THEORY OF MODELING AND SIMULATION

by Bernard P. Zeigler, Herbert Praehofer, Tag Gon Kim

2nd Edition, Academic Press, 2000, ISBN: 0127784551

Given the many advances in modeling and simulation in the last decades, the need for a widely accepted framework and theoretical foundation is becoming increasingly necessary. Methods of modeling and simulation are fragmented across disciplines making it difficult to re-use ideas from other disciplines and work collaboratively in multidisciplinary teams. Model building and simulation is becoming easier and faster through implementation of advances in software and hardware. However, difficult and fundamental issues such as model credibility and interoperation have received less attention. These issues are now addressed under the impetus of the High Level Architecture (HLA) standard mandated by the U.S. DoD for all contractors and agencies.

This book concentrates on integrating the continuous and discrete paradigms for modeling and simulation. A second major theme is that of distributed simulation and its potential to support the co-existence of multiple formalisms in multiple model components. Prominent throughout are the fundamental concepts of modular and hierarchical model composition. These key ideas underlie a sound methodology for construction of complex system models.

The book presents a rigorous mathematical foundation for modeling and simulation. It provides a comprehensive framework for integrating various simulation approaches employed in practice, including such popular modeling methods as cellular automata, chaotic systems, hierarchical block diagrams, and Petri Nets. A unifying concept, called the DEVS Bus, enables models to be transparently mapped into the Discrete Event System Specification (DEVS). The book shows how to construct computationally efficient, object-oriented simulations of DEVS models on parallel and distributed environments. In designing integrative simulations, whether or not they are HLA compliant, this book provides the foundation to understand, simplify and successfully accomplish the task.

MODELING HUMAN AND ORGANIZATIONAL BEHAVIOR: APPLICATION TO MILITARY SIMULATIONS

Editors: Anne S. Mavor, Richard W. Pew

National Academy Press, 1999, ISBN: 0309060966. Hardcover - 432 pages.

This book presents a comprehensive treatment of the role of the human and the organization in military simulations. The issue of representing human behavior is treated from the perspective of the psychological and organizational sciences. After a thorough examination of the current military models, simulations and requirements, the book focuses on integrative architectures for modeling the individual combatant, followed by separate chapters on attention and multitasking, memory and learning, human decision making in the framework of utility theory, models of situation awareness and enabling technologies for their implementation, the role of planning in tactical decision making, and the issue of modeling internal and external moderators of human behavior.

The focus of the tenth chapter is on modeling of behavior at the unit level, examining prior work, organizational unit-level modeling, languages and frameworks. It is followed by a chapter on information warfare, discussing models of information diffusion, models of belief formation and the role of communications technology. The final chapters consider the need for situation-specific modeling, prescribe a methodology and a framework for developing human behavior representations, and provide recommendations for infrastructure and information exchange.

The book is a valuable reference for simulation designers and system engineers.

HANDBOOK OF SIMULATOR-BASED TRAINING

by Eric Farmer (Ed.), Johan Reimersma, Jan Moraal, Peter Jorna

Ashgate Publishing Company, 1999, ISBN: 0754611876.

The rapidly expanding area of military modeling and simulation supports decision making and planning, design of systems, weapons and infrastructure. This particular book treats the third most important area of modeling and simulation – training. It starts with thorough analysis of training needs, covering mission analysis, task analysis, trainee and training analysis. The second section of the book treats the issue of training program design, examining current practices, principles of training and instruction, sequencing of training objectives, specification of training activities and scenarios, methodology of design and optimization of training programs. In the third section the authors introduce the problem of training media specification and treat technical issues such as databases and models, human-simulator interfaces, visual cueing and image systems, haptic, kinaesthetic and vestibular cueing, and finally, the methodology for training media specification. The final section of the book is devoted to training evaluation, covering the topics of performance measurement, workload measurement, and team performance. In the concluding part the authors outline the trends in using simulators for training.

The primary audience for this book is the community of managers and experts involved in training operators. It can also serve as useful reference for designers of training simulators.

CREATING COMPUTER SIMULATION SYSTEMS:

An Introduction to the High Level Architecture

by Frederick Kuhl, Richard Weatherly, Judith Dahmann

Prentice Hall, 1999, ISBN: 0130225118. - 212 pages.

Given the increasing importance of simulations in nearly all aspects of life, the authors find that combining existing systems is much more efficient than building newer, more complex replacements. Whether the interest is in business, the military, or entertainment or is even more general, the book shows how to use the new standard for building and integrating modular simulation components and systems. The HLA, adopted by the U.S. Department of Defense, has been years in the making and recently came ahead of its competitors to grab the attention of engineers and designers worldwide.

The book and the accompanying CD-ROM set contain an overview of the rationale and development of the HLA; a Windows-compatible implementation of the HLA Runtime Infrastructure (including test software). It allows the reader to understand in-depth the reasons for the definition of the HLA and its development, how it came to be, how the HLA has been promoted as an architecture, and why it has succeeded. Of course, it provides an overview of the HLA examining it as a software architecture, its large pieces, and chief functions; an extended, integrated tutorial that demonstrates its power and applicability to real-world problems; advanced topics and exercises; and well-thought-out programming examples in text and on disk.

The book is well-indexed and may serve as a guide for managers, technicians, programmers, and anyone else working on building simulations.

HANDBOOK OF SIMULATION:

Principles, Methodology, Advances, Applications, and Practice

edited by Jerry Banks

John Wiley & Sons, 1998, ISBN: 0471134031. Hardcover - 864 pages.

Simulation modeling is one of the most powerful techniques available for studying large and complex systems. This book is the first ever to bring together the top 30 international experts on simulation from both industry and academia. All aspects of simulation are covered, as well as the latest simulation techniques. Most importantly, the book walks the reader through the various industries that use simulation and explains what is used, how it is used, and why.

This book provides a reference to important topics in simulation of discrete- event systems. Contributors come from academia, industry, and software development. Material is arranged in sections on principles, methodology, recent advances, application areas, and the practice of simulation. Topics include object-oriented simulation, software for simulation, simulation modeling, and experimental design. For readers with good background in calculus based statistics, this is a good reference book.

Applications explored are in fields such as transportation, healthcare, and the military. Includes guidelines for project management, as well as a list of software vendors. The book is co-published by Engineering and Management Press.

ADVANCES IN MISSILE GUIDANCE THEORY

by Joseph Z. Ben-Asher, Isaac Yaesh

AIAA, 1998, ISBN 1-56347-275-9.

This book about terminal guidance of intercepting missiles is oriented toward practicing engineers and engineering students. It contains a variety of newly developed guidance methods based on linear quadratic optimization problems. This application-oriented book applies widely used and thoroughly developed theories such LQ and H-infinity to missile guidance. The main theme is to systematically analyze guidance problems with increasing complexity. Numerous examples help the reader to gain greater understanding of the relative merits and shortcomings of the various methods. Both the analytical derivations and the numerical computations of the examples are carried out with MATLAB Companion Software: The authors have developed a set of MATLAB M-files that are available on a diskette bound into the book.

