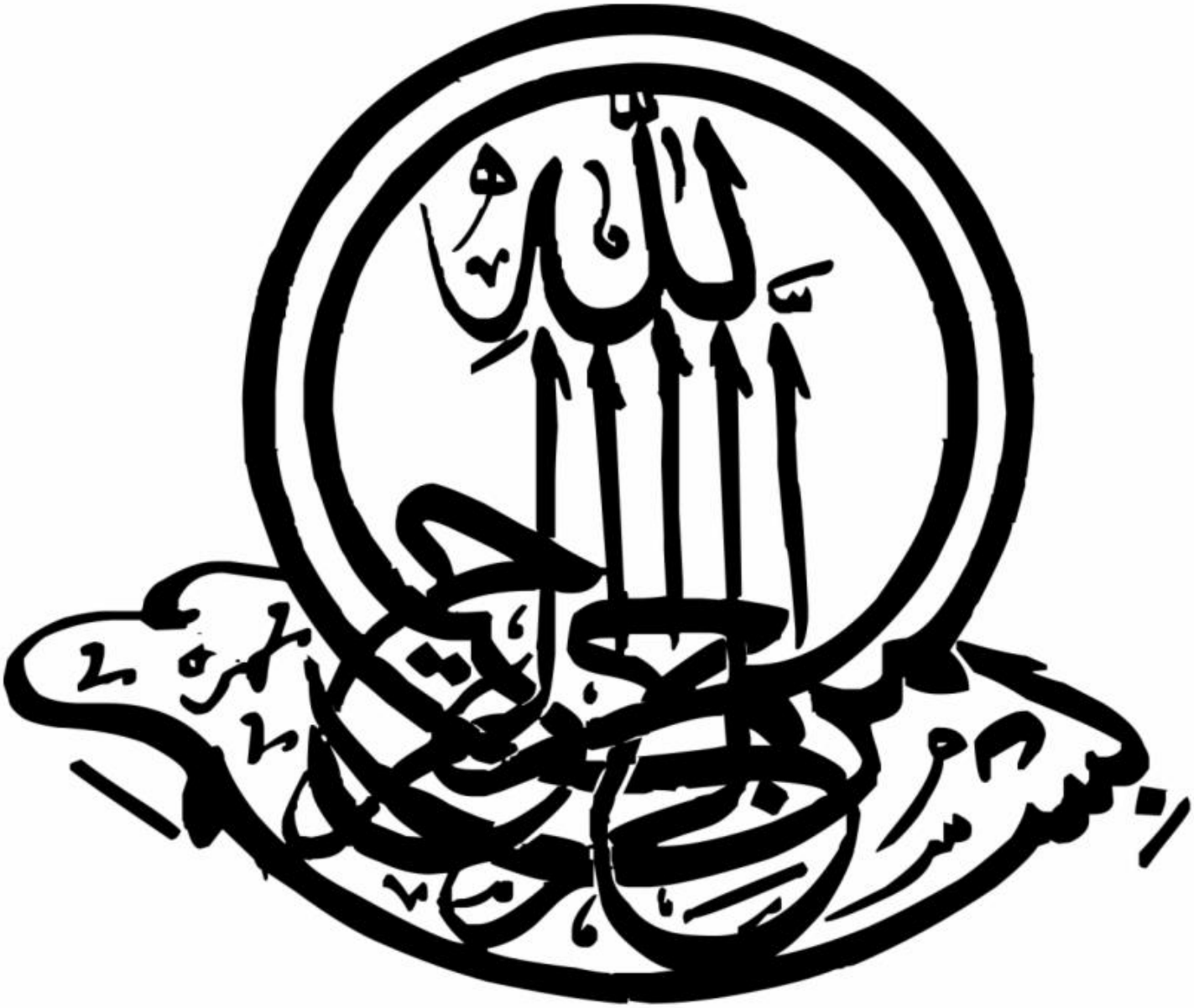
بسم الله الرحمن الرحيم

آزمایشگاه ملی نقشه‌برداری مغز

وبینار

(جلسه دوم)

با موضوع

کاربرد رویکردهای چند مدالیته‌ای برای درک پدیده‌های شناختی "انجام دادن" یا "انجام ندادن"

سخنران

دکتر سید عابد حسینی

استادیار گروه مهندسی برق دانشگاه آزاد اسلامی مشهد

رئیس مرکز خدمات آزمایشگاهی و تحقیقاتی دانشگاه آزاد اسلامی خراسان رضوی

خردادماه ۱۳۹۹

۲۱

چهارشنبه

ساعت: ۱۱ الی ۱۲

- لینک حضور در وبینار از طریق ایمیل و پیامک ارسال خواهد شد.
- در پایان وبینار از طرف سخنران ۲ سوال طرح می‌شود به دونفر از کسانی که پاسخ درست ارائه کنند ۱ساعت استفاده رایگان از خدمات آزمایشگاه داده خواهد شد.

