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AUSA 95 DI Demonstration

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ABSTRACT

At the October 1995 Association of the United States Army Conference in Washington DC, The Naval Postgraduate School and SARCOS Research Corporation demonstrated the interconnection of two different human mobility platforms with sensed upper bodies, a stick and throttle controlled human figure, and ModSAF based human icons. Of these varied control paradigms, one mobility platform was located remotely in Fort Benning, Georgia and the rest were at the conference. Communications with the remote entity was done over the Distributed Simulation Internet. Local communications was done via a three tiered hierarchical network scheme, the top two layers using the Distributed Interactive Simulation protocols. The lowest level protocol is device dependent. This paper covers a generic network structure developed to support the demonstrations.

INTRODUCTION

At the recent Association of the United States Army (AUSA) Conference in Washington DC, The Naval Postgraduate School (NPS) and SARCOS Research Corporation (SRC) demonstrated significant progress in the development of the ability to represent the Dismounted Infantryman in a Distributed Interactive Simulation (DIS) environment. Specifically, the new capabilities included the ability to have the icon move around a multi-story building, the integration of two different mobility platforms, the use of hierarchical networking schemes for bandwidth conservation and interoperability, and the ability to represent fully articulated human icon over Defense Simulation Internet (DSI) using DIS Protocol Data Units (PDUs). This paper covers the network structure that was developed to support this demonstration.¹

The overall system represented a collaborative effort between NPS, SRC, The Dismounted Battle-space Battle Laboratory (DBBL), The Army Research Laboratory (ARL), Hughes Research, and the Simulation, Training, and Instrumentation Command (STRICOM). STRICOM and DBBL provided coordination, scenario development, and support for the remote First Generation Indi-

vidual Portal (UniPort) located at Ft. Benning. ARL provided the initial leadership and technical guidance for the entire I-Port development project. Hughes built the modified version of ModSAF 1.5 to support the Individual Combatants (ICSAF). SRC built the both the UniPort and Treadmill Portal (TreadPort) mobility platforms. They also developed the low and mid level controllers to the hardware devices. NPS developed the visualizations, Bunker Stealth, Sound System, the Stick and Throttle Portal (StickPort), and upper body sensor software. NPS also served as the integrator of the system developing the networking software needed to have the virtual humans interact in the same virtual battle space.

In order to fully describe the challenges involved in the demonstration, a brief presentation of the scenario is needed. As shown in Figure 1, the basic mission was to have a fire team assault a two story building that contained a sniper on the second floor. The sniper was physically located in Ft. Benning on the Uniport with a Polhemus based upper body tracking system monitoring the soldier and his weapon. The base of fire was comprised of three members of an M60 machine gun team. When the sniper fired, the ICSAF M60 team would start to lay down suppressive fire. At this time the TreadPort Soldier would get up from one knee and give the "Follow Me" signal. This was the signal for the two ICSAF members of the assault element to start running to the building. These two constructive soldiers were followed by the

1. While this paper covers the network and software architectures, no attempt is made to minimize the outstanding work done by SRC on the development of the new treadmill based motion platform.

soldier on the TreadPort and the soldier manning the StickPort. When they approached the building, the TreadPort assumed the lead followed by the StickPort and went up the stairs. Once upstairs, they maneuvered

around the rooms containing furniture and shot the sniper. The TreadPort then Soldier moved to the window where the sniper was and gave an “All Clear” hand and arm signal.

