Toward Dimensional Reality: Animatronics and Other Practical Mechanical Effects in Simulation Training

William J. Butler, Garner L. Holt
Garner Holt Productions, Inc.
San Bernardino, CA 92408
billbutler@garnerholt.com, garner@garnerholt.com

Kevin Dill
Lockheed Martin
Burlington, MA 01803
kevin.dill@lmco.com

ABSTRACT

"Animatronics and Other Practical Mechanical Effects in Simulation Training" seeks to define, illustrate, and explore the implementation of animatronics and other "theme park" technologies in immersive simulation. Building on the realism achievable through effective use of the medium—in motion replication, realistic skins, hair, costumes, voice, interactivity, and other proven and emerging methods—the paper will underscore the viability of such technologies in simulation training. The paper follows the fall 2010 premiere of seven Garner Holt Productions-created animatronic characters, five automated show systems, an interactive AK-47 prop, and an innovative control system offering basic real-time control at the Infantry Immersion Trainer at the Camp Pendleton Marine Corps Base.

The paper will explore four major aspects of the emerging animatronics technologies for immersive training: adaptability, realism, control systems, and efficacy. The first will focus on the special considerations in adapting proven theme park technologies to the uniquely demanding world of immersive training. The second will explore the benefits of animatronics' realism versus other virtual characters, like projected avatars and role players, in addition to items like simulated explosions. The third section will discuss emerging systems that will give simulator operators unprecedented control of animatronics and other effects within scenarios. The last will attempt to collate and plot the pedagogical benefits of implementing animatronics technologies in existing and new environments, based on GHP's direct involvement with the Spiral II effort at Camp Pendleton's IIT.

Although a technology generally available for decades, animatronics are only a recent addition to the tools used every day in immersive training. This paper aims to illuminate this untapped resource for unmatched dimensional and interactive realism as a complement and replacement for numerous current-use simulation technologies. It will also illustrate the dramatic capabilities of GHP's contributions to innovative practical adaptations of entertainment technology in the training world.

ABOUT THE AUTHORS

William J. Butler is the creative lead for Garner Holt Productions, Inc., and designed the company's contributions to the Spiral II effort at Camp Pendleton's Infantry Immersion Trainer (IIT). Including seven fully-animated theme park-quality animatronic characters, five pieces of disguised mechanical show action equipment, and an interactive animated AK-47 prop, the effort was the first to introduce animatronics and other theme park-style effects into immersive training. Butler brought his background on dozens of theme park and other design projects to the IIT in order to create an authentic-seeming experience for trainees. He is the author of 2009's *March Air Force Base*, a history of the famous Southern California air base, published by Arcadia.

Garner L. Holt is the founder and president of Garner Holt Productions, Inc. (GHP), the world's largest designer and builder of animatronics, show action systems, special effects, sets, props, and other specialty items for theme parks, museums, and themed dining and retail locations. Since 1977, Holt has overseen the design and fabrication of nearly 3,000 animatronic figures, including nearly 400 for Disney theme parks around the world. Today, GHP is the primary vendor of animatronics to the Walt Disney Company, a leading source for Universal Studios, builder of more than 400 animated shows for Chuck E. Cheese Restaurants worldwide, and hundreds of other domestic and international projects. Holt is a recognized authority on the history and progress of animatronics, and has personally developed many of the medium's striking breakthroughs. He was the technical designer for the animatronic characters added to the IIT and drives emerging technologies at GHP.

Kevin Dill is a staff software engineer at the Lockheed Martin Advanced Simulation Center. He is a recognized expert on game AI and a veteran of the game industry, with seven published titles under his belt.

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INTRODUCTION

Beginning in late 2009, Garner Holt Productions, Inc. (GHP), the world's largest animatronics designer and fabricator, became involved with plans for Spiral 2 of the Future Immersive Training Environment (FITE) Joint Capabilities Technology Demonstration (JCTD) program at Camp Pendleton's groundbreaking Infantry Immersion Trainer (IIT). Building on the demonstrated success of that facility's Spiral 1 accomplishments (described in detail in the 2010 I/ITSEC paper "The Future Immersive Training Environment (FITE) JCTD: Improving Readiness Through Innovation") Spiral 2 sought to augment the location-based simulation of an Afghani village inside a disused 32,000 square foot packing plant outfitted with advanced technologies, including animatronics and other practical mechanical effects. This step marked the first time such technologies had been used in infantry-level simulation training, and was a pioneering effort in the use of this unique form of entertainment-originated technology for training in general, when the additions contributed by GHP went online in October, 2010.

