Structured ISR Fusion

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Problem

Fusing Sensor Data and Non-Numerical Evidence

- Many ISR tasks require fusion of data collected from multiple sensors and/or multiple platforms over extended periods of time with non-sensor evidence
- Existing "classical" data fusion methods have limited ability to:
  - Combine sensor data and vague and/or ambiguous non-exhaustive information

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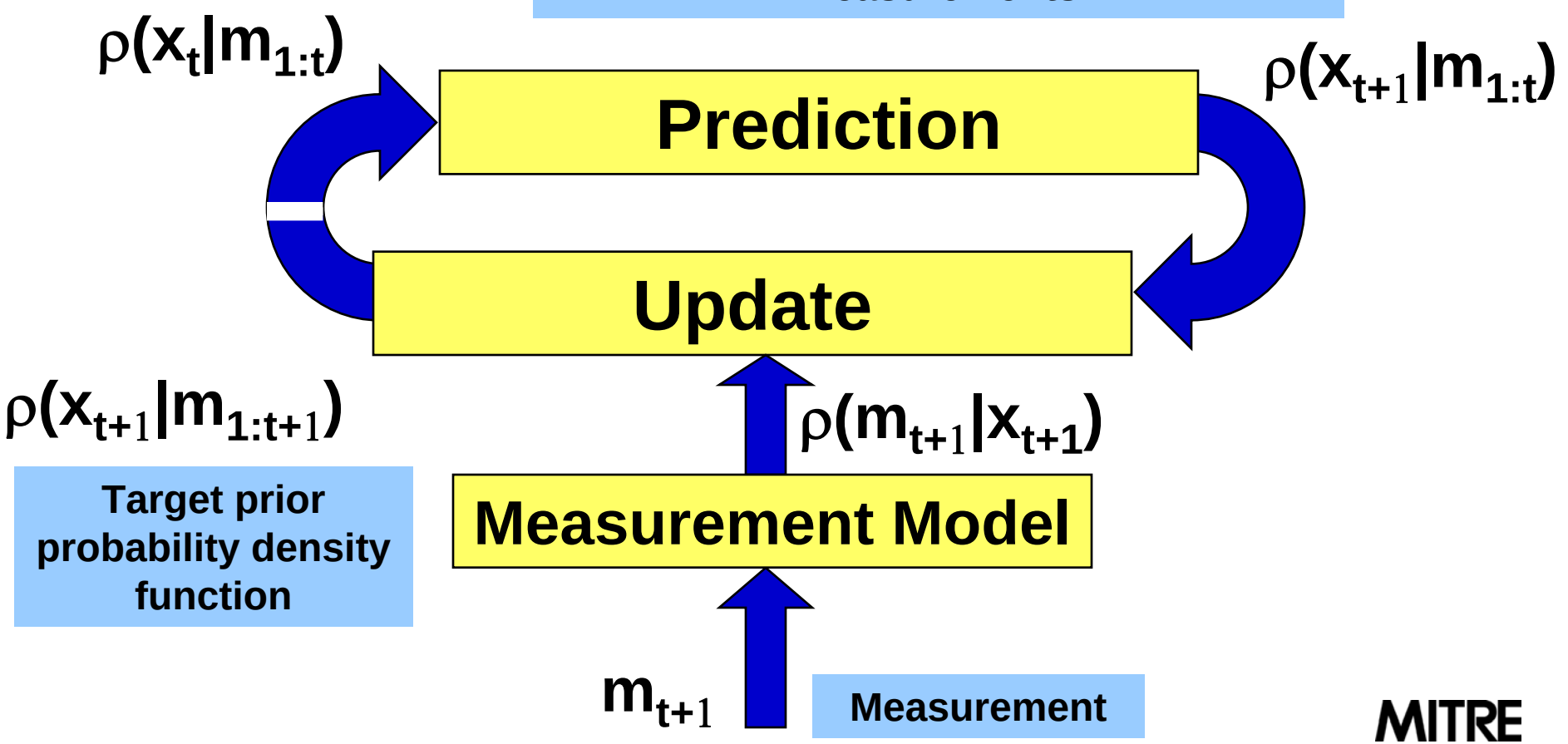
Background: Single-Entity Unambiguous-Measurement Data Fusion (Bayesian Filtering)

"Output" information & knowledge derived from posterior probability density

Prediction of posterior density evolution (i.e., spatial-temporal target change in tracking applications) "between" measurements



Target prior probability density function

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Objective

Develop a Method to Fuse Vague and Ambiguous Data in JDL 2 Applications

- Attain high-level situational awareness about the activities/ purpose/ status of a site based on
  - Quantitative data collected from sensors
  - Qualitative data from eye witnesses or expert analysis of data that is difficult to quantify
    - This is a cooling tower with a steam plume
- High-level situational awareness requires sorting through volumes of disparate data or observations from many different sources and combining it in a systematic and meaningful manner
- In cases where data volume is too great for human analysis, computer assistance would be invaluable

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Activities

JDL 2 Data Fusion Test Case

- Determine the status, job title, or primary educational background, etc., of a MITRE employee (AC#) based on contents and properties of his/her office as observed
  - A person's status is obviously a situation
- Observations will be reported by eyewitnesses who see a brief video clip of the room and are then asked to recall details
- Data provided by eyewitnesses will be
  - quantitative (number of chairs observed)
  - qualitative (messy/tidy)

