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MIO Cortex: Memory Mechanisms for Operator-Expert Networked Decision Support

Topic 8: Networks and Networking

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Abstract

In this paper we consider the phenomenon and functionality of a memory system capable of supporting collective expert networks. In this instance, we apply the context of networked decision support to a maritime interdiction operation (MIO). There are two dimensions of knowledge in such networked decision support systems (NWDSS): social or organizational memory as exemplified by reach back to subject matter experts, and software encoded knowledge bases distributed across a MIO services network. We consider a transactive memory system (TMS) as a mechanism unifying network knowledge flow, formation and sharing. In the context of MIO, the TMS is considered as a knowledge network that forms and evolves through the process of discovery and formation of strong and weak ties between the information sensors and expert nodes producing shared analyses. We examine the nature of bursts and clustering in social networking between mobile operators and reachback experts, and describe the potential architecture of a human-machine "cortex" using a MIO-related social network.

A. MIO Networked Decision Support: the Need for a Memory

Since 2010, a team of researchers led by the U.S. Naval Postgraduate School has conducted a series of MIO experiments which specifically address the threats to the U.S. and NATO installation overseas. The experiments examine means to detect and interdict nuclear/ radiological materials based aboard small maritime and ground vehicles. The areas of research activity include areas of the Baltics and the Mediterranean Sea. The results provide vital operational models which directly contribute (green inserts) to development of the Global Nuclear Detection Architecture (Figure 1). These experiments further address unique operator—expert networked decision support systems (NWDSS) relationships and roles.

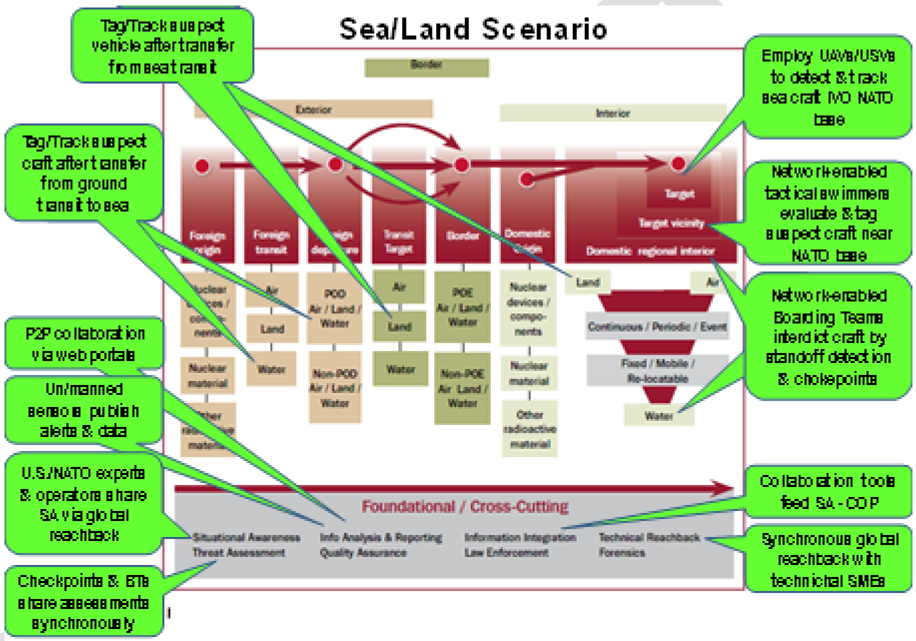

Figure 1. Operator-Expert collaboration tasks within Global Nuclear Detection Architecture.

