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Computer Generated Forces
Layout and Architecture

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Report Documentation Page

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Notes for Slide 1

Summary

This presentation provides an overview of computer generated forces simulations. Computer generated forces have applicability to all aspects of defense analyses, including training, mission rehearsal, force structure assessments, and system acquisition. The basic simulation architecture is presented along with discussion of the key technical areas. Issues bearing on future development of computer generated forces are also presented.

Topics

- Definition of Computer Generated Forces
- Simulation System Architecture
- Broad Range of Applications
- 5 Technical Areas
- Issues

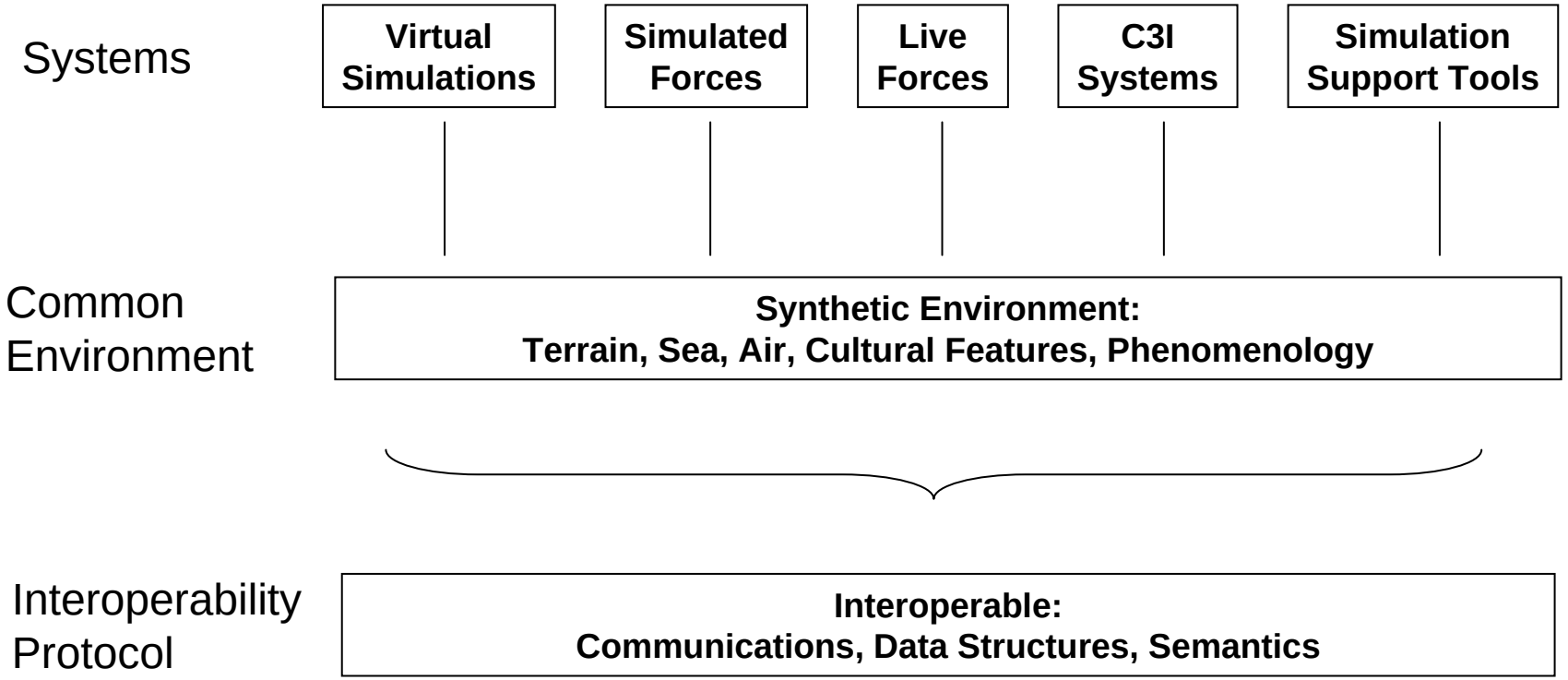
Notes for Slide 2

The purpose of this presentation is to give a basic understanding to how CGFs are constructed. It discusses the main elements of the overall architecture of a simulation system, giving a context for the CGF part of the system.

Five basic technology areas are reviewed: Synthetic Environment, Simulation Systems Architecture, Modeling of CGF, Human behavior Representation, and Human-System Interactions.

