

What is Realism?

Navigating the Obstacles and Forging a Path to Achievement

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ABSTRACT

At last year's (2007) Interservice/Industry Training, Simulation & Education Conference (IITSEC) Flag Panel, many leaders mentioned the need for improving *realism*, and that it was a topic of interest for their service or organization. However, a community-wide agreement or consensus understanding as to how realism is defined seems to be lacking. For example, realism may be defined as high-definition graphics in some cases, as realistic environmental factors (e.g., simulation of strong winds) in other cases, or even as culturally-sensitive battle and negotiation tactics in others. So precisely, what does someone mean when they use the term realism, and is the meaning consistent across disciplines and across services and organizations? In a related vein, there is wide community agreement regarding the need to advance the practice of non-kinetic effects representation to the same level as our abilities in kinetic effects. As such, it would be useful to understand the relationship between realism and the concepts and practices in the modeling and simulation of kinetic and non-kinetic effects. The paper provides some examples of how these concepts are related, and also addresses the concepts of fidelity, resolution, and verification, validation, and accreditation (VV&A). The objective of this paper is to systematically describe a scheme to characterize realism in a way that provides insight into its significance, the obstacles to achieving it, and methods to enhance it, with regard to modeling and simulation efforts employed in training and education curricula and programs. Principally, this paper intends to begin the discussion of representation primitives required to support the improvement of realism in order to enhance warfighter readiness, and to ultimately understand how to build more effective training and education products to maximize the Government's return on investment.

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INTRODUCTION

Improved realism in modeling and simulation (M&S) efforts is increasingly seen as a requirement across a wide spectrum of projects throughout the Department of Defense (DoD). Unfortunately, the definition of realism for M&S differs considerably across the interdisciplinary community of practice, which has resulted in a poor understanding of the concept in general.

The purpose of this paper is three fold: to clarify the requirements for realism; to clarify the meaning of realism as it pertains to different communities; and to frame key concepts in the representation of reality. To help frame the paper, we'll begin by discussing DoD M&S objectives at a high level, and drill down. In general, M&S efforts in the DoD support a variety major functional areas, including: training, mission rehearsal, test and evaluation, experimentation, acquisition, analysis, and planning.

Consider training, analysis, and acquisition as examples. The goal for M&S training is to cost-effectively challenge the skills of the warfighter at the tactical, operational, and strategic levels. The skills should be challenged without risking injury to people, or damage to equipment. Training should encompass the full range of peacetime and wartime activities the warfighter would engage in. M&S must provide realistic portrayals of the world to support that goal. Likewise, the goal for M&S analysis is to provide a powerful set of tools to systematically evaluate and optimize alternative force structures against a range of foes, who may utilize potentially different tactics. The goal for M&S acquisition is to safely, cost-effectively and iteratively design virtual prototypes to assess the viability of future systems prior to production.

M&S realism needs to play a central role to support these activities and achieve the aforementioned goals. In order to guide our intuition and understanding of realism, the perspective from each of the activities listed above will be discussed. The role of realism, along

with modeling paradigms and implementation ideas, will also be addressed. First however, several common sense questions regarding realism will be posed to prime our imagination:

- Is it visual?
 - Is it related to M&S resolution and fidelity?
- Is it the physical motions and characteristics of simulated entities (e.g., kinetic aspects)?
- Is it the cognitive (e.g., non-kinetic) behaviors?
- Are terms like kinetic, non-kinetic, visual, and non-visual sufficient?
- Does the representation of the environment fit in terms of a kinetic/non-kinetic taxonomy that currently appear in the vocabulary of M&S today?
- How do we measure the realism of a model or simulation?
 - What is the relationship between realism, verification, validation, and accreditation (VV&A)?
- How do we describe differences in realism across various models or simulations?
- What underlying M&S development capabilities are needed to support the implementation of realistic simulated entities?
- What type of computational infrastructure is required to realistically portray a large scenario in a military M&S supported activity?

For example, the environment affects both kinetic and non-kinetic phenomena, so how must we consider it? Case in point, weather affects sensors and vehicle mobility, but these same environmental conditions also affect behavior at the human-in-the-loop grain of analysis. Thus, it is important to consider how we represent the environment. Should there be a

representation of individual environment phenomena, or a correlated, consistent phenomenology representation?

Unfortunately, there is no unified or widely accepted understanding for representing, or implementing, the interaction of entities and different phenomenologies. The DoD has invested extensively into military M&S efforts, but the community has not been able to answer the above questions definitively. Hence, objective assessment of M&S efforts is made difficult, since the realism enmeshed in each effort may be defined differently from one project to the next.

