



Maritime Domain Awareness via Agent Learning and Collaboration

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Motivation



- U.S. counter-terror agencies need search capability
 - Alternative spellings
 - Standard for name-checks
 - Once a U.S. visa is granted
- Intelligence information is fragmented and embedded in large volumes of multi-source data
- Data correlation is difficult
- Dissemination of the intelligence reports to *all-source* analysts is delayed



Solutions



Agent Learning and Collaboration

- *Discovery search*
 - Allows real-time system self- awareness
- *Anomaly search*
- Correlate all-sources data, cross-validate warnings and reduce false alarms
- Search and learning from distributed raw data using Parallel Computing
 - Facilitates timely gathering, analysis and dissemination of intelligence



What is a Learning Agent?



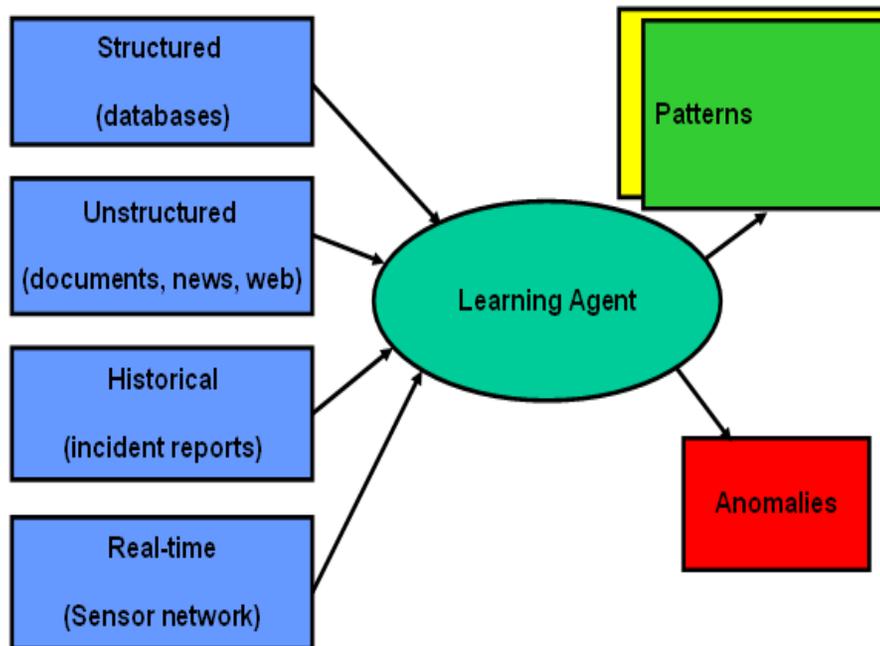
- A computer program or software
 - Installed in a computer with permission
 - Perform automatic tasks
- Multi-agent, distributed networks are capable of
 - Self-managing (Hinchey et al., 2006)
 - Self-healing (Dashofy et al., 2002)
 - Self-optimizing, self-configuring, self-adapting...
- Our learning agent
 - Related to
 - Reinforcement learning (Sutton 1998)
 - Bayesian belief networks (Pearl, 1986; Ben-Gal, 2007)
 - Hidden Markov Models (Huang 1990)
 - Learning patterns and anomalies