CGFs will be under active development for the foreseeable future. The key issues guiding this development are discussed.

Simulation System Architecture



Notes for Slide 3

A simulation system will have many different kinds of components: CGFs, Synthetic Environments, Models of domain entities, forces, tasks, Analysis Tools, Scenario Generation Tools, Visualisation Tools, Mobile Devices, Multimodal Human-Machine Interfaces, C4I systems, Embedded evaluation and monitoring agents, algorithms for continuous, discrete event and Monte Carlo simulations, embedded tutor components, tools for after action review, and many other kinds of automated assistance. In addition to these resources that have immediate utility to the user, there are a number of resources that are necessary components to managing these resources in a flexible way; they are indirectly seen by users in the ease with which the system can be tailored because of the needs of different users, new field requirements or new parts of the system. Among these types of components are domain-specific models that define the configuration for a subset of components, with the detailed specializations that will allow them to be tailored for a given application.

Notes for Slide 3 (Continued)

We need flexibility in the architecture, because components and even architectures change with technology. That is, the variety of components, the different kinds of uses of components, and the dynamic nature of technology, together require a flexible interconnection architecture. It is therefore necessary to define the semantics of the shareable data, that is, the meanings that the users of that data are expected to attach to it, rather than fixing the structure if the systems that will use the data. It is convenient to define the syntax of the data (data formats and structures), but not nearly as important as defining the semantics. If the data syntax is explicit for each data item, then it can be translated or converted appropriately as needed.

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Technologies

- Synthetic Environment
- Simulation Systems Architecture
- Modeling of CGF
- Human behavior Representation
- Human-System Interactions

Notes for Slide 4

Synthetic environments are the computerized representations of the natural and man-made environment.

Simulation system architecture deals with how to construct and organize CGFs so that they communicate well between them and their environment.

The next two topics deal with the modeling of CGFs in general, i.e. the interaction between the virtual human and virtual physical entities, and the methods for representing and modeling the outcomes of what in the real world are human behaviors and related decision processes.

Human-system interactions encompasses technologies for interfacing the CGF with a human decision maker or other operator.

Synthetic Environments

A definition:

Synthetic Environments (SE) are computerized representations of the natural and man-made environment that are amenable to simulations of man-made or naturally occurring processes.

Typically, SEs comprise representations of land, sea, air, space, and man-made features and structures.

Notes for Slide 5

Synthetic environments form the basis of all combat simulation, and other simulations such as those for factory production, urban traffic, weather, and the like.

The main research in SEs deals with the creation of more detailed synthetic environments and the creation of validated, sharable (by a variety of simulation systems) synthetic environments.

Synthetic Environment are represented to an appropriate level of detail required for the particular application domain. Synthetic Environment allows the realistic interaction of CGF components rather than just their visualisation.

Key Research Areas of Synthetic Environments (continued)

- Content
  - Composition
  - Correlation

Notes for Slide 6

Content relates to the elements that should be included within the Synthetic Environment at an appropriate level of representation, and ensuring correlation between the applications. Two specific research areas were identified under content.

Composition. Specifically what components of the physical environment should be included and defining the level of detail required, examples include: micro terrain, weather effects, illumination sources, air and sea state, objects (buildings, vehicles, etc) and their associated properties. These models must also include a description of their properties to allow proper interaction, and also to ensure consistency between the different applications.

Notes for Slide 6 (Continued)

Correlation. This is somewhat related to representation, but concentrates on the mechanisms which could be used to ensure there is correlation of the data at different levels of representation (e.g. aggregated versus dis-aggregated), and between different simulation applications, especially when data is derived from different sources. Correlation must also be maintained in the temporal domain in addition to the static case, e.g., during a CGF simulation the environment may change (due to weather, dynamic effects, etc.)

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Key Research Areas of Synthetic Environments (continued)

- Production
  - Automatic data collection and processing
  - Definition of requirements
  - Verification and validation
  - Representation

Notes for Slide 7

Production relates to the initial definition and creation of the synthetic environment representation. Four research areas were identified in this categorisation.