CONTROL OF SPACECRAFT AND AIRCRAFT

by Arthur E. Bryson, Jr.

Princeton University Press, 1994, ISBN 0-691-08782-2.

This text provides an overview and summary of flight control, focusing on the best possible control of spacecraft and aircraft, i.e., the limits of control. The minimum output error responses of controlled vehicles to specified initial conditions, output commands, and disturbances are determined with specified limits on control authority. These are determined using the linear-quadratic regulator (LQR) method of feedback control synthesis with full-state feedback. An emphasis on modeling is also included for the design of control systems. The book includes a set of MATLAB M-files in companion software

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MATHWORKS

http://www-europe.mathworks.com

Initial information MATLAB is given in this volume to allow to present next the Simulink package and the Flight Dynamics Toolbox, providing for rapid simulation-based design. MATLAB is the foundation for all the MathWorks products. Here we would like to discus products of MathWorks related to the simulation, especially Code Generation tools and Dynamic System Simulation.

Code Generation and Rapid Prototyping

The MathWorks code generation tools make it easy to explore real-world system behavior from the prototyping stage to implementation. *Real-Time Workshop* and *Stateflow Coder* generate highly efficient code directly from Simulink models and Stateflow diagrams. The generated code can be used to test and validate designs in a real-time environment, and make the necessary design changes before committing designs to production. Using simple point-and-click interactions, the user can generate code that can be implemented quickly without lengthy hand-coding and debugging. Real-Time Workshop and Stateflow Coder automate compiling, linking, and downloading executables onto the target processor providing fast and easy access to real-time targets. By automating the process of creating real-time executables, these tools give an efficient and reliable way to test, evaluate, and iterate your designs in a real-time environment.

Real-Time Workshop, the code generator for Simulink, generates efficient, optimized C and Ada code directly from Simulink models. Supporting discrete-time, multirate, and hybrid systems, Real-Time Workshop makes it easy to evaluate system models on a wide range of computer platforms and real-time environments.

Stateflow Coder, the standalone code generator for Stateflow, automatically generates C code from Stateflow diagrams. Code generated by Stateflow Coder can be used independently or combined with code from Real-Time Workshop.

Real-Time Windows Target, allows to use a PC as a standalone, self-hosted target for running Simulink models interactively in real time. Real-Time Windows Target supports direct I/O, providing real-time interaction with your model, making it an easy-to-use, low-cost target environment for rapid prototyping and hardware-in-the-loop simulation.

xPC Target allows to add I/O blocks to Simulink block diagrams, generate code with Real-Time Workshop, and download the code to a second PC that runs the xPC target real-time kernel. xPC Target is ideal for rapid prototyping and hardware-in-the-loop testing of control and DSP systems. It enables the user to execute models in real time on standard PC hardware.

By combining the MathWorks code generation tools with hardware and software from leading real-time systems vendors, the user can quickly and easily perform rapid prototyping, hardware-in-the-loop (HIL) simulation, and real-time simulation and analysis of your designs. Real-Time Workshop code can be configured for a variety of real-time operating systems, off-the-shelf boards, and proprietary hardware.

The MathWorks products for control design enable the user to make changes to a block diagram, generate code, and evaluate results on target hardware within minutes. For turnkey rapid prototyping solutions you can take advantage of solutions available from partnerships between The MathWorks and leading control design tools:

- *dSPACE Control Development System:* A total development environment for rapid control prototyping and hardware-in-the-loop simulation;
- *WinCon:* Allows you to run Real-Time Workshop code independently on a PC;
- *World Up:* Creating and controlling 3-D interactive worlds for real-time visualization;
- *ADI Real-Time Station:* Complete system solution for hardware-in-the loop simulation and prototyping.
- *Pi AutoSim:* Real-time simulator for testing automotive electronic control units (ECUs).
- *Opal-RT:* a rapid prototyping solution that supports real-time parallel/distributed execution of code generated by Real-Time Workshop running under the QNX operating system on Intel based target hardware.

Dynamic System Simulation

Simulink is a powerful graphical simulation tool for modeling nonlinear dynamic systems and developing control strategies. With support for linear, nonlinear, continuous-time, discrete-time, multirate, conditionally executed, and hybrid systems, Simulink lets you model and simulate virtually any type of real-world dynamic system. Using the powerful simulation capabilities in Simulink, the user can create models, evaluate designs, and correct design flaws before building prototypes.

Simulink provides a graphical simulation environment for modeling dynamic systems. It allows to build quickly block diagram models of dynamic systems. The Simulink block library contains over 100 blocks that allow to graphically represent a wide variety of system dynamics. The block library includes input signals, dynamic elements, algebraic and nonlinear functions, data display blocks, and more. Simulink blocks can be triggered, enabled, or disabled, allowing to include conditionally executed subsystems within your models.

FLIGHT DYNAMICS TOOLBOX – FDC 1.2

report by Marc Rauw

FDC is an abbreviation of Flight Dynamics and Control. The FDC toolbox for Matlab and Simulink makes it possible to analyze aircraft dynamics and flight control systems within one software environment on one PC or workstation. The toolbox has been set up around a general non-linear aircraft model which has been constructed in a modular way in order to provide maximal flexibility to the user. The model can be accessed by means of the graphical user-interface of Simulink. Other elements from the toolbox are analytical Matlab routines for extracting steady-state flight-conditions and determining linearized models around user-specified operating points, Simulink models of external atmospheric disturbances that affect the motions of the aircraft, radio-navigation models, models of the autopilot, and several help-utilities which simplify the handling of the systems. The package can be applied to a broad range of stability and control related problems by applying Matlab tools from other toolboxes to the systems from FDC 1.2. The FDC toolbox is particularly useful for the design and analysis of Automatic Flight Control Systems (AFCS). By giving the designer access to all models and tools required for AFCS design and analysis within one graphical Computer Assisted Control System Design (CACSD) environment the AFCS development cycle can be reduced considerably. The current version 1.2 of the FDC toolbox is an advanced proof of concept package which effectively demonstrates the general ideas behind the application of CACSD tools with a graphical user- interface to the AFCS design process.

MODELING AND SIMULATION TERMINOLOGY

MILITARY SIMULATION
TECHNIQUES & TECHNOLOGY

Introduction to Simulation

Definitions. Defines simulation, its applications, and the benefits derived from using the technology. Compares simulation to related activities in analysis and gaming.

DOD Overview. Explains the simulation perspective and categorization of the US Department of Defense.

Training, Gaming, and Analysis. Provides a general delineation between these three categories of simulation.

System Architectures

Components. Describes the fundamental components that are found in most military simulations.