A BRIEF HISTORY OF ANIMATRONICS

Developed by the WED Imagineering branch of Walt Disney Productions (today's Walt Disney Company) in the early 1960s, modern animatronics technologies actually trace their lineage to the time of the ancient Greeks, who created simple machine-driven figures that simulated human and animal movement. Technological gains over the following centuries were, as now, largely contingent on breakthroughs in sectors seemingly unrelated to mechanical representations of life: horology in the 16th-19th centuries, military and exploratory computation in rocketry during the 20th. Advances in clockwork mechanism throughout this time and especially during golden age of automata in the 19th century drove the development of automata that could through purely mechanical means not only move, but draw images and words, manipulate musical instruments, and even speak.

Mechanical figures were a mainstay in magic shows, amusement parks, and traveling fairs throughout their development. With the opening of Disneyland in Anaheim, California in 1955, however, the technologies behind these animations began to advance with unprecedented rapidity. At first employing modern variations on proven proto-animatronic technologies of motor-driven cams and levers, Disney began experimenting with pneumatic and hydraulic air-craft and manufacturing grade linear servo actuator motion as early as 1959. While robust and providing a greater range of realistic motion than simple rotational actuation, these experiments with linear actuators were hampered by the lack of readily available control devices. As the United States lavished funding and research on rockets for defense and space exploration, new early computer-type-controlled technologies for the control of valve and solenoid-driven actuation emerged. It was not until 1963, with the opening of Disneyland's *Enchanted Tiki Room*, that the control technology necessary to operate true animatronics as a system of precisely timed and controlled motion not reliant on cyclical motion but rather electrical impulse input was proven enough to operate in a demanding theme park environment. The first fully-functional human animatronic figure (the Disney-created Abraham Lincoln for the Illinois Pavilion at the 1964/65 New York World's Fair) followed in 1964. This system, a precise, tune-coded tape-based system for the opening and closing of valves in specific, pre-programmed sequences continues to be the basic trait of animatronics in nearly all their modern incarnations, albeit with a computerized version of the same effect.

Technological innovation in animatronics since that time has generally favored control rather than mechanical hardware with the exception of increasingly more efficient actuators and advanced chemical processes and compounds used in synthetic skin formulation. Where in 1963 an entire 600 square foot sub-basement was required to house the reel-to-reel control and audio cabinets for the *Enchanted Tiki Room*, today's animatronic figures and even entire rides and shows can be controlled from devices no larger than a laptop. Animatronics technologies have since been adapted for use in other mechanical effects simulating otherwise natural motion, such as the opening and closing of doors and curtains, automated raising and lowering of platforms, and the manipulation of non-character objects like vehicles, barrels and other large objects and props, including weaponry.

ANIMATRONICS FOR THE IIT

A primary component of the Spiral 2 effort at the IIT was its Mixed Reality (MR) capability. Although the first phase of the IIT's development had utilized a significant number of projection systems for avatar-based characters, in addition to its practical use of effects like ordinance explosions simulating Rocket Propelled Grenades (RPGs), Improvised Explosive Devices (IEDs) and visceral bullet impact simulations on man-worn augmented reality systems, in addition to human role-players, the demands of Spiral 2 and the mission change from Iraq to Afghanistan necessitated a facility-wide enhancement. To this end, animatronics were an early source of inspiration for how characters unavailable as role-players (such as children and the elderly) might be represented and to present ways in which the increasingly frequently implemented computer-generated avatar projections and even live role-players might be supplemented or, given certain conditions, replaced.

When GHP was first approached, the range of animatronic figures and systems requested by IIT designers included many considerations in use every day in the technology's more typical theme park environment: the ability to run continuously; relative imperviousness to a somewhat harsh indoor environment; longtime usage without the need for specialized maintenance; minimized impact to existing facility infrastructure; adaptability to multiple scenario-based situations; and, perhaps most of all, an aesthetic realism greater than that available from virtual-reality systems. The central role for animatronics would be to add realistic sound and motion to an ostensibly busy marketplace environment and to balance live role-players' actions within their performance zone. Other early concepts called for a figure that could interact in real time with trainees, a suicide bomber that could realistically attack trainees and quickly reset, a series of automated sniper weapons that could track trainees across the IIT landscape, animatronic animals, and other larger scale mechanical effects like exploding transport vehicles, and more intense pyrotechnics effects than those already in place via simulated IEDs, RPGs, and others.

