The Emergence of Agent-Based Technology as an Architectural Component of Serious Games

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Abstract. The evolution of games as an alternative to traditional simulations in the military context has been gathering momentum over the past five years, even though the exploration of their use in the serious sense has been ongoing since the mid-nineties. Much of the focus has been on the aesthetics of the visuals provided by the core game engine as well as the artistry provided by talented development teams to produce not only breathtaking artwork, but highly immersive game play. Consideration of game technology is now so much a part of the modeling and simulation landscape that it is becoming difficult to distinguish traditional simulation solutions from game-based approaches. But games have yet to provide the much needed interactive free play that has been the domain of semi-autonomous forces (SAF). The component-based middleware architecture that game engines provide promises a great deal in terms of options for the integration of agent solutions to support the development of non-player characters that engage the human player without the deterministic nature of scripted behaviors. However, there are a number of hard-learned lessons on the modeling and simulation side of the equation that game developers have yet to learn, such as: correlation of heterogeneous systems, scalability of both terrain and numbers of non-player entities, and the bi-directional nature of simulation to game interaction provided by Distributed Interactive Simulation (DIS) and High Level Architecture (HLA).

1. INTRODUCTION

The worlds of traditional simulation and serious games are converging in many ways. Each of these worlds is seeking traction in the military training market and each discipline brings its own strengths to the challenge of military training. Traditional simulation has always focused on high fidelity, academic accreditation, and validation – building systems that had lofty goals, but often unwieldy solutions. These ambitious solutions often attempted higher fidelity and more overall simulation capability than was necessary to provide baseline training value. By contrast, game development has been consumer driven and deadline focused with less emphasis on fidelity, demonstrating good results with relatively short development cycles. Despite the game industry's success, there is still lingering doubt when it comes to connecting lower-fidelity game play to formal training objectives. The US Department of Defense (DOD) is keen to find ways to merge the approaches to provide the best training value. We feel the hybrid approach should focus on "rightsizing" the amount of simulation and fidelity for each application. Additionally we believe the future of military training must incorporate Non-Player Characters (NPCs) to derive maximum training value and satisfaction from participants. NPC development has long been viewed as "too hard" – but by applying the same "task worthy" approach, we should be able to provide the right amount of character automation for each application.

2. GAMES AS SIMULATIONS

2.1 Are Games and Simulations the Same Thing?

Key distinctions between simulations and military games can be made in terms of origin and expectations. The need for modern constructive military simulations grew from the need to replace live field exercises and tabletop war games with a solution that was both realistic and cost-effective. As these exercises moved to electronic environments, trainers envisioned multi-part systems that could not only implement a war-game, but also to allow analysis, trainee performance measurement, and After Action Review (AAR) capabilities. Validation and Verification (V&V) of these simulations was considered a vitally important and often problematic part of the system development. Initial simulations required very powerful mainframes or mini-computers. As microcomputers evolved and became ubiquitous and cheap, simulation customers saw the advantages of moving to that platform.

The growth of micro computing was also a huge economic boon to the gaming industry – everyone had a PC and many found free time to play. Games based on military or near-military themes were naturally engaging – they involved danger, weapons use, and strategy that appealed to the prime early demographic - young men. High-fidelity representation of true military tactics was not

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necessary, and although some games were fairly realistic, there was never any formal V&V process. To satisfy the requirement that a game must be entertaining and immersive, much of the development effort went into creating realistic 3D worlds with animated characters and vehicles whose appearance could be tailored to game-player preferences.