Automatic data collection and processing. The process of collecting data and processing has been traditionally manpower intensive. Thus there is a requirement to automate this process in an error free manner and including the only appropriate information. Also, typically many systems require different formats of the data in order to operate efficiently, thus a generic interchange mechanism is required to allow accurate translation of the data to different formats. There are a number of facets to Data Collection; firstly, due to the complexity of collecting the data from sources (e.g. satellite images), and correlating data from different sources progress in this area is seen as longer term. Secondly, the process of data collection must be seen as a continuous process reflecting that the environment and simulation models are continuously changing. Currently, there are programmes examining the process of data interchange (e.g. SEDRIS). Although there are a number of research programmes, (e.g. using Global Co-ordinates), it is viewed that basic research is still required (e.g. to process the basic images to extract terrain features).

Notes for Slide 7 (Continued)

Defining Requirement. When SE's are used it is important to define the requirement which that Synthetic Environment should fulfil in order that the needed components can be included at an appropriate level of detail.

Verification and Validation. This area encompasses the problems of ensuring the data are correct, consistent when merging different sources, the problem of co-ordinates on very large databases (curved earth), and integrity (i.e. ensuring consistency between simulation sites, and that the data has not been changed by an unauthorised party).

Representation. This area extends to include representation at multiple levels of simulation and between different applications. Taking the first point, CGFs increasingly include a number of command levels, each of which places different demands on the Synthetic Environments representation (i.e. the level of detail). Similarly, different applications will require different emphasis on the data, for example comparing a CGF to a visualisation system.

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Key Research Areas of Synthetic Environments (concluded)

- Use
  - Environmental reasoning
  - Dynamic terrain
  - Data distribution

Notes for Slide 8

Use relates to the actual use of Synthetic Environments during simulations. Research areas include the following:

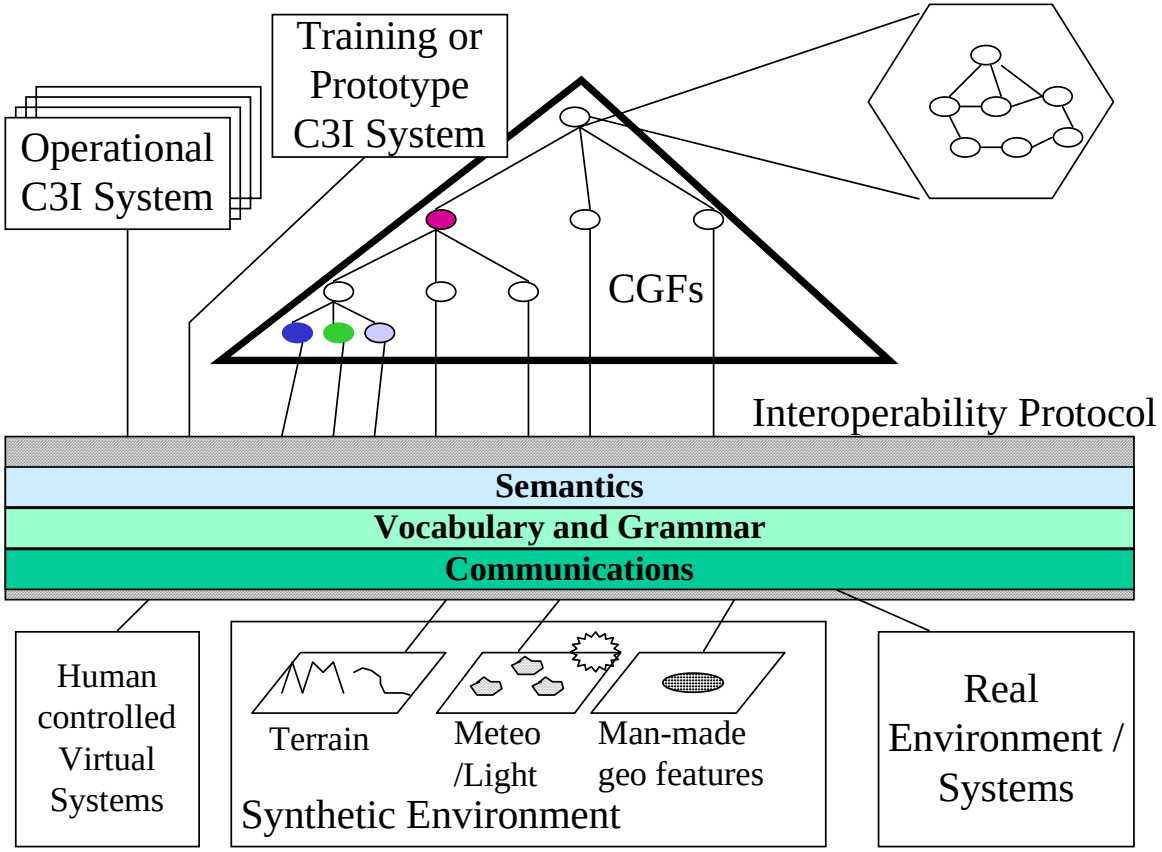
Environmental Reasoning. This is not how to perform reasoning but the required representation within Synthetic Environments in order to successfully support the reasoning. Specific problems identified include: identification of significant features during the course of an operation, intelligence preparation of the battlefield, inclusion of land, sea and air state, and environmental effects. All these effects are computationally expensive especially compared to the bandwidth required to transmit the information. Thus it is undesirable to duplicate this processing on each application but instead use a central server(s) and transmit the required information over the network.