Ultimately, these more advanced concepts were not implemented. Based on scenario development sessions held at the IIT in late 2009, seven pneumatically powered non-combatant figures were created for use in the marketplace section of the IIT: four shopkeepers in their late 40's to early 50's, a tribal elder, and two young boys, each with multiple shows and unique audio. Each figure could perform a "background" show of simply standing and making small gestures like turning eyes and heads. Longer shows and dialogues between adjacent shopkeepers and the village elder and a child were also part of the pre-programmed menu of animations, as were select brief statements for each character, such as "Salaam," "Allahu Akbar," and, more menacingly "Go home Americans," all in native Pashto. Conceptually, this made the figures have a form of real-time quasi-interactive control, but they were not intended nor were they successful in providing a believable sense of artificial or non-pre-scripted reactivity.

In addition to the animatronic figures, each of the stalls for the shopkeepers featured either automated show action equipment (SAE) driven rollup-style door or a curtain on a track. On a signal from the master control system (see CONTROL SYSTEMS AND SOFTWARE section), these shopkeeper figures could retract into their respective stalls and their associated coverings roll into the closed position.

Figure 1. Shopkeeper Animatronic Figures in the IIT with Role Players and USMC Trainees

The village elder and young boy figures were mobile in the sense that they could be moved throughout the facility to any place where compressed air and power were accessible. Providing for this, numerous staging areas were placed within the marketplace area where compressed air fittings, power connections, and lines running to the central control area were available for the mobile animatronic figures, with the intent of increasing their utility through variation. GHP also created two animatronically-operated moving window curtain SAE as stimulation devices inviting investigation in adjacent buildings, and an animated rooftop-mounted AK-47 prop capable of firing blank rounds. Each was operable in a relatively limited form in real time from the Instructor/Operator Station (IOS).

Figure 2. Mobile Animatronic Village Elder and Children Placed in a Marketplace Stall

Adaptations for the Training Environment

Fulfilling one of the core qualifications for a technology's inclusion in the IIT, animatronics have demonstrated exceptional durability and resilience in their more than fifty years as a mainstay of theme parks across the globe. As a result, the technology made a good fit amongst other proven systems with little need for design and production methodology-driven alteration when added to the IIT's roster of Spiral 2 MR technologies in a manner similar to digital avatar systems originating in the entertainment field and being adapted to immersive training, where they are now an almost inextricable part. The facility impact of adding animatronics amounted to adding a small workshop-style air compressor to an existing outbuilding, lining compressed air hoses throughout the marketplace to locations of the various figures and effects, providing additional power outlets at figure locations, and running Ethernet control lines from figure locations to the central control area in another part of the facility.

The daily demands on animatronics in a theme park environment where figures can operate continuously for up to eighteen hours every day of the week all year long meant that the relatively infrequent use (no more than a few hours per day total, and not usually for more than a few days in succession) of figures and effects in the IIT would be more or less insignificant. Proven methods like using aluminum and anodized stainless steel framing components coupled with sealed pneumatic actuators and high strength interior air lines meant the figures would be impervious to the dust-filled and un-insulated environment of the IIT facility. Watertight boxes for local control equipment at animatronic figure locations ensured their long-term durability in the facility much like their theme park counterparts which are often positioned outdoors in direct sunlight with only partial protection, or exposed to humidity and temperature fluctuations.

Figure 3. Figure Finish Detail of Animatronic Shopkeeper in the IIT

Silicone skins, cloth costumes, details like real human hair beards, and acrylic eyes were all selected and specially treated to provide optimum performance over time in the IIT environment without the need for specialized, or even infrequent, maintenance. Although in use at the time of installation, the paintball-based Special Effects Small Arms Marking System (SESAMS) was intended to be disused and was not therefore a consideration in the production methodology of the figures, which were never intended to sustain hits of any type.