SPECIFIC ACTIVITIES

a) Deployed units must be able to collaborate in real time with partner forces, partner/allied operations centers:

- Large vessel boarding/search
- Small vessel boarding/search
- Ground tracking/search

b) Deployed unit ability to access reachback subject matter expert (SME) support to assist in adjudicating MIO tasks:

- Operate networked sensors/detectors

c) Augmentation of tracking and interdiction with a nano satellite based orbital node when out of cellular or radio range

d) Capability to analyze impact of cyber distortion on:

- Reachback operations
- Knowledge architectures (knowledge bases, transactive memory, social networking hubs)
- Visibility/vulnerability of networked detectors

1. NATO & NATO SPECIAL FORCES HEADQUARTERS

a) NATO agency capability to:

- Fuse data and collaborate with reachback rad/nuc and site exploitation SMEs
- Integrate reachback rad/nuc site exploitation and SMEs into a command and control (C2) networking architecture
- Achieve SME reachback network interoperability

2. MARITIME OPERATIONS CENTER (MOC)

a) MOC capability to

- Conduct cooperative mission C2
- Transfer situational awareness among MIO forces

b) MOC capability to:

- Monitor vessel traffic on a Common Operational Picture (COP)
- Integrate tagged (tracked) craft into the same COP

3. PORTS OF EMBARKATION (PoE)

a) Overseas PoE operator capability to collaborate with boarding teams (BT) and SMEs during:

- Network-controlled choke point setup
- Drive-by primary and secondary screening
- Stand-off detection at high-speed pursuit

b) PoE and BT operator capability to:

- Detect and interdict small, fast maritime unmanned surface vehicles (USV) transporting rad/nuc materials in the vicinity of allied coastal installations
- Cooperatively screen and pursue small craft by remotely controlling/ maneuvering POE manned patrol boats

4. MIO BOARDING TEAMS (BT)

a) TTPs concerning locating, tagging, monitoring, and regaining lost threat tracks to/in the vicinity of a military site

b) Real-time support during detection of:

- Rad/nuc sources
- Chemicals/explosives
- Biometric and other information at sites during site exploitation.

The networked decision support for a collective expert network, such as the MIO network example described here, requires a new form of expert knowledge capture and knowledge flow support. As discussed in [1], there are two dimensions of knowledge in a NWDSS: a social or organizational memory as exemplified by SME reach back, and a technological ICT-based knowledge base such as the nuc/rad material database in the MIO network that is discussed below.

B. Characteristics of Operator-Expert Knowledge Network Nodes

a. Heterogeneity. NWDSS environments involve many different players and agents who form a constantly evolving virtual team (cluster), for the purpose of achieving a set of objectives (e.g., containing a fire, monitoring and interdicting narcotics traffic, search and rescue). The knowledge contained within this network is a critical parameter in the effectiveness of the decision-making required to achieve the organization's objectives. How this knowledge is distributed in the network is critical, because there will be nodes which contain both explicit knowledge and implicit (tacit) knowledge. We find that knowledge links may be either strong or weak, in the social network sense. This distribution profoundly affects the efficacy of the overall organizational memory.

b. Transient membership. A common characteristic of a NWDSS is its fluidity of participants. A highly defining aspect of a mobile network is the constant entry and departure of nodes to/from it, generally in an unanticipated manner. Whether these nodes are humans who join and drop based upon functional participation requirements, or unattended sensors which provide data bursts upon sensory activation, one can expect a constant ebb and flow of nodes.

c. Homophily. Following [2], a significant aspect of a NWDSS and one that impacts its performance is the commonality of traits or function among the nodes in the member clusters. For example, the hub of the MIO nuclear and radiological analysis cluster seeks and links to numerous similar nuc/rad analytical entities. They share a common purpose of collaborating on the nature of illicit materials that are sent via data burst from human or other sensors that are detecting and tracking such items. There is a natural tendency for the nuc/rad hub to work with entities that share its functionality, interests, or specific objectives, even if for short periods of membership. This commonality may be attributable to close physical proximity, but location is decreasingly a factor in a networked DSS.

The analysis of operator-SME relationship dynamics in a MIO scenario (see figure 2) indicate that the ad hoc trans-organizational nature of an NWDSS knowledge flow provides a fertile environment for applying TMS models. In the context of a MIO expert network, a TMS offers a rich conceptual framework to integrate the social and technological dimensions of a NWDSS.

The MIO TMS could be described as "a system through which groups collectively encode, store, and retrieve knowledge."

