The URREF Ontology for Semantic Wide Area Motion Imagery Exploitation

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“…The commander is compelled ... to reach decisions on the basis of situations that cannot be predicted ... The problem is to grasp, in innumerable special cases, the actual situation which is covered by the mist of uncertainty, to appraise the facts correctly and to guess the unknown elements, to reach a decision quickly and then to carry it out forcefully and relentlessly.”

Helmuth von Moltke, 1800-1891

Types of Uncertainty

• Uncertainty about matters of fact [clarity test*]
  ‣ Intrinsically stochastic
  ‣ Exhibiting reliable long-run frequencies
  ‣ Unique events – past unknown / future

• Evidence regarding matters of fact
  ‣ Sensors with well-defined false positive & false negative rates
  ‣ Direct “soft” evidence (e.g., HUMINT, free text)
  ‣ Indirect evidence [reports on related events]

• Ambiguity / vagueness [no clarity test*]

* A proposition satisfies the clarity test if a clairvoyant with all knowledge of past, present and future facts could unambiguously ascertain its truth-value
Semantically Rich Uncertainty Representation

• A *relational representation* encodes knowledge about domain semantics:
  ‣ Entities of different types
  ‣ Attributes of entities
  ‣ Relationships among entities
  ‣ Behaviors of entities

A relational representation can recognize
• *Jamal is a member of the Taliban*
• *Abdul is a member of Al Quaeda*

and can reason about the inner structure of hypotheses such as these

• In a *relational uncertainty representation* we may have:
  ‣ Attribute value uncertainty
  ‣ Type uncertainty
  ‣ Existence uncertainty
  ‣ Reference [slot-filling] uncertainty
  ‣ Relationship uncertainty

A *relational uncertainty representation* can express knowledge about uncertainty at the class level for use in reasoning at the instance level

• Languages and algorithms for relational representations with uncertainty are under active development
Evaluating URR* Frameworks

- Objective: evaluate contribution of URR* methods to fusion results
  - Not the same as evaluating system performance!

- “Gold standard” experiment:
  - Apply systems differing only in URR method to set of benchmark problems
    - With URR method A / Without URR method A
    - With URR method A / With URR method B
  - Compare results on key metrics
    - Accuracy / Computational resources / Timeliness / etc.

- How well can we approximate gold standard?

* URR = uncertainty representation and reasoning
Evaluation Metrics

- Performance on benchmark problems
  - False positive / false negative / ROC AUC / scoring rules
  - SME judgment [blind!]

- Computational performance / scalability

- Range of problems addressed

- Model specification difficulty
  - KE burden / data requirements / input requirements

- Maintainability

- Interoperability

- Explanation of results
Precision and Significance in the Real World

A 1500 kg mass is approaching your head at 45.3 m/s

Precision

Significance

LOOK OUT!!
ETURWG

• **Evaluation of Technologies for Uncertainty Reasoning Working Group**

• Official working group of the International Society for Information Fusion (ISIF)

• Forum to evaluate techniques for assessing, managing, and reducing uncertainty
  ▸ Establish features required for uncertainty representation to support exchange of information;
  ▸ Develop use cases requiring reasoning and inference under uncertainty; and
  ▸ Define evaluation criteria to support comparison of approaches.
Evaluation Framework Scope

Evaluation Framework

Input
- Relevance to problem
- Weight of evidence
- Credibility

System Processes

Uncertainty Reasoning
- Computational cost
- Performance
- Consistency
- Correctness
- Scalability

Uncertainty Representation
- Evidence handling
- Knowledge handling

Output
- Interpretation
- Quality
- Traceability

Information Fusion Process

World being sensed

World being reported
In other established research communities, evaluation of new algorithms on benchmark data sets is the norm

- Standard benchmark data sets embraced by community
- Standard evaluation metrics

Example benchmark archives:

- Machine learning: UCI machine learning data repository
- Computer vision: Pilot European Image Processing Archive benchmark data sets
ETURWG Approach*

- Determine URR requirements
- Develop set of use cases that covers requirements
  ‣ Each use case has evaluation plan and is linked to data set(s)
- Develop criteria to evaluate how well URR method addresses requirements pertaining to use case
- Conduct evaluation of major approaches
  ‣ Typically will consist of applying URR method to use case

* See http://eturwg.c4i.gmu.edu/?q=approach

ETURWG = Evaluation of Techniques for Uncertainty Representation Working Group
ETURWG Use Cases

- Ship Locating and Tracking
- Situation Assessment
- Vehicle-Borne IED
- Image Fusion and Tracking
- Vehicle Identification
- Asymmetric Threat Detection
Example: Image Tracking and Fusion
Evaluation Criteria

Criteria class of URREF Ontology
Use Case: Image Tracking and Fusion

Completeness
(Area requested)
(Day-Night)

Accuracy
(CEP)

Precision
(point requested)

Credibility

EO UAV

Wide-Area Motion Imagery

MWIR UAV

Building-mounted EO

Specificity
Challenges / Way Ahead

• Key challenge: establish a culture of evaluation
• Enablers:
  ‣ Use cases
  ‣ Benchmark data sets
  ‣ Commonly accepted evaluation criteria
  ‣ Demand from funders to perform rigorous evaluation
Thank You!