From a performance standpoint, theme park animatronics generally operate fairly autonomously once given a signal to begin their pre-programmed motions. In the IIT environment, however, GHP's animatronics were required to interface with the IOS. Cameras positioned near figure locations monitored their real-time performance at any given time, which could be altered with a series of selectable pre-programmed sequences. This meant that instead of a standard routine found in general animatronics applications, the IIT figures operated similarly to projected avatars in that multiple sequences could be selected at the touch of a button, simulating a form of real-time control but reliant on a human operator manipulating the figures from the central control area.

DIMENSIONAL & PERFORMANCE REALISM OF ANIMATRONICS

Although philosophically related to other forms of simulated persons in an immersive training environment, animatronics have the advantage of dimensionality not available to projection-based systems. Outside human role-players, animatronics are the only fully-dimensional representations of people within the IIT and as such provide a development platform for pedagogic interactivity that other simulations cannot achieve. The figures installed at the IIT featured many of the exceptionally realistic production methods celebrated in theme parks and films, like prosthetic-grade silicone skin, hand-punched hair, authentic costuming, point-source voice audio, and lifelike animation programming. Adding to their realism as characters, the figures had scripting written specifically for each and voices of Pashto-speaking actors recorded by language and cultural training experts Alelo, who also produced many of the MR enhancements, including an advanced digital projected avatar.

The Animatronic Advantage

The most striking feature of animatronics is their aesthetic realism versus that afforded by projections or other computer-generated means of simulation. Many systems, especially Head Worn Display (HWD) systems in use in training, require interrupting the natural field of vision (FOV) for trainees either in ways both close to the eyes of individual trainees or on larger projection surfaces, where projector quality, dust in the air, and other external factors can disrupt graphic quality. In either case, the believability of digital avatars is compromised by the relative weakness of the graphics display versus a fully-dimensional figure whose motions and audio effects can mediate the dissonance between two dimensions and three, simulated and real. The suspension of disbelief in the trainee is, therefore, more demanding with non-dimensional figures.

When an animatronic figure moves, it is passing through real space with real volume and mass and at least a simulacrum of genuine human patterns, and is not always locked to a single plane, like those IIT figures capable of retracting into market stalls. Already limited by their lack of dimensionality, digital figures are also at a disadvantage for their often less-than-lifelike representation of motion with the subtleties of skin and gesture available to animatronic means even under the most basic circumstances. Added to this, the sense of engagement, head motion, eye contact, and weighted gesture favor the animatronic as a platform for adaptive interaction when the superior control over digital avatars might be afforded them, especially in figures with a significant number of functions. Likewise, the centralized control over doors, windows, weapons, and other automated non-character items is a valuable asset for maximum kinetics in the training environment coupled with variability—accomplished easily with objects other than simulated people.

The number of axes of motion available for animatronics largely mirrors digital avatars, albeit in dimensional form. As a result of budget constraints, the figures at the IIT exhibit only a fraction of functions available to animatronics, an average of fifteen digital and one analog function per character, where figures of greater realism often have thirty functions at minimum, a large proportion of them analog. Digital functions display performance where actuators are either fully extended or fully retracted for only two positions per axis without variable speed. Analog functions can be paused at any point along the length of their travel and moved at altering speeds, affording much greater realism through increased control throughout an animatronic figure's range. Analog functions are considerably more expensive than digital ones as a result of the increased cost of their associated actuators. A nearly all analog figure can easily cost twice what a mainly digital one does, with the same level of aesthetic detail in both. The superior performance advantage of analog functions, however, offsets the cost when true realism is required.

From a purely economic standpoint, animatronics do serve as a cost-saving alternative to human role-players. When first introduced, animatronics were hailed as actors who would "never miss a cue, forget a line, or need bathroom breaks." Similarly, in immersive training, animatronics would require almost no further investment past their initial production price, no salary, benefits, or need for vacation. Although they could never replace all human role-players in scenario-based training, they could go a long way in reducing their numbers and associated ongoing costs. Numerous theme park shows use a mixed-media approach of both live actors and animatronic characters, to a good measure of success.