Notes for Slide 8 (Continued)

Dynamic Terrain. During the course of a simulation it is likely that the state of the terrain changes due to various effects. This includes the environment itself by for example weather effects, cratering, and objects such as buildings, bridges (which are tactically very significant). Each of these effects need to be generated, updated in all participating simulations in a timely manner (i.e. maintaining time correctness). The generation of such effects should be “transparent“ to the environmental reasoning, i.e. any system reasoning about the environment should not be aware of any “special“ processes or objects. Unlike environmental effects, the processing of changes to the environment are not generally as computationally expensive, and because of the rapid data access required by CGFs the processing should be done locally.

Data Distribution. This area address the problem of distributing databases between sites, the availability of the data, and selecting appropriate components. One of the main problems is that although there are a large number of databases available, more common than not is the difficulty of access to the data. In order to prevent duplication and facilitate easy common access to data (which can then be centrally configuration managed) a central repository with easy access is required. Accessing the data can be either on-line (i.e. internet) or off-line (i.e. tape distribution). The former poses more technically challenging because of the need to maintain security and integrity of the data.

Simulation System Architecture



Simulation Architectures

- Emerging Architectural Concepts
  - CGFs are meaningful only within a context that includes an entire simulation (or operational) SYSTEM: the CGFs, the MMIs, the Synthetic Environment, the human behavioral models (HBMs) and other components
  - Future uses of CGFs will involve applications requiring the integration with live systems (e.g., C4I), the incorporation of multi-modal man-machine interface devices, the flexible combination of different CGFs, and the embedding of the CGFs into very different types of synthetic environments
  - Architectural frameworks must enable flexible and open architecture for the future applications of CGFs.
  - Flexible architectures allow leveraging commercial partners; they can participate to different degrees.

Notes for Slide 10

There is more to military simulation systems than the important content of the CGFs themselves.

CGFs are only meaningful within a context that includes an entire simulation (or operational) SYSTEM: the CGFs, the MMIs, the Synthetic Environment, the human behavioral models (HBMs) and other component.

Although CGFs may indeed be useful in a number of applications not requiring all of the above components, many of the future uses of CGFs will involve applications requiring the integration with live systems (e.g., C4I), the incorporation of multi-modal man-machine interface devices, the flexible combination of different CGFs, and the embedding of the CGFs into very different types of synthetic environments. The issue here is to not just develop an architecture that can allow reasonable interoperability of today's CGF components and capabilities, but rather to set down the framework and issues in order to create an appropriately flexible and open architecture for the future wide-ranging applications of CGFs.

Notes for Slide 10 (Continued)

The required flexibility and openness is not only for the economic and scientific benefits of quickly building CGF applications out of existing, diverse components, but also to give different organizations the flexibility to participate to the extent that they want to in different applications, while still retaining the advantages of leveraging other's investments and developments in this area. This is an important part of the strategy for leveraging off the commercial marketplace while retaining the requirements for specialised military systems; flexible architectures allow commercial partners to participate to different degrees.

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Desirable Attributes of Simulation Architecture

- Customer pull as a well policy push
- Sharable, reusable architectures, components, and infrastructures
- Increased object reuse; decrease system risk, time to insert the technology, and model development, maintenance costs
- Interoperability is a matter of degree
- A simulation object repository
- Common transport layers, common messaging systems, and neutral data formats
- Semantic integration via common ontologies is the critical challenge.
- Open architecture and protocols track trends and standards in the commercial world

Notes for Slide 11

Successful architectures have to be driven by customer pull as a well a policy push otherwise they will become obsolete due to economic forces.

