A System for Maritime Awareness and Decision Support for Improved Safety and Security for Maritime Operations in Artic Border Areas

NATO ARW on „Meeting Security Challenger Through Data Analytics and Decision Support“
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Outline

- Arctic challenges to security
- PASSAGES: a system architecture approach
- Sensor concept for a more comprehensive surveillance
# PASSAGES

Protection and **Advanced Surveillance System** for the **Arctic: Green, Efficient, Secure**

A Canadian-German research project

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<td>exactEarth Ltd.</td>
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Arctic challenges

- 25% of the world's oil and gas reserves may be in the Arctic
- Increased intercontinental flights over the poles
- Increased ship traffic
- Environmental monitoring for global warming
- Scientific and research activity
- Search and Rescue
Project Motivation:
Traffic Safety and Efficiency & Border Security


http://www.nationalgeographicexpeditions.com/expeditions/northwest-passage-cruise/detail


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Project Motivation:
Decrease of Ice Coverage of the Arctic Waters
Challenges of Navigable Arctic

- very large and remote surveillance area
- difficult to achieve sensor coverage of surveillance area
- Not / sparsely populated, no infrastructure
- few existing ground-based assets
- extreme climatic conditions
- hazardous conditions for maritime operations due to icebergs and floating ice sheets
- difficult to model dynamic behavior of ice & quality of ice
- difficult to predict which channels will be open at what time
- many stakeholders, conflicting interest
- Politically independent indigenous population
Northwest Passage: Arctic Marine Corridor

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Operational Scenarios


Route 1→2: $t_{1,m}$ → $t_{2,p}$

- prediction

- comparison
- decision

- anomaly
- action

E.g. ice forecast, optimal route

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Operational Scenarios

1. Surveillance of shipping lanes, bottlenecks and assets with integrated “standard”-sensor suite
2. A detected risk/anomaly is monitored with sensors of “high-risk”-sensor suite
3. Distributed communication and control network
The PASSAGES System

**PASSAGES is:**

A vessel-traffic-management System

for government agencies and

a maritime navigation-support System

for commercial & private clients

operating in Arctic waters

**PASSAGES supports:**

Protection of special areas

Surveillance of:
- transit traffic
- destination traffic
- resource development traffic
- fishing activities
- cruise and private ships

Safety and Security operations

Efficient planning, execution & resource management

**PASSAGES uses:**

Advanced data fusion:
- AIS, LRIT reports
- synthetic-aperture radar
- active coastal radar
- passive radar
- passive AIS
- optic & IR imagery
- env., nav. & ship information

Advanced risk models

Advanced anomaly detection

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Vessel Traffic Management System = Vessel Traffic Monitoring and Control System for secure and safe Maritime operations

Support System for Planning and Executing Safe and Efficient Sailing Voyages

government agencies, e.g.:
- CCG,
- TC,
- Env. Can.

commercial and private operators, e.g.:
- commercial ships,
- shipping companies,
- ship insurers,
- maritime industry,
- fishing vessels,
- private ships,
- northern communities

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PASSAGES supports: long/medium-term planning of an operation

Government agencies

- Initial op. plan
- Risk analysis

Recommendation

- Archiving, add. contextual information, in-time risk analysis

Other clients, e.g.: northern communities

- Final op. plan

Commercial/private operators

- Initial op. plan

Recommendation

- Modified/Refined op. plan

- Final op. plan

PASSAGES supports:

- Long/medium-term planning of an operation

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PASSAGES supports: execution of an operation

near-real time

 recursice update of operational plan required
Risk analysis within the PASSAGES Project

**Risk ➔ Surveillance**
- Use risk assessments to prioritize surveillance needs
- Yields guidance on spatial distribution of diverse risks
- Aligns with Canadian Coast Guard Arctic marine corridors

**Surveillance ➔ Risk**
- Use traffic monitoring system for:
  i. Planning: generate/improve risk models to develop mitigation strategies
  ii. Operations: assist with near real time risk assessment & reduction

Dr. Laurent Etienne

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Interfaces

Observations

Government Agencies

Northern Communities

Ship/ Shipping Company

Other Companies e.g. mining

PASSAGES

Services:

- contextual information
- situation picture
- warnings of abnormal ship behavior
- notification of maritime risks

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Benefits for Clients

During Planning Phase

- ensure a **systematic** and **timely planning** of activities
- follow a **pre-defined** and **automated planning procedure**
- **keep** government agencies and commercial / private operators (incl. northern communities) **involved and informed during entire planning phase**
- minimize **individual** and **overall** navigational risks
- help **coordinate** multilateral efforts and **share** resources
- **archive** operational plans and decisions for later use
- act as **single point of contact** for all involved actors
- act as **communication nexus** between government authorities and operators
Benefits for Clients

During Execution Phase

• provide clients with **maritime domain awareness**

• **continually update and disseminate** important environmental and navigational information