Agent Learning and Collaboration

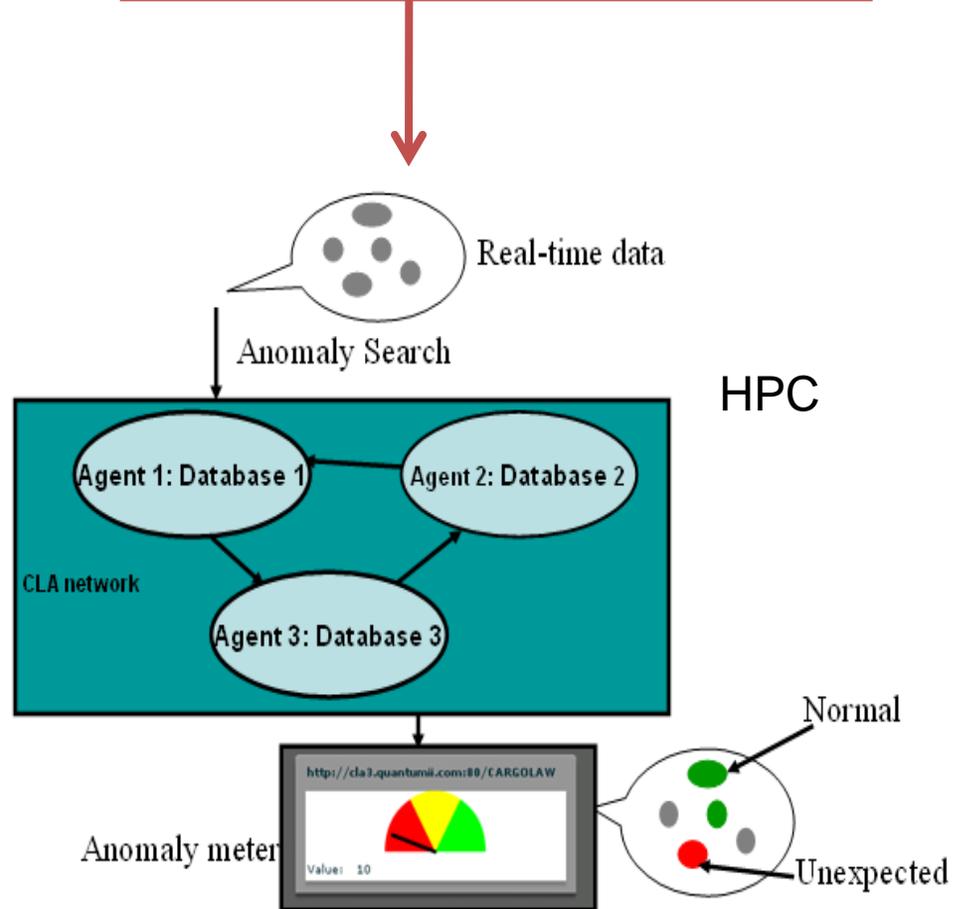
Collaborative Learning Agents (CLA)

Quantum Intelligence, Inc.



A learning agent ingests structured, unstructured, historical or real-time data and separate patterns and anomalies.

Agent collaboration: multiple agents work together for anomaly detection





Discovery Search



- Analysts lack overall situational awareness
 - Sometimes don't know what questions to ask, or
 - What search keywords should be explored
- By sifting and displaying all of the data, CLA helps discover the questions and key words that are most interesting to the analyst



Anomaly Search



- Typical searches (e.g. Google) are based on
 - Popularity or *authority* scores
- Useful in marketing and advertising applications
 - Not as useful for intelligence applications
 - Finding anomalous information can be the goal
- Our solution is an *anomaly search* mechanism
 - Sorts information according to the degree of *anomalousness*
 - Favors new, different, and interesting information



Correlation

All-source(s) Data



- Agents make collaborative decisions
- Critical events are identified from fusing all results from all agents
 - Red is an anomaly event
 - Green is a pattern event



Parallel Computation

For large data sets



- Network of ~10 to 100 learning agents
 - NPS (Naval Postgraduate School) High Performance Computing Center (HPCC)
 - Hamming Linux cluster



Anomaly Search, Parallel Computing via NPS Hamming Linux Cluster Dashboard Output



KPS Dashboard - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Refresh Home Search Favorites