- Elemental processes [3]:
  - Directory updating: "knowing who knows what in a group"
  - Information allocation: "assigning memory items to specific group members"
  - Retrieval coordination: "accessing, or retrieving knowledge by leveraging who knows what"

- Knowledge Mesh and EKP:
  - Knowledge Distribution (implicit-explicit)

- Knowledge Links (strong-weak)
- Knowledge Flow
- SME Reach Back

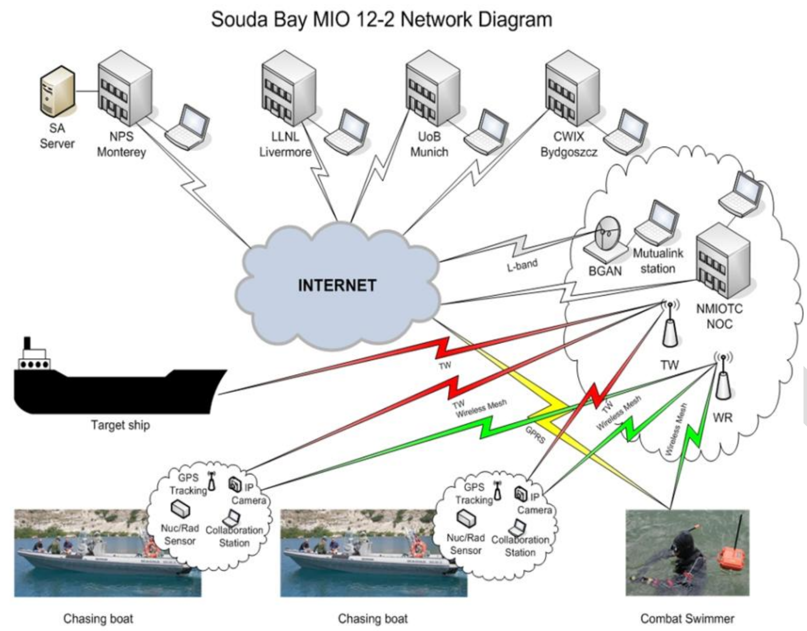

Figure 2. MIO Experiment Network Diagram.

C. MIO Transactive Memory as a Network

In the classic sense, a TMS has been defined as "a system through which groups collectively encode, store, and retrieve knowledge" [8]. Wegner began TMS theory with research into shared memory between intimate couples. This dyadic level of analysis was to remain a strong research area, although in his later articles he and others expanded discussion to small work groups, and offered a metaphoric example of a TMS as a computer model. He expressed concerns about the feasibility of expanding his concept well beyond the dyad, out of concern that empirical research would become too unwieldy. Transactive memory systems now present a well-established paradigm with nearly three decades of research.

In a retrospective survey article evaluating the directions of research into TMS theory that have been taken since its inception, Ren and Argote [3] identify four main research gaps. The last two issues are particularly germane to our work with a tactical networking testbed in a MIO scenario. Research gaps include:

- A lack of consistency in measuring TMSs
- The challenges of research into TMS as a multidimensional construct
- The need for further investigation of TMS at the organizational-level of analysis
- Research in conjunction with field experimentation, vice laboratory settings

We propose a paradigmatic variation on original TMS theory by extending Wegner. We seek to address the third and fourth research gaps above, drawing from his computer model of TMS [9]. We suggest that a TMS can serve as a unifying mechanism to characterize a network. In an ongoing campaign of experimentation, we investigate how organizational knowledge is distributed and shared across a network. Our particular focus is on the case of ad hoc or emergent organizations which underlie many NWDSS environments.

Using a TMS as a basis for network knowledge is not a new idea. Wegner explicitly introduces it, specifying a structural component of TMS that reflects how individual memories link in a collective network. Three basic computer related design factors are associated with TMS in a network context: 1) directory updating, 2) information allocation, and 3) retrieval coordination. These correspond to 1) learning who knows what in a group, 2) assigning memory items to specific group members and 3) knowing how to access or retrieve information by leveraging knowledge of who knows what. [3]

A TMS represents a knowledge network that forms and evolves through discovery and formation of strong and weak ties between the sensors of information and expert nodes producing their shared analysis. As a network, a TMS unifies knowledge flows and formation sharing. It relies on solutions to each of the three basic design factors above.