In addition, extensive funding has been invested in the study of interoperability, but the foundational modeling issues have been largely ignored. Consequently, these efforts are not able to maximize the benefit that has been gained by making M&S assets interoperable, because the foundations of each component are fundamentally sub-optimal. An effort is needed to identify and understand the “building blocks” required for successful entity and phenomenology interaction that underlie realism.

In conjunction with the (theoretical) understanding, the implementation characteristics of the building blocks must also be explored and codified. In general, the implementation must scale to permit millions of independent entities to execute in real-time. Figure 1 provides some intuition as to the scalability requirements necessary to represent a system relative to the complexity. Another important question is then raised: how can coding be simplified to permit the implementation of large numbers of extremely complex entities, phenomenologies, and systems?

according to known rules – we stop when the light is red and accelerate when it turns green. We recognize external stimuli and events around us – a ball rolls into the street and we slam on the brakes or swerve to avoid it. We also strategize – what is the best way to navigate around a traffic jam?

To model these behaviors, we must have an infrastructure that can not only accept rule-based implementations of decision making and behavior, but execute many different model types that represent different aspects of behavior simultaneously. The ability to integrate other techniques that we consider representative of certain aspects of behavior is critical. For example, consider neural networks to recognize phenomena from a collection of data or the ability to implement strategic planning activities – for example, utilizing techniques like genetic algorithms (GA) or evolutionary programming (EP).

As human beings, we constantly strategize and make “optimal” decisions based on certain metrics – such as driving to a destination in the least amount of time. A warfighter will strategize, and choose a course of action to minimize casualties. GA, can be utilized to model these types of mental activities. The computational methods must be flexible enough to operate synchronously (serial execution) or asynchronously (simultaneous execution). Other natural examples will be discussed later to describe the above concepts more fully.

As previously stated, the goal of this paper is to help clarify why realism is important, how it relates to different activities and communities, and to frame key concepts in the representation of reality.

THE ROLE OF REALISM

In order to begin detailed discussion of realism, consider the role of realism from the perspective of the training community. The ultimate goal is to provide training and educational materials for the warfighter. The training should be strikingly close to actual combat situations - on all fronts of interactions the warfighter would expect to have. As such, phenomenologies such as visual depictions, and the ability to move in the environment must be correct. It is also necessary to obtain realism from a cognitive simulation point of view.

The system should behave in accordance with the behavior of the entities in the relevant battlespace. The interactions would then be cognitively and culturally plausible. If the training is not cognitively plausible, it

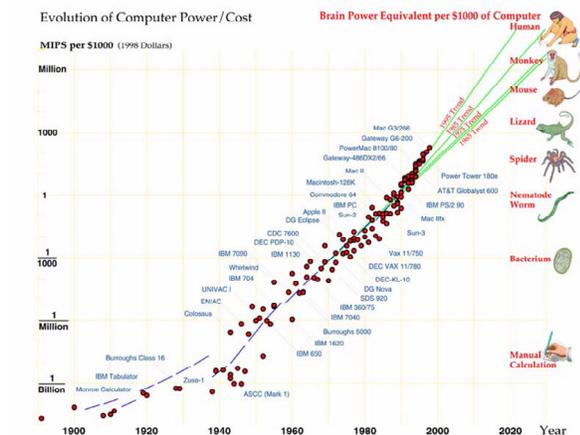


Figure 1. System complexity and computational power relationship
 For example, consider the representation of human behavior, and the act of driving. At times, we behave

may be ineffective, and will ultimately be a disservice to the warfighters protecting our country.

Providing responsive training and rehearsal - to real world battlefield conditions is a related problem. Our warfighters have reported that the battlefield is dynamic and changes day in/day out. However, training and implementation of new battle tactics lag; and the warfighters don't get the right training fast enough. Software must be readily updated, or interoperated with new software or systems, in order to provide the correct training with expedience.

Many systems are unable to fully benefit from the astounding visual resolution and fidelity, because the cognitive plausibility of the threats is not implemented. This paradox can be likened to a big budget movie with amazing special effects but minimal plot.

Renewed effort is being made to fine tune the representation of individual pieces of the system, given the challenges of our existing training systems (e.g., fighting an enemy who uses unconventional tactics, an enemy who hides among civilians and may not be identified as a male soldier in uniform, lacking cultural awareness, understanding, and sensitivity to local peoples in war-torn areas). Fine tuning individual pieces of the system may lead to major integration issues that could force system components to be compromised in the very areas extensive effort had previously been placed.