Address <http://hamming.uc.nps.edu:8080/USCG/Dashboard.jsp> Go Links

Dashboard

Last Updated: 14:18:43 GMT-0700 Sequence: 60 Start Stop

Agents

<http://hamming.uc.nps.edu:8080/USCG>

Value: 100

<http://hamming.uc.nps.edu:8080/FIATA>

Value: 25

<http://hamming.uc.nps.edu:8080/RELIEFWEB>

<http://hamming.uc.nps.edu:8080/MARITIMECALAMITIES>

Critical Events

Sequenc	Time	Input	Event Name	Category
60	Thu Oct 22 14:18:42 PDT 2009	CINEMA SOURCE 1	Expected	Relevant
59	Thu Oct 22 14:18:41 PDT 2009	FRESNEL LENSES 1	Expected	Relevant
58	Thu Oct 22 14:18:40 PDT 2009	RADIOS RESPONDER 1	Immediate Attention	Anomaly
57	Thu Oct 22 14:18:39 PDT 2009	RESULTS GAMES 0.5	Expected	Relevant
56	Thu Oct 22 14:18:38 PDT 2009	RATE HIKE 1	Expected	Relevant
55	Thu Oct 22 14:18:37 PDT 2009	LISTINGS TV 0.2857142857142857	Expected	Relevant
54	Thu Oct 22 14:18:36 PDT 2009	COMMENTS NEWSCHANNEL 1	Expected	Relevant
53	Thu Oct 22 14:18:35 PDT 2009	UW DEMAND 1	Expected	Relevant

Investigate

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Done Internet



Analyzed Data - Trident Warrior 2008



Maritime Domain Awareness (MDA)

- Navy: Automatic Information Systems (AIS)
 - SPAWAR DS COI AIS/alerts (google earth/web service)
 - MDA DS COI Data (<https://mda.spawar.navy.mil>), DOD PKI
 - The MDA DS COI has AIS based track information and publishing associated alerts including AIS data from Navy Organic Sensors aboard Navy ships, The Department of Transportations (DOT), The United States Coast Guard (USCG), Office of Naval Intelligence (ONI) to track merchant shipping. The data is published as the NCES Messaging Service that can be integrated with standard web services.
- Police, Coast Guard's contextual information
 - Maritime commercial activities, weather, terrain, environmental conditions, maritime incidents, casualties, and military exercises
 - JOC: journal of commerce (email/html)
 - MPC: Maritime Press Clippings (pdf)
 - 2008, 2007,...
 - Fairplay: daily RSS
 - Freight Forwarder Associations/Custom Brokers
 - (<http://www.fiata.com/>)
 - News
 - Arrival schedules
 - Financial links



