requirements. The resulting synergistic effect reduces the cost and time required to implement required changes. It also makes increases in quality and depth of services economical. That is, changing a single MBR engine is far less costly than making the corresponding change in all application documentation or all application programs of the affected type.

**THE GSIM CONCEPT**

GSIM is intended to make MBR technology affordable and accessible to the engineering community at large. Figure 5 illustrates the driving forces behind the design of GSIM that are considered necessary to support the engineering task described earlier.

As depicted in Figure 6, GSIM combines spreadsheet and simplified CAD schematic metaphors, to provide a readily understandable user interface requiring minimal training. Models are defined using standard configurations of low cost PC and Unix workstations. No special software or hardware is required. The performance objective for office computers is that a subsystem model, e.g. Environmental Control System, should be able to run on a PC compatible 386 running at 25 MHz. Model classes may also be defined across platforms. This level of portability is obtained by establishing a standard interface layer for graphics and other computational
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Figure 4: Focus on capture of system knowledge versus process knowledge

<table>
<thead>
<tr>
<th>GSIM Objectives</th>
<th>GSIM Approach</th>
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</thead>
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<tr>
<td>• Efficient model capture</td>
<td>Schematic capture mode entry</td>
</tr>
<tr>
<td>• No special H/W, S/W or S/W environment requirements</td>
<td>Only requirement is C++ compiler</td>
</tr>
<tr>
<td>• Model development &amp; testing on existing office and personal computers</td>
<td>Presently runs on PC/ATs and PS/2s running DOS, Sun/compatables and Apollo running Unix/XWindows</td>
</tr>
<tr>
<td>• Portable</td>
<td>Readily rehostable portable I/F layer</td>
</tr>
<tr>
<td>• High fidelity/efficient performance</td>
<td>Hi-fi at LRU object level with adequate subsystem model performance on 25 MHz PC</td>
</tr>
<tr>
<td>• Generic tools customizable without changing tool</td>
<td>Formalized interfaces used for rehosting and embedding in RT applications</td>
</tr>
<tr>
<td>• Real-time embeddable in future control systems</td>
<td>Through tool customization above.</td>
</tr>
<tr>
<td>• Data interchange with existing MBR and COTS CAD tools</td>
<td>SQL MBR library planned with filters for specific tools</td>
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</tbody>
</table>

Figure 5: GSIM is designed for efficient low cost exploitation of MBR technology.
services. All GSIM tools and engines conform to these standards. This permits the GSIM to be ported to a new machine by writing a small library of routines that map GSIM standard interface calls to those available on the new machine.

Using a schematic capture approach for entry and maintenance of models, allows engineers to efficiently develop and test models. They use a graphical and non-programming method that is quickly learned by users of either CAD or spreadsheet applications. During the proof of concept phase of GSIM, a miniature Liquid Oxygen loading model was developed including about 20 new classes and 851 objects in about 2 man-weeks. Current estimates of improved productivity over the current approach are about 10:1. Model fidelity is significantly higher since models are defined down to the schematic element level or class. Classes are then defined supplying transfer functions for each class. Analog transfer functions are defined to GSIM typically, by entering transfer curves graphically while referencing vendor specifications. Classes also declare animation and specification data.

GSIM's tools and engines are general and modular in nature permitting them to be applied readily to new applications. The Controlled Model Data Store is equipped with import/export services. These services act as filters to convert between the GSIM standard MBR data format of the controlled library and those used by other MBR or COTS tools. This permits each of these other tools to view GSIM MBR standardized data as if it were defined in the format of that tool.

![Figure 6: The GSIM architecture is modular and open.](image)

The GSIM user does not normally deal directly with MBR tools and engines. Instead, an environment is established for the user that is a collection of the appropriate tools, engines and glue to do something useful. Figure 7 outlines the key GSIM environments and their functions. GSIM environments add a user-friendly and consistent coating and accomplish a set of services. Both tools and engines are designed to support integration into different environments.
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<table>
<thead>
<tr>
<th>Model Development Environment</th>
<th>Class Development Environment</th>
<th>Real-time Simulation</th>
<th>Access to Partner Projects/COTS</th>
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</thead>
<tbody>
<tr>
<td>• Schematic capture</td>
<td>• Heirarchical classes</td>
<td>• Workstation/Ethernet</td>
<td>• KATE</td>
</tr>
<tr>
<td>• Maintenance</td>
<td>• Maintenance</td>
<td>• VME standalone</td>
<td>• LES like online analysis</td>
</tr>
<tr>
<td>• Validation &amp; CM</td>
<td>• CAD DXF import</td>
<td></td>
<td>• CAD</td>
</tr>
<tr>
<td>• Schematic/MBR oriented analysis</td>
<td>• Project specific &amp; shared classes</td>
<td></td>
<td>• CAD plotters</td>
</tr>
</tbody>
</table>

Figure 7: GSIM environments combine MBR engines and tools for specific tasks.

LOCKEED'S PROGRESS & PLANS

Work on GSIM began in November 1990 in conjunction with a Simulation Host Study for the Launch Team Training System. This study sought to determine if present KSC computational resources and models were sufficient for an expanded launch team training role. GSIM's part in the study was to determine if new technology should be applied to simulation. GSIM's proof of concept work showed that the new modeling technique and environments offered by GSIM, had the higher fidelity desired and a higher productivity rate than anticipated. Also the GSIM MBR approach yielded models that could be used for far more than simulation and training. The part of the Simulation Host Study reviewing present models and computational resources showed that present resources were adequate and current models could be upgraded to accomplish an adequate amount of the training mission. Thus GSIM was no longer funded under the Simulation Host Study.

Lockheed determined that the GSIM technology was a vital approach and began company sponsored IRAD funding in 1992 and continuing at least through 1993. The purpose of the IRAD is to spin off a production tool development task from the Simulation Host Study concept work done on GSIM. In 1992 the Model and Class Development Environments will be developed into production tools. Lockheed believes that a key to the success thus far has been to keep focused on the final delivery objective rather than just the research. This helps ensure development of an usable end product. In keeping with this philosophy, Lockheed will be using a team of system design engineers in conjunction with the GSIM developers. The design engineers will review and approve requirements and test and accept incremental stages of GSIM development. Further the design engineers will apply GSIM to a difficult system design project actually being built by the design group. In this way we can determine the effectiveness of the tool and allow its direction and complexion to be influenced by its ultimate users. This application of GSIM will result in productivity and performance statistics as well as the more valuable benefit of gaining user insight during the formation stages.

CONCLUSION

• Lockheed sees potential in the MBR approach for both increased quality and depth of launch processing at KSC, not only for Shuttle, but also for future programs as well.

• Refocus of future work around a synergistic multi-reuse approach such as MBR, opens a way to more efficient and cost effective space programs.

ACKNOWLEDGEMENTS

The pioneering work of MBR has been accomplished through the LES and KATE projects led by John Jamieson followed by Jack Galliher both of NASA. Without their work, follow-on MBR projects such as
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GSIM would have nothing to follow on. The SCAN project was the first MBR project to make it to production status at KSC. SCAN was led by Bob Giffen, followed by the author, and presently Jim Tulley all of LSO.C.

The Model-based Autonomous Test Engineer (MATE) project is the first known commercial application of MBR. Mate is the product of John Jamieson of CIT in Titusville, Fl.

John Jamieson of NASA, is also the co-author of the GSIM concept and originator of the GSIM idea.

BIBLIOGRAPHY