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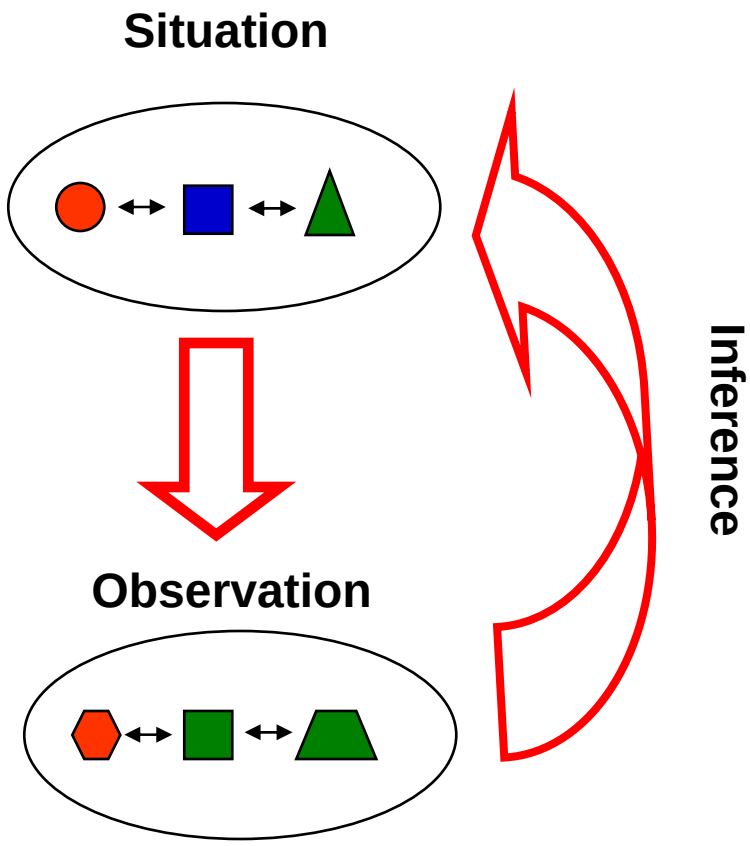
Highlight: Random Set Approach to JDL 2 Fusion

- A situation is a collection of objects and relations between these objects.
- Classification of the situation is based on determining the probability of certain objects or relations appearing in the situation
  - i.e., a situation is an occurrence of a random set. The class influences the probability of the set.
- Observations are a recollection of the objects and relations.
  - They are also random sets.



The structure of observations and objects with relations supports structuring data through ontological methods and analyzing with BN

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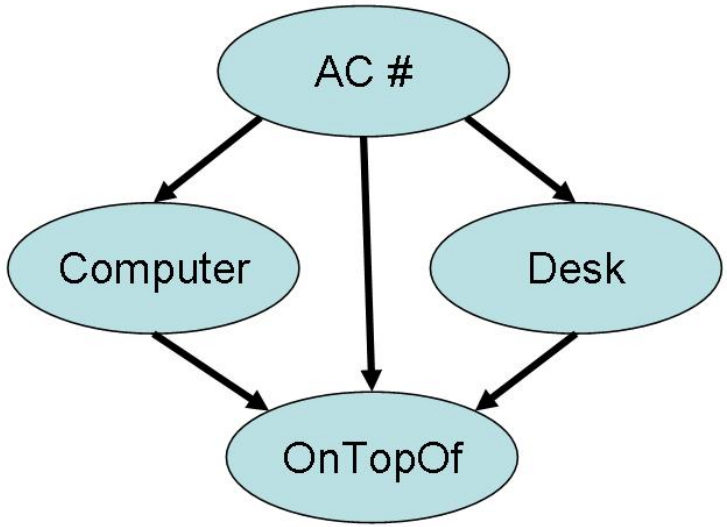
Highlight: Bayesian Network Implementation of Fusion Process



- We choose a BN graphical model of a situation
  - rigorous mathematical basis
  - mature technology especially in classification
- BN naturally assume exhaustive enumeration of data, which does not directly address uncertainties expressed in nature language statements
  - RST can bridge the gap between BN's enumeration and natural language
- May desire to construct BN components from an ontology (not in scope of research)
- Fuzzy logic, Dempster-Shafer, ontological data mining, relational graphs suffer from one or more of the following
  - Non-rigorous mapping to reality, (but theory may be mathematically self-consistent)
  - Make many assumptions that are hard to track and often invalid
  - Mix evidence with reality

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Impact

- **The ability to fuse sensor data with HUMINT reports that contain vague and ambiguous statements will solve many situational awareness problems that are currently beyond the scope of existing data fusion methods.**

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Future Plans

- Collect additional image data and complete image data base
- Develop forms for interviewing eyewitnesses that allows them to quantify ambiguity and vagueness
- Implement interviews on AC# task through a Web server system
- Construct and add interview data to evidence data base
- Develop rigorous Bayesian methods of reasoning with imprecise data
- Augment a Bayesian network software package with the methods of addressing imprecise data
- Find and process data from an application relevant to DoD sponsors

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