Integrating the skeletal framework of system components, and developing an effective overall system in concert, could be a seemingly plausible solution. However, problems of scalability may arise due to inability to apply modern computing resources and techniques.

The current generation of integration and interoperability techniques and technologies has focused around a network of workstations-type infrastructure which does not address all the new and needed requirements. System components frequently run in serial rather than parallel, and the inter-processor communication primitives have high latency and relatively low throughput. Hence, full integration of phenomenology models is limited in creating a realistic whole.

Another problem arises when different phenomenology representations and implementations are combined. Often, a certain type of phenomena is represented in multiple M&S components, but is not represented consistently across all of the components. This leads to the "fair fight" problem currently recognized by the

interoperability community, with no clear understanding of how to mitigate the shortcoming.

For example, the representation of various atmospheric effects impacts the representation of sensors, which impacts the ability of weapons to target and destroy entities in the battlespace. Simplistic atmospheric models should lead to "better" sensor and weapons performance, but may ultimately produce unrealistic and skewed results that don't correlate with true performance in the field.

The unmanned autonomous systems (UAS) and robotics communities face problems with sensor modeling as well as challenges with communications systems and mobility models related to the underlying environment representations. For example, a UAS may perform well in a simulated environment, but when real-world conditions are encountered disrupting its communication (or GPS) signals, erratic or unplanned behavior may result.

Hence, problems of realism are not restricted to the recognized need to address non-kinetic effects, but also persist in the kinetic domain. The problems will persist until a comprehensive understanding of the interplay between representation infrastructure, computational infrastructure, and underlying system architecture are addressed.

PERSPECTIVES ON REALISM

This section focuses on realism as it relates to a variety of DoD M&S activities. The requirements for realism vary depending on individual perspectives from different domains. The following discussion provides broad, overarching coverage, but is not comprehensive.

Training

The requirements in realism for training vary widely depending on the task being trained. Pilot training requires realistic graphics and behaviors of synthetic entities to be represented in an accurate and credible way. Alternatively, training staff commanders, in general, requires less visual presentation than pilot training (except sensor visualization of unmanned and robotics systems), and rely more on the ability to populate the information displays.

Underlying phenomena needs to be represented in a way that does not require as much fine scale physical detail (such as pitch, roll, and yaw of an entity). Rather, it relies on the ability to represent underlying cognitive, or decision making, behaviors of the simulated entities (and gross physical motion) to respond realistically to

the trainee input. The input, as sensed by the trainee and the subsequent response of the system, needs to be plausible. Negative training could occur in this circumstance, and must be avoided (negative training refers to practicing procedures in a manner inconsistent with how an action would be performed in combat, which results in developing bad habits¹).

Figure 2 below illustrates the architecture required to support a large command post training exercise. A wide variety of warfighter C4ISR Systems are stimulated by a wide variety of M&S assets to populate a joint common operating picture. Reliably and realistically representing the behavior of many entities in the real world creates the challenge.

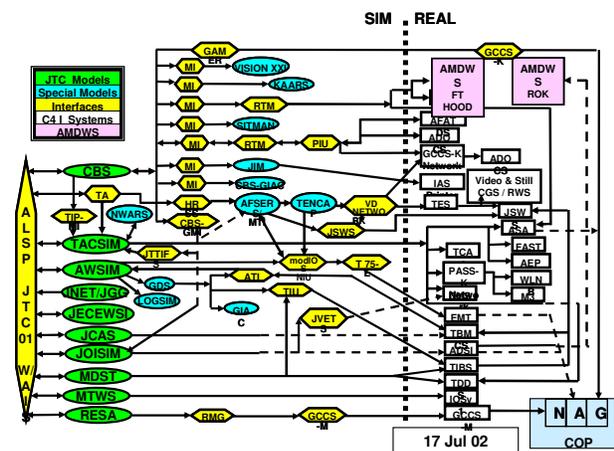


Figure 2. Major Command Post Training System Architecture

At the other extreme, some training systems require high fidelity of visual and physical realism (e.g. representation of military equipment and human beings in a variety of capacities). Some characteristics are shared with the previous training example; however, flight simulators and “first person shooter” games used to teach culture, customs, and protocol are particularly dependent on accurate real world replications.