Designs. Describes the basic differences between functional and object oriented designs for a simulation system.

Infrastructures. Emphasizes the importance of providing an infrastructure to support all simulation models, tools, and functionality.

Frameworks. Describes the newest implementation of an infrastructure in the forma of an object oriented framework from which simulation capability is inherited.

Interoperability

Dedicated. Interoperability initially meant constructing a dedicated method for joining two simulations for a specific purpose.

DIS. The virtual simulation community developed this method to allow vehicle simulators to interact in a small, consistent battlefield.

ALSP. The constructive, staff training community developed this method to allow specific simulation systems to interact with each other in a single joint training exercise.

HLA. This program was developed to replace and, to a degree, unify the virtual and constructive efforts at interoperability.

JSIMS. Though not labeled as an interoperability effort, this program is pressing for a higher degree of interoperability than have been achieved through any of the previous programs.

Event Management

Queuing. The primary method for executing simulations has been various forms of queues for ordering and releasing combat events.

Trees. Basic queues are being supplanted by techniques such as Red-Black and Splay trees which allow the simulation store, process, and review events more efficiently than their predecessors.

Event Ownership. Events can be owned and processed in different ways. Today's preference for object oriented representations leads to vehicle and unit ownership of events, rather than the previous techniques of managing them from a central executive.

Time Management

Universal. Single processor simulations made use of a single clocking mechanism to control all events in a simulation. This was extended to the idea of a "master clock" during initial distributed simulations, but is being replaced with more advanced techniques in current distributed simulation.

Synchronization. The "master clock" too often lead to poor performance and required a great deal of cross-simulation data exchange. Researchers in the Parallel Distributed Simulation community provided several techniques that are being used in today's training environment.

Conservative & Optimistic. The most notable time management techniques are conservative synchronization developed by Chandy, Misra, and Bryant, and optimistic synchronization (or Time Warp) developed by David Jefferson.

Real-time. In addition to being synchronized across a distributed computing environment, many of today's simulators must also perform as real-time systems. These operate under the additional duress of staying synchronized with the human or system clock perception of time.

Principles of Modeling

Science & Art. Simulation is currently a combination of scientific method and artistic expression. Learning to do this activity requires both formal education and watching experienced practitioners approach a problem.

Process. When a team of people undertake the development of a new simulation system they must follow a defined process. This is often re-invented for each project, but can better be derived from experience of others on previous projects.

Fundamentals. Some basic principles have been learned and relearned by members of the simulation community. These have universal application within the field and allow new developers to benefit from the mistakes and experiences of their predecessors.

Formalism. There has been some concentrated effort to define a formalism for simulation such that models and systems are provably correct. These also allow mathematical exploration of new ideas in simulation.

Physical Modeling

Object Interaction. Military object modeling is be divided into two pieces, the physical and the behavioral. Object interactions, which are often viewed as 'physics based', characterize the physical models.

Movement. Military objects are often very mobile and a great deal of effort can be given to the correct movement of ground, air, sea, and space vehicles across different forms of terrain or through various forms of ether.

Sensor Detection. Military object are also very eager to interact with each other in both peaceful and violent ways. But, before they can do this they must be able to perceive each other through the use of human and mechanical sensors.

Engagement. Encounters with objects of a different affiliation often require the application of combat engagement algorithms. There are a rich set of these available to the modeler, and new ones are continually being created.

Attrition. Object and unit attrition may be synonymous with engagement in the real world, but when implemented in a computer environment they must be separated to allow fair combat exchanges. Distributed simulation systems are more closely replicating real world activities than did their older functional/sequential ancestors, but the distinction between engagement and attrition are still important.

Communication. The modern battlefield is characterized as much by communication and information exchange as it is by movement and engagement. This dimension of the battlefield has been largely ignored in previous simulations, but is being addressed in the new systems under development today.

More. Activities on the battlefield are extremely rich and varied. The models described in this section represent some of the most fundamental and important, but they are only a small fraction of the detail that can be included in a model.

Behavioral Modeling

Perception. Military simulations have historically included very crude representations of human and group decision making. One of the first real needs for representing the human in the model was to create a unique perception of the battlefield for each group, unit, or individual.

Reaction. Battlefield objects or units need to be able to react realistically to various combat environments. These allow the simulation to handle many situations without the explicit intervention of a human operator.

Planning. Today we look for intelligent behavior from simulated objects. Once form of intelligence is found in allowing models to plan the details of a general operational combat order, or to formulate a method for extracting itself for a difficult situation.

Learning. Early reactive and planning models did not include the capability to learn from experience. Algorithms can be built which allow units to become more effective as they become more experienced. They also learn the best methods for operating on a specific battlefield or under specific conditions.

Artificial Intelligence. Behavioral modeling can benefit from the research and experience of the AI community. Techniques of value include: Intelligent Agents, Finite State Machines, Petri Nets, Expert and Knowledge-based Systems, Case Based Reasoning, Genetic Algorithms, Neural Networks, Constraint Satisfaction, Fuzzy Logic, and Adaptive Behavior. An introduction is given to each of these along with potential applications in the military environment.

Environmental Modeling

Terrain. Military objects are heavily dependent upon the environment in which they operate. The representation of terrain has been of primary concern because of its importance and the difficulty of managing the amount of data required. Triangulated Irregular Networks (TINs) are one of the newer techniques for managing this problem.

Atmosphere. The atmosphere plays an important role in modeling air, space, and electronic warfare. The effects of cloud cover, precipitation, daylight, ambient noise, electronic jamming, temperature, and wind can all have significant effects on battlefield activities.

Sea. The surface of the ocean is nearly as important to naval operations as is terrain to army operations. Sub-surface and ocean floor representations are also essential for submarine warfare and the employment of SONAR for vehicle detection and engagement.

Standards. Many representations of all of these environments have been developed.

Unfortunately, not all of these have been compatible and significant effort is being given to a common standard for supporting all simulations. Synthetic Environment Data Representation and Interchange Specification (SEDRIS) is the most prominent of these standardization efforts.

Multi-Resolution Modeling

Aggregation. Military commanders have always dealt with the battlefield in an aggregate form. This has carried forward into simulations which operate at this same level, omitting many of the details of specific battlefield objects and events.

Disaggregation. Recent efforts to join constructive and virtual simulations have required the implementation of techniques for cross the boundary between these two levels of representation. Disaggregation attempts to generate an entity level representation from the aggregate level by adding information. Conversely, aggregation attempts to create the constructive from the virtual by removing information.

Interoperability. It is commonly accepted that interoperability in these situations is best achieved though disaggregation to the lowest level of representation of the models involved. In any form the patchwork battlefield seldom supports the same level of interoperability across model levels as is found within models at the same level of resolution.