National Brain Mapping Laboratory

آزمایشگاه ملی نقشه‌برداری مغز
NBML
National Brain Mapping Lab

رایگان

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NBML

web-99020031

Multi-modal approaches to understanding cognitive phenomena

"to-do" or "not-to-do" ?

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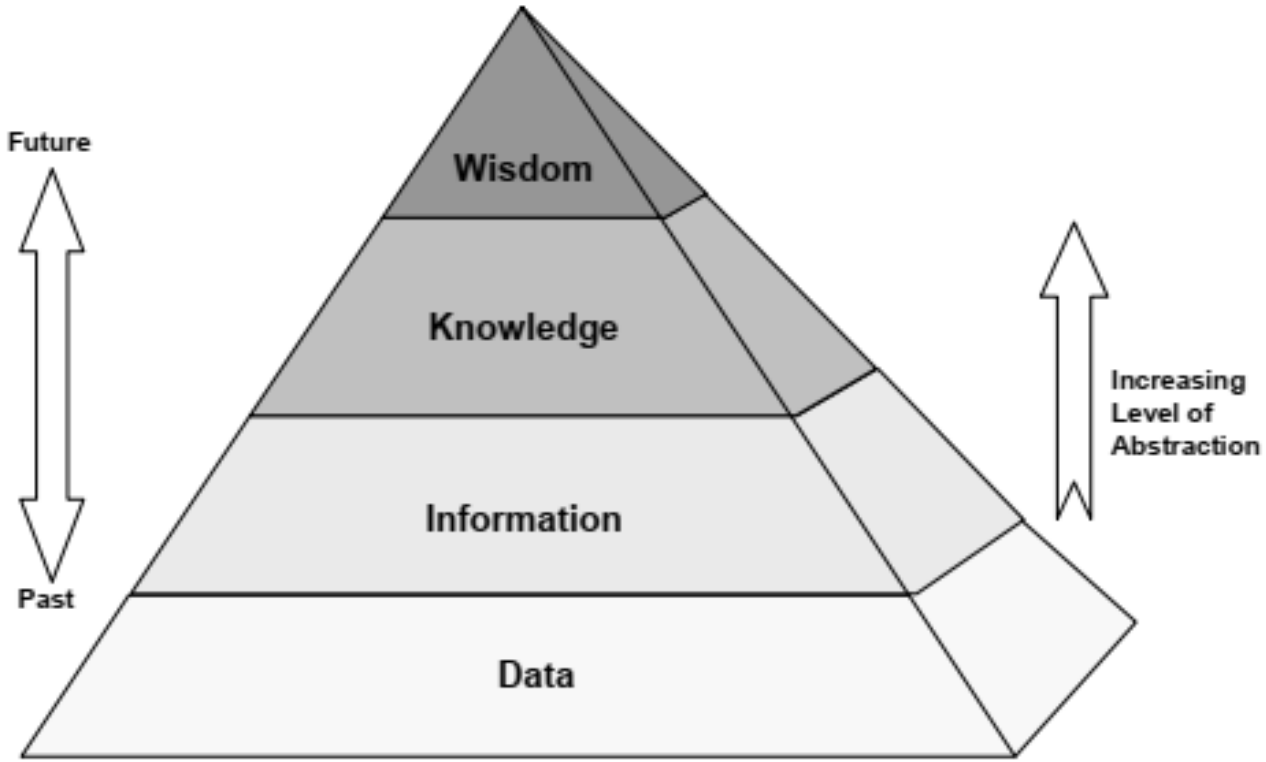
June 10, 2020

Overview

- The knowledge pyramid
- Data fusion: Definition and Concept
  - Illustration of the human data fusion system
- Three approaches to Multi-modal Neuroimaging
- Benefits in the use of multiple sensor
- Data fusion applications
- Multi-sensor data fusion system
- Three approaches to multi-modal neuroimaging
- Advantages and Limitations of Neuroimaging Techniques
- General data fusion methods
- A three-level fusion paradigm
- …