Heterogeneous communities may require different architectural services with different constraints at each layer. Appropriate incentives can help individual and groups to see co-operating in shareable architectures as an advantage; the shared infrastructure and reusable components must be harvested, and made easy to use and accessible globally.

A good simulation architecture should increase object reuse, decrease system risk, time to insert the technology, and eventually model development and maintenance costs.

Interoperability is matter of degree, depending upon the needs of the simulation, training, and C4I communities.

Notes for Slide 11 (Continued)

A simulation object repository provides information on objects, their public attributes, associations, interactions, level of resolution, and key models and algorithms used to represent entities in the simulation.

Simulation architecture needs common transport layers, common messaging systems, and neutral data formats to provide limited interoperability and maximum flexibility. This will allow commercial companies and developers to gradually “buy-in” to joint applications.

Systems integration at the communication level is a necessary but insufficient goal. Semantic integration via common ontologies is the critical challenge.

Selection of open architecture and protocols needs to track trends and standards in the commercial world in order to leverage off commercial investments for specific military uses.

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Interactions of Simulation Architecture with Other Technology Needs

- Automatic configuration and inclusion of simulation objects (including models) from repositories
- Decision processes connected to simulation elements
- Human controlled allocation of decision-making by CGFs
- Support for different sources of information input and output

Notes for Slide 12

These is a need for flexibility in the architecture, to allow different approaches to hard problems to be considered, and to allow rapid construction and modification of problem-specific simulations.

The automatic configuration and inclusion of simulation objects (including models) from repositories, the availability of models at multiple resolutions, and tools for construction and composition of objects. To configure an object automatically requires the composition tool to have the right kind of information about what that object is, what it does, in what context it is appropriate to use it, and what assumptions or limitations are built into it. The architecture should support the use of explicit selection information and both automatic and semi-automatic methods of using that information to configure a simulation.

Decision processes connected to simulation elements, so that it is possible to include a man-in-the-loop in the simulation support side, not only in the simulation application subject problem area, and that models include multiple levels of command. The architecture should support explicit interfaces between the decision processes and the simulation components requiring decisions, including what kinds of information are to be made available to the CGF by the simulation and what kinds of decisions it can make.

Notes for Slide 12 (Continued)

Models have multiple levels of command, and the architecture should allow for humans to determine what decisions are made by CGFs and what decisions are made by humans.

Realistic voice synthesis (and possibly transport, which places some stringent constraints on the acceptable variability of information delivery times), instrumentation of mobile entities (e.g., users), direct manipulation of simulation time (i.e., compression or expansion), multiple senses (e.g., haptic, tactile, pressure, smell, taste), and the use of sound for location (360 degrees, up and down, foreground and background). The architecture should support the use of different kinds of information sources, since the architecture should not depend on the choice of which models to use in a particular simulation run, but rather the architecture should help make it easy to use different collections of models for different runs.