• support government agencies in **monitoring and controlling** vessel traffic

• **automatically detect and warn** of anomalous ship behaviour

• **in-time** and **spatio-temporal** risk analysis

• act as **communication nexus**

• **archive** suggestions and decisions for later use
Main System Functions

PASSAGES

Information & Data Acquisition
- collect sensor data & contextual information
- monitor vessel traffic

Maritime Domain Awareness
- fuse & integrate sensor data & inform.
- maintain situation picture

Analysis and Decision Support
- detect anomalies
- analyze risks

Information Archiving & Dissemination
- archive products & communications
- disseminate products & information as needed

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Building blocks for Situation Picture:

- Which objects are there?
- How many?
- Where and when?
- How do they behave?
- What are their properties?
- Do they interact?
- Who exactly? (ID)
- What are their intentions?
- …

Sensor data
- Remote sensing
- Medium range
- Short range
- Persistent
- On demand
- Cooperative
- Active/passive sensing

Context information
- Geography
- Weather and Ice
- Sea lanes
- Ship schedules
- …

Sensor and Information Fusion

detect anomalies
analyze risks

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Backbone: Satellite AIS

Commercially available (e.g. exactEarth)
Required for:
• All ships >300 tons gross on international voyages
• Cargo ships >500 tons on any route
• Passenger ships of any size built after 2002

Weaknesses
• Not required for small ships
• Provide position reports, not tracks
• Possible false reports, spoofing, or switched off
• Limitations due to spacecraft availability
  – Temporal and spatial gaps

Cumulative AIS position reports, August 2013
Generated Tracks August 2013
Space Borne Imaging Sensors (active / passive)

Commercially available

Sensors
- Still and Motion Imagery
- Optical, Infrared, Multi-spectral, Polarimetric
- Synthetic Aperture Radar (SAR)

Output
- Images (multi-spectral)
- Potentially elevation
- Object detection and classification
- Change detection
- Possibly tracks

Weaknesses
- Weather dependent (EO, IR)
- Limited resolution
- Limitations due to spacecraft availability

Small-medium range sensors: gap filling

Contributions to situation awareness close to ports and choke points
- Traffic monitoring
- Harbor / environmental protection

Ports, protected areas and accidents

Choke points according to Dr. J. Luc Forand, Northern Watch Lead Scientist. © Defence Research & Development Canada
Medium Range Sensors and Platforms

- **Surveillance radar**
  - Air surveillance radar (primary, secondary)
  - Coastal radar

  **Weaknesses**
  - Not (yet) available/installed

- **Airborne sensors**
  - Platforms:
    - Patrol aircraft
    - UAS (MALE)
    - Airship / balloon

  **Sensors:**
  - Electrooptics (EO)
  - Infrared (IR)
  - SAR
  - EM direction finding antenna

  **Weaknesses**
  - Not persistent
  - Limited availability

  **Examples:**
  - Dash-8 surveillance aircraft, Transport Canada
  - Saab 340 MSA: EO, IR, SAR, AIS
  - Qinetiq Zephyr HAP
    - Up to 14 days endurance
  - IAI Heron 1
  - Example: aircraft detection from aerial SAR
Short Range Sensors and Platforms
perimeter control, choke point surveillance

- **SONAR**
  - Fixed Sonar arrays
  - Rapidly Deployable Sonar (RDS)
  - AUV missions

**Output:**
- Object detection
- Bearings
- Localization
- Classification

**Weaknesses**
Maintainability and communication requirements

- **Fixed or Airborne Sensor Nodes**
  - EO + ...

**Weaknesses**
- Need local infrastructure
- Weather dependence of sensors and platforms
- Airborne: small endurance

Digital Hydrophone array LDHA-2279 (Omnitech Electronics Inc.)

Schiebel Camcopter S-100 VTOL

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Proposal: Passive Radar

Sensor principle
Multistatic radar using non-cooperative illuminators,
e.g. GSM, UMTS, LTE, DAB, FM, HF, VHF

Output
• Object detection
• Tracks
• Short-medium range surveillance

Platforms
• Antenna arrays installed on hill, tower, lifting platform
• Potentially aircraft, UAS, airship

Weaknesses
Availability of broadcasting stations
Sensor Data Fusion

Goal: Extraction of Situation Picture Building Blocks

Tasks:

Data alignment
- Common coordinate system
- Time synchronization (out-of-sequence data)

Centralized fusion
- Align, correlate, and fuse sensor data
- Theoretically optimal use of (heterogeneous) sensor data
- Requires high communication bandwidth
- More susceptible to false data, misalignments, etc.

Decentralized fusion
- Tracking of data from each sensor
- Correlate tracks: which tracks describe the same object?
- Aggregate tracks: combine heterogeneous information, e.g. position and ID
- Fuse tracks: improve estimates, bridge gaps, etc.

Integration and Fusion with background information
- Ice situation, weather
- Coastlines, bathymetry
- Arctic marine corridors, sea lanes, shipping schedules
PASSAGES: support operations in the arctic

High-Risk Sensor Suite
- airborne surveillance
- surveillance radar
- ship borne surveillance

Standard Sensor Suite
- satellite data
- sonar array

bottleneck
bottleneck with sonar array

CCG-operational center


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