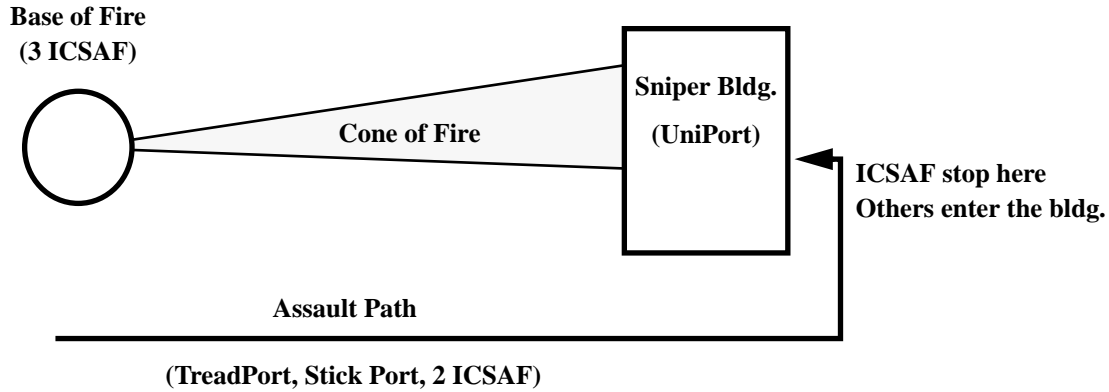


Figure 1: Dismounted Infantry Scenario

NEW HUMAN FIGURE FEATURES

In order to accomplish the scenario several new features were incorporated in the baseline version of NPSNET. To give the soldiers the mobility and flexibility required to operate the Uniport and TreadPort, NPS developed an upper body sensing system consisting of a total of four six Degrees of Freedom (DoF) magnetic sensors and a single emitter. (the SensorSuit used previously was based on mechanical linkages which would interfere with some of the planned user postures). The initial locations of the sensors are shown in Figure 2. The actual system used at Ft. Benning and Washington, DC used a large projection screen vice a Helmet Mounted Display (HMD) for the visual system. In order to continue the track the shoulders, the HMD sensor was moved to the back of the base of the neck. With the three sensors attached to the soldiers we were able to represent the real-time motion of the upper body while they were executing hand and arm signals. The rifle was tracked using a single sensor located on the stock. This position was less than optimal but was dictated by the weapon mock-up. A much better option would have been to mount the sensor along the sight line. The icons hands were snapped to the rifle when they came within a certain distance of the rifle to compensate for the magnetic noise generated by the motion platforms.

The scenario called for the soldiers to enter the building, go up a flight of stairs, down a hallway, into a room, around some furniture, and shoot the sniper. To accom-

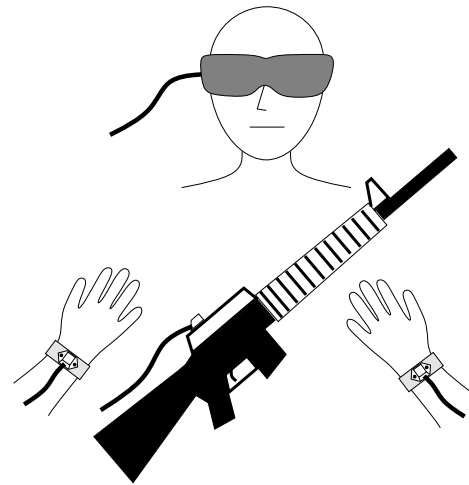


Figure 2: Prototype Upper Body Sensors

plish this, NPSNET had to be modified to support multi-story buildings. This is a limited case of the “multiple Z” problem. To solve this problem, rather than casting the elevation ray from high overhead, which guarantees a terrain intersection (but in this case would just return the top of the building), a ray was cast from waist height plus the previous elevation. If the ray did not intersect anything, as in the case of running up a step incline where the computed new elevation is below the terrain surface, a ray was recast from a slightly higher elevation. When combined with forward cast rays to determine if the sol-

dier walked into anything, it provided an efficient and effective means to maneuver in an urban virtual environment.

Most notable was the construction of a generic hierarchical network architecture to allow the efficient communication of highly articulated entities over standard protocol networks. The generic interfaces allowed us to interface the two different mobility platforms, the TreadPort and UniPort, and the StickPort with a single piece of software. The network architecture is the main topic for the remainder of the paper.

