Semantic Coherence

Military command and control (C2) systems often have similar functionality, but use different message systems which are not interoperable. Patchwork communication links are commonly called stovepipe systems which only work within specific systems, not broadly across multiple systems. These incompatibilities surprise many people: if trained experts can understand such correspondences, why can't systems translate them also? Data format incompatibility is the primary cause of non-interoperability in communications for robotics, command & control (C2), and Modeling & Simulation (M&S) systems.

Achieving clarity. A fundamental consideration in the design of programming and data languages is that they consist of two primary components: syntax (form) and semantics (meaning). If both challenges are solved, then a language is effective. NPS has performed several projects that explore coherent syntax and consistent semantics for tactical messaging in the robotics, C2, and M&S domains. The Extensible Markup Language (XML) is the basis for syntax, and definition of common terms can provide the semantics. A broad harmonization appears to be possible between diverse protocols in military-relevant contexts. Messaging might become compatible, stovepipe connections might become links to a common coherent communications bus. The single most-important data exchange that can benefit from interoperability: *contact track information.*

Historic example. Well-known fact: the English Navy's signal-flag book was a critical factor in the Battle of Trafalgar which enabled coordination despite melee and English victory. Lesser-known fact: each night for the previous two years Admiral Lord Nelson went to dinner aboard every ship in his fleet. After dinner they laid out the charts on the wardroom table and he explained the details of the battle plans, what each signal-flag hoist actually meant, and how forces should proceed if communications were interrupted. As a result, the officers on every ship understood both commander's intent and the specific semantic significance of each of the signal messages. These ships were able to act both independently and collectively, even amidst cannon fire and smoke and confusion and "fog of war," winning this critical major battle.

Reclaiming past strengths. There are countless examples throughout naval history where commanders acted independently with only intermittent communications to achieve coordinated goals. We are examining how semantic coherence might produce a concise and effective "signal book" for Naval messaging that improves interoperability while reducing both size and stove-piped complexity of at-sea message traffic. Our research is now applying these concepts to help connect three important domains: robotics tasking interoperability, C2 protocol interoperability, and simulation protocol interoperability.

Robot Tasking Interoperability for Ethical Operations

Robots tend to have many different purposes, capabilities, hardware suites, and command dialects. In many respects robot forces resemble the capabilities and challenges associated with coordinating maritime forces. These similarities make unmanned systems interesting and realistic proxies for broad interoperability testing.

- NPS Autonomous Underwater Vehicle (AUV) Workbench is experimental open-source software that supports physics-based mission rehearsal, real-time task-level control of robot missions, and replay of recorded results in support of autonomous unmanned underwater, surface and air vehicles.
- NPS Autonomous Vehicle Command Language (AVCL) is a command and control language for autonomous unmanned vehicles, enabling common XML-based representations for mission scripts, agenda plans and post-mission recorded telemetry. Operators can utilize a single archivable and validatable format for robot tasking and results that is directly convertible to and from a wide variety of different robot command languages.
- Practical Approach to Robot Ethics using AVCL is ongoing work that is extending AVCL to enable tasking that has embedded ethical constraints. We avoid philosophical debates that mistakenly confuse the issues by anthropomorphizing automated systems. Measurable ethical prerequisites have the potential to increase autonomy of unmanned systems when military professionals retain ethical control of potentially dangerous capabilities.

Using Semantic Web techniques to adapt AVCL and other XML-based command languages holds particular promise for explainable, understandable and repeatable logic supporting military tactics, techniques and procedures.

- Childers, Candace M, Applying Semantic Web Concepts to Support Net-Centric Warfare using the Tactical Assessment Markup Language (TAML), Masters Thesis, Naval Postgraduate School, Monterey California, June 2006.
- Candace Childers, Don Brutzman, Curtis Blais, Paul Young, "A Case Study in Applying Semantic Web Technologies to the XML-Based Tactical Assessment Markup Language (TAML)," *Association for the Advancement of Artificial Intelligence (AAAI) 2006 Fall Symposium on Semantic Web for Collaborative Knowledge Acquisition,* Arlington Virginia, 13-15 October 2006.

C2 Protocol Interoperability

Numerous protocols exist for sharing C2 information. Typically they use different data formats yet say the same types of things (and most of the data items are related to tracking of other contacts).