With respect to directory updating, each node, whether in a particular cluster or independent, must actively update its relevant information. In a social network context, this means coordinating retrieval based upon a mature taxonomy. All nodes would be expected to know and adhere to a specific internal model or structure in order for the directory system to be accessible and of value to other knowledge-seeking or knowledge contributing nodes.

D. CORTEX Model of MIO Transactive Memory

We suggest that a TMS as a network represents a parallel to a human cortex [2], [4]. There is a correspondence between a human sensory-to-processor-to-cortex and a network as we have constructed in several examples below.

In our experimentation, a frequently used tool among the various nodes is a combination white board and audio chat tool, known as Elluminate. It is highlighted in the figure below. Figure 3 represents a snapshot of expert nodes’ reactions to spectra that have been detected, as a part of the MIO cortex functionality.

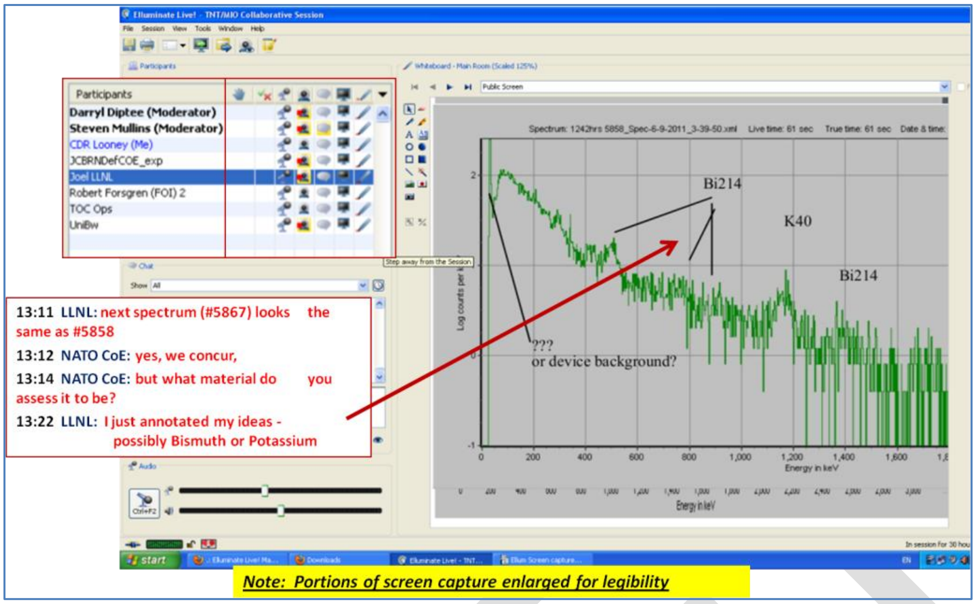

Figure 3. Collaboration on sensor-produced spectra.

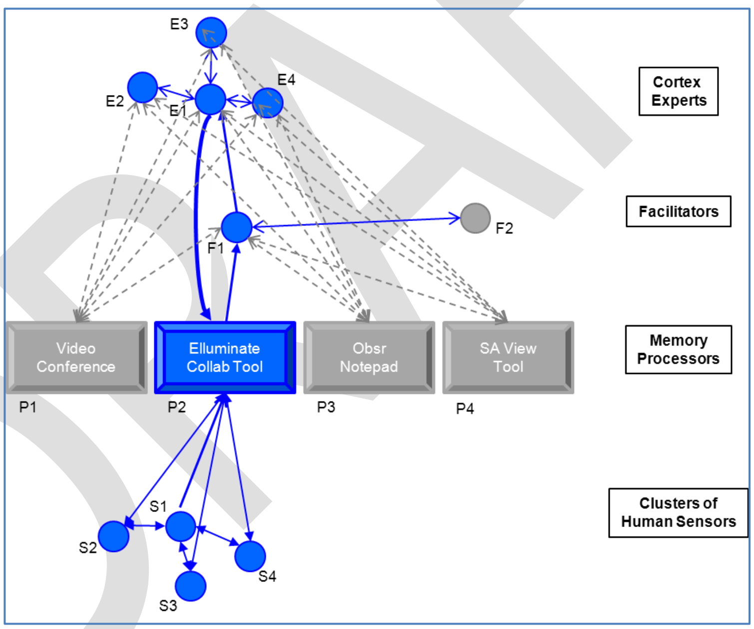

Figure 4: MIO cortex as a whiteboard centered network.

