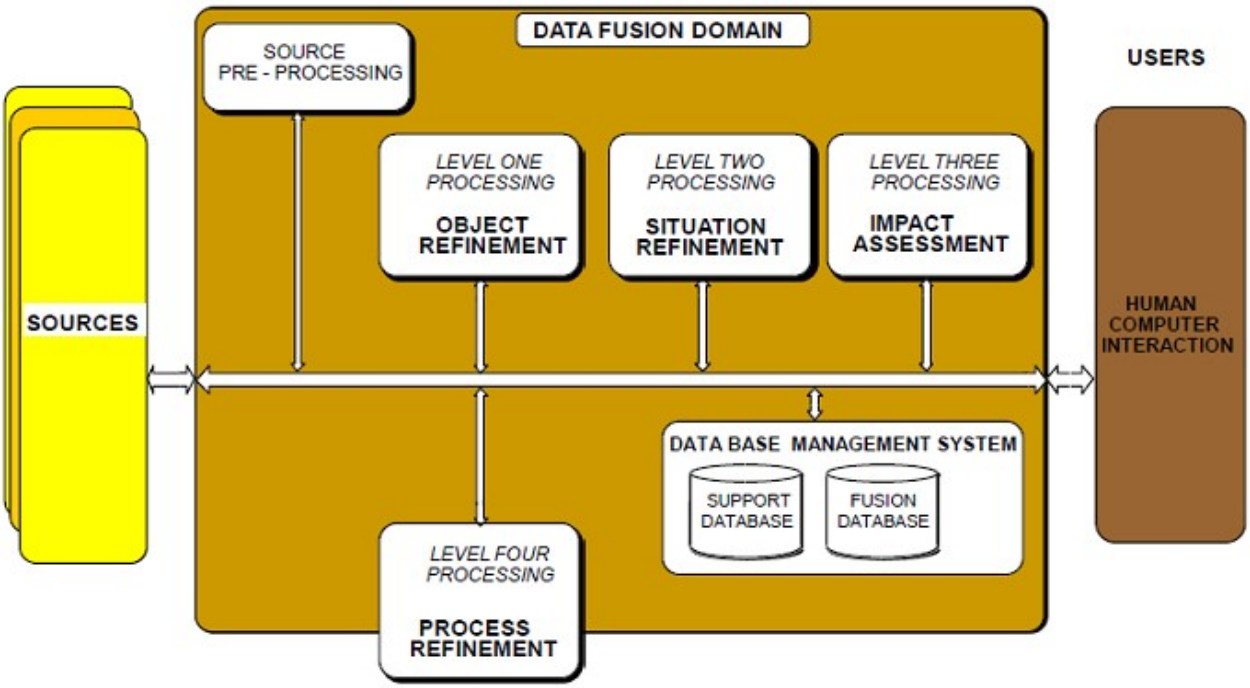
Sensor Fusion

Basic Definitions:

- ***Data*** **is a set of discrete, objective facts-often about events.**
- ***Information*** **is a message-it's intended to inform someone about something. Information is built from data through a value-adding transformation. This may be, for example, categorizing or placing in context.**
- ***Knowledge*** **is a fluid mix of frame experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It is built from information through a value-adding transformation. This may be, for example, comparison with other situations, consideration of consequences and connections.**

- ***Data Fusion*** **is a process of combining information to estimate or predict the state of some aspect of a process or system.**

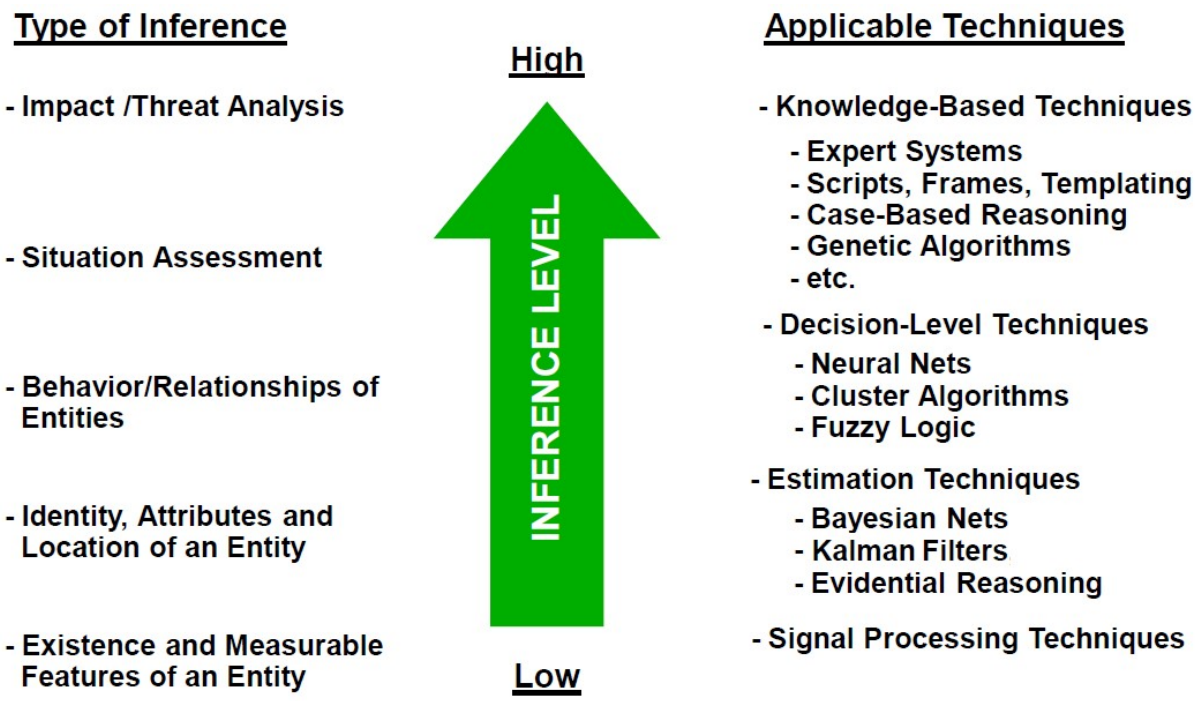
Sensor Fusion = Data Fusion from Multiple Sensors (same or different sensor types)