Experimentation

Requirements for realism in experimentation are similar to training. As warfare transitions to the asymmetric nature of threats, accurate portrayal of new systems is increasingly significant. The ability to virtually predict the outcome of new military systems will play a critical role in making better investment decisions in a budget-constrained future (e.g., prior to full-scale production,

¹ General Accounting Office, “MILITARY TRAINING: Limitations Exist Overseas but Are Not Reflected in Readiness Reporting,” April 2002.

or prediction of change outcomes in tactics, techniques, and procedures (TTP) before employment in real-world scenarios).

The need to improve outcome prediction has led to the realization that we must improve our ability to model human behavior, groups, and organizations - hence, the term “non-kinetic” modeling. There is increasing need to understand how to better represent the highly connected nature of non-kinetic phenomena, and the role of stochastic and deterministic models and modeling constructs.

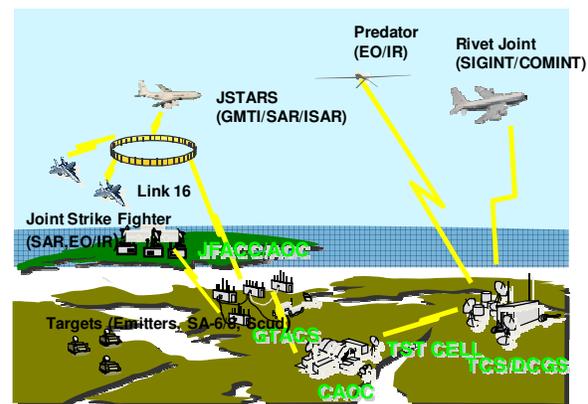


Figure 3. Net-Centric Warfare Experiment Architecture

Consider a new autonomous version of a Predator and new automated target recognition (ATR) for the Joint Strike Fighter. As depicted in Figure 3, the assets are used in combined-arms net-centric warfare experiment to test and understand new time sensitive targeting (TST) tactics, techniques, and procedures (TTP). In order to stimulate the new capabilities, the experimental systems information inputs need to be realistic, along with the other participating systems (such as JSTARS and Rivet Joint platforms, sensors, and crews). As such, a credible representation of the entire battlespace must be created, including the natural environment, civilian activity, and civilian and military infrastructure. An architecture of this nature is foundational for irregular warfare response.

Test and Evaluation (T&E)

Realism pertaining to T&E is similar to training and experimentation. It has focused on representation of physical phenomena, and interaction with system-under-test (SUT). Physical phenomena representation - with increased detail in real-time - drive the state-of-the-art. Due to the advent of net-centric warfare (NCW), the need exists to represent different types of phenomena accurately. NCW also requires representation of diverse

systems, and system interactions, over various networks. Requirements include:

- Creation of complex, realistic, and scalable networks of component inter-relationships
- Distribution of autonomous controls and monitors
- Implementation of complex webs of cause and effect
- Dynamic alteration of the component execution structure
- Adaptation and evolution of the system

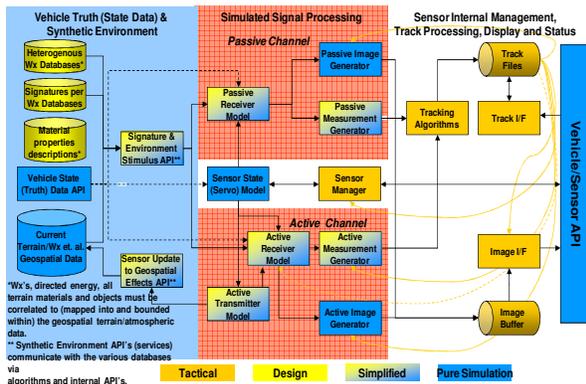


Figure 4. T&E of Tracking and Sensor Management

Figure 4 shows the case of bench testing the critical components of a new sensor suite. Potentially, even low level circuit inputs must be replicated. This provides another example of the extreme detail and complexity needed for realistic simulation/stimulation of live systems with virtual or constructive systems.

The T&E domain frequently requires greater accuracy in replicating the characteristics of a real entity than in training or experimentation. In this way, the T&E domain is similar to the acquisition domain, which is discussed next.

Acquisition

In general, the use of M&S in acquisition relates to the design and engineering of military systems and processes employing new systems. The ability to accurately predict the physical behavior of new systems and their components is required. The military “system of systems” philosophy requires replicating reality, like NCW. Networks of complex assemblies of components must be replicated accurately.

An example of next-generation M&S in acquisition is the Department of the Navy’s (DoN) Future Carriers

Program (PMS 378) which produces advancements in carrier design. PMS 378 is also instrumental in making the centerpiece of the US power projection become a more measurable capability-based program through careful investment in M&S.