Google Maps Mediation Service

MDA DS COI SPAWAR ENVIRONMENT

WHO WE ARE

GOOGLE MAPS
MEDIATION SERVICE

GOOGLE EARTH
MEDIATION SERVICE

COI DEVELOPERS
INFORMATION PAGE

COI DATA PROVIDERS
INFORMATION PAGE

METRICS & REPORTING
INFORMATION PAGE

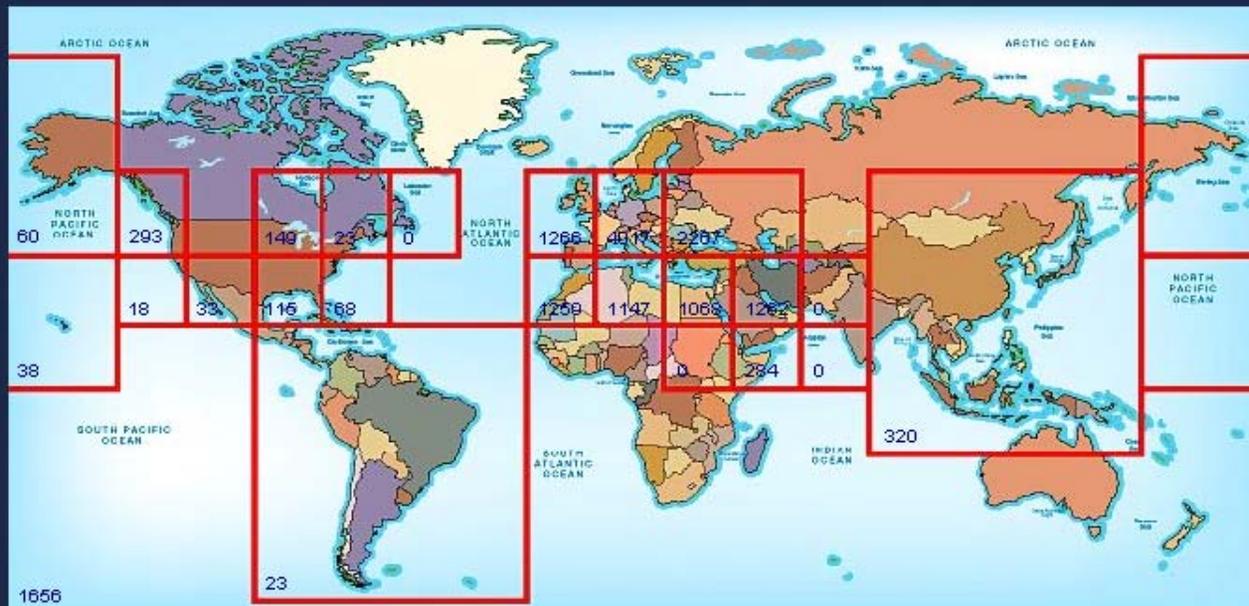
ALERTS
INFORMATION PAGE

CONTACT INFO/FEEDBACK

MDA WIKI SITE

ATMOSPHERE
PROPAGATION SERVICE

Welcome to the MDA DS COI's Google Maps Mediation Service (GMMS). This is the MDA DS COI's demonstration service hosted at SPAWAR Systems Center - San Diego. The operational version of the GMMS may be found [here](#) at our operational environment at the Defense Enterprise Computing Center - Columbus. This demonstration service is used as our pre-production environment to test new functionalities, bug fixes, etc and therefore is subject to unexpected downtimes. The map below depicts the various NCES Messaging Channels that carry the MDA data. Click on a box to view the data for that area within Google Maps:



NAVY C5F NAVY_C2F NAVY SMS NAIS MSSIS AMRS



Agent Learning in TW08



TRIDENT WARRIOR '08 Collaborative Learning Agent How do I identify something out of the ordinary?



Three agents: each represent data sources from Navy, Police and Coast Guard respectively



TW08 Results

Participant Reactions



- What did you like MOST about the tool?
 - The readily available data from open sources all in one place
 - The intuitive and intelligent nature of the tool is refreshing
- The overall accuracy for the CLA predictions is 72%, worse than human accuracy, yet CLA is much faster



Conclusions



- Demonstrated
 - Agent learning and collaboration architecture
 - Key characteristics and innovations
 - Anomaly and discovery search mechanisms
 - Agent collaborative decision making
 - Parallel computation



Future Extensions

- Extended to System Self-awareness (SSA) and Lexical Link Analysis (LLA) for future intelligence analysis
 - Make real-time
 - Provide more discovery
 - Expanded correlation
 - Provide MDA regional awareness



System Self-Awareness (SSA)

MDA Regional Awareness



- A system may be expressed in terms of “features”
 - specific vocabulary or lexicon to describe attributes
- Borrowed from notions of “awareness”
- *System Self-Awareness*
 - The collective and integrated understanding of system features
 - Like “situational awareness” this carries a sense of immediacy and cognitive understanding of the warfighting situation



Potential MDA Data

Scaled-up Open Sources



Vessel ID, Location, Images

<http://82.146.41.123/ships.htm>
<http://www.vesseltracker.com/en/VesselArchive.html>
<http://www.digital-seas.com/start.html>
<http://www.marinetraffic.com/ais/default.aspx?centerx=30¢ery=25&zoom=2&level1=140>

Piracy Reporting

<http://www.lloydslist.com/ll/media/presentation.htm>
http://www.icc-ccs.org/index.php?option=com_fabrik&view=visualization&controller=visualization.googlemap&Itemid=219
http://www.imo.org/Circulars/mainframe.asp?topic_id=334&offset=0

Port Operations

<http://www.portvision.com/Public/index.aspx>
<http://www.pier2pier.com/>

Container tracking & security

<http://www.track-trace.com/container#>
<http://www.transportsecurity.com/company.php>

Weather

<http://www.sailwx.info/shiptrack/index.html>
<http://news.bbc.co.uk/weather/>
http://earth.esa.int/ers/eeo4.10075/atrs_med.html
<http://www.mediterraneanweather.com/satimages.htm>
<http://oceancolor.gsfc.nasa.gov/>