The knowledge pyramid

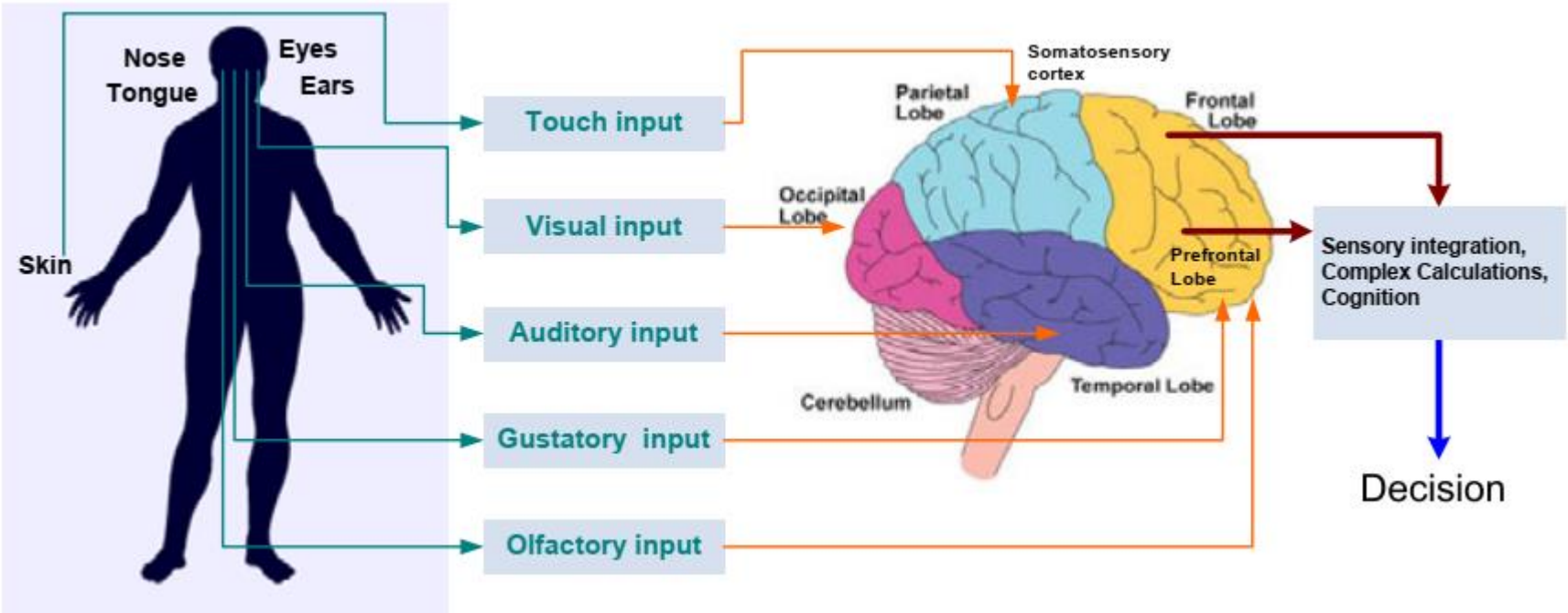


Data Fusion: Definition and Concept

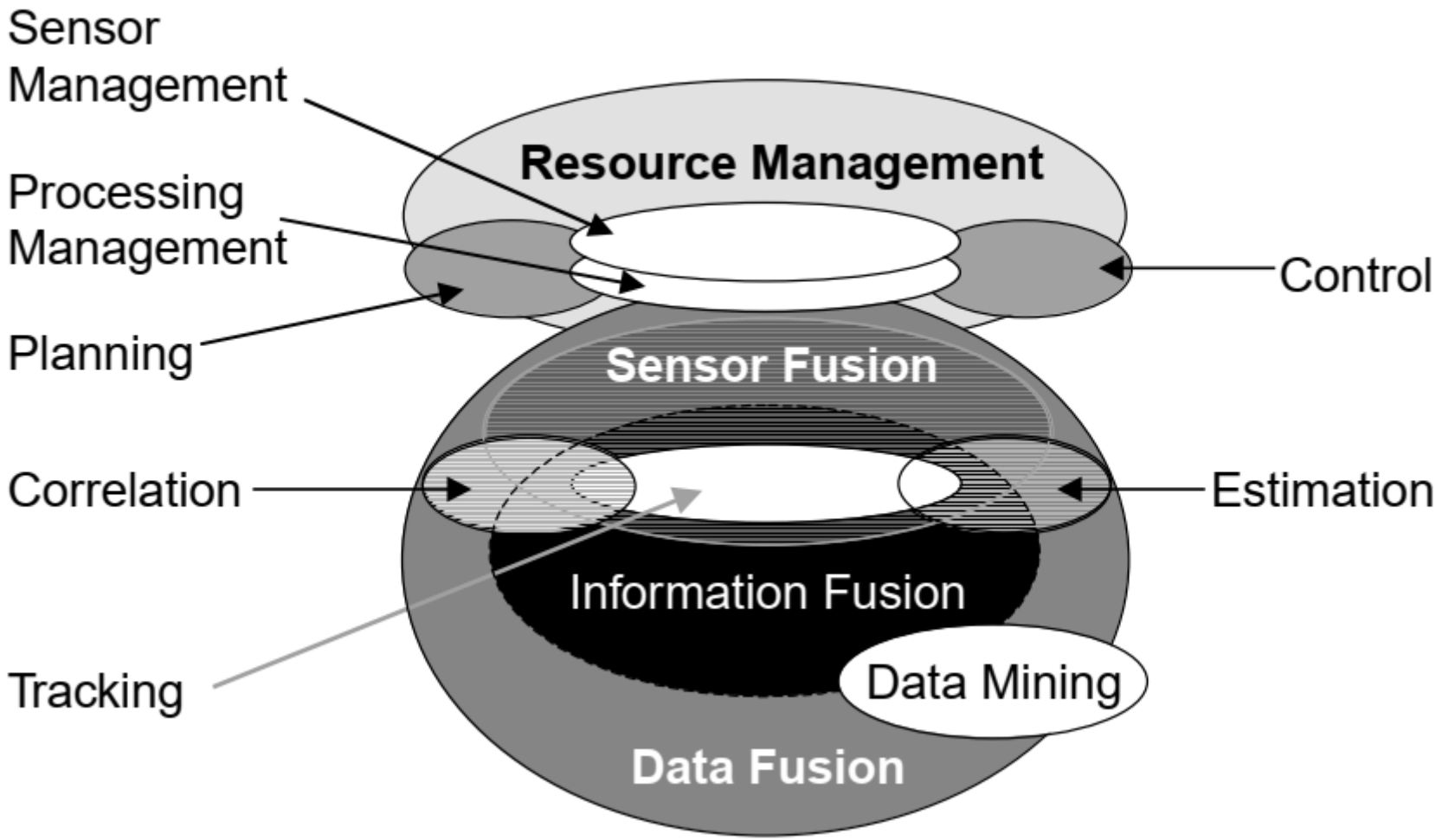
- Human and animals use combination of multiple senses.
- "The analysis of **several datasets**, such that different datasets can interact and inform each other."
- "A process that combines **data** and **knowledge** from **different sources** with the aim of maximizing the useful information content, for improved reliability or discriminant capability, while minimizing the quantity of data ultimately retained."
- The analysis of **⩾2** brain imaging modalities collectively

DOI: 10.1109/JPROC.2015.2460697

Illustration of the human data fusion system (decision)