The Virtual Carrier concept (Figure 5) represents the aviation operations functions, processes, organizations, personnel, systems, elements and components of the CVN 78 Class. All of the system components must interact to successfully achieve required sortie generation capabilities of the embarked Air Wing, in order to accomplish the missions assigned to the carrier. The M&S representations of these components must replicate the key measures of performance of the overall system in order to usefully guide the total engineering of the ship. This provides an example of an extremely large and extremely complex system to be synthetically replicated.

From the DoN perspective, the Virtual Carrier signifies a critical investment in representing key functions required to evaluate capabilities for conducting missions based on ship design. The inherent capacity of M&S to interface and tackle aspects of Sea Strike, Sea Shield and Sea Basing, and measure design impact and cost while tied to warfighting capabilities, is a component of the overall strategy for a Virtual Carrier. However, current near-term efforts generally focus on narrow applications of M&S development. From an industry perspective, the Virtual Carrier represents a new way of doing business in major ship building.

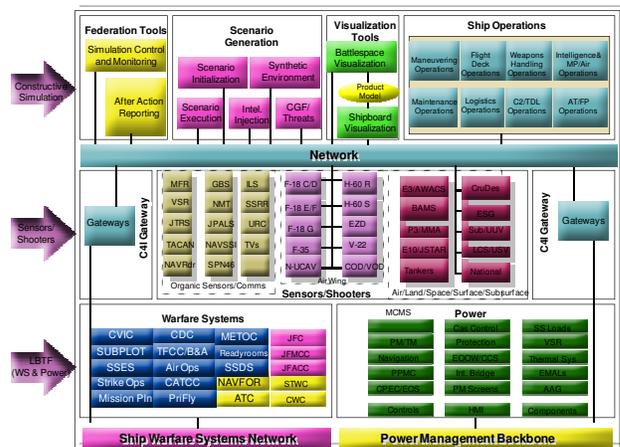


Figure 5. High-Level Conceptual View of Virtual Carrier Functions and Interfaces

For the first time in history, a carrier will be developed in a 3D product model. Multi-level simulations can be tied to the physical model, and used to analyze and test the design at varying levels of resolution. The

collaborative, government-industry development of the Virtual Carrier allows M&S technology to surpass traditional carrier design, and offers opportunities for industry to support the DoN across a much broader range of M&S applications.

Analysis

M&S used in military analysis is different than the previous domains. The goal is to accurately predict aggregate behavior and data, requiring different mathematical approaches, versus replication of detailed physical characteristics and behaviors. The language of probability and statistics tends to dominate modeling in this domain, leading to very different implications (in terms of realism).

Accurate prediction and representation of asymmetric threats, or irregular warfare, is a primary challenge to the abstract, or aggregate, type of M&S. The challenge is shared by all the disciplines, but particularly by analysis and planning. These threats are low-probability events with impact inversely proportional to the size of the organization that commits the event. A specific example of this would be the impact of improvised explosive devices (IEDs) and other terrorist activities, which have a large impact and are committed by a relatively small number of people. Cognitive modeling of Political, Military, Economic, Social, Infrastructure, and Information (PMESII) effects is another example.

Planning

The challenges facing the planning community are similar to analysis. Traditionally, abstract and aggregate M&S techniques have been used. The nature of modern world threats is difficult to represent and predict in this computational paradigm. With initiation of adaptive planning, there is greater need to predict military outcomes over shorter time spans. Representations for adaptive planning require increased detail across kinetic and non-kinetic phenomena.

OBSTACLES TO GREATER REALISM

Achieving realism requires complex and simplistic phenomenology representation methods and techniques. The ability to relate models, and the influences between one another, is a key limitation. Representing cause and effect networks between models, with all of the interrelationships, in a manner that scales, remains a key goal not yet achieved. For example, representing the human nervous system, how activation and information sweep through the body, or the intricacy of an accurate cognitive model that provides real behavior prediction capabilities, presents extreme challenges.

Significant need exists to easily represent a wide variety of asynchronous behavior (many independent activities). The independent, yet connectivity of the real world is difficult to represent in current approaches to computer languages and programming. Some techniques provide a few of the required capabilities. However, there are no techniques that scale to millions of independent, interacting entities.

Another feature needed to realistically represent phenomena involves representing sequences of associated activity, or behavior. Some systems have methods to support this capability, but scalability and ease of programming remain a challenge. The need to easily start and stop an action, based on the dynamically-changing conditions, is a related challenge.