The Performance Gap

Mirroring the challenges faced by the progenitors of animatronics technologies in the early 1960s, control continues to pose the greatest roadblock to further integration of animatronics into the training environment. Here, the advantage is held by projected avatars and other digital means, where a limited form of speech or gesture recognition on the part of the software interface can replicate intelligent reaction and interaction with trainees, in addition to puppeteering by a live actor with full control over the avatar. Alongside this, multiple unique actions and messages are possible with digital representations, in multiple configurations. Although a very limited form of this was available with GHP's animatronics at the IIT (with independent trainee-directed "shows" for "Salaam," "Allahu akbar," etc., in addition to non-engagement banter amongst the animatronics themselves), there was no provision for making them truly interactive. The observations of those in the control room and blind luck made possible a provisional version of interaction and engagement between animatronic figure and trainee, but this deficit quickly made trainees aware of the scripted nature of their performances. Illustrating the value of real interactivity found in some avatars as directed by human puppeteers, according to the *FITE JCTD OD 2 Independent Assessment Report*, "The screen-projected virtual character, which was animated by a live, Pashto-speaking puppeteer, was perceived as much more reactive than those animated purely through software scripts." A similar system and setup utilizing animatronics might result in an even more positive and valuable response.

Additionally, funding limitations reduced the overall number and quality of functions available for the IIT animatronics. Paired with increased real-time interactivity found in digital avatars and budgetary allowances for more detailed animatronics, figures could represent a very real alternative to projections in the near term. Their primary strength might lay in the augmenting of cultural and language training presented as a complement role-players, or in a capacity where neither role-players nor other technologies would suffice or be appropriate, in addition to their ability to perform some functions not possible by either humans or digital avatars.

CONTROL SYSTEMS AND SOFTWARE

At the lowest level, there are two ways to control the motion of the animatronic characters and props used for FITE. The first is to play a prerecorded "show." A show can control one or more characters, and includes not only their motion but also any dialog that they should play. For example, a simple show is initiated to move all of the characters back into their stalls, and then close the door or curtain on the stall. Shows can also be used to play individual lines of dialog (such as "Salaam" or "Allahu Akbar"), or even extended conversations between two or more characters.

The second way to control the characters is to create a "custom animation," which takes direct control of the actuators from managed C code, setting joint positions on analog actuators and turning digital actuators on or off at programmer-specified intervals.

Two custom animations were created for FITE. The Idle animation randomly generates small movements so that the character doesn't freeze in place (which will quickly break the suspension of disbelief). The Look At animation uses the tracking system to determine the locations of the Marines and human roleplayers in the marketplace, selects from among them, and then turns the character's head to look at one after another of them, as if he were watching them go by.

Using computer code to build the custom animations is obviously not the most natural way to engage in what is fundamentally an artistic endeavor, but it did allow us to quickly achieve reasonably good results for simple performances, while creating enough variation and reactivity to increase the believability of the characters. An interesting area for future research would be to create a virtual model of the animatronic's behavior, and then explore the possibility of allowing artists to create animations for the animatronic using their usual tools (e.g. 3DS Max, Maya, MotionBuilder, etc.), with that virtual model as their test bed. This could potentially allow developers to leverage the powerful tools which allow artists to create the compelling animations often seen on virtual characters, while maintaining the physical reality and visual realism of animatronics.

Shows and custom animations can be called directly by a human operator (such as when the animatronics are retracted if a firefight breaks out), they can be built into a scenario using the same event system that drives most of the other systems that make a scenario work (e.g. the scent machines, ambient sounds, and many of the reactions of the MR characters), or they can be called by the Animatronics AI (AAI).

Action Selection in the Animatronics AI

The AAI is a simplified version of the Component Reasoner, which is a dual-utility reasoner used for FITE's Angry Grandmother character and is described in a parallel paper (Dill 2011). As with the Angry Grandmother, the purpose of the AAI is to give our animatronic characters a modicum of realistic motion, avoiding freezing or obvious repetition, and attempting to maintain believability for as long as possible. In this case, the characters under control are background characters who are shopkeepers and visitors in the town's open-air marketplace.

Similar to Component Reasoner, the AAI is a dual-utility reasoner, which means that it uses two utility values to select actions to execute. However unlike the Angry Grandmother, the AAI doesn't have any modularity or an overarching hierarchical structure. In addition, the interpretation of the utility values is slightly simplified.

The first utility value, *force*, is used to divide actions into categories and then ensure that we only consider actions in the most important category. This is done by calculating the force for each action, finding the maximum among them, and then eliminating any actions which do not match that force value.