In the mid 1990s, the DOD embarked on an ambitious program to create a joint simulation environment called Joint Simulation System (JSIMS) (FY01 Annual Report Joint Simulation System, 2001). JSIMS boasted a complex, distributed architecture (The JSIMS Program and Architecture, 1997) aimed at providing a single simulation solution for all the services (Tiron, 2003). Unfortunately, delays, cost overruns, internal disagreements, and system complexity spelled doom for JSIMS and the program was cancelled. An Analysis of Alternatives (AoA), conducted by the DOD detailed goals and methods for shaping the future of joint training (Gardner & Hartman, 2004). The AoA study spurred the adoption of technologies that were not traditionally considered part of the modeling and simulation community. Specifically, the AoA recommended a hybrid approach to reinvent the way training systems are developed for the DOD that included incorporating gaming solutions and innovative acquisition techniques. Already worldwide simulation customers had become increasingly interested in using game approaches. They recognized early on that the great size of the game industry, predicted to approach $50 billion by 2011 (Szalai, 2007), was effectively driving innovation.

As the traditional simulation industry begins to adopt some game industry practices, it is important to note that, while all games may be simulations, not all simulations are games. Games may not attempt to realistically represent the emulated environment or tactics – but they could still be considered "low-fidelity simulations." Simulations, however, are usually not developed with the specific goal of reality escape or performance reward (e.g. moving to a new level, scoring points) as games are. It is possible that reward systems might be useful for training. In coming together to produce the next generation of simulations, we must view requirements with a fresh perspective and derive a hybrid product that best fits the training needs of the DOD rather than preconceived notions of what constitutes simulation versus games. Forward thinking companies have begun to merge with other companies to satisfy the need, e.g. Kynogon and Autodesk (Autodesk Acquires Kynogon SA, 2008) and BioTech and Presagis (Engenuity Technologies Acquires BGT BioGraphic Technologies, 2005), while other companies independently develop technologies that span both industries (CityScape 1.7: Real Cities Real Fast, 2009).

2.2 How much simulation do you need?

Simulations, both traditional and game-based, vary greatly in the fidelity of their representation of entities and the environment in which they exist. This is usually related to the original intent of the simulation.

A simulation developed for large scale military exercises will usually support large terrain areas at a low to mid level of fidelity (10+ meter) whereas one built based on a "first person shooter" (FPS) will usually have a relatively small terrain area at very high resolution (sub 1 meter) and include building interiors.

Other areas where fidelity or implementation differs among simulations include:

- Aggregation level - are simulation objects entities or units (e.g. a soldier versus a platoon)?

- Kinematic, sensor and combat models - are they fully physics-based including flout of projectiles and weather effects on sensors or are they effects-based with a "die roll" followed by a lookup in a probability of hit/probability of kill (p-h/p-k) or detection tables?

- Level of 3D modeling and animation of entities – are individual entities observable in a 3D environment or is a symbolic representation in 2D enough?

- Number of units - are large groups large groups such as populations modeled statistically or explicitly as individual entities?

- Automation of simulation objects - are high-level orders available or do objects require significant low-level management of behaviors?

The primary challenge is selecting the right simulation components for the task at hand. This is complicated by the difficulty of managing user perceptions of their simulation needs. For example, a user that has seen a high fidelity flight simulator may be resistant to using a low to mid fidelity flight model, even though the only way to observe the modeled aircraft in the target system is as a symbol on a C2 display.

2.3 Interoperability

The simulation community has long understood the need to develop standards which promote interoperability between simulation components. These standards range from communications protocols such as DIS, HLA and TENA[1] to file and message protocols (e.g. MSDL[2], C-BML[3]) and beyond.

While no formal standards have been developed, the game community has converged on pseudo-standards owing to the nature of the components they have needed to develop. Comparable components developed by different companies have evolved similar APIs because they perform analogous actions and they are designed to be used within the same game development frameworks.

There are two main areas of interoperability that simulations have had to deal with that many game systems have not: terrain correlation and sharing of simulation objects. It is crucial that all participants in a distributed simulation provide position data that is correlated to an agreed-upon datum. For many

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[1] Test and Training Enabling Architecture
[2] Military Scenario Definition Language – SISO-STD-007-2008
[3] Coalition - Battle Management Language – SISO (under development)

game-based systems the notion of exporting data to another simulation (game-based or traditional) is completely foreign. Even games which are meant to be used by large numbers of players in different locations are based on a homogeneous set of servers and clients with known capabilities. Adapting a game-based simulation to accept externally controlled simulation objects can present significant challenges (Scolaro, McNamara & Little, 2008).