One of the most difficult requirements to develop realistic, complex models involves representing a network of activities triggered by changes in the physical world, or the logical world (e.g., cognitive events). Furthermore, the need exists to trigger a large number of processes based on a single changing activity.

While not usually considered a phenomenology representation primitive, it is necessary to do so in order to represent control of physical and non-physical systems. In this way, multiple disparate sources of control inputs, or dynamically generated inputs in the case of non-physical systems, to a model can be efficiently implemented. Flexibility provides value in the context of Live-Virtual-Constructive environments, including ability to implement external and internal sources of control.

The topic of non-kinetic modeling, and the need to improve it, has received much attention in the industry. The need remains to identify cognitive phenomena and accurately represent cognitive events. The next section discusses methods in which this type of representation can occur, and uses analogies in nature describe the methods.

Finally, no discussion on the topic of obstacles to realism would be complete without mentioning scalability. Scalability refers to the ability to represent and execute large numbers of active physical and non-physical processes simultaneously in real time. At the present time the execution of millions of processes in real-time is beyond most systems. This is a function of software algorithm design and the interplay with compiler construction, processor design and capabilities, the network capabilities, as well as memory and storage. In general, these relationships are not

universally well understood in a variety of DoD M&S development endeavors and operational systems.

COMPLEX SYSTEM REPRESENTATION PRIMITIVES AND REALISM

Complex system representation (CSR) [1] [2] employs a set of primitives that provide a powerful tool used not only in the development of highly complex systems and applications, but also in the development of realistic models and simulations. There have been a few cases of application development and integration software products which contain *some elements* of the CSR approach, however, no products exist that offer the full spectrum of representation primitives that allow functional, causal, and temporal synchronization and execution characteristics, as found in the framework employed on the Joint Strike Fighter Shared Synthetic Environment project [1] [2].

This discussion utilizes several biological examples to highlight aspects of representing reality that have been historically difficult to solve in a scalable, yet easily comprehensible framework. This section outlines a set of representation primitives that enable improvements in representational realism. Worth noting is that the DoD is beginning to invest in biological M&S. These examples have wide explanatory value since the human body is more complex than any mechanical system built to date.

The following sections describe various complex system representation paradigms and the biological analogs which motivate them:

- Asynchronous and synchronous *internal* characteristics or mechanisms
- Asynchronous and synchronous *external* characteristics or mechanisms
- Irregular time-scale *internal* characteristics or mechanisms
- Irregular time-scale *external* characteristics or mechanisms

Asynchronous and Synchronous Behavior

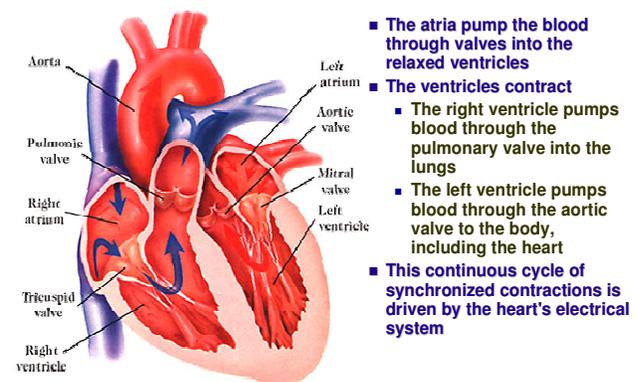
The human heart is used as an example to illustrate CSR principles. Figure 6 depicts a synchronized sequence of activities that occur naturally each time the heart beats (without thinking about it). The heart operates asynchronously from the rest of the body; but within the heart itself, a tightly synchronized set of activities occurs. The ideal system development methodology

should permit this type of system development, implementation, and operation.

Threads and processes [3] [4] [5] are commonly used to instantiate such implementation paradigms. However, numerous problems exist, including:

- **Scalability** – threads and processes rely on saving and restoring large amounts of memory or storage, which breaks down when millions of active threads and processes are required in both serial and parallel fashions.
- **Performance** – when underlying activity or processes are fairly simple, the overhead of memory storage and retrieval may limit utility.
- **Implementation complexity** – implementation syntax is typically arcane and complex usage is beyond the reach of all but the most talented programmers
- **Portability** – most thread and process packages are not portable

Eliminating the use of stack frames is central to resolving the difficulties. Typically, large amounts of data needed to restore the computational context. The framework should provide a method to minimize the data required to restore the process state once it has been suspended. Some mechanism is needed to indicate which variables must be saved and restored. In this way, a large amount of memory can be saved; and the execution performance of processes can be drastically improved.