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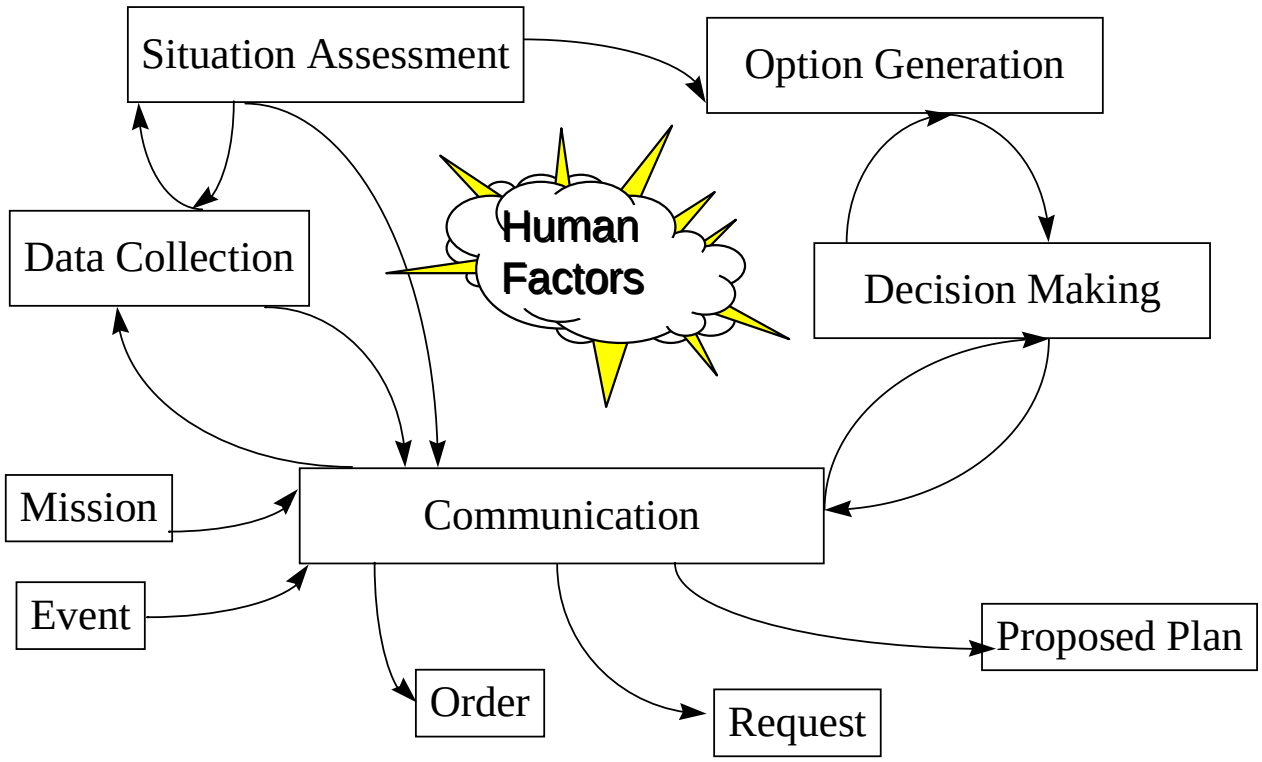
CGF Architecture



Notes for Slide 13

The role of each of the modules can be described as follows:

The data collection module is responsible for gathering the detailed data elements as instructed by the situation assessment module;

The situation assessment module defines the detailed data requirements that need to be collected, interprets the mission received by the CGF, updates the current assessment of the situation and defines and monitors critical and meaningful events;

The option generation module develops courses of action based on the triggering event, mission statement and current situation assessment;

Notes for Slide 13 (Continued)

The decision making module evaluates the various courses of action and ranks them according to a set of pre-determined and derived criteria. It will also support the negotiation process between CGFs or human decision makers that may be required to develop a solution for the larger context in which the CGFs decision is included;

The communication module supports the exchange of data between the CGF and all other elements of the simulation system. It transforms data into the appropriate format for local and external interpretation.

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Technologies for Modeling CGFs

Module	Technology
Data Collection	Current database and browsing technologies
	Data mining (e.g. Selection and discrimination techniques)
	Knowledge discovery
	Pattern recognition
	Knowledge based systems
	Current database and browsing technologies
Situation Assessment	Knowledge discovery
	Translation techniques
	Rule-based systems
	Task and domain specific data fusion algorithms
	Pattern recognition
	Neural networks
	Image recognition
	Natural language processing
	Flexible object schema for situation description
	Blackboards for consistency maintenance
	Knowledge based systems
Option Generation	Search algorithms
	Simulation
	Knowledge based systems
	Operations Research
	Fuzzy logic
Decision Making	Simulation
	Operations Research
	Fuzzy Logic
	Planning techniques
	Search techniques
	Cooperative planning
Communication	Speech recognition
	Gesture recognition
	Image generation

Notes for Slide 14

This chart shows the various technologies that support the CGF functional components.

Continued advances are needed in many areas to enable more sophisticated CGF behaviors. For example, in the area of situation assessment, the CGFs need to automatically process information about their environment and respond appropriately. This information can come from simulated sensors or from human players in a simulation exercise.

A second key area is option generation. To be able to demonstrate realistic behaviors, the CGFs must be able to examine a similar range of options as would a human for any given situation.

Human Behavior Representation

- HBR
  - The “thinking” part of CGF

- Approaches
  - Model thinking process
  - Model output of process
  - Examples: SOAR, ModSAF

- Important when
  - Humans affect use of a system
  - Individual differences are key
  - Cannot afford to use real people

Notes for Slide 15

Human behavior Representation (HBR) is the most difficult issue in devising successful future CGFs with high quality. Technically, one can think of a HBR as a software module that "interacts" with the rest of a CGF and/or with the real world - depending on the application. This interaction must be controlled through the simulation architecture, via HBR objects that access information from real or simulated sensors through real or simulated C4I systems.