2.4 Success of Traditional SAF Approaches to Agent Development

Traditional SAF and Computer Generated Forces (CGF) approaches to Human Behavior Representation (HBR) have had some success in supporting the needs of DOD customers. Pew and Mavor (1998) summarized 18 months of study by the Panel on Modeling Human Behavior and Command Decision Making. The panel focused on realism in HBR based on psychological, organizational, and sociological theory and generated recommendations based on what they observed. They focused on the most ambitious, high-fidelity HBRs, ones that attempted to represent full human cognition, and were used to develop agents tailored to very specific military areas. Citing the extreme difficulty of the tasks of HBR and cognitive modeling the panel recommended the collection and dissemination of human performance data to aid in model development, creation of accreditation procedures for agents, demonstrated agent validation, and accepted analysis capabilities. The study documented the wide variety of approaches used to create CGFs and the lack of coordination and consensus in the modeling community. Also, the modeling and simulation community may have become too insular in its approach to software development. Many SAF solutions have been developed as Government Off-The-Shelf (GOTS) products or demonstrations with no real follow on market. They have been very costly to produce and have only a small customer base. Traditional HBR solutions may have also been too ambitious, trying to represent all aspects of human behavior, and cognition in particular, in all products.

Some companies have achieved wider commercial success by selling partial HBR solutions to a greater number of customers. For example pathfinders, applications that calculate a travel route through a navigation mesh, are used in many commercial games (Yap, 2002). Many companies including Presagis, Kynogon, and Xaitment now have path finding products. These path finding systems were not aimed at emulating higher level cognitive behavior; rather they were developed to solve game design and play problems by allowing artists and software developers to work together to improve the speed to market of a title by creating compelling interactive scenes for the consumer market. Game-based pathfinders had the additional burden of needing to support a wide range of game engines which, in turn, supported a production pipeline of commercial tools from a variety of manufacturers. The result was development of efficient, effective, adaptable middleware. Traditional HBR solutions had never achieved that level of modularity but

customers were beginning to demand it. This shift in thinking opened the door for other game based middleware approaches in the areas of physics, scene-graphs, artificial intelligence and interface design.

One of the earliest examples of the use of a path engine to solve military research problems was the development of the Crowd Federate at the Virginia Modeling and Simulation Center (VMASC) in 2003 (Flanagan, 2008). Since then, there have been numerous examples of the use of path engines to animate complex scenes where many NPCs would be needed to represent a population. One example is the army's use of AI-Implant to automate large crowds at the Institute for Creative Technologies (Lawlor, 2007). The use of commercial based path planning engines has mostly been limited to automation of large numbers of characters in scenes where traditional SAF-based systems would have had difficulty navigating and managing the scale of animation. However, traditional SAF approaches do have the advantage of a richer behavior representation allowing more complex interaction. It seems clear that many applications could benefit from a combination of the two approaches – or better yet a new approach borrowing the best from both.

3. THE FUTURE: PERSISTENT, SOCIAL ENVIRONMENTS

3.1 Persistent Social Communities

Virtual worlds are emerging as the next platform for both games and traditional simulations. The platform already boasts a market sector with revenues approaching $2 billion a year (Economic Activity in Virtual Worlds, 2006). Beginning as extensions of Massively Multiplayer Online (MMO) games, virtual worlds have become environments that elude categorization. Both business and pleasure activities are conducted in virtual worlds, which are really seen as 3D collaborative spaces for social networking of all types. They have evolved from the traditional escapism of games to virtual extensions of the real world. Virtual Worlds Review (2006), discusses the many current applications of virtual worlds including: commercial gaming (e.g. World of Warcraft, Habbo Hotel), socializing (e.g. Second Life), education (e.g. Mokitown), political expression (AgoraXchange), and military training (Forterra Systems – On-Line Interactive Virtual Environment).