Internal Processes – Synchronous or Asynchronous – Intrinsic Capabilities

Figure 6. Asynchronous and Synchronous Internal Behavior Example: Operation of the Heart

This same situation occurs in many militarily significant situations – from the representation of complex kinetic phenomena to non-kinetics. The ability to have millions

of active processes that can be synchronous or asynchronous, with the ability to be suspended and resumed, would be quite valuable in simulating cognition or social phenomena.

Any method on an object should be able to become a *process*. A process can be represented as an event that passes time by suspending execution and resuming (maybe several times) before exiting (sometimes called “persistent events”) due to persistence over time. In this manner, a unified execution environment could be developed.

Processes should support at least two ways of passing time, which include:

WAIT(Time to Wait)

WAIT_FOR(Semaphore, Timeout Duration)

In the **WAIT** primitive, a fixed amount of time elapses before the process and resumes. **WAIT_FOR** begins when a specified condition occurs, and releases if the condition does not occur within a specified timeout interval. This approach is surprisingly flexible, and permits a wide variety of phenomenology to be implemented. For instance, both time-steps in the numerical integration of differential equations, and events from classical discrete event modeling and simulation can be implemented with the **WAIT** primitive.

The framework for realism, ideally, should provide at least three types of primitives in order to provide the ability to represent and implement complex functional, causal, and temporal synchronization between components:

- **Logical Semaphores** assume two values: 0 or 1. **WAIT_FOR** blocks when the logical semaphore has a value of 0, and is invoked and continues without blocking if the semaphore value is 1.. However, if the logical semaphore value is 0, **WAIT_FOR** initiates when set by another process, event, or event handler; or the timeout condition occurs. Through operator overloading, logical semaphores act as Boolean data types.
- **Counter Semaphores** extend from logical semaphores. They assume numerical values greater than 1. **WAIT_FOR** blocks when the counter semaphore is 0, and activates when the counter semaphore is non-zero.
- **Resource Semaphores** request and release resources as needed, and require a different macro,

WAIT_FOR_RESOURCE. Through operator overloading, they act as double precision data types.

Figure 7 illustrates the heart being regulated with a pacemaker. The device generates rhythmic impulses transmitted to the heart by fine wires. The analogy represents a system being monitored and controlled asynchronously or synchronously by another system. The framework should support this primitive, providing an implementation called processes as objects.

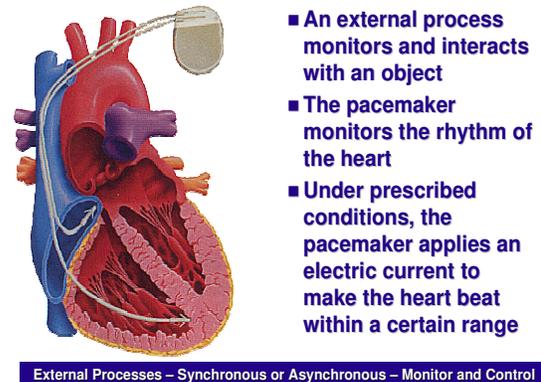


Figure 7. Processes as objects: The pacemaker analogy

Irregular Time-scale Behavior

As an example of irregular time-scale behavior, consider the example of a heart attack. A heart attack is the death of heart muscle, from the sudden blockage of a coronary artery by a blood clot, or heart malfunction (illustrated in Figure 8). Hence, a heart attack represents an internal occurrence that has no pre-established time scale.

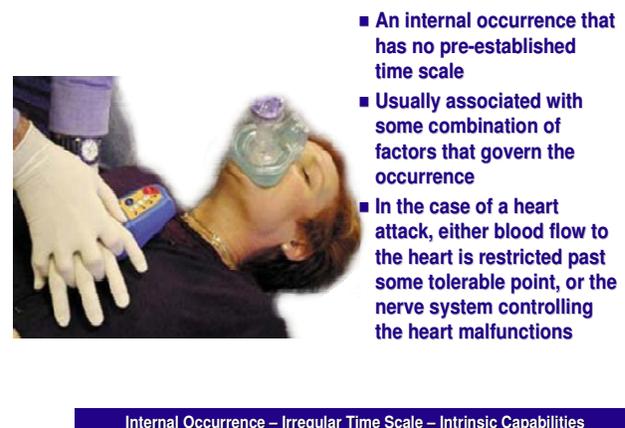


Figure 8. Events as methods on objects: Heart attack analogy

A military example would be equipment that fails, or some other unpredictable event that is a deviation from nominal behavior. In order to represent such functionality, events are commonly used. In a realistic model of the heart, the heart attack event would trigger a wide variety of other activities. This requires a representation scheme that allows an event to trigger not only other events but a wide variety of asynchronous or synchronous processes.