NETWORK ARCHITECTURE

In order to demonstrate this scenario, several new network technologies were developed. Perhaps the most significant was the use of three hierarchical logical net-

works. The interconnections of the top two network levels are shown in Figure 3. The rationale for the hierarchical layering is quite simple: not all data is pertinent to all nodes on the network and each level presents progressively more processed and abstract data. In addition, the segmentation of the network, similar to the ModSAF's Network Architecture which has three major networks (DIS, Stealth, and Persistent Object Networks), allows for protocol and network interface optimization. By using different ports and multicast groups, we can avoid the computational penalty imposed by the use of the DIS PDU's exercise field for application level multicasting while still using the same physical network.

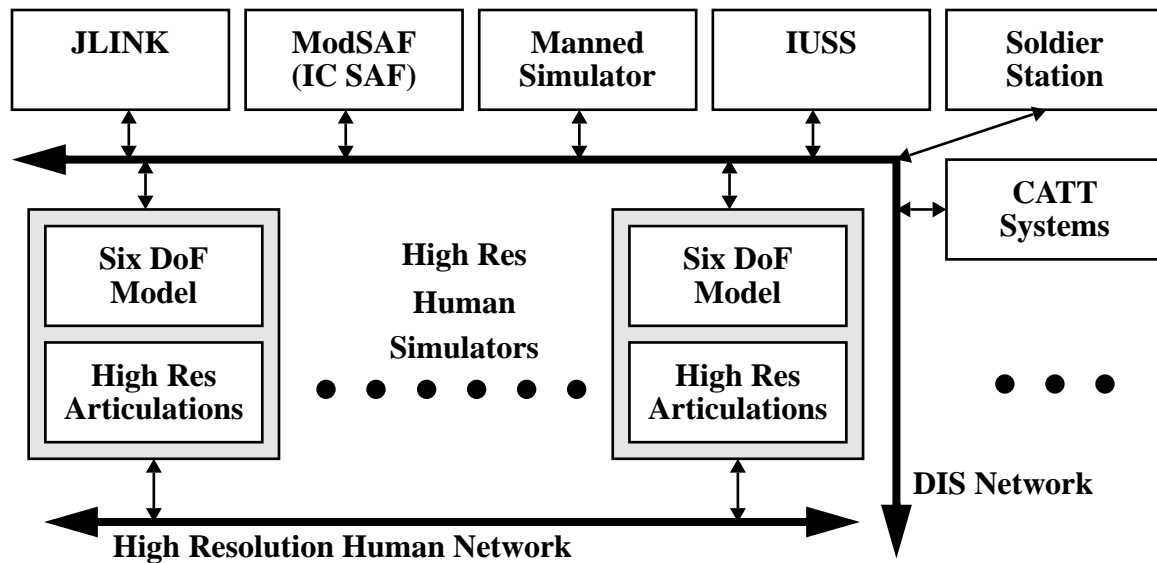


Figure 3: Top Two Levels of the Hierarchical Network Scheme

At the top of the network hierarchy was the DIS network shown at the top and right of Figure 3. This network uses the standard DIS protocols. For the demonstration, we used the Fire, Detonate, and Entity State PDUs. This allowed us to communicate with system that only model humans at a low resolution. ModSAF and ICSAF participated on this network only. Over this network we communicated the data required by DIS type, six degree of freedom, simulators to model human figures; e.g. gross postures, location, speed, and status. While this provided a representation of the human figures on lower resolution platforms, it could not efficiently model the human articulations. To compensate for this, two approaches were taken. The first was the use of the a heavily modified version the University of Pennsylvania's JackML library to

provide human figure animation on the visualization platforms in response to the description of the entity in the Entity State PDU (ESPDU). The other was to encode an enumerated value in the unused portion of the Entity State Dead Reckoning Parameters. This value was used to trigger special animations. Thus, the StickPort could carry out hand and arm signals despite the lack of a sensed upper body and have the signals displayed in the UniPort, TreadPort, and in the Bunker Stealth.