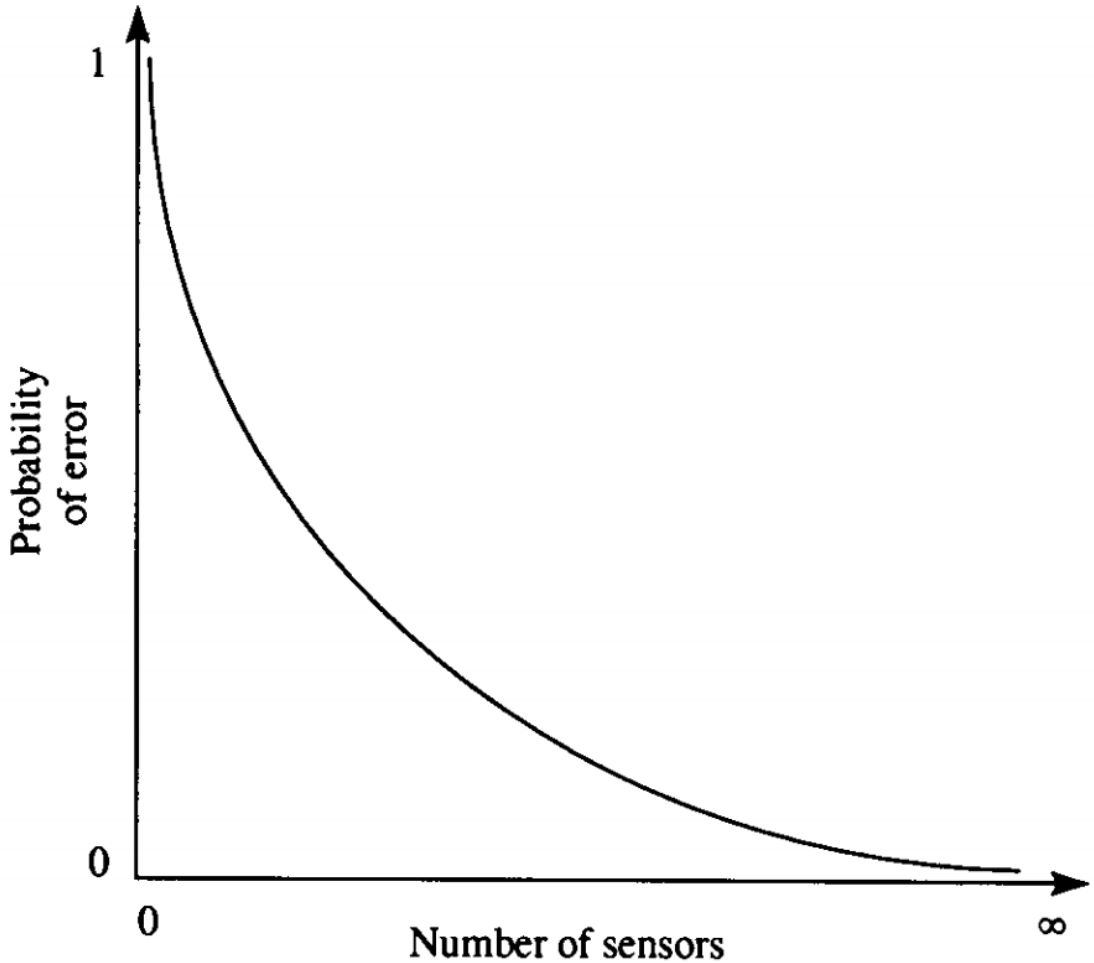
(Con)fusion of terminology



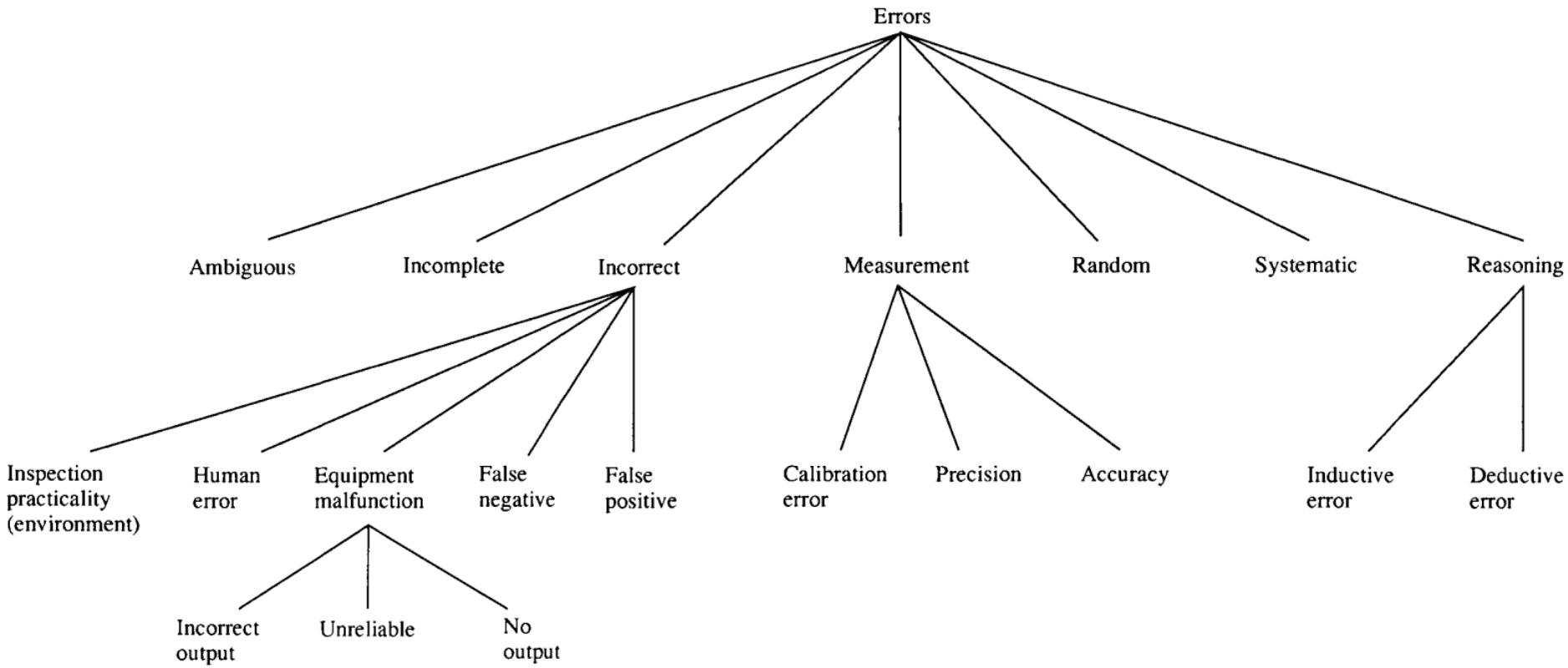
Benefits in the use of multiple sensor

- a reduction in measurement time
- a downtime reduction and an increase in reliability
- redundant and complementary information
- a higher signal-to-noise ratio
- a reduction in measured uncertainty
- a more complete picture of the environment

Probability of error versus number of sensors



Common types of errors

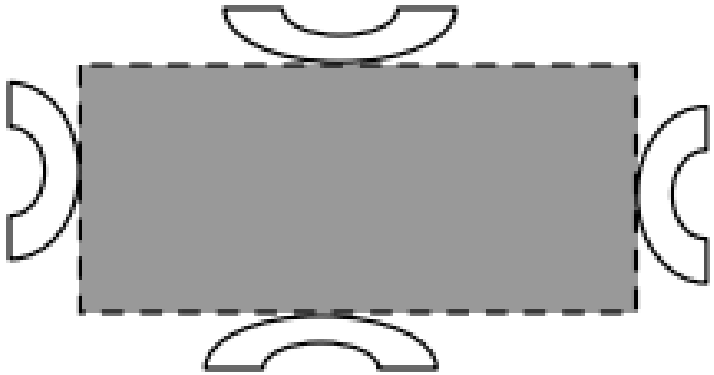


Data fusion applications