The second utility value, *weight*, serves two purposes. First, any action with a weight less than or equal to zero is considered to be *invalid*, and will not be selected regardless of its force. Second, a well-known technique called weight-based random is used to select from among those actions that have maximal force. This is done by adding up all of the weights of all of the actions under consideration, and then selecting among them such that the probability of selecting a particular action is equal to that action's weight divided by the total weight in the system.

To reiterate, decision making follows these steps:

1) Calculate the weight of each action, and eliminate actions with weight <= 0.
2) Calculate the maximum force, and eliminate lesser force actions.
3) Use weight-based random to select from among the actions that remain.

This process is continuously repeated dozens of times per second, and any time that the selection changes the controller can halt the old action and begin execution on the new one. Thus the AAI has the ability to change its mind very frequently, but in practice hysteresis is applied through the selection of force and weight values (as described below).

Since the AAI only controls the ambient behavior of the character while the market is "open for business," there are only three actions from which it will select: the Idle custom animation, the Look At custom animation, and the Conversation show. When choosing between these actions, there are two major factors to consider:

- **Duration**: Once an action starts executing, it must continue for a reasonable period of time. The duration is randomly selected for custom animations, but in the case of a Conversation it is simply the length of the show.
- **Cooldown**: When an action finishes execution, it may be necessary to prevent it from executing again for some period of time (so that the same action is not seen over and over again).

In order to implement duration, the force of the currently executing option is set to 1, while setting the force of all other options to 0. When the duration of the executing action is complete, its weight is set to 0, forcing the AAI to select a different action despite the increased force.

The cooldown is implemented more simply: the weight of any option on cool down is set to 0.

The result is that if the currently executing option has a duration that has not yet expired, it will be selected. Otherwise, the controller eliminates any options that are still on cooldown, as well as the one whose duration just expired, and selects randomly from among those that remain.

One advantage of the dual utility approach is that, while it has considerable expressive power, when the decision that you're making is very simple, configuration of the AI can be very simple as well. This can be seen from the fact that the AAI configuration can be fully described in just the few paragraphs above. In addition, the implementation of the dual utility architecture itself is extremely simple: just a few for loops going through the actions and eliminating them based on weight or force, and then a final loop that does the weight-based random selection.

Scenario Configuration

Obviously, the animatronics are used in different ways for different scenarios. During the Initial Patrol scenario, for example, some of the animatronic characters may not be needed in order to portray the market as less busy. During the Market Day scenario, on the other hand, they will all be in use, and during the IED Scenario (when the village is spookily quiet) none will be out.

The AAI configuration settings may vary from scenario to scenario as well. For example, the characters may use the Look At action to stare at the Marines more frequently during the Market Place scenario, as a subtle indication of their resentment at the presence of these intruders, and they may have conversations more frequently during the Initial Patrol, since the marketplace is not as busy.

Thus for each scenario the operator needs to be able to specify not only which characters should be active, but also the duration, cooldown, and default weight of each action. These controls are shown in Figure 4.

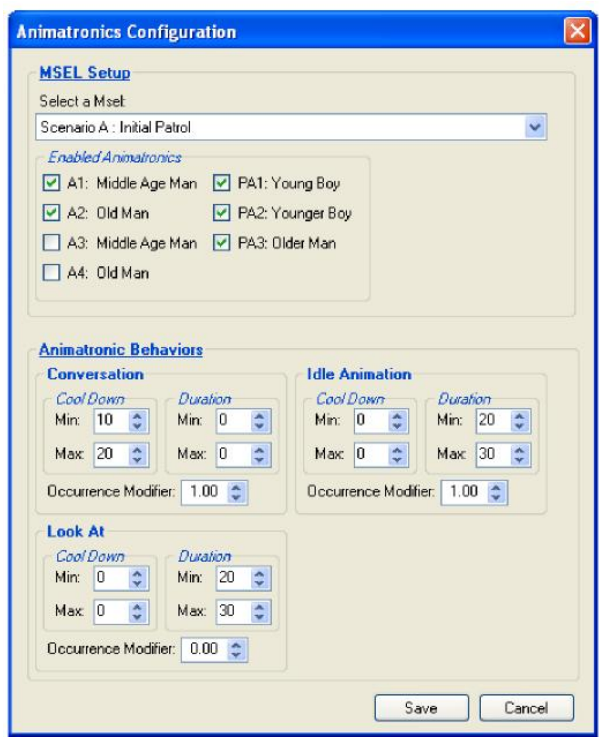

Figure 4: The scenario configuration controls

On this panel, the MSEL Setup section allows an operator to specify the scenario that to be configured, and to select the animatronic characters which will be enabled for this scenario (any others will be kept retracted within their stalls). In the illustration, the Initial Patrol scenario, all of animatronics except A3 and A4 are enabled. Thus the market is fairly busy, but not as full as it can be.

