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New Real-time Modeling and Simulation Products and Applications

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ABSTRACT

This paper examines recent developments in modeling and simulation products formulated for use in soldier-in-the-loop laboratories utilizing motion base simulators. New, real-time, ground platform mobility and terrain models have been demonstrated that show vehicle mobility interactions in soft soils. Laboratory data collections have been vastly improved via the incorporation of a new product called SimObserver ™. The paper also provides example experiment results recently performed to quantify soldier performance in moving vehicle environments. The new products and results help evaluate manned and un-manned ground platform concepts and technologies. Most of these new technology products have been developed by partnerships with the Ground Vehicle Simulation Laboratory located at the Tank-Automotive Research Development Engineering Center (TARDEC) in Warren, Michigan.

INTRODUCTION

The Ground Vehicle Simulation Laboratory (GVSL) described by Nunez, Brudnak, and Paul, [1,2] develops and applies motion simulation technology to US Army ground vehicle design and readiness. The GVSL is capable of evaluating typical automotive characteristics such as vehicle ride, component durability, and human factors. Simulation models are integrated in the GVSL to create a virtual prototype that can be evaluated at the systems level. The need for models and simulations that feature real-time capabilities continues to increase. An example is the requirement to develop efficient alternative power and energy sources for the combat vehicle of the future. An accurate duty cycle of the vehicle is required to properly determine the right size and mix of power supplies in these vehicles.

Fortunately, advances in modeling and simulation real-time products help address the increased need as well as improve the fidelity and quality of data obtained from experiments in the real time laboratory.

VEHICLE MOBILITY MODELING

The basic vehicle and terrain models used within the GVSL are flexible real-time, constrained multi-body models. The models are flexible in the sense that they are able to be used as unmanned ground vehicle models, computer generated force models, or, in the case of the GVSL soldier-in-the-loop laboratory, as a vehicle that is interactively driven by an operator. This capability is known as the Vehicle Dynamics and Mobility Server (VDMS) and is described by Brudnak, Nunez, Reid, [3]

VDMS entities may be controlled via desired speed and heading instructions, a series of waypoints (route), or tele-operation commands (brake, throttle, steer, and gear). VDMS may operate stand-alone, or it may be used within a distributed simulation environment and used to update ground platform mobility state values. The stand-alone version provides an off-line analytical tool. The distributed version is being used by the GVSL to investigate the performance of vehicle operators while exposed to a motion environment. In addition, the distributed version is used by the RDECOM Modeling Architecture for Technology Research and Experimental (MATREX), the Development Test Center (DTC) Virtual Proving Ground (VPG) projects (Figure 1) by Docimo, Hinkle, Sauerborn, [4], and the Warfighter Systems Integration Laboratory (Boeing Phantom Works laboratory used for Warfighter Machine Interface requirements.

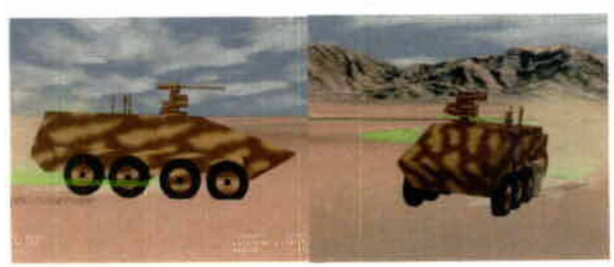

Figure 1 VDMS Executing Hard Brake and Turning for DTC VPG Operations

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The overarching goal of the VDMS modeling effort is to establish a method of improving the resolution and fidelity of the ground vehicle used in military experimentation (both operational and engineering). Figure 2 demonstrates the level or resolution that is available from VDMS compared to a common Army simulation package – the OneSAF Test Bed (OTB).

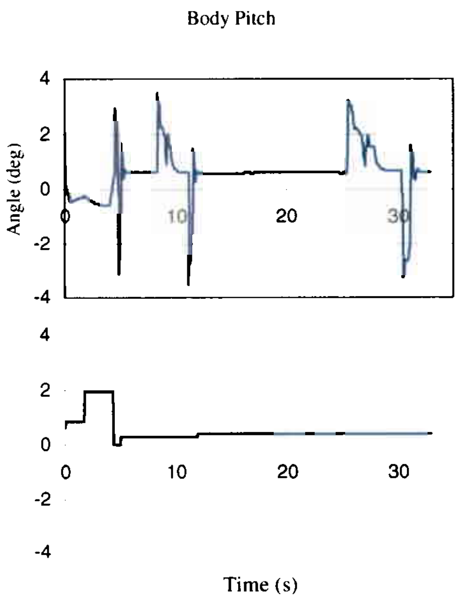

Figure 2 Comparison of VDMS (top) and OneSAF Test Bed Vehicle Pitch Motion

This goal of increased resolution is achieved through two connected paths. The first path takes advantage of ever increasing computer hardware capabilities to improve the run-time speed of models that previously were too complicated to run in real-time. High performance computing facilities are used by VDMS developers within the GVSL to execute vehicle models, and multiprocessor capabilities are being used in order to execute large numbers of ground platform entities within a distributed environment.