- Maintenance engineering
- Robotics
- Pattern recognition and radar tracking
- Mine detection
- Military applications
- Remote sensing
- Traffic control
- Aerospace systems
- Law enforcement
- Medicine
- Finance
- Metrology
- Geo-science

Multi-sensor data fusion system

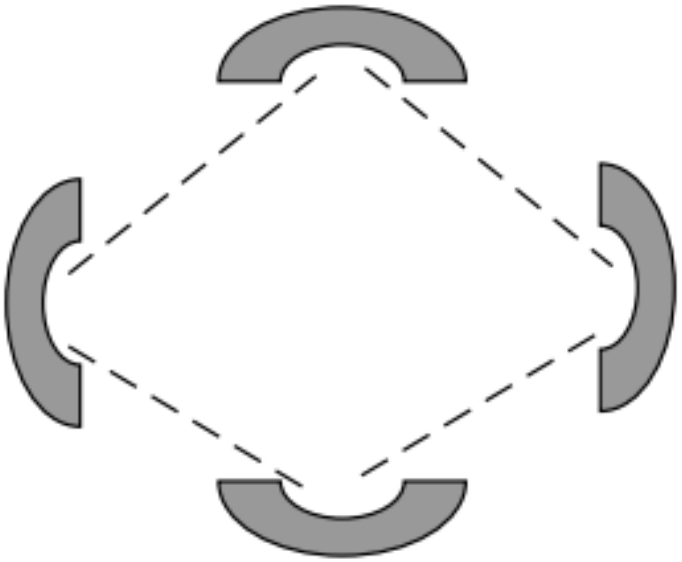
- **Complementary:** The sensors do not directly dep end on each other, but can be combined in order t o give a more complete image of the phenomenon under observation.
  - Help to resolve the problem of incompleteness



