Dynamic Data-Driven Application System (DDDAS) for Multimedia Content Analysis

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Sponsor  
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OUTLINE

• DDDAS Overview for **Cooperative Sensing**
  • DDDAS for MultiModal/MultiScale multi-sensor Fusion
  • DDDAS contributions to command and control sensing

• **DDDAS Focus** – **Context Enhanced Information Fusion**
  • Using Data to Drive the Situation Understanding
  • Multimedia Modeling and Data for Situation Awareness

• **DDDAS Application: Threat Analysis**
  • Modeling the uncertainty (large parameter space)
  • Leverage **data flow in statistical analysis**

• **Example: DDDAS Implementation**
  • Comparison of measurement sampling for activity analysis

• **Summary: DDDAS support to data analytics**
DDDAS Research Areas

- Multi-INT Analysis
  - Multi-Modal
  - Multi-Scale
  - Graphical Fusion

- Cooperative Sensing
  - Video-Text Fusion
  - Cyber Trust Info
  - Cloud Applications

Systems Level DDDAS for advanced Information Fusion
• **DDDAS: Feedback Updates**
  - Feedback could be real/live sensed data or simulated data (beyond next state prediction)
• **DDDAS**: Feedback update loops

- **High Dimension ≠ High Accuracy**
  - Need the correct mix between physical modeling and sensor/data collections

- **High value ≠ High Fidelity**
  - Get the right mix of sensors and features in modeling
### DDDAS Applications

**DDDAS: Review**

<table>
<thead>
<tr>
<th>Model</th>
<th>Measurement</th>
<th>Application</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Monitoring</td>
<td>Aircraft</td>
<td>Piezo-electric wing</td>
<td>UAV Flights</td>
</tr>
<tr>
<td>Tracking</td>
<td>Kinematic</td>
<td>Radar</td>
<td>Surveillance</td>
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<tr>
<td>Classification</td>
<td>Shape</td>
<td>Visual</td>
<td>Detection</td>
</tr>
<tr>
<td>Architecture</td>
<td>Software</td>
<td>Networked Sensors</td>
<td>Dataflow</td>
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<tr>
<td>Cyber-Physical</td>
<td>Patterns</td>
<td>Cyber Attacks</td>
<td>Security</td>
</tr>
<tr>
<td>Environment</td>
<td>Natural</td>
<td>Energy</td>
<td>Power, Wind</td>
</tr>
</tbody>
</table>
Context-Enhanced Information Fusion: Boosting Real-World Performance with Domain Knowledge

Editors: Snidaro, L., García, J., Llinas, J., Blasch, E. (Eds.)

May 2016

DDDAS Approaches

Ch04 - Contextual Tracking Approaches in Information Fusion
Ch05 - Context Assumptions for Threat Assessment Systems
Ch15 - Algorithms for Context Learning and Information Representation for Multi-Sensor Teams
Ch18 - Context-Based Fusion of Physical and Human Data for Level 5 Information Fusion
Ch19 - Context Understanding from Query-Based Streaming Video
Ch21 - Entity Association Using Context for Wide Area Motion Imagery Target Tracking
Modeling - Context-Based Fusion

**COGNITIVE DOMAIN**
(Level 5-6 Fusion)

- Situation Understanding
- Sensemaking
- Judgment
- Decision (COAs)

**INFORMATION DOMAIN**
(Level 2-4 Fusion)

- Information (context)
- Data (representation)

**PHYSICAL DOMAIN**
(Level 0-1 Fusion)

- Objects/Events

**Processes**

- Decision Support Models and Tools
- Enterprise Processes (Data flow models)
- FUSION Processes (Sensor models)
- Sensor Management Synchronization

**Shared Awareness**
Temporal, Spatial Uncertainty

**Key Actions**

- OBSERVE
- ORIENT
- DECIDE
- ACT

Blasch/Aved, Bhattacharyya, DDDAS 2016
Measurements: Multimedia (Context) Data

- **Context Data**
  - (unstructured)
  - (structured)

<table>
<thead>
<tr>
<th>Data Dimensionality</th>
<th>Example of Data</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Characters, text</td>
<td>Discrete</td>
</tr>
<tr>
<td>1</td>
<td>Audio, output from sensor</td>
<td>Continuous</td>
</tr>
<tr>
<td>2</td>
<td>Image, Graphics</td>
<td>Discrete</td>
</tr>
<tr>
<td>3</td>
<td>Video, Animations</td>
<td>Continuous</td>
</tr>
</tbody>
</table>