We believe that aligning data formats via XML-based conversion, and performing semantically correct mappings between them, provides a path towards broad future interoperability.

- NPS Track Data Conversion Suite (TDCS) open-source code base to facilitate conversion between a growing variety of track data formats (diagram).
- DeVos, Daniel A., *XML Tactical Chat (XTC): The Way Ahead for Navy Chat* , Masters Thesis, Naval Postgraduate School, Monterey California, September 2007.
- Armold, Adrian D., XML Tactical Chat (XTC) Extensible Messaging and Presence Protocol for Command and Control Applications, Master's Thesis, Naval Postgraduate School, Monterey California USA, September 2006.

> *XML-based chat using the XMPP protocol offers multiple opportunities for semantic interoperability. Each chat message can be mapped to a variety of other private/proprietary chat protocols, and is also allowed to carry an additional XML-based payload. Interestingly, this research occurred when we were working on XML SCHEMA-BASED BINARY COMPRESSION (XSBC) which was one of the contributions leading up to EXI.*

- Hodges, Glenn A., *Designing a Common Interchange Format for Unit Data using the Command and Control Information Exchange Data Model (C2IEDM) and XSLT* , Master's Thesis, Naval Postgraduate School, Monterey California, September 2004.

> *For our team, this thesis first showed a strategy for unlocking the possibility of semantic reconciliation between dissimilar Command and Control (C2) dialects. The C3IEDM has continued to evolve as the JC3IEDM and subsequently evolved into the Multilateral Interoperability Programme (MIP) by 29 NATO and non-NATO nations. These insights continue to inform our work.*

Modeling & Simulation (M&S) Protocol Interoperability

The IEEE Distributed Interactive Simulation (DIS) Protocol is the most widely implemented and thorough of military-related protocols for modeling and simulation. It is designed to support real-time operations, which makes it a good fit for matching C2-related track protocols.

- Open-DIS open-source software distribution provides protocol support across a variety of computer programming languages.

> *Open-DIS is an open-source implementation of the Distributed Interactive Simulation (IEEE-1278) standard in C++, C-Sharp, Objective-C, Java, Javascript and XML. Example applications including sending and receiving native DIS traffic, X-Plane plugin, and WebSocket/Javascript/WebGL applications.*

- Serin, Ekrem, Design and Test of the Cross-Format Schema Protocol (XFSP) for Networked Virtual Environments, Master's Thesis, Naval Postgraduate School, Monterey California USA, March 2003.
- Fischer, William D., Enhancing Network Communication in NPSNET-V Virtual Environments using XML-Described Dynamic Behavior Protocols (DBP) , Master's Thesis, Naval Postgraduate School, Monterey California, September 2001.
- Zeswitz, Steven R., NPSNET: Integration of Distributed Interactive Simulation (DIS) Protocol for Communication Architecture and Information Interchange, Master's Thesis, Naval Postgraduate School, Monterey California, September 1993.

Rich Semantic Track

Rich Semantic Track (RST) is a research project to identify and describe the fundamental semantics of track data for data exchange and common processing across multiple systems. The work originated in papers by Prof Rick Hayes-Roth in association with his concept of "valued information at the right time" (VIRT), where the information enterprise is aware of specific user information needs based on user activities and can find and direct such information to the user to meet those needs.

- Blais, Curtis, Rich Semantic Track: Formalizing the semantics and pragmatics of track data for interchange and common processing, Presentation to the 2015 MOVES Academic Working Group (MAWG), Naval Postgraduate School, 20 May 2015.
- Blais, Curtis, Rich Semantic Track: Formalizing the semantics and pragmatics of track data for interchange and common processing, Poster Session, 2015 MOVES Academic Working Group (MAWG), Naval Postgraduate School, 20 May 2015.

TODO

- Dynamic Behavior Protocol (DBP) description, C-BML, semantic track with VIRT, etc.
- Get reference on Trafalgar-preparations story
- Significance of track interchange as a semantic common denominator for maritime C2
- Track Data Converter documentation and slideset
- NIEM editor

Stay tuned, a variety of completed past work is being added here with lots more to follow. We have not yet "turned the corner" on achieving semantic interoperability, but it does appear that we are surrounding the problem.

Contact

All questions and comments are welcome, please let us know what you think.