Inevitability. Models are abstractions of the real world generated to address a specific problem. Since all problems are not defined at the same level of physical representation, the models built to address them will be at different levels. The modeling an simulation problem domain is too rich to ever expect all models to operate at the same level. Multi-Resolution Modeling and techniques to provide interoperability among them are inevitable.

Verification, Validation, and Accreditation

Verification. Simulation systems and the models within them are conceptual representations of the real world. By their very nature these models are partially accurate and partially inaccurate. Therefore, it is essential that we be able to verify that the model constructed accurately represents the important parts of the real world we are try to study or emulate.

Validation. The conceptual model of the real world is converted into a software program. This conversion has the potential to introduce errors or inaccurately represent the conceptual model. Validation ensures that the software program accurately reflects the conceptual model.

Accreditation. Since all models only partially represent the real world, they all have limited application for training and analysis. Accreditation defines the domains and conditions under which a particular model can be reliably used.

VV&A Principles. The Department of Defense has established specific guidelines for conducting VV&A. Simulation researchers have also defined fundamental principles that are important for this activity.

Model Building Exercises

Modeling. In-class projects to explore the concepts presented in the lectures. These exercises demonstrate the process and product of modeling the real world.

Exploration. Students explore the questions involved in modeling. Learn to identify the objective of the system, interactions in the virtual world, objects that must be defined, and dynamic and static attributes of the objects.

Models and Infrastructure. Practical exercises demonstrate the power of a simulation infrastructure and how it is related to the models of the real world.

ACRONYMS

ADS	Advanced Distributed Simulation
AMG	Architecture Management Group
AMSO	Army Modeling and Simulation Office
API	Application Programmer Interface
ASOC	Air Sovereignty Operations Center
BBS	Brigade/Battalion Battle Simulation
C3	Command, Control and Communications
CAX	Computer Assisted (Aided) Exercise
CBS	Corps Battle Simulation
CCTT	Close Combat Tactical Trainer
CGF	Computer Generated Forces
CGI	Computer Graphic Interface / Common Gateway Interface

CONOPS	Concept of Operations
CORBA	Common Object Request Broker Architecture
COTS	Commercial off-the-shelf
CSSTSS	Combat Service Support Training Simulation System
CTDB	Compact Terrain Database Base
DARPA	Defense Advanced Research Projects Agency
DBMS	Data-Base Management System
DCOM	Distributed COM (Component Object Model)
DCS	Data Coding Standard
DIS	Distributed Interactive Simulation
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
DOM	Document Object Model
DRM	Data Representation Model
EXCIMS	Executive Council for Modeling and Simulation
FEDEP	Federation Development and Execution Process
FIFO	First In First Out
FOM	Federation Object Model
FZD	Fire Zone Defense
GIAC	Graphics Input Aggregate Control
GVT	Global Virtual Time
HLA	High-Level Architecture
HOP	Hasty Occupy Position (algorithm)
HTTP	Hyper-Text Transfer Protocol
IDL	Interface Definition Language

IIOP	Inter-ORB Communication Protocol
IMACCS	Integrated Monitoring, Analysis and Control COTS System
IMT	Information Management Terminal
JDBC	Java Database Connectivity
JSIMS	Joint Simulation System
JTC	Joint Training Confederation
JTLS	Joint Theater Level Simulation
JWORB	Java Web Object Request Broker
LAN	Local Area Network
LOC	Line-Of-Code
M&S	Modeling and Simulation
MILES	Multiple Integrated Laser Engagement System
MoD	Ministry of Defense
ModSAF	Modular Semi-Automated Forces
MODSIM	Modular Simulation Language
MOSAIC	MOdels & Simulations: Army Integrated Catalog
MPP	Message Processor Program
MRM	Multi-Resolution Model
MSIAC	Modeling and Simulation Information Analysis Center
MSRR	(Army) Modeling and Simulation Resource Repository
MTWS	Marine Air Ground Task Force Tactical Warfare Simulation
NC3A	NATO's Command Control and Consultancy Agency
NMCC	National Military Command Center

NPAC	Northeast Parallel Architectures Center (Syracuse University)
NTC	(Army) National Training Center
ODBC	Open Database Connectivity
OLEDB	Object Linking and Embedding – Data Base
OMDT	Object Model Development Tool
OMG/DARPA	Object Management Group/ Defense Advanced Research Project Agency
OPLAN	Operations Plan
PIMS	Partnership Information Management System
PSS	Persistent State Service
RDBMS	Relational Data-Base Management System
RDF	Resource Description Format
RENAISSANCE	Reusable Network Architecture Interoperable Space Science, Analysis, Navigation, and Control Environment
RESA	Research, Evaluation, and Systems Analysis
RMI	Remote Method Invocation
SAM	Surface-to-Air Missile
SAMPEX	Solar Anomalous Magnetospheric Particle Explorer
SMTP	Simple Message Transfer Protocol
SQL	Structured Query Language
SSN	Space Surveillance Network
STF	SEDRIS Transmittal Format
TACSIM	Tactical Simulation
TIN	Triangulated Irregular Networks
TRP	Target Reference Point

TVR	Televirtual
UML	Unified Modeling Language
VICTORS	Variable Intensity Computerized Training System
VRML	Virtual Reality Modeling Language
VV&A	Verification, Validation and Accreditation
WAN	Wide Area Network
XML	Extensible Markup Language

MODELING AND SIMULATION RELATED WEB SITES

Defense Modeling, Simulation & Tactical Technology Information Analysis Center (DMSTTIAC)

ADS	www.ads.msrr.dmso.mil	Authoritative Data Sources [DMSO]
AEDC	www.arnold.af.mil	Arnold Engineering Development Center [AF]
AFAMS	www.afams.af.mil	Air Force Agency for Modeling & Simulation
AFCA	www.afca.scott.af.mil	Air Force Communications Agency
AFIT	www.afit.af.mil	Air Force Institute of Technology
AFSAA	www.afsaa.hq.af.mil	Air Force Studies Analyses Agency
AIR FORCE	www.af.mil	Air Force Home Page

Air Force MSRR	www.Afmsrr.afams.af.mil	Air Force M&S Resource Repository
ALSP	www.stricom.army.mil/hla/amg/PRODUCTS/ALSP	Aggregate Level Simulation Protocol
AMG	www.hla.dmso.mil/hla/amg	Architecture Management Group [DMSO – HLA]
APG	www.apg.army.mil	Aberdeen Proving Ground [ARMY]
ARDEC	www.pica.army.mil	Armament R,D, &E Center [ARMY]
ARDEC – DIS	www.Dis.pica.army.mil	Armament R,D, &E Center - DIS [ARMY]
ARL	www.arl.mil/	Army Research Laboratory
ARMY	www.army.mil	Army Homepage
ARMY MSRR	www.msrr.army.mil	Army M&S Resource Repository
ASA, RDA, (ASA, AL&T)	www.sarda.army.mil	Asst Secretary of the Army for Research, Development, &Acquisition [effective 16 Feb99 ASA, AL&T]
ASNE MSEA	www.Msea.afccc.af.mil	Air & Space Natural Environment MSEA