There are two main approaches to HBR. One is mainly concerned with mimicking human thought processes and is hence here called HBP (Human behavior Process). The other is more concerned with a correct representation of the output of a thought process, and is here termed HBO (Human behavior Output). The implementation of HBR in software is referred to as HBM (Human behavior Model).

Notes for Slide 15 (Continued)

HBR emulates human behavior; either decision processes or the result of these. Hence, HBR should be used whenever the outcomes of a process with a human behavioral element is critical to the overall outcome of a CGF. The prime goals of a behavioral representation in a computing process are to enhance the quality and intelligence of the CGF. A secondary consideration is to make applications less resource intensive. The taxonomy of when to include an explicit focus on HBR in a CGF consists of, but is not limited to:

When the human significantly determines the outcome of the real system or CGF.

When individual differences are assumed important, and sensitivity analysis of technical parameters are not sufficient to highlight these differences.

Experimentation requiring faster than real time execution (e.g. the real human is too slow, such as in Monte Carlo simulation used for analysis - or the time compression needed when training higher level commanders in operational art).

Cost or resource savings by not using real commanders or other humans are substantial.

When HBR is considered in a CGF, a detailed task analysis should be applied to the problem. This will help determine which HBR issues to be included in the CGF.

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Human-System Interactions

• Natural interface	Speech recognition
	Video conferencing
	Realistic graphics
	Gestures for gross manipulation
• Time compression	Expansion to allow students to catch up
	Compression to save time or to create stress
• Multi-modal	Output: audio, still & motion video, graphics
	Input: keyboard, mouse/ trackball, touch panels, single utterance speech
	Video conferencing
• Abstract concepts	Text, maps, flags, simple icons
• Drill down	Lot of data [problem is converting to information; primarily self selection]
• Agents	Organizers Push technology Intelligent agents

Notes for Slide 16

This chart lists a variety of modes for human-system interactions.

In the area of natural interfaces, multi-modal, and drill down, commercial research and development will address most defense needs.

Defense applications particularly benefit from advances in the other areas. For example, the use of intelligent agents enables a commander’s staff member or a CGF operator to more effectively work with his information environment.

Key Problems for Human-Systems Interactions

- The effects of time compression and expansion on learning and performance
- The development of intelligent agents which can be subjected to verification.
- How to represent abstract concepts in operationally meaningful terms
- The effect of cultural differences on interface design and effectiveness.
- Theory of, and automated means for, display of complex information

Notes for Slide 17

Some of the human-system interface long-term research areas for defense applications are listed here.

These problems apply to both CGFs and to real systems. As information technologies make it possible for each soldier to access, or be presented with, unlimited amounts of data, new approaches are needed to allow the user to effectively obtain just what he needs, at just the time it is needed.

Issues

- Lack of appropriate representation of group and individual behaviors
- Data non-existent or difficult to collect
- Disconnected tools, little common use
- Little validation or assessment of CGFs
- Expensive to use

Notes for Slide 18

A more common data, process, and software basis will be critical for investigations in the future. To effect this, the following areas and characteristics of CGFs need improvement:

Lack of appropriate representation of group and individual behaviors: In current applications, the representation of human decision making is generally restricted to the lower echelons. At higher echelons, greater flexibility is needed.

Data non-existent or difficult to collect: CGF decision making capabilities need a better empirical basis. Little data has been gathered on higher echelon behaviors in operational environments. When considering future concepts, new methods are needed to elicit such data and make them computable in decision making terms.

Notes for Slide 18 (Continued)

Disconnected tools, little common use: Most CGF systems are used independently and are developed without the benefit of common repositories of force data, descriptions of tactical and other behaviors, or the ability to share other components of the system, e.g., the synthetic environment.

Little validation or assessment of CGFs: As the common use becomes more widespread, there is a need to assess CGF performance, both to ensure valid multinational representations, and to provide guidance for what must be improved upon.

Expensive to use: CGF systems often require significant amounts of human effort in the set-up, execution, and post-execution analysis phases. The time involved and the systems' inherent flexibility add to the overall costs of use.

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