- **Context Features**
  - (similarity mapping)
  - (statistical)
  - (multimodal)
  - (time, space)

- **Context Sensors**
  - scene
  - exploitation
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- Summary: DDDAS support to data analytics
• Goal – to replicate the ability developed in nature to accomplish a wide variety of tasks
  • some without additional measurements (thus using exformation) or computations – manipulation of perceptions evoked by the measurements (this is how we define conscious reasoning)
• Manipulation of perceptions (conscious reasoning)
  • General purpose ability of nature to recognize patterns
• Unexpected query – deliberating with perceptions to provide a representation that facilitates abstraction
• Computing with qualia (conscious reasoning)
• Inference – sensor and information fusion

QUEST

QUalia Exploitation of Sensing Technology

Computation for Situational Consciousness
QUEST TENETS

• Structurally Coherent
  – Exformation is the reduction of uncertainty resulting from the process of ‘thinking’
  – the manipulation of the qualia results in setting values for qualia without additional sensation – that is exformation (imagine thoughts)

• Situated Conceptualization
  • Information
    – (i) perceptions of relevant people and objects,
    – (ii) actions, (iii) introspections, and (iv) settings

• Simulated Experience
  • Inference via pattern completion (narrative)
  • Experience of being there
  • Derive meaning (conclusion on sensation)

QUALIA TENETS
1) Stable (cohesive)
2) Situated (context)
3) Simulated (imagined)

Computation for Situational Consciousness
Context-Driven Threat Assessment

- DDDAS requires **contextual modeling** to address common to relate perceived data to knowledge of reality
DDDAS Application: Threat Analysis

 Threat Assumptions

Assumptions:
1. Problems Statement is precise (L5 Fusion)
2. Data can be acquired (L0 Fusion)
3. Data/Evidence can be integrated (L1 Fusion)
4. Decisions are reproducible (L2/3 Fusion)
5. Decisions are actionable (L4 Fusion)
6. Error quantified (All levels of fusion)
• DDDAS requires contextual modeling to address common assumptions (A) to relate perceived data to known reality.
DDDAS Threat Analysis

• (Assumption 1 – Problem specific). Situation awareness is needed to determine the importance of the information for societal safety.

• (Assumption 2 – Data acquireable). The notional application system collects raw measurements on the data situation, such as Boston Bomber activities as an attack.

• (Assumption 3 - use of context data). With a prior knowledge, data exploitation can be used to determine the situation.

• (Assumption 4 – reproducible) The collection and processing should be consistent for decision making over the data acquisition timeline.

• (Assumption 5 – actionable). Increase the timeliness of the machine fusion result for human decision making.

• (Assumption 6 – quantifiable). In the example, we assume that policies of threat analysis are accepted and that the trust assessment of must determine whether the dynamic data is trustworthy, threatening, or under attack.
Math (Physics) Models

**Empirical**

\[ f = ma \]

- Car

**Analytical**

\[ f = m \left( \frac{dv}{dt} \right) + \frac{dm}{dt} (a) \]

- Rocket

**Emergent**

- Person

**Ad Hoc**

- Person

**Car**

Threat Reduction through modeling

- Target modeling
- Kinematic (Behavior) Modeling

Blasch/Aved/, Bhattacharyya, DDDAS 2016
Object (Sensor/target) Models

Physics-based Hybrid Algorithms
Problem Focused

Innovative Algorithms

Development

Data Models

Simulation & Modeling

User Applications Characterization Performance Theory

V&V

Demonstration & Experimentation

13 m
Data (Software) Models

Stack

Array

Linked List

Hash Table

Push

Pop

Keys

Indexes

Key Value Pairs
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Query-based analysis

- Live Video Based Querying: Architecture
Computational representation of query:

- Intelligence
  (Situational Analysis)
- Knowledge
  (includes temporal correlations)
- Information
  (structured)
- Data
  (unstructured)

Result

Textual representation of query:

Action 'Count v90 05 50' on count(appear(v90.*,50))

Operands:
- $O_{a_1}$
- $O_{p_1}$
- $O_{p_2}$

Knowledge

Resultlogfile = 'app_50_05.txt';

Period '0:0:0.5'

Query relations

Blasch/Aved/, Bhattacharyya, DDDAS 2016
Results: w/ Data Flow

Case 1: Intersection with road traffic, mostly vehicle maneuvers

Intersection Activity Recognition for different sampling rates for a fixed object size.

(Sampling improves accuracy)

Patch (sensor) to object (target) size

CNN

SD: Baseline method
PS+number: Deep models
GT: Ground truth
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