To represent the large number of articulations of the human icon, a High Resolution Human (HRH) network was used. This network represents the middle layer of the network hierarchy. As shown in Figure 3, this network only connects those system that are capable of interact-

ing with fully articulated humans. At the AUSA demonstration, the TreadPort and UniPort both received and sent PDUs on the DIS and HRH networks since the application maintained both models to present a consistent view to all nodes in the exercise. The StickPort read from the HRH and DIS networks, but only wrote to the DIS network. The NPSNET bunker view listened to both networks but did not send any PDUs. In order to transmit the data over the DSI network down to Ft. Benning, we used the DIS Data PDU to transport the data. Encoding the

joint angles as part of the fixed datum records, we were able to transmit the articulations efficiently. As shown in Figure 4, each joint angle had a unique tag associated with it. For the demonstration all the joints were used except the wrist angles. This allowed only data for the changing joints to be sent, increased the flexibility of the scheme, and eliminated the need for positional dependencies in the PDU. By using a standard PDU format, we were able to use the DSI and standard DIS bridging software to communicate with the long haul site.

```
// These tags are used to fill the datum_id portion of the fixedDatumRecord
// structure. Thus the DataPDU only need contain one joint angle if that
// is all that is needed.
// The number of joints contained in the packet is stored in num_datum_fixed
const unsigned int LS0_TAG = ~(0xFFFFFFFF & 0x01); // left shoulder dof 1
const unsigned int LS1_TAG = ~(0xFFFFFFFF & 0x02); // left shoulder dof 2
const unsigned int LS2_TAG = ~(0xFFFFFFFF & 0x03); // left shoulder dof 3
const unsigned int LE0_TAG = ~(0xFFFFFFFF & 0x04); // left elbow
const unsigned int LW0_TAG = ~(0xFFFFFFFF & 0x05); // left wrist dof 1
const unsigned int LW1_TAG = ~(0xFFFFFFFF & 0x06); // left wrist dof 2
const unsigned int LW2_TAG = ~(0xFFFFFFFF & 0x07); // left wrist dof 3
const unsigned int RS0_TAG = ~(0xFFFFFFFF & 0x08); // right shoulder dof 1
const unsigned int RS1_TAG = ~(0xFFFFFFFF & 0x09); // right shoulder dof 2
const unsigned int RS2_TAG = ~(0xFFFFFFFF & 0x0A); // right shoulder dof 3
const unsigned int RE0_TAG = ~(0xFFFFFFFF & 0x0B); // right elbow dof
const unsigned int RW0_TAG = ~(0xFFFFFFFF & 0x0C); // right wrist dof 1
const unsigned int RW1_TAG = ~(0xFFFFFFFF & 0x0D); // right wrist dof 2
const unsigned int RW2_TAG = ~(0xFFFFFFFF & 0x0E); // right wrist dof 3
const unsigned int RCX_TAG = ~(0xFFFFFFFF & 0x0F); // rifle coord X
const unsigned int RCY_TAG = ~(0xFFFFFFFF & 0x10); // rifle coord Y
const unsigned int RCZ_TAG = ~(0xFFFFFFFF & 0x11); // rifle coord Z
const unsigned int RCH_TAG = ~(0xFFFFFFFF & 0x12); // rifle coord Heading
const unsigned int RCP_TAG = ~(0xFFFFFFFF & 0x13); // rifle coord Pitch
const unsigned int RCR_TAG = ~(0xFFFFFFFF & 0x14); // rifle coord Roll
```

Figure 4: Datum Joint Encodings for the Data PDUs

As shown in Figure 3, the high resolution human modeling systems are connected to both the DIS and HRH networks. Since they send PDUs out on both networks, problems of the other nodes having two representations of the same icon arise. To ensure that only one representation is used, the remote site is responsible for monitoring the HRH network for PDUs for a known entity. If a PDU comes across for the HRH network for an entity that also exists on the DIS network, the lower resolution representation is turned off and all further updates from the DIS network are ignored. Since there is a possibility that a node can drop off the HRH network yet stay on the DIS network, an one second time-out interval was set up. If after one second, there has not been an update on the HRH network, control and representation reverts back to

the DIS network. If there is not an update on the DIS network during an additional time-out interval, the entity is removed from the simulation.