The second path is to improve the methods used in model execution in order to more efficiently solve the equations of motion. The latter path is being followed within the GVSL through an Army Technology Objective (ATO) program – the High-Fidelity Ground Platform and Terramechanics Modeling (HGTM) ATO.

It should be noted that higher resolution models are not always required, and when not required, the complications associated with increasing resolution are not usually worth the effort. A related effort within the GVSL is examining methods to determine exactly what resolution is required for an experiment and methods to ensure that different resolution mobility models give consistent results.

OFF-ROAD VEHICLE TERRAIN INTERFACE

A large part of the effort related to improving resolution and accuracy of ground mobility models used for human factor experimentation involves the relationship between the vehicle and the ground. An all season virtual terrain has been developed by Shoop, Coutermarsh, and Reid [5] with the capabilities to spatially distribute soil and snow properties and an interface to incorporate terrain deformation and the consequent forces on the wheel or track on variable strength terrain surface. Listed below, and illustrated in figure 3, are modeling efforts which represent a significant step forward in our ability to accurately simulate all-season vehicle performance in a real-time simulator.

- Methods to generate high-resolution terrain from lower resolution databases and statistical descriptions of the terrain by Morrison, Romano, Reid, Gorsich, [6].
- Three-dimensional, all-season (soil, snow, ice) terrain mechanics models, including surface deformation, moisture, and temperature effects along with the generation of tractive forces described by Richmond, Jones, Creighton, Alvin, [7].
- Obstacle layers capable of accommodating high resolution obstacle negation experiments.
- Dynamic terrain models that allow for soil deformation memory and obstacles that change because of natural and man-made events.

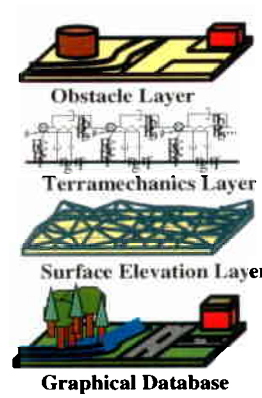

Figure 3. Database Generation

This vehicle terrain interface has been recently demonstrated at the Association United States Army and is currently undergoing a major validation effort. Once validated, the interface will be incorporated into GVSL human factor experiments.

VIRTUAL EVALUATION SUITE

The off-line, stand alone version of VDMS described above provides an analysis tool to evaluate vehicle designs and as the core verification and validation tool for HGTM ATO developed models described by Nunez, [8]. Since VDMS is flexible in how it is controlled, a wide set of simulated test conditions may be set up and executed.

A new evaluation product is called the Vehicle Evaluation Suite (VES) is currently being developed by Nunez, Reid, Jones, Shoop, [9]. The goal of this product is to create a virtual evaluation course that contains a full spectrum of automotive performance tests over geographically distant terrains and under various weather conditions. Standard output reports and full design and performance characteristic sheets will be automatically generated. The VES is a test bed within which the vehicle modeling technologies developed under the ATO are tested and evaluated.

Five sets of test suites are planned;

- Interface Compliance/Common Problem Test Suite: check the vehicle model interface compliance and common problems
- Vehicle dynamics suite: evaluates typical vehicle stability, handling, and ride and shock quality
- Soft-soil Mobility suite: evaluates soft-soil capabilities in varying soils and soil conditions
- Obstacle suite: evaluates obstacle negotiations including gaps and walls and complex obstacle groupings
- Power train suite: evaluates propulsion system performance (acceleration and braking) and fuel consumption/power management.

EXPERIMENTATION, DATA ACQUISITION AND ANALYSIS

MOTION CAPTURE

The successful utilization of motion capture system on a motion simulator has been described by Brubacher, Shyu, Oldaugh, and Zywiol, [10]. This is an optical system that utilizes special video cameras to track the motion of reflective markers attached to joints of the subject's body. Multiple camera systems operating at 200 frames per second are necessary for full human body capture. The motion capture system provides positional accuracy better than 1mm.

