Increasing Selectivity and Sensitivity in Ion Mobility Spectrometry using Ion Beam Modulation

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Chem/ Bio/ Explosive Detection

FACILITIES

• Unique 25,000 Sq. Ft. Chemical/Biological Detection Center
• Physical Plant Replacement Value of $4.0M
• Specialized Chemical/Biological Detection Equipment with Replacement Value of $5.0M
  • Thermal Collimators
  • Chemical Vapor Diagnostic Test Sets
  • Chemical Vapor Generators
  • Chemical Hazard Containment Room

CAPABILITIES

• Develop & Review Specifications
• Develop Procurement Technical Data Packages
• Contract for Products, Components or Services
• Acceptance Test New Systems
• Repair Chemical Detection Devices
• Provide On-Site Fleet Support and Training
• Initiate & Implement Engineering Change Proposals
• Provide Sustainment Logistics Support for New & Existing Systems
• Perform Failure Analysis
• Hold Navy Radioactive Material Handling Permit

PERSONNEL

• Highly Technical Workforce of 51 Professionals with Extensive Chemical/Biological/Explosive Detection Experience
• Skills Mix of Thermal Imagers, and IMS Expertise
• 19 Engineers and Scientists
• 32 Skilled Technicians/Logisticians/Equipment Specialists
Code 805D Customers

• Navy
  • Naval Sea Systems Command
  • Naval Special Warfare Command
  • Navy Inventory Control Point, Mechanicsburg
  • Navy Explosive Ordnance Disposal Units
  • Navy Construction Battalions
  • Office of Naval Research

• Other
  • Defense Threat Reduction Agency
  • Soldier, Biological, Chemical Command
  • Joint Program Office – Biological Defense
Code 805D Tasking

- Acquisition Engineering Support
- Production Acceptance Testing
- Installation & Fielding Support
- In-Service Engineering Support
  - Product Improvement Programs
  - Configuration Management - Hardware and Software
  - Intensified Leak Test Tracking for Radioactive Sources
- Depot Maintenance and Repair
- Support New Construction Ships
- Product Integration (System Design and Integration)
IMS in the Field

- Automatic Chemical Agent Detection Alarm (ACADA)
- Improved Chemical Agent Monitor (ICAM)
- Improved Point Detection Sys. (IPDS)
- Shipboard ACADA
- VaporTracer II (Explosives)
Ion Mobility Spectrometry: System Block Diagram

Inlet System  

Ion Source  

Drift Tube  

Detector  

Atmosphere  

Sample  

Radioactive Source  

Ions  

IMS Drift Tube  

Accelerating Electric Field  

Counter current buffer gas  

BN Gate Driver  

Signal Processor  

Readout Device
Field Portable IMS System

Drift Flow

Sample Inlet

Acetone Flow

Collector

Gating Grid

Am241

Exhaust
Typical IMS Signature: Positive Cell

DPM from Confidence Tube
IMS Response at Low Concentration

0.027 mg/m³
BNG Driver Timing

Time-of-flight
~1% Duty Cycle

Ion Beam Modulation
50% Duty Cycle
Wavelet Decomposition

Background
Wavelet Decomposition

DPM
Time-of-flight Measurement

- Background
- 1-propanol
Wavelet Decomposition

Background 1 - propanol
Neural Networks

Adaptive Learning Rule:

\[ W_{\text{new}} = W_{\text{old}} + (t - a) \cdot X^T \]

- Benefit of Multi-layered NN: They can approximate any function
- Difficulty: Updating weights in the hidden layers
- Solution: Back-propagation of error
  - Gradient Descent:
    \[ \Delta W = -\eta \frac{\partial E}{\partial W} \]
    \[ E = \frac{1}{2} \sum_i (t_i - a_i)^2 \]

\[ a_i = f \left( x_1 w_1 + x_2 w_2 + \Lambda + x_n w_n \right) = f \left( \sum_{i=1}^{n} x_i w_i \right) = f \left( W' T \right) \]
Results

- Collected data sets using ion beam modulation
  - Background
  - DPM
  - 1-propanol
- Performed Wavelet Decomposition
- Used 5 new statistical evaluators
- Trained 5-node Neural Network (Feed forward)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Results</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>3/3</td>
<td>100%</td>
</tr>
<tr>
<td>DPM</td>
<td>5/5</td>
<td>100%</td>
</tr>
<tr>
<td>Propanol</td>
<td>3/3</td>
<td>100%</td>
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Conclusions and Future Work

- Wavelets can help improve S/N
- Wavelets can be used to decompose signal for further analysis
- Ion beam modulation improves selectivity and sensitivity
- Neural networks can be used to detect modulated ion beam data

- Investigate modulation schemes
- Determine algorithm robustness
- Decrease IBM scan time
- Decrease IBM data acquisition rate
- Expand training sets
- Look at other metrics (cell temperature, humidity)
Acknowledgements

Funding:
Integrated Detection of Hazardous Materials (IDHM) Program, a Department of Defense project managed jointly by Center for Sensing Science and Technology, Purdue University, and Naval Surface Warfare Center, Crane, Indiana.

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