At the bottom of the network hierarchy is the Interface Network. As shown in Figure 5, this network goes between the physical devices controllers and the high resolution simulators. On the simulator side of the network is the interface manager. The interface manager communicates with the physical devices using a multicast scheme. The use of multicast, rather than broadcast or unicast, allows for a rapid configuration of the network interfaces and applications. Thus, a single physical device can control several simulations, or multiple physical devices can interact with a single simulation. By using the multicast scheme a single port address can be set aside for the interface network, and each node's network card discards

the packets that are not for a group that the system belongs to. As a result, several different logical networks are created from the same port address. Since the Interface network uses a multicasting scheme, we can also use

the Multicast Backbone (MBONE) routing service over the InterNet to interface to remote devices and simulations.

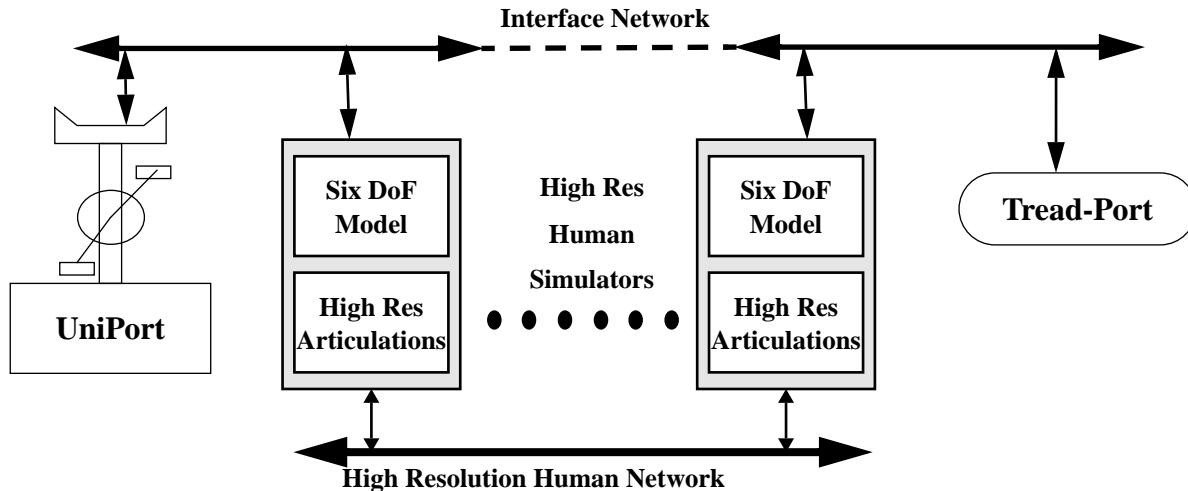


Figure 5: Interaction of the Interface Network and the High Resolution Human Network

We can isolate changes in the data formats required to communicate with the physical devices from the application by keeping all of the device specific interface code in the Interface Manager. This allows us to have a standard set of calling routines from the application to the Interface Manager. The amount of redevelopment required when a new motion platform is integrated into NPSNET is greatly reduced.

RESULTS

During the three days of the demonstration, the system proved to be extremely robust. The only major problems were user errors and the computers inadvertently losing power. In order to provide smooth feedback to the motion platforms, the Interface Network ran at 30 or 60Hz. The HRH Network ran at frame rate which normally ranged between 15 to 30 Hz. While we have not carried out a rigorous testing of the network capabilities (because the motion platforms are just not available) our es-

timates show that it would be possible to have a whole platoon of infantrymen on motion platforms engage an ICSAF based platoon yet not exhaust the bandwidth available on an EtherNet network.

ACKNOWLEDGMENTS

This demonstration could not have been possible without the inspiration, vision, and hard work of Ron Spencer and Brenda Thien of ARL. Rick Burtnett and Ed Jennings had a tremendous amount of patience working with a bunch of wireheads. All the folks at SARCOS, past and present, have done a wonderful job on the two generations of motion platforms. We thank Dr. Bruce Hoff of Hughes for rapidly fixing the minor problems in the ICSAF and getting it to work robustly. Most of all, we are very grateful to the soldiers from the DBBL and the 82nd Airborne who manned the exhibit. The hamsters did a great job.