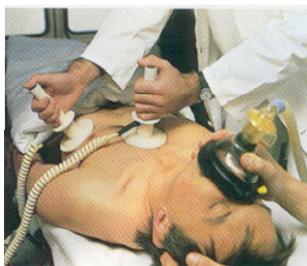
Ideally, the framework should support events as both methods on objects and as objects themselves. In this way both internal and external phenomena with irregular time-scales can be effectively modeled. These phenomena do not require any persistent state; and as such, does not call for the computational overhead of the process model techniques.

Internal Events

Events as methods on objects provide a mechanism for interaction and external integration, without exposing encapsulated internal data. In this paradigm an object should not directly schedule an event for a class contained by another object, to avoid internal exposure and violation of object-oriented encapsulation principles.

External Events

An example of an external event, following along with the heart example, would be defibrillation. This is a process in which an electronic device gives an electric shock to the heart (Figure 9). Shock helps reestablish normal contraction rhythms in a heart with dangerous arrhythmia or cardiac arrest. In this case the representation of the phenomena is as an external event (defibrillation) on an object (the heart).



- An external object acts upon a passive object to change its state
- Most basic representation method
- In this case, a defibrillator is used to perform cardiopulmonary resuscitation
 - An external electrical shock is applied to a patient whose heart is not beating

External Occurrence – Irregular Time Scale – Monitor and Control

Figure 9. Events as objects: defibrillation analogy

An example in the military domain would be commander behavior – the commander is monitoring plan execution and situational awareness. An order is given to a subordinate that alters the behavior of the overall system. Another obvious example would be a missile targeting an aircraft, and the subsequent response of the pilot.

Behavior Activation Mechanisms

The concept of event handlers provides polymorphism in event scheduling. Event handlers are methods on any object, and do not require inheritance. Two macros define interfaces and implementations separately. Event handlers can be directed or undirected towards a specific System Object. A subscription mechanism determines which System Objects receive undirected events when they are scheduled.

Interactions Between Individual Models, Components, or Systems

The construct of interactions provides a mechanism to represent and implement both data transfer and functional activation between models, components, or systems. They also provide polymorphism in event scheduling and processing, and are active, interoperable, and synchronous. Data can be transferred in sets of parameters, which is a container class used to store values of known types, and pass parameters in interaction handlers. They can contain values of type integer, float, double, string, and buffer (a byte array of arbitrary length) and are accessed through keys of type integer or string. This provides a general and scalable method for conceptualizing and implementing complex relationships between different aspects of the system, and flexibility in changing one part of the system without breaking the overall functioning of the overall system.

SUMMARY

This paper highlights the major problems of realism in M&S development and systems integration. Scalable solutions to complex, real-world problems are still elusive, as is seen in the lack of realistic non-kinetic models and simulations. As such, the time is ripe to begin cross-disciplinary discussions to define what realism means in the DoD context, and to identify potential solutions.

Not surprisingly, the concept and meaning of the phrase “realism in M&S” is purpose-specific. There are, however, some common themes. The ability to represent complex webs of synchronized cause and effect is central to the implementation of realistic M&S

systems. Representing many simultaneously evolving phenomena that are interrelated is part of this capability, and critical to implementing realist non-kinetic and complex kinetic phenomena.

Another key feature is to be able to stop one activity based on some arbitrary web of logic, and start another in response to changing conditions. Not the least, scalability must be achieved while providing all these capabilities. This means the ability to support 10^6 or larger entities or distinct phenomena – to which there are few known solutions.

Robust solutions are the gold standard, because they do not fail with perturbations to the information transacted. A robust solution is easy to maintain when systems are modified or upgraded, and straightforward to alter when new information is required, or additional constituent systems are added.

Unless the problems of realism in complex phenomena and systems representation are studied and addressed, the value of M&S investments will underperform; consequently M&S investments will be devalued. Increasingly complex architecture theories, and computer software infrastructure fads, require developers and resource sponsors to re-implement basic behaviour. As such, solutions to the hard problems are avoided. Warfighters, in turn, do not receive the effective training and tools to improve mission performance.

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