ASTT	www.astt.com	Advanced Simulation Technology Thrust [DARPA/JSIMS]
ATDNet	www.atd.net	Advanced Technology Demonstration Network
AWSIM	www.wg.hanscom.af.mil/AWSIMR/	Air Warfare Simulation [AF}
BMD SSC	www.jntf.osd.mil/bmdssc/	Ballistic Missile Defense Simulation Support Center
BMDO	www.jntf.osd.mil/	Ballistic Missile Defense Organization
BMDOLINK	www.acq.osd.mil/bmdo/bmdolink/html	BMDOLink
BMDO MSRR	www.jntf.osd.mil/bmdssc/	BMDO M&S Resource Repository
C4ISR DSC	www.dsc.osd.mil	[Joint] C4ISR Decision Support Center
C4ISR JBC	www.jbc.js.mil	C4ISR Joint Battle Center
C4ISR Model	www.diisa.mil/D8/html/c4isr.html	DISA C4ISR Model [Federation]
CFS	www.itsi.disa.mil/	Center For Standards [DISA JIEO]
CMMS	www.dmso.mil/projects/cmms/	Conceptual Model of the Mission Space [DSMO]

COMPASS	www.Compass.saic.com	Common Operation Modeling, Planning, &Simulation Strategy
DARPA	www.darpa.mil	Defense Advanced Research Projects Agency
DDR&E	www.dtic.mil/ddre	Director Defense Research & Engineering [OSD]
DEEM	www.dis.anl.gov/DEEM	Dynamic Environmental Effects Model
DEFENSLINK	www.defenselink.mil	DefenseLINK
DIAS	www.dis.anl.gov/DIAS	Dynamic Information Architecture System
DISA	www.disa.mil	EFENSE information Systems Agency
DISA C4ISR Model	www.disa.mil/D8/html/c4isr.html	DISA C4ISR Model [Federation]
DISA Standards	www.itsi.disa.mil/links.html www.disa.mil	DISA Standards Links DISA Standards Site Index
DMSO	www.dsmo.mil	Defense Modeling and Simulation Office

DMSO Projects>		

>M&S Awards	www.dmso.mil/dmso/projects/award	DMSO M&S Award Program
>ADS	www.Ads.msrr.dmso.mil	Authorities Data Sources
>CMMS	www.dmso.mil/dmso/projects/cmms	Conceptual Model of the Mission Space
>DAVIE	www.dmso.mil/projacts/davie	Data Verification Interactive Editor
>DS	www.dmso.mil/ds	Data Standardization
>DMSTTIAC	www.Dmsttiac.iitri.org	Defense Modeling, Simulation, & Tactical Technology Information Analysis Center
>HLA	www.Hla.dmso.mil/hla	High – Level [Simulation] Architecture
>HBR	www.dmso.mil/dmso/projects/hbr`	Human Behavior Representation
>MEL	www.Mel.dmso.mil	Master Environment Library
>MSOSA	www.msosa.mil.inter.net	Modeling & Simulation Operational Support Activity
>MSRR	www.msrr.dmso.mil	Modeling &Simulation Resource Repository
>SEDRIS	www.sedris.org	Synthetic Environment Data Representation & Interchange Specification
>UOB	www.dmso.mil/dmso/projects/uob	Unit Order of Battle
>TMPO	www.tmpo.nima.mil	Terrain Modeling Project Office

>VV&A	www.dmso.mil/dmso/projects/vva	Verification, Validation, and Accreditation

DMSTTIAC	www.Dmsttiac.iitri.org	Defense Modeling, Simulation, & Tactical Technology Information Analysis Center [DMSO/DISA/DTIC]
DREN	www.arl.mil/HPCMP/DREN	Defense Research & Engineering Network
DS	www.dmso.mil/projects/ds	Data Standardization [DMSO]
DSC	www.dsc.osd.mil	[Joint C4ISR] Decision Support Center
DTIC	www.dtic.mil	Defense Technical Information Center
E2DIS	www.Vader.nrl.navy.mil/e2dis_www/home.html	Environment Effects for Distributed Interactive Simulation
EADSIM	www.smdc.army/mil/eadsim.html	Extended Air Defense Simulation
EADTB	www.smdc.army.mil/eadtb~2.html	Extended Air Defense Test bed
EXCIM	www.dmso.mil/dmso/wrkgrps/excims	Execute Council on Modeling &Simulation [DMSO]
HBR	www.dmso.mil/dmso/projects/hbr`	Human Behavior Representation [DMSO]
HLA	www.Hla.dmso.mil/hla	High – Level Architecture [DMSO}

HPCMP	www.hpcm.dren.net	High Performance Computing Modernization Program
ISOC	www.isoc.org	Internet Society
IST	www.ist.ucf.edu	Institute for Simulation & Training, Univ of Central Florida
ISTI	www.Disa11.disa.atd.net	Information Systems Technology Insertion [DSA]
ITEA	www.itea.org	International Test &Evaluation Association
JADS JTF	www.jads.abq.com	Joint Advanced Distributed Simulation Joint Test Force
JASA	www.nawcwpns.navy.mil/~jasa	Joint Accreditation Support Activity
JBC	www.jbc.js.mil	Joint [C4ISR] Battle Center
JSC	www.dtic.mil/jsc	Joint Chief of Staff
JDBE	208.245.129.4	Joint Data Base Element
JEL	www.dtic.mil/doctrine/jel/index.html	Joint Electronic Library
JMASS	www.jmas.wpafb.af.mil	Joint Modeling and Simulation System
JSF	www.jast.mil/html/jst_homepage.htm	Joint Strike Fighter
JSIMS	www.jsims.mil	Joint Simulation System
JTA	www.acq-ref.navy.mil/narsoc/jta021	Joint Technical Architecture [DoD]

JTASC	www.jtasc.acom.mil	Joint Training, Analysis, and Simulation Center [USACOM]
JWARS	www.dtic.mil/jwars	Joint Warfare System
JWFC	www.jwfc.acom.mil	Joint War fighting Center [USACOM]
MARINES	www.usmc.mil	Marine Corps Homepage

M&S Master Plans>	
>DoD	www.dmso.mil/dmso/docslib/mspolicy/msmp
>Army	www.amso.army.mil/mstrplin
>Navy	www.nawcad.navy.mil/tems/references/html
>Air Force	www.afams.af.mil/webdocs/afmsmp/
>Marine Corps	www.dmso.mil/dmso/docslib/mspolicy/usmcplan/
>NATO	www.dmso.mil/dmso/dicslib/mspolicy/nato_msmp/