The centers of the marker images are matched from the various camera views using triangulation to compute their frame-to-frame positions in 3D space. These markers are reflective and the human subject is free to move without the constraints of cable connecting the body to other equipment.

A photo of a subject participating in an experiment is shown in figure 4. Note the reflective marker balls placed at key locations on his body and motion simulator cab structure.

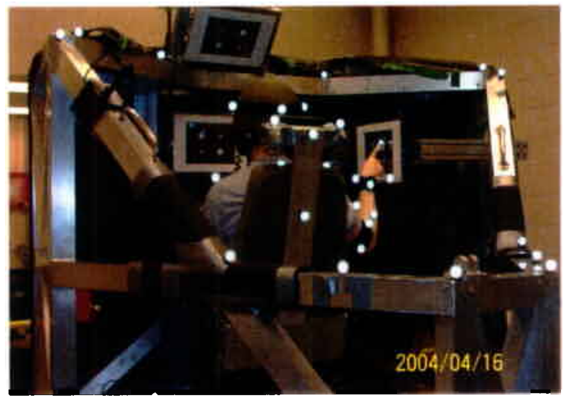

Figure 4: Motion Simulator Cab with Reflective Markers

Data acquisition systems such as the motion capture system can quantify suspected degraded subject performance in confined motion environments. The degraded accuracy of reach motions by a subject has been recently demonstrated by McDowell, Rider, Truong, and Paul [11]. The accuracy of reach motion within a moving environment is displayed in figure 5.

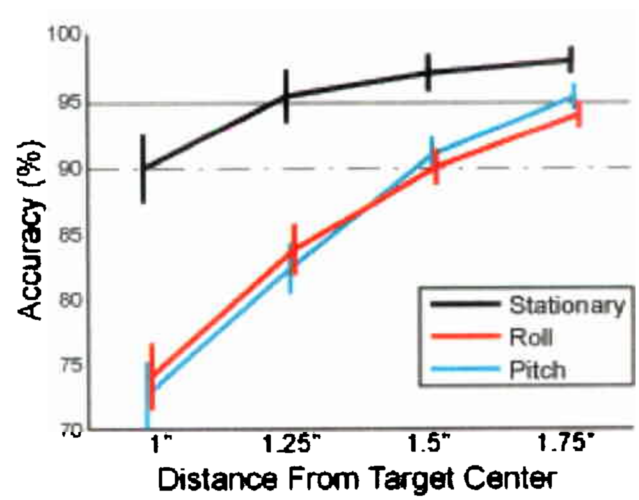

Figure 5. Accuracy as a function of distance from target center.

The solid, light horizontal line indicates 95% of the reaches in the Stationary condition fell within 1.25" of target center, while in the Roll and Pitch conditions, 95% fell within approximately 1.75". The 0.5" difference between the Stationary and moving conditions was also observed at the 90% accuracy line.

DIGITAL VIDEO COLLECTION AND REVIEW

Another new data acquisition product called SimObserver is a stand-alone digital collection and review system that allows you to capture and play back synchronized views of a simulation experience and is described by Real-time Technologies Incorporated, [12]. SimObserver captures video and compresses it in MPEG-2 format, maintaining 30 fps capture rate. SimObserver records simulation activity from up to four vantage points. These views are simultaneously displayed in quad view upon play back.

While you record a simulation using SimObserver, you can mark significant events with key strokes on the SimObserver computer or through remote commands issued from other applications. These events are recorded into an events file which is used to rapidly cue the video to the significant events you tagged during capture. Fast play, slow play, or frame-by-frame play back, combined with event seeking, gives you maximum flexibility when closely analyzing simulation captures.

SimObserver is designed so that it can be controlled from the SimObserver computer, itself, or through remote commands issued from some other device such as the simulator host computer or another third-party application. These commands are sent to SimObserver over an Ethernet network connection. See figure 6. You can remotely control nearly all of the

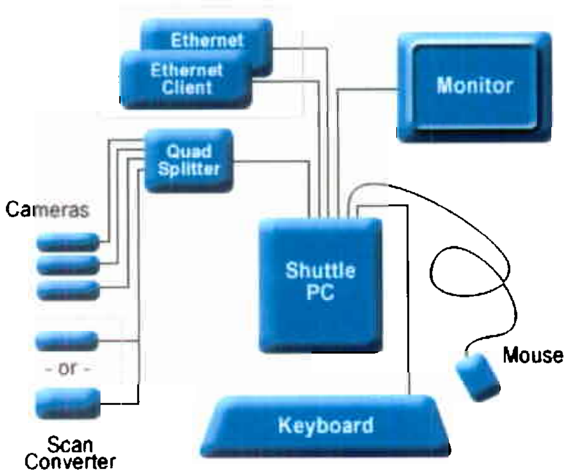

Figure 6. Hardware Configuration for SimCreator Product

video collection activities. Multiple applications can send commands to SimObserver during video collection.