Figure 1 shows how both traditional simulations and games are converging on virtual worlds as the platform of choice. Moving to virtual worlds has many implications for the future of simulation. As the figure shows, even as virtual spaces evolve into training and analysis venues the social aspect remains. Players in virtual worlds expect social interaction no matter what the focus of the virtual space. These spaces are also persistent because they are hosted on the internet and available 24/7. The combined effects of increased social expectations and persistence must spur new technology development from both the gaming and simulation communities. For example, a classic problem with commercial virtual worlds is that, if there is not active communal

participation, use dwindles quickly. The success of these worlds relies on the active participation of human role players driving avatars to perform functions key to an objective.
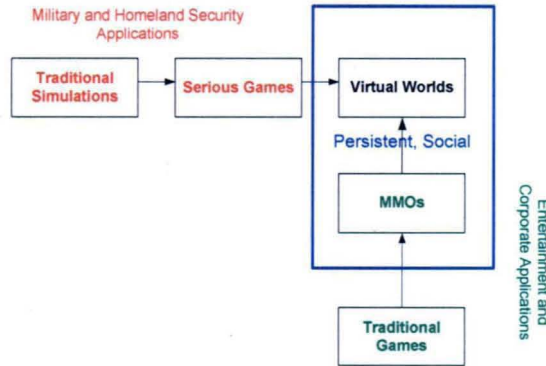

Figure 1: Evolution from Traditional Simulation and Gaming to Virtual Worlds

3.2 NPCs as a Solution

The growth of virtual worlds for simulation and gaming has introduced a new requirement to provide non-player-characters (NPCs) that can move, communicate, and act in predictable and useful ways. Figure 2 shows an NPC assisting a human represented by an avatar in Second Life. The site is a Second Life location, or slurl, for the company MASAGroup (Empowering Life, 2009). The purpose of the NPCs is to show the company's products and services to visiting human-controlled avatars.

Figure 2: NPC Communicates with Human in Second Life

There are four key areas where NPCs could support humans in virtual worlds:

1. Presence: arrival into a virtual location can feel very similar to arriving in a real but unfamiliar location. The use of NPCs can assist in reassuring a player or visitor that they are in the right place and are supported.
2. Performance Support: NPCs also provide the equivalent of online help by having specific knowledge valuable to a player or visitor in a new location. This knowledge includes a thorough understanding of the venue and all of its features to assist in orienting the play to the space and their task.
3. Vigilance: virtual spaces focus a great deal of attention into a very narrow visual channel. NPCs can support the human by making them aware of events and ensuring that if they are not paying attention due to fatigue or distraction that they can be brought back to task subtly.
4. Role-Playing: as serious gaming and military training use virtual spaces, on-demand NPC teammates and adversaries will grow in importance

4. THE IMPORTANCE OF PLAUSIBLE HUMAN-LIKE BEHAVIOR

4.1 HBR in the New World

While nothing matches human adaptability and flexibility, NPCs will need to supplement human role-players to enhance training in virtual worlds and beyond. For serious game applications NPCs can help to direct and focus activity to meet training objectives. They can even act as intelligent tutors providing real-time feedback and coaching.

The challenge for HBR is to find a practical middle ground between the high fidelity, high cost of many traditional HBR approaches and the relatively narrowed scope of the path finding that often constitutes game AI. This middle ground must not only provide a useful and compelling level of functionality for NPCs but also be easy to integrate within systems along the traditional simulation, game, virtual world spectrum. Additionally, HBRs should be ready to integrate with other HBRs in order to maximize the strengths of each.