M&S Management Office>		
>DMSO	www.dsmo.mil	Defense Modeling and Simulation Office
>AMSO	www.amso.army.mil/	Army Model and Simulation Office
>NAVMSMO	www.Navmso.hq.navy.mil	Navy Modeling and Simulation Management Office
>XOC	204.34.204.77/	AF Directorate of Command &Control [has M&S mgmt]

>> AFMS	www.afams.af.mil	Air Force Agency for Modeling and Simulation

MEL	www.Mel.dmso.mil	Master Environment Library [DMSO]
MORS	www.mors.org	Military Operations Research Society
MOVES	www.moves.nps.navy.mil	Modeling, Virtual Environment, and Simulation
MSOSA	www.msosa.mil.inter.net	Modeling & Simulation Operational Support Activity [DMSO]

MSRR>	www.msrr.dmso.mil	Modeling and Resource Repository [DMSO]
>Air Force MSRR	www.afsaa.hq.af.mil/index.html	Air Force Studies &Analyses Agency
>Army MSRR	www.msrr.army.mil	Army M&S Resource Repository
>Navy MSRR	www.Navmsmo.hq.navy.mil/nmsiscat/	Navy M&S Information System (NMSYS) Catalog
>BMDO MSRR	www.jntf.osd.mil/bmdssc/	BMDO M&D Resource Repository
>MEL	www.Mel.dmso.mil	Master Environmental Library [DMSO]
>ADS	www.ads.msrr.dmso.mil	Authoritative Data Sources [DMSO}
>C4ISR DSC	www.dsc.osd.mil/	C4ISR Decision Support Center [Joint]
>DIA	On SIPRNET	Defense Intelligent Agency

MSOC	www.dmso.mil/SOC	DoD M&S Staff Officer Course
MSTP	www.mstp.quantico.usmc.mil/	MAGTF Staff Training Program Center
MSTTF	www.dmso.mil/dmso/wrkgrps/tf/msttf.html	M&S Terminology Task Force [Glossary]
MSWG	www.dmso.mil/dmso/wrkgrps/mswg/	M&S Working Group [DMSO]
NASA	www.nasa.gov	National Aeronautics & Space Administration
NASA SW IV&V	www.ivv.nasa.gov	NASA Software Independent Verification & Validation Facility
NASM	www.nasm.hanscom.af.mil/NASM	National Air &Space (Warfare) Model [AF]
NAVSMO	www.Navsmo.hq.navy.mil	Navy Modeling & Simulation Management Office
NAVY	www.navy.mil	Navy Homepage
Navy MSRR	www.navmsmo.hq.navy.mil/nmsiscat/	Navy M&S Information System (NMSIS) catalog

NAVY TEMS	www.nawcad.navy.mil/tems	Navy Test & Evaluation Modeling & Simulation
NAWCTSD	www.ntsc.navy.mil	Naval Air Warfare Center, Training System dev9ision
NIMA	www.nima.mil	National Imagery and Mapping Agency
NIST	www.nist.gov	National Institute of Standards and Technology
NPSNET	www.npsnet.nps.navy.mil	Naval Postgraduate School NPSNET Research Group
NRL	www.nrl.navy.mil	Naval research laboratory
NSC	www.leav.army.mil/index.htm	National Simulation Center
NTERMS	www.Nterms.mugu.navy.mil	Navy Test &Evaluation Repository for Models & Simulation
ODCI	www.odci.gov/ic/icagen2.html	US Intelligence Community Links [ODCI]
OEA	www.nrl.navy.mil/OceanEA/	Ocean Executive Agent for M&S
OSI	www.Osi.usmc.mil	Office of Science and Innovation [Marine Corps]

SBA SIA	www.msosa.dmso.mil/sba	Simulation Base Acquisition – Special Interest Area
SCS	www.scs.org	Society for Computer Simulation
SEDRIS	www.sedris.org	Synthetic Environment Data Representation & Interchange Specification

SIA's>	www.msosa.dmso.mil/msosa-net/sia.asp	Special Interest Area [MSOSA/DMSO]
>HOBM	www.msosa.dmso.mil/hobm/	Human &Organization Behavior Modeling SIA
>IA	www.msosa.dmso.mil/ia	Impact Assessment SIA
>MSMP	www.msosa.dmso.mil/msmp	DoD M&S Master Plan Revision SIA
>MSRR	www.msosa.dmso.mil/msrr	MSRR Board of Directors &User's Conference SIA
>OOTW	www.msosa.dmso.mil/ootw/	Operations Other Than War SIA
>SBA	www.msosa.dmso.mil/sba	Simulation Based Acquisition SIA

SISO	www.Siso.sc.ucf.edu	Simulation Interoperability Standards Organization
SMART	www.Sba.iitri.org	Simulation & Modeling for Acquisition, Requirement and Training [Army SBA]
SMC/XR	www.afbmd.laafb.af.mil/org/xrm	SMC M&S Home Page [AF]

SPAWAR	www.C4iweb.spawar.navy.mil/pd13/pmw131/	Warfare Analysis, M&S Program [Navy]
SSBLaRC	www.larc.nasa.gov/fltsim/index.html	Simulation System Branch – Langley Research Center
STEP	www.acq.osd.mil/te/programs/tfr/step.htm	Simulation, Test &Evaluation Process Guidelines [OSD]
STOW	www.Stow98.spawar.navy.mil	Synthetic Theater of War – 98
STRICOM	www.stricom.army.mil	Simulation, Training, Instrumentation Command [ARMY]
TAFIM	www.library.itsi.disa.mil/tafim.html	Technical Architecture Framework for information Management [DISA]
TARDEC	www.tacom.army.mil/tardec/	Tank – Automotive research Development & Engineering Center [ARMY]
TEMS	www.nawcad.navy.mil/tems	Navy Test &Evaluation Modeling & Simulation

THUNDER	www.s#i.com/Default.htm	Homepage for THUNDER, theater – level campaign simulation [AF]
TMPO	www.tmpo.nima.mil	Terrain Modeling Project Office
TRAC	www.trac.army.mil	TRADOC Analysis Command
UK SWING	www.Siwg.dra.hmg.db/	UK Simulation Interoperability Working Group
USASMDOC	www.smdc.army.mil	U.S. Army Space & Missile Defense
USASMDC SMULATION CENTER	www.army.mil	Command U.S. Army Space &Missile Defense Command Simulation Center
USMC	www.usmc.mil	US Marine Corps Homepage
VPG	www.Vpg.tecom.army.mil	Virtual Proving Ground [ARMY]
VV & A	www.dmso.mil/dmso/projects/vva/	Verification, Validation, & Accreditation
WARSIM	www.stricom.army.mil/stricom/pm-warsim/	PM-Warfighters' Simulation [Army]

XOC	204.34.204.77/	AF Directorate of Command &Control [M&S [mgmt]

INSTITUTE OF CONTROL AND SYSTEM RESEARCH

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The Institute of Control and System Research (ICSR) at the Bulgarian Academy of Sciences carries out scientific research on the problems of control, analysis and modeling of complex processes and systems.