Figure 4 illustrates observed MIO cortex reactions, by forming a network centered on a whiteboard memory processor. The following key explains the abbreviations within the network examples.

Nodes	Name	Description	Linkages
E1-E4	Cortex Experts	Members of a cluster of subject matter experts	bidirectional
F1-F2	Facilitators	(aka stewards, connectors)	
P1-P4	Processors	The four principal tools used in MIO experimentation	directed
S1-S4	Sensors	Human Sensors (possibly aided by unattended sensors)	

Table 1. Legend

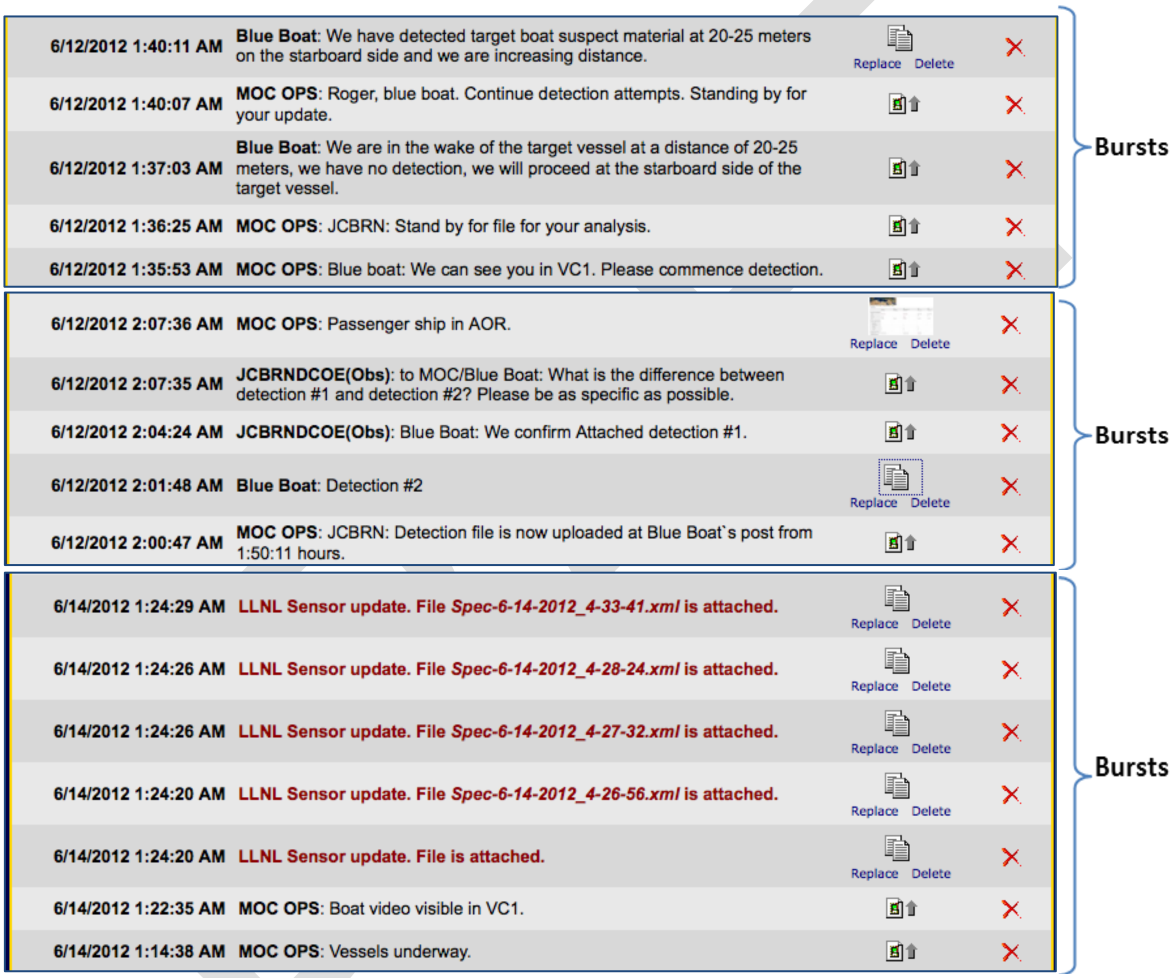

Figure 5. MIO cortex actions centered on sharing in threaded text chat tool.