Data Fusion Level Descriptions

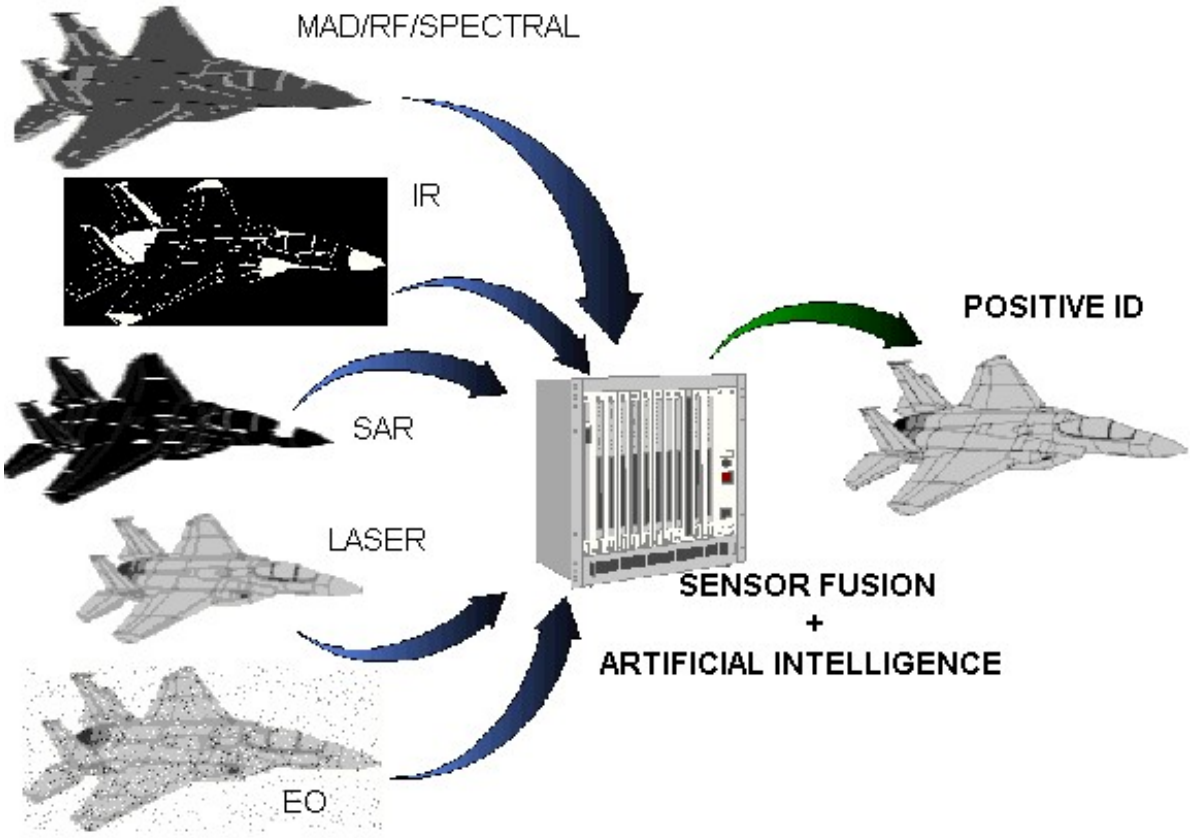
OBJECT REFINEMENT (Level 1)	Level 1 processing combines locational, parametric, and identity information to achieve representatives of individual objects. Four key functions are: • transform data to a consistent reference frame and units; • estimate or predict object position, kinematics, or attributes; • assign data to objects to permit statistical estimation; and • refine estimates of the objects identity or classification.
SITUATION REFINEMENT (Level 2)	Level 2 processing attempts to develop a contextual description of the relationship between objects and observed events. This processing determines the meaning of a collection of entities and incorporates environmental information, *a priori* knowledge, and observations.
IMPACT ASSESSMENT (Level 3)	Level three processing performs the task of projection of the current situation to perform event prediction, threat intent estimation, own force vulnerability, and consequence analysis. Routinely used as the basis for actionable information
PROCESS REFINEMENT (Level 4)	Level 4 processing is a *meta-process*, i.e., a process concerned about other processes. The three key Level 4 functions are: • monitor the real-time and long-term data fusion performance; • identify information required to improve the multi-level data fusion product; and • allocate and direct sensor and sources to achieve mission goals.
DATABASE MANAGEMENT SYSTEM	Database management is the most extensive ancillary function required to support data fusion due to the variety and amount of managed data, as well as the need for data retrieval, storage, archiving, compression, relational queries, and data protection.
HUMAN-COMPUTER INTERACTION	In addition to providing a mechanism for human input and communication of data fusion results to operators and users, the human-computer interfaction (HCI) includes methods of directing human attention as well as augmenting cognition, e.g., overcoming the human difficulty in processing negative information.