The Institute consist of seven departments and laboratories:

1. Knowledge Based Control Systems

Field of Research: Synthesis and analysis of multilevel decentralized intelligent control systems, fuzzy control systems, neural networks and structures for control, management of research/design projects, intelligent monitoring and diagnostic systems for autonomous moving objects.

Department Head: Assoc. Prof. Valentine PENEV, Ph.D.

2. Sensor Systems and Modeling

Field of Research: Microsensors, intelligent sensor systems, microsystem technologies, non-contact automation, hardware and software for system applications in automotive, medical, environmental, security, energetics, multimedia and others. Numeric modeling of technological processes, system analysis and identification of technological processes and systems.

Department Head: Prof. Chavdar ROUMENIN, Ph.D., D.Sc.

3. Optimal Control

Field of Research: Modeling and intelligent motion control of autonomous dynamic objects via learning structures and parallel transputer nets, methods for unconditional and conditional optimization, state estimation of dynamic objects, Kalman filtering, association, integration and data fusion from sensory information systems.

Department Head: Assoc. Prof. Ognian MANOLOV, Ph.D.

4. Adaptive and Robust Control

Field of Research: Design of models for biotechnological processes: deterministic, fuzzy, and memory-based models, development of biological state observers, methods and algorithms for on-line estimation of biological variables and parameters including time delay, development of methods and algorithms for robust and adaptive control for biotechnological processes, including time delay systems and sliding mode control.

Department Head: Assoc. Prof. Trayana PATARINSKA, Ph.D.

5. Hybrid Systems and Management

Field of Research: Analysis and synthesis of complex control systems, computer-integrated control systems, distributed intelligence control systems, integrated control and management systems. Artificial and hybrid (human-computer) intelligence control systems, modeling of the human-operator, cognitive task analysis in hybrid intelligence systems, cognitive modeling for adaptive interface design, on-line task allocation in hybrid intelligence systems. Investigation and design of hardware and software for control systems, sensors and sensor systems, automation for scientific experimentation, electromagnetic compatibility in control systems, information and control systems in the National Power System, fuzzy regulators.

Department Head: Assoc. Prof. Dimcho BOYADJIEV

6. Research and Development of Technical Systems

Field of Research: Information security systems for distributed objects, radiochannel computer communications, stationary and mobile ecological monitoring systems.

Department Head: Assoc. Prof. Ivanka VIDENOVA, Ph.D.

7. Scientific Research Applications and Training – Plovdiv

Field of Research: Computer-aided design in machine construction, automated systems for information processing and control.

Department Head: Assoc. Prof. Hristo VARBANOV, Ph.D.

Actively involved in defense and security related research in modeling and simulation is the

DEPARTMENT OF "KNOWLEDGE BASED CONTROL SYSTEMS"

Sample of accomplished projects

- AntiTank Wire-Guided Missile Simulator /ATGMS/
- Tank gun simulator for T-55
- Flight simulator
- Simulator for Paraglider
- Fuzzy controlled autopilot for paraglider
- Fuzzy control for missile
- Digital Servo controller for DC motor with position and speed control on Intel 8051 (C and assembler)
- Digital servo controller for stepper motor with position and speed control on Intel 8051 (C and assembler)

Modeling of dynamic characteristics of moving platforms

For modeling dynamical characteristics of moving platforms we six or more nonlinear equations which describe linear and angular positions of rigid body in 3D space with 6 degrees of freedom. We rely on adequate dynamical models for Fagot missile, F-18, Cessna, Mig 21. Reconfigurable flight dynamics is presented in every application..

Analysis and synthesis of control loops for moving platforms

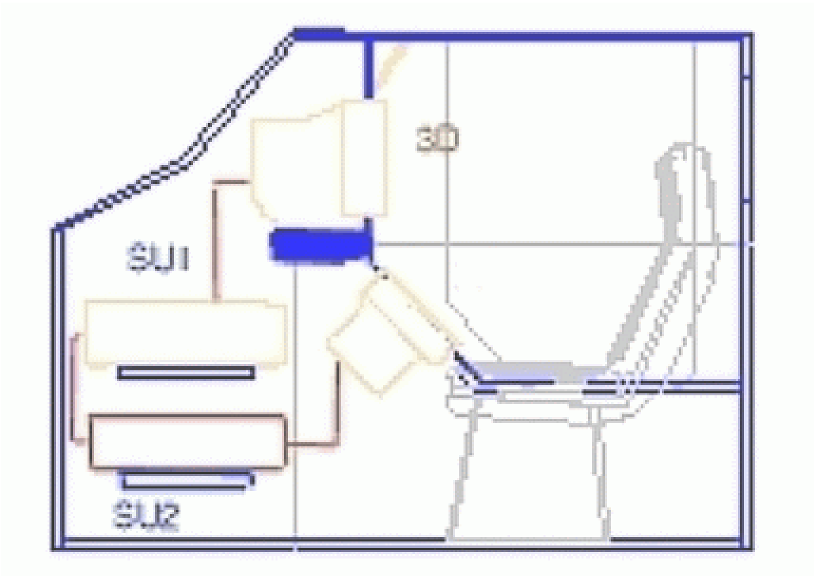
The control loops of our moving platforms were designed on the base of fuzzy control theory. Fuzzy control as an approach to nonlinear and complex control design has attracted a great deal of research interest in the past decade. The basic idea of the approach is to incorporate fuzzy IF-THEN rules into the control design, that is, fuzzy control combines two resources: input-output data and the experts' experience expressed by rules. Therefore, fuzzy control is always applied to the system, which is too complex to get the mathematical model precisely. The autopilot design for flying objects, which are highly nonlinear-coupled system, is good place to implement fuzzy control. Usually we apply fuzzy control in two general ways. First one is to use only fuzzy controller. The second one is to use fuzzy rules like tuning machine for original controllers. Of course, fuzzy control is not a tool, which can be applied everywhere. Therefore, we use fuzzy rules coupled with the transfer functions. We have developed original and elegant approaches to parametric and structural tuning of control loops.