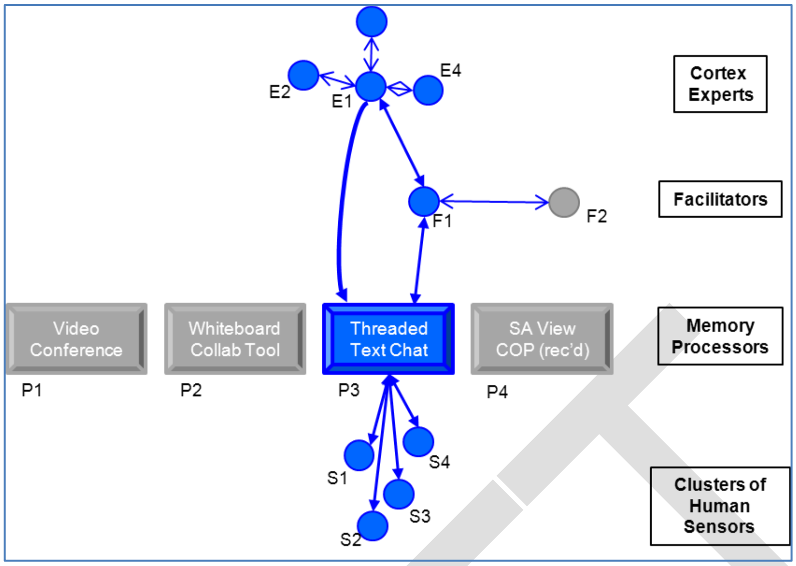

Figure 6: MIO cortex as a threaded text chat centered network.

Figures 5 and 6 illustrate the capture of MIO cortex reactions during the experiment, by the formation of a “strong ties” network centered on a shared chat memory processor.

Figure 7. MIO cortex actions centered on sharing of a situational awareness view.

Figure 7 illustrates situational awareness sharing by SMEs and operators to control BT locations and movements.

Figure 8. MIO cortex actions centered on sharing of a situational awareness view.

Figure 8 illustrates situational awareness sharing by SMEs and operators to locate suspected threat vessels in the area of operations.

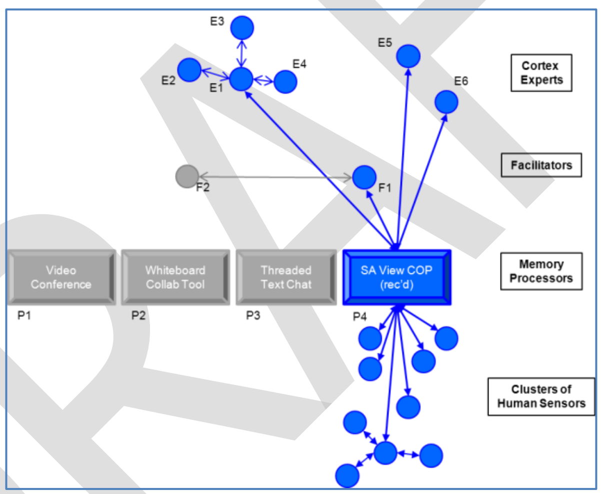

Figure 9: MIO cortex formation as a Situational Awareness view sharing network.

Figures 7-9 illustrate experimentation captures of MIO cortex reactions by the formation of a network of “strong ties” centered on a Situational Awareness view memory processor.

E. Conclusion

We describe the emergence of transactive memory structures for a collective network of experts and operators (sensors), based upon observations of MIO detection and interdiction experiments. We consider the memory mechanism supporting a MIO networked decision support system environment, as a network parallel to a human cortex. The MIO cortex reveals itself through observation of its expert nodes. Reactions to sensor (operator) inputs act as a network of strong ties, which morph from one topology to another when applied to different memory processors. In the environment of a MIO experiment, different collaborative tools play the role of memory processors.

References

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