The Animatronics Behavior section allows you to specify the min and max cooldown, the min and max duration, and the default weight (labeled as the "Occurrence Modifier" on this panel). The actual duration and cooldown are calculated randomly each time the action executes.

For the Conversation action, the duration is ignored, since the actual duration will be the length of the show. This action can be given a cooldown, however, which prevents it from running too frequently. This can be important, since each character only has one conversation, and it is necessary that there not be much repetition as it impacts the suspension of disbelief. In this case, that action has been granted only a short cooldown, preventing it from executing twice in immediate succession, as well as a weight of 1.

The Idle action is not given a cooldown in this case, although it could be. Each time it is selected, it will execute for 20-30 seconds. And again, it is given a weight of 1.

Finally, the Look At action is entirely disabled. This is done by setting its default weight to 0, which means that it will always be invalid.

The end result is that the characters will alternate between having their conversations, and then playing the Idle custom animation for 20-30 seconds. After that time, they will play the conversation again.

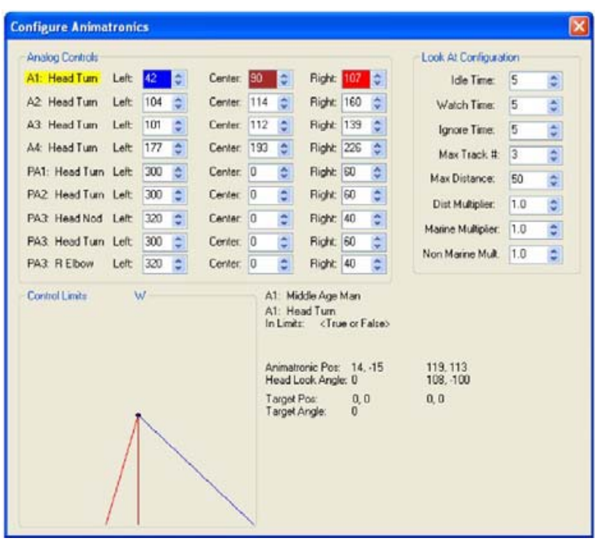

Figure 5: The Look At configuration controls. The lines on the bottom left display the extent to which the head can turn left and right, while the values on the right of the panel control target selection

In addition to the above, the Look At action needs to be configured in order to be used. At a minimum, the operator needs to specify the default orientation of the head, and the extent to which it can be turned to the left and right. These are physical limitations built into the animatronic characters, which are exposed to the operator in order to make them easier to tune. The operator can also specify AI parameters controlling things such as whether the character only looks at Marines or whether he will also look at human roleplayers, how long to look at each target, and how long to look away before a past target is available to be looked at again. These controls are shown in Figure 5.

EFFICACY OF ANIMATRONICS IN TRAINING

The after action feedback, chronicled in the January 2011 official independent assessment report of the Joint Technology Assessment Activity (JTAA) section of the Naval Surface Warfare Center Crane Division, of trainees who utilized the IIT during technical demonstrations and normal cycling of Spiral 2 MR enhancements was largely favorable to the animatronics installed as part of that effort. The overall realism of the FITE-dictated systems in the IIT was praised, especially the human role-players, where the animatronics and other virtual figures were singled out for their comparative lack of realism. However, JTAA's report does underscore the interpreted importance of the multi-layer, multi-technology approach where animatronics played a key role in emphasizing immersion into the intended locale. Said one trainee, "I felt like I was actually 'there' in the situations that FITE presented during the scenarios."