viewing different regions

Multi-sensor data fusion system

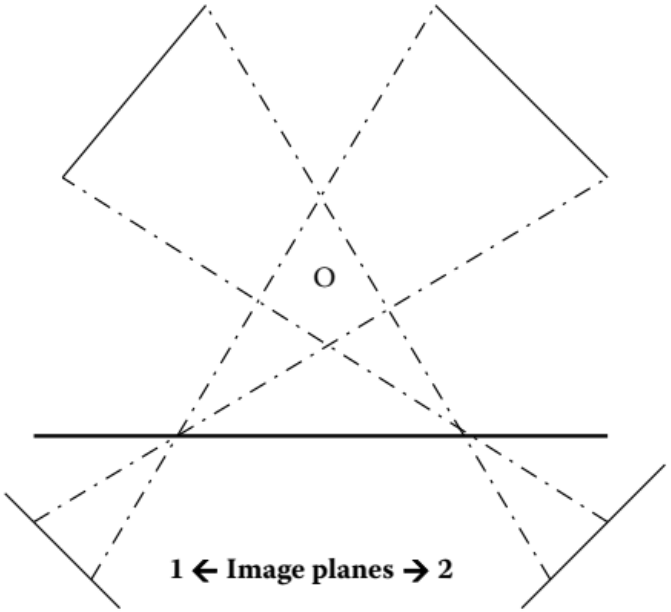
- **Competitive.** Each sensor delivers an independent measurement of the same property.
  - Reduce the effects of uncertain and erroneous measurements



viewing the same area

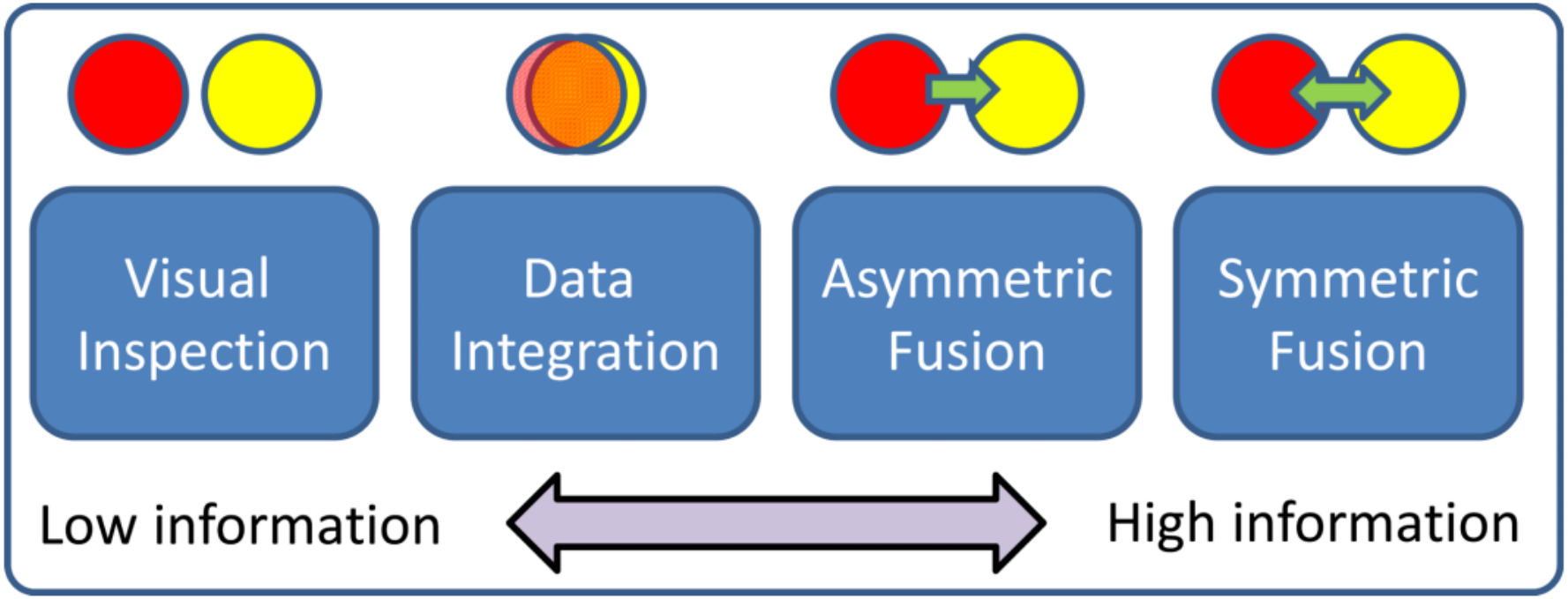
Multi-sensor data fusion system

- **Cooperative** It uses the information provided by two, or more, independent sensors to derive inform ation that would not be available from the single sensors.



two vision cameras producing a single 3D image of “O.”