4.2 Approaches to HBR

During the 1990s alliances between industry, government, and academia worked to create integrated cognitive architectures to be used to build CGFs in simulations such as Modular Semi-Automated Forces (ModSAF), and Joint Semi-Automated Forces (JSAF). The Agent-Based Modeling and Behavior Representation (AMBR) effort compared many of the key behavior modeling technologies (Gluck & Pew, 2005). Included in the comparison were: Elements of ACT-R, Soar, and EPIC (EASE), Distributed Cognition (DCOG), Cognition as a Network of Tasks (COGNET), and Atomic Components of Thought – Rational (ACT-R). Although the AMBR evaluation team did not specifically rank the architectures, it compared cognitive agent performance on multitasking and category learning to human performance using a common simulation test-bed. The research concluded that all of the approaches had merits and weaknesses, and that no single approach emerged as a clearly superior HBR representation, but that the state of the art was strong from a theoretical perspective.

While the architectures developed in the 1990s focus almost exclusively on cognition, the following decade saw growth in representation of behavioral factors traditionally considered to be outside cognition, such as culture and emotion. The rise of these factors acknowledges that behavior is more than a consequence of pure logic. Decision making encompasses "fuzzier" areas such as personal preference, affects, desires, and belief systems (Evertsz, Ritter, Busetta, and Bittner, 2008).

Additionally, socio-cultural factors, such as leader and follower behavior, can have a significant effect on behavior (Silverman, Bharathy, Nye, & Eidelson, 2007). As the field matures the relative influence of all factors on behavior will evolve. NPC architectures must be able to respond quickly to new advances in HBR.

AI for games has followed a somewhat different path than traditional HBR for simulations. First, the term AI has been used to represent any "intelligent" or "automatic" behavior on the part of NPCs. Game AI can be hardcoded reactions to simple stimuli, mathematical algorithms to deal with specific problems like path finding, or a more complex framework including behavior and knowledge representation (Isla & Gorniak, 2009). Game AI generally has a more pragmatic goal than traditional HBR – commercial viability. Development lifecycles must be constrained and products must be robust and reliable. Performance and attractiveness are critical as game users expect to be immersed in an entertainment experience that runs on their home computer. Fidelity of behavior representation will be sacrificed to make sure the product looks good and ships on time.

As we move toward the new world of merging traditional simulation and games we should apply lessons learned in both areas.

4.3 Typical HBR Components

One thing many different HBR approaches have in common is a low-fidelity description of what AI "means." Figure 3 depicts the generic AI representation, or "AI loop," that shows the cycle from what is perceived in the world, to a decision engine that determines what action to take, and the resulting action performance (which in turn modifies the world and leads to new perception). The components shown are always accounted for somewhere in an HBR system whether it's a rich cognitive architecture or a narrowly-focused movement algorithm.
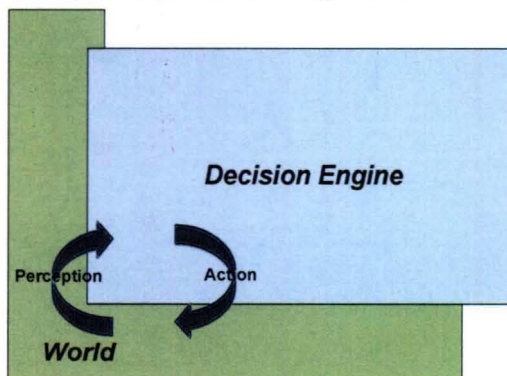

Figure 3: Generic AI Representation

In reality the contents of the "Decision Engine" box are the most interesting – and the most divergent depending on the HBR type. Figure 4 shows a decomposition of different areas that have been modeled over the past two decades. Often, an HBR will attempt to represent multiple areas, e.g. memory, cognition, and learning. Other HBRs concentrate on a single area (like path finding or action selection).