Hierarchy of Inference Techniques



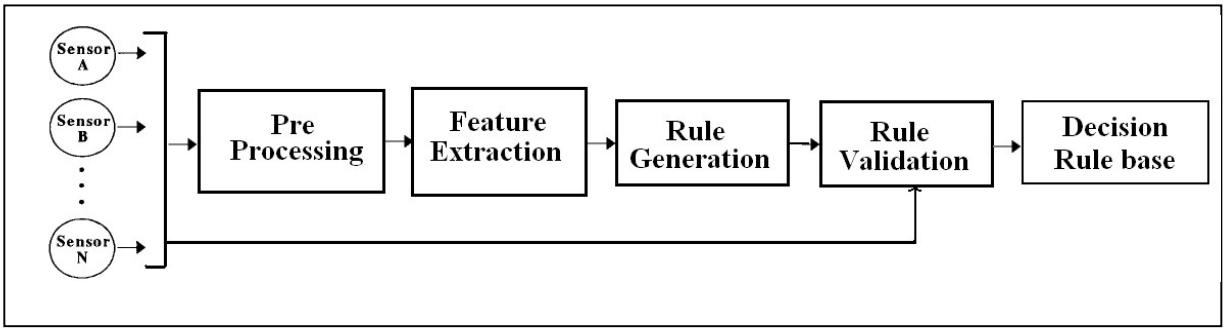
Applications	Purpose	Observable Data	Surveillance Volume
Condition-Based Maintenance	• Detection, characterization of system faults • Recommendations for maintenance corrective actions	• EM signal • Acoustic signals • Magnetic • Temperature • X-rays • Vibration	• Microscopic inspection to hundreds of feet
Robotics	• Location, identification of obstacles, and objects to be manipulated	• TV • Acoustic signals • EM signals • X-rays	• Microscopic to tens of feet about the robot
Medical Diagnostics	• Location, identification of tumors, abnormalities, and disease	• X-rays • NMR • Temperature • IR • Visual inspection • Chemical/biological data	• Human body volume
Environmental Monitoring	• Identification, location of natural phenomena (earthquakes, weather)	• SAR • Seismic • EM radiation • Core samples • Chemical/biological data	• Hundreds of miles • Miles (site monitoring)

Example:

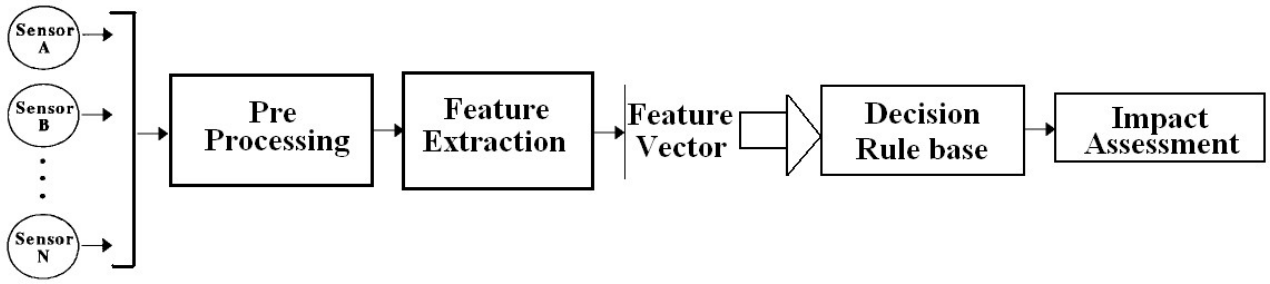

MAD/RF/SPECTRAL
IR
SAR
LASER
EO
POSITIVE ID
SENSOR FUSION
+
ARTIFICIAL INTELLIGENCE

Sensor Fusion Process Model

a)Rule Generation Phase



b)Operating Phase



- Fusion is an Estimation Process (not Control)
- There is no substitute for a good sensor
- The fused answer may be worse than the best sensor
- There is NO Golden Algorithm
- There will never be enough training data
- It is difficult to quantify the value of data fusion
- Fusion is not a static process

References:

Handbook of Multisensor Data Fusion, ed. David L. Hall & James Llinas, CRC Press, 2001

Handbook of Multisensor Fusion: Theory and Practice - Second Edition, ed. Martin Liggins, David L. Hall, James Llinas, CRC Press, 2009