Visualization and final design of 3D simulation software

Currently, we are developing simulation programs under Windows 95, 98 with Visual C++ 5.0 and Microsoft SDK DirectX 3 and

ActiveX. We can encompass the whole process of the simulator creation including the following:

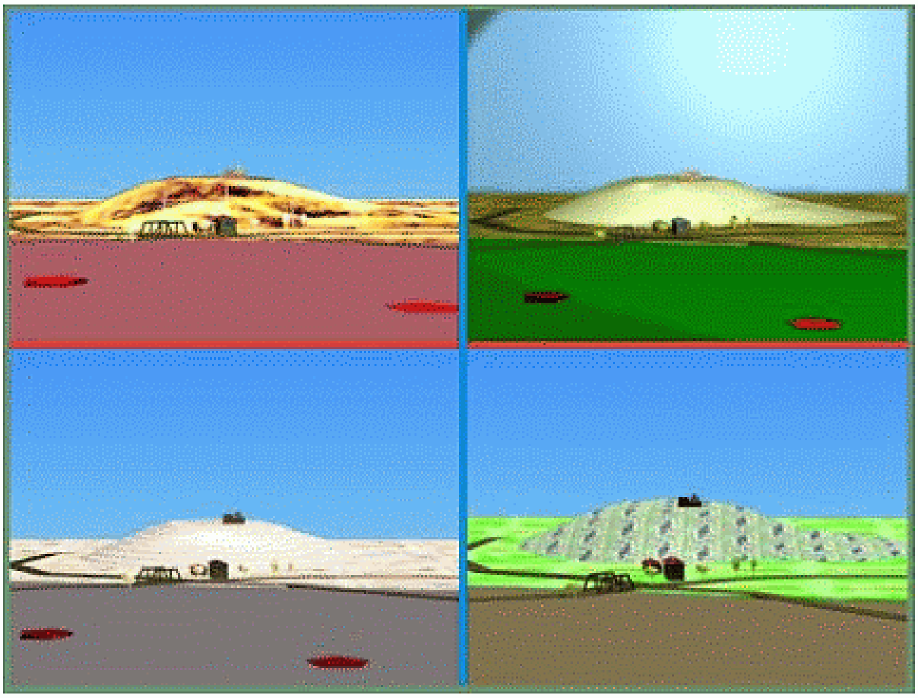
- To create the sensation of real combat conditions the computer simulation display is used. Because the system uses actual background terrain pictures, a variety of realistic environments from the desert to winter scene can be used. A number of ground features such as buildings, rivers, threes, etc., may be incorporated. The visual display simulation of weather, with particularly good representation of scud, fog are presented. Terrain is created by 3DStudio and 3D Max.
- Moving objects were designed by 3D Studio and 3D Max. The following items are presented: fighters F-4, 15, 16, 18 Mig-21, 23, 25, 27, 29, Su-27; B-1 bomber; anti-tank helicopters: AH-64, Mi-24, Mi-28; transport helicopters: K28, UH-60; armored vehicles; tanks: T-55, T-80, M1-Abrams, Merkava; missile launchers: "Squd".
- Audio equipment realistically replicates engine and weapon sounds and 3D sound effects may be implemented in software.
- Developing the software for simulators. In our application we use Direct3D, which is Microsoft's real-time, interactive 3D technology for mainstream computer users on the desktop and the Internet. Above all, Direct3D is designed for speed. Direct3D provides the API services and device independence required by developers, delivers a common driver model for hardware vendors, enables turnkey 3D solutions to be offered by PC manufacturers, and makes it easy for end-users to add high-end 3D to their systems. Because the system requires little memory, it runs well on most of the installed base of computer systems. Direct3D is a complete set of real-time 3D graphics services that delivers fast software-based rendering of the full 3D rendering pipeline (transformations, lighting, and rasterization) and transparent access to hardware acceleration. API services include an integrated high-level Retained-Mode and low-level Immediate-Mode API, and support for other systems that might use Direct3D to gain access to 3D hardware acceleration. Direct3D is fully scalable, enabling all or part of the 3D rendering pipeline to be accelerated by hardware. Direct3D exposes advanced graphics capabilities of 3D hardware accelerators, including z-buffering, antialiasing, alpha blending, mipmapping, atmospheric effects, and perspective-correct texture mapping. Tight integration with other DirectX technologies enables Direct3D to deliver such advanced features as video mapping, hardware 3D rendering in 2D overlay planes—and even sprites—providing seamless use of 2D and 3D graphics in interactive media titles. Direct3D is implemented in two distinctly different modes: Retained Mode, a high-level API in which the application retains the graphics data, and Immediate Mode, a low-level API in which the application explicitly streams the data out to an execute buffer.

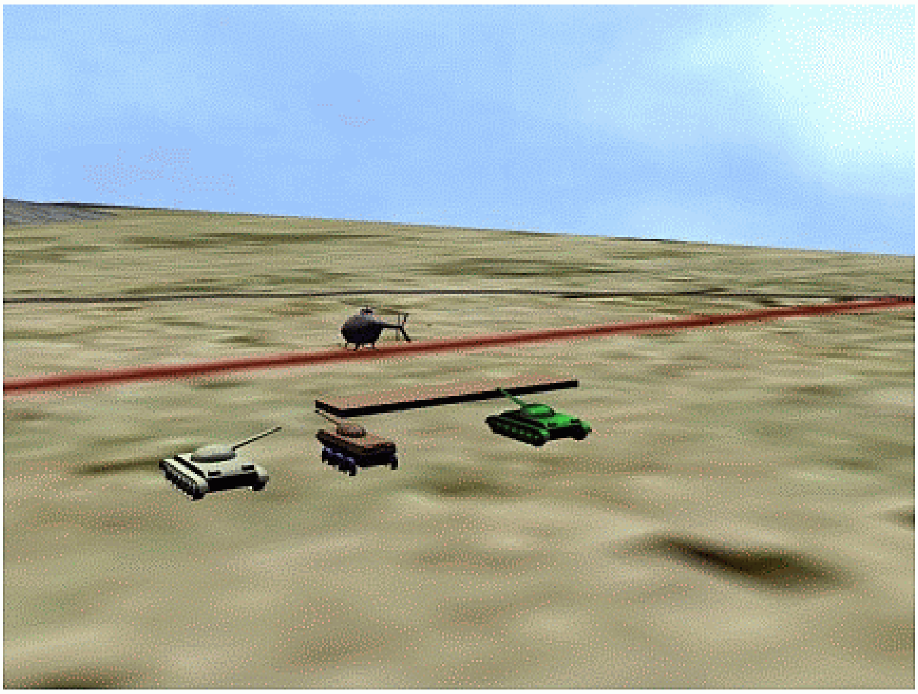


Especially for flight simulator we have a good set of flight instruments for visual and dead reckoning navigation practice. For example artificial horizon, airspeed indicator, turn indicator, inclinometer position of the throttle, altimeter, vertical speed indicator can be used depending on situations. Flight panel is realized on the single computer and 3-D environment on the second with TCP/IP. Flight simulators may be connected into group work system.

Also, we can develop the following kinds of software "Scenario maker" and "Tactical and Technical Characteristics Evaluator", which are useful tools for creating tactical scenario and evaluation of tactical and technical skills of crew.

Some background terrain pictures from the screen





Some of the moving objects

Screen view from the flight simulator

For further information:

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