According to the JTAA report, "All participants *Agreed* or *Strongly Agreed* [paper's emphasis] that the FITE mixed reality environment realistically replicated the four physical aspects of the operational environment (i.e. visual, auditory, olfactory, and tactile aspects) as well as the overall combat environment." In this sense, the IIT animatronics fulfill a key collaborative role where they enhance the overall experience—especially on a cultural basis—without too much reliance on their individual capabilities, in the same manner as the other digital/virtual characters. A trainee commented that, "When shooting starts, the animatronics should be withdrawn so when you scan the area, you see realism." This sentiment was echoed by other trainees who rated the aesthetic replication of combat environments as supported by the animatronic figures and effects very highly but their functional role somewhat less so. More realistic animatronics, especially those equipped with situational awareness software or controlled in real time, might further enhance a kinetic situation. Aforementioned constraints made these options unavailable for Spiral 2. Such enhancements would almost certainly eliminate the spirit of this comment from a squad leader: "When I first saw the animatronics, it made me take a second look, but after that they were ignored." Taken in the context of their prescribed role in the marketplace section of the IIT as added population, movement, and sound, rather than scenario-drivers, they are intended to support rather than carry the scene. But the investment in animatronics would be better rewarded if they tended not to melt into the background, but rather become more active participants in the overall experience. The JTAA report recommends continued investment in animatronics technologies in order to "enhance the immersive nature of the training."

Animatronic Sustainability and Maintenance

The animatronics were among the few technologies added as part of Spiral 2 that did not experience any operational downtime during the technical and operation demonstrations at the IIT prior to their going online in October, 2010. They remain a robust and operationally sound technology nearly a year into their operational life at the facility. They have required extremely minor GHP-supervised maintenance only twice during this time. Most maintenance issues result from the improper activation and deactivation of systems at the beginning and end of each operational period.

RECENT INNOVATIONS

Since installing the animatronics and other practical mechanical effects at the IIT, GHP has developed and is in the process of field testing a vision and motion-tracking system for animatronics. Utilizing a small camera placed in a figure's eye and operating with the help of customized software, the vision system, called "YETI Vision," will enable figures to see and follow audiences and trainees face to face with a number of pre-selected variables, such as facial and uniform/civilian clothing recognition, among others. The system would also serve as a stimulus engine for triggering various pre-programmed animations based on the observations of this system. GHP hopes to have the technology available for use in immersive training by the end of 2011.

Alongside the facial recognition and tracking advancements, GHP is developing new capabilities for unmatched realism in facial expression. Soon, figures will have the ability to exhibit a range of unique, subtle, and realistic expressions from confusion to anger, and fear to joy. The realism of the functions will continue to advance the lifelike qualities of animatronic technologies, toward the goal of blurring the line between mechanical and living.

In the interest of increased interactivity and deviation in scenario-based immersive training, GHP is also developing animatronic characters with special variable functions. For instance, a figure of a typical townsperson might be peaceable during one scenario. For the next, this special function might enable the same figure to produce a hidden weapon, thus turning the character into a threat and requiring quick decision-making. Any number of weapons or other objects might be made to appear in the character's hand during one scenario, only to reveal an empty hand in the next.

CONCLUSIONS

While animatronics and other associated mechanical effects have proven a viable and valuable asset to the IIT environment, they are still greatly underdeveloped for immersive training. Expanded use and investment would result in more lifelike figures from both a hardware mechanical aspect and from the view of control-centered operation. More fluidly moving characters coupled with performances simulating interaction or with increased linguistic and cultural pedagogic intent will make the technology a suitable replacement for less dimensional digital-projection systems. In addition, animatronic animals and larger-scale non-character-based mechanical and pyrotechnic effects will increase the immersive realism of squad-level training facilities in the same manner. The uniquely realistic aestheticism of animatronics makes them a very attractive candidate technology for expanded implementation in training, as they have proven irreplaceable as an entertainment medium for precisely the same reason.

REFERENCES

Wood, G. (2003) *Living Dolls*, London: Faber & Faber.

Dill, K. (2011) A Game AI Approach to Autonomous Control of Virtual Characters, *I/ITSEC 2011 Paper 11136*. Forthcoming.

Gordon, B. & Mumford, D. (2000) *Disneyland: the Nickel Tour*, Milan: Camphor Tree Publishing.

Muller, P. (2010) The Future Immersive Training Environment (FITE) JCTD: Improving Readiness Through Innovation, *I/ITSEC 2010 Paper 10148*

Gerrond, J.S. & Reist, J. (2011) Future Immersive Training Environment: Joint Capability Technology Demonstration: Operational Demonstration 2, *Independent Assessment Report*