Shipping Schedules and Lines

<https://www.oceanschedules.com/schedules/search.do>
<http://www.howdydave.com/maritime/shipping.html>

Distance Measurement tool

<http://jan.ucc.nau.edu/~cvm/latlongdist.html>

Marine Services directories

<http://www.infomarine.gr/index.php>
<http://www.madmariner.com/?gclid=CLSgsbrAg50CFvtB5godckpvbw>
<http://seann.org/Directories/introNew2.asp>
<http://www.infomarine.gr/greece/>
<http://www.best-maritime.info/index.php//en/mod/companies>
<http://www.m-i-link.com/directory/profile.asp?bz=21&id=12446&cat=Ship+Manager+%26+Owner>

Shipwreck Database and Casualty Reports



And More Potential MDA Data

Scaled-up Open Data Sources



http://www.lloydslist.com/content/rss/lloydslist/piracy_security.xml
http://www.lloydslist.com/content/rss/lloydslist/ports_terminals.xml
http://www.lloydslist.com/content/rss/lloydslist/print_edition.xml
http://www.lloydslist.com/content/rss/lloydslist/ship_management.xml
http://www.lloydslist.com/content/rss/lloydslist/shipbuilding_repair.xml
<http://www.lloydslist.com/content/rss/lloydslist/tankers.xml>
http://www.lloydslist.com/content/rss/lloydslist/towage_salvage.xml
<http://www1.apan-info.net/>
<http://www.cargobusinessnews.com/>
<http://www.cargolaw.com/>
<http://www.uscg.mil/>
<http://www.piersystem.com/>
<http://feeds.feedburner.com/CoastGuardNews>
<http://www.fairplay.co.uk/feed.aspx>
<http://www.marinelink.com/Story/>
<http://www.shipspotting.com/modules/altern8news/?>
<http://www.ifw-net.com>
<http://maritimecalamities.blogspot.com/>
<http://www.maritimematters.com/shipnews.html>
<http://www.maritimematters.com/shipnewspics.html>
<http://www.fiata.com/index.php?id=95>
<http://www.airbus.com/en/>
<http://www.asycuda.org/>
<http://www.biac.org/>
<http://www.bimco.org/>
<http://www.cen.eu/cenorm/homepage.htm>
<http://www.boeing.com/>
<http://www.ecac-ceac.org/index.php>
<http://www.clecat.org/>
<http://www.efta.int/>
<http://www.fao.org/>
<http://www.fidi.com/index.html?page=40&lang=en&>
<http://www.gfptt.org/Entities/NewsList.aspx?list=all>
<http://www.iaphworldports.org/>
<http://www.iccwbo.org/>



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DISE



Backup Slides



Lexical Link Analysis (LLA)



- Lexical Analysis (LA wiki, 2009) is a form of text mining
 - Learns
 - Word and context associations are dynamically updated with more data
- Link analysis
 - Like network analysis, explores and illustrates associations between objects
- Lexical Link Analysis (LLA)
 - Combines data mining with network analysis
 - Can dynamically identify, assess and predict trends, patterns and features
- Data mining tools
 - For structured and unstructured data
 - Confirms previously known patterns, or to discover patterns that as yet are unknown.
 - Implements innovative visualization and navigation techniques
- Facilitates concept discovery, automated classification and categorization of unstructured documents.



Abstract



- Maritime security is vital to US security. Enhanced Maritime Domain Awareness (MDA) of potential threats in this dynamic environment can be achieved, yet requires integrated analysis from numerous sources. We will present a learning agent technology that integrates structured and unstructured data and discovers behavior patterns from varied sources such as: Navy's Automatic Information Systems (AIS), Coast Guard and Police contextual information including: maritime commercial activities, weather, terrain, environmental conditions, maritime incidents, casualties, and military exercises. These discovered patterns can help cross-validate warnings and reduce false alarms in support of maritime security. We will show our test results of this technology using data from the Trident Warrior (TW08) exercise.