HBR types not only differ in scope and fidelity of human behavior emulation, they also differ in how they choose to represent the behavioral areas. Figure 5 shows some of the documented strategies for representation. Each representation has its advocates – from those who argue it better represents how a human brain works to those who argue it is the most efficient strategy.
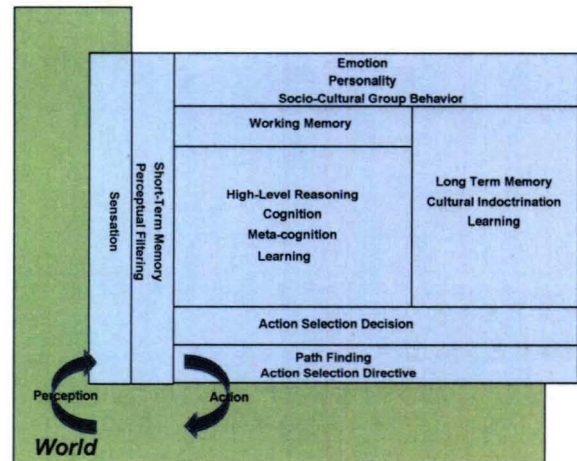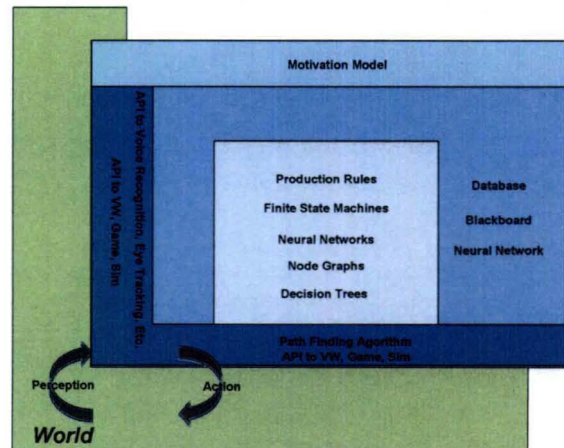

Figure 4: AI Representation Decomposition

Figure 5: Heterogeneous HBR Representations

4.4 Architectural Building Blocks

The state of the art in HBR could be described as fractious – with many competing strategies and definitions of the basic HBR components. Giordano (2004) describes the challenges of obtaining realistic HBR within the current state of the practice. He notes that some areas of HBR are farther along than others, including some limited conversational ability using state of the art speech recognition. Despite many advances, and many novel approaches to HBR from both traditional simulation and gaming communities, many areas are still immature, or too costly in terms of time and resources.

Rather than attempting to resolve the HBR conundrum with a one-size-fits-all solution, we should instead be looking to create an open, component-based architecture that allows different HBR players to focus on specific behavioral areas. These areas would become building blocks to a larger HBR

system. Some solutions might encompass multiple blocks. For example a neural network may encompass memory and cognition. But developers would still need to create an API to connect to the rest of the system.

Using an open architecture to deliver HBR for modern NPCs has other benefits as well. Just as developers should be providing just enough simulation to suit requirements, so should HBR providers seek to deliver just enough behavior. For some applications, or for some subset of the NPCs within an application, path-finding along with some rudimentary motivation may be enough to satisfy the goals. For example in a training application, crowds may be implemented in this way, while the key players (adversaries, allies) require a more complex brain and set of behaviors.

A valuable lesson to be learned from the game industry is that processes must be streamlined to accommodate tight development schedules. One way to accomplish this is by adopting a "just enough" approach to HBR using an open architecture. But to truly trim unnecessary cost and complexity from the process, we should also consider unifying the NPC brain authoring process. Not only would HBRs need to show they can integrate an agent into the architecture, they would also need to incorporate their authoring tools into a single development environment. Advancing a single development environment would not be a popular constraint – as it requires extra effort on the part of HBR creators. But to meet the goals set out by the JSIMS AoA and Panel on Modeling Human Behavior and Command Decision Making seemingly radical approaches may be necessary.

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