The video and real time data you collect using SimCreator can be archived to DVD media format for safe and efficient long term storage.

A sample video capture and event marking is displayed in figure 7.

Figure 7. Sample Video Capture

ARMY POWER BUDGET MODEL AND DUTY CYCLE EXPERIMENTATION (APBM-DCE)

The GVSL is performing a set of experiments in order to estimate power requirements (duty cycles) on the future battlefield. The duty cycles will be included in the Army Power Budget Model (APBM) - a tool being developed in parallel with the simulation experiments in order to facilitate power system design at the systems level and examine how new technologies in survivability, lethality, propulsion and C4ISR will affect power requirements.

The APBM integrates dynamic models and hardware components of power producing systems (i.e. hybrid power train systems), a hybrid set of dynamic and static power consumption models and hardware components (i.e. mobility, survivability, lethality, C4ISR subsystems), and a library of mission profiles (duty cycles) to which future military vehicles will be subjected. The integrated set of models will be designed to provide both a desktop analysis capability and a distributed simulation capability as shown in figure 8.

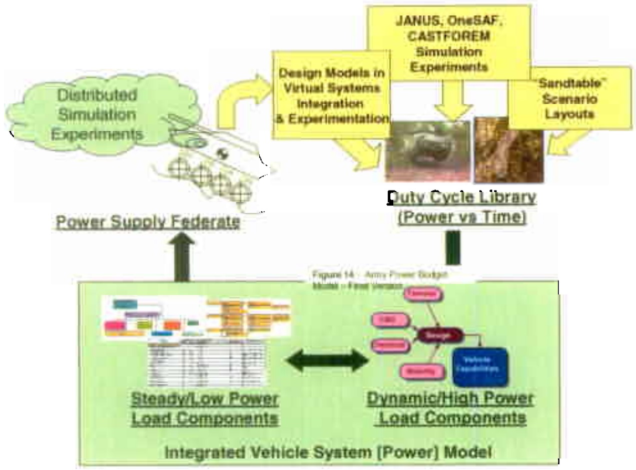

Figure 8. Army Power Budget Model Components

The APBM consists of three main components – two sets of models that together form an integrated power system model, and a library of duty cycles. In addition, the APBM is capable of generating real-time model representations of the components that are used in further duty cycle estimation efforts.

The main components of the APBM are;

- Dynamic/Large Power Load Components: Power loads that vary quickly and are large enough to require a higher-resolution model. This set of models represents the dynamic behavior of the system. High-fidelity power train component models and external (i.e. non-mobility) high-fidelity power consumption models for those components that are of a primarily dynamic nature should be included here.

- Steady/Low Power Load Components: Minimal power consumption models/data/requirements.

- Duty Cycle (Power vs. Time): A set of duty cycles to represent several use cases of FCS scenarios.

The first two components taken together represent a complete power generation, power consumption, and mobility system. The third component approximates how that system may be used and is the subject of the second part of this project – Duty Cycle Experimentation (DCE).

Data from RDECOM and TRADOC simulation experiments will be used to estimate the power requirements during future army operations. The experiments will involve operational scenarios.

The army power budget model and duty cycle experimentation effort planned provides an opportunity to further utilize the realtime modeling and simulation products described in this paper.

RESULTS

Several real-time simulation products geared for soldier performance measurement in motion base environments have been developed. Flexible, multi-body dynamics vehicle models are utilized in several test centers and laboratories. A Virtual Evaluation Suite can evaluate performance of analytical mobility models. A vehicle terrain interface featuring higher resolution terrain, terrain mechanics, obstacles, and dynamic terrain has been designed and demonstrated. Motion capture technology has been proven to be useful in determining 3-Dimensional human motion for a motion base simulator. The SimObserver TM product has been very helpful in presenting correlated event-video data. Finally, the Army power budget model and duty cycle experimentation can utilize the products described in this paper.

CONCLUSION

New products for real-time mobility simulations featuring soldier performance are available for use in laboratories. These products include advanced vehicle terrain interfaces and desirable data acquisition features. These products are welcome as real-time experiment demands increase to achieve results early in the system development process.

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ABBREVIATIONS