Three approaches to multi-modal neuroimaging



Three approaches to multi-modal neuroimaging

- **Visual inspection**

Uni-modal analysis results are visualized separately

This is the least informative, but is used quite extensively, and can highlight the different results that are provided by each modality in a qualitative manner.

- **Data integration**

data obtained with each uni-modal technique are analyzed individually and then overlaid, which prevents any interaction between different types of data

For example, a data integration approach would not detect a change in gray matter concentration between patients and controls that is related to fMRI activation maps

DOI: 10.1177/1550059418782093

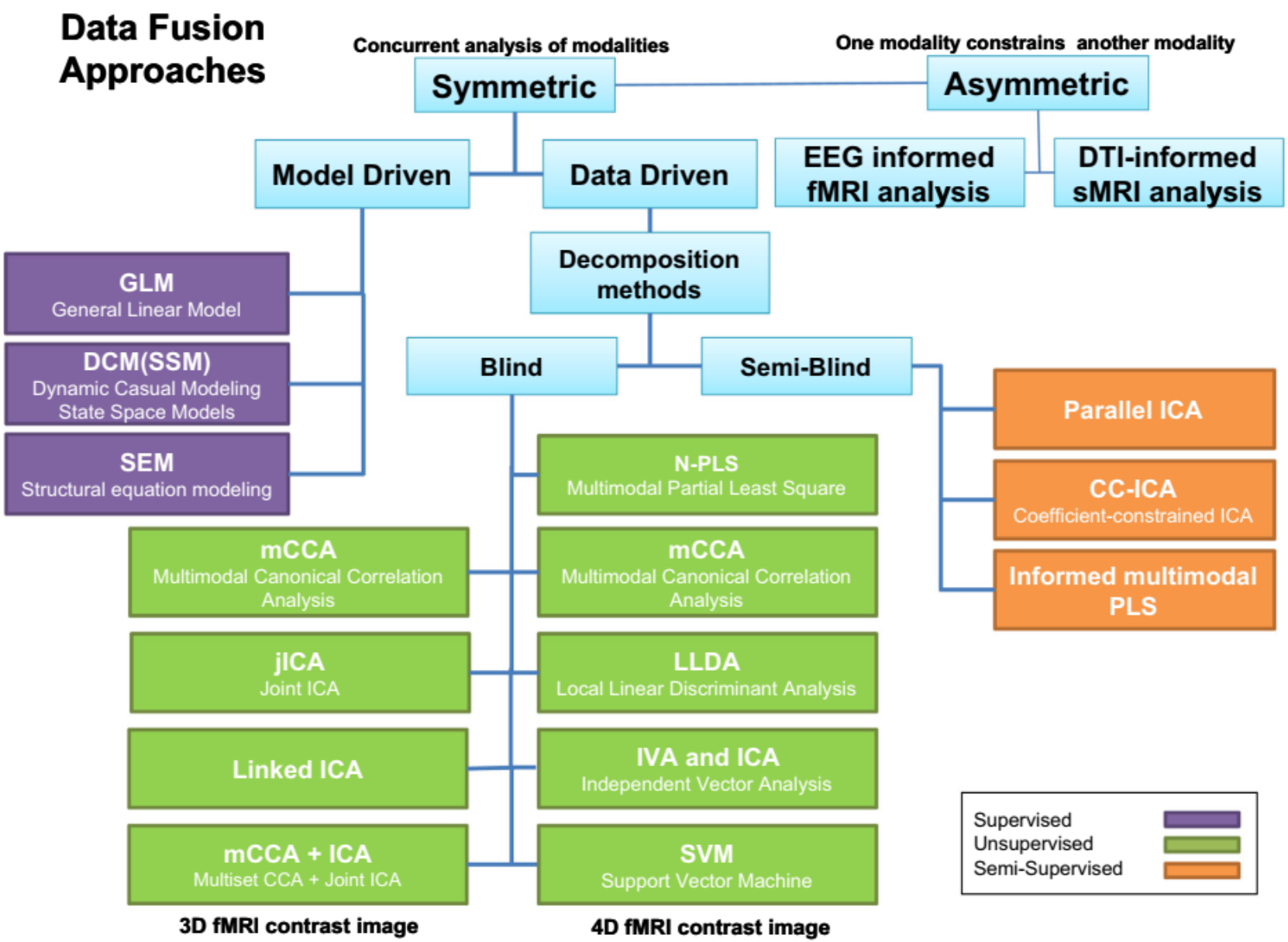
Three approaches to multi-modal neuroimaging

- **Data Fusion**
  - ✓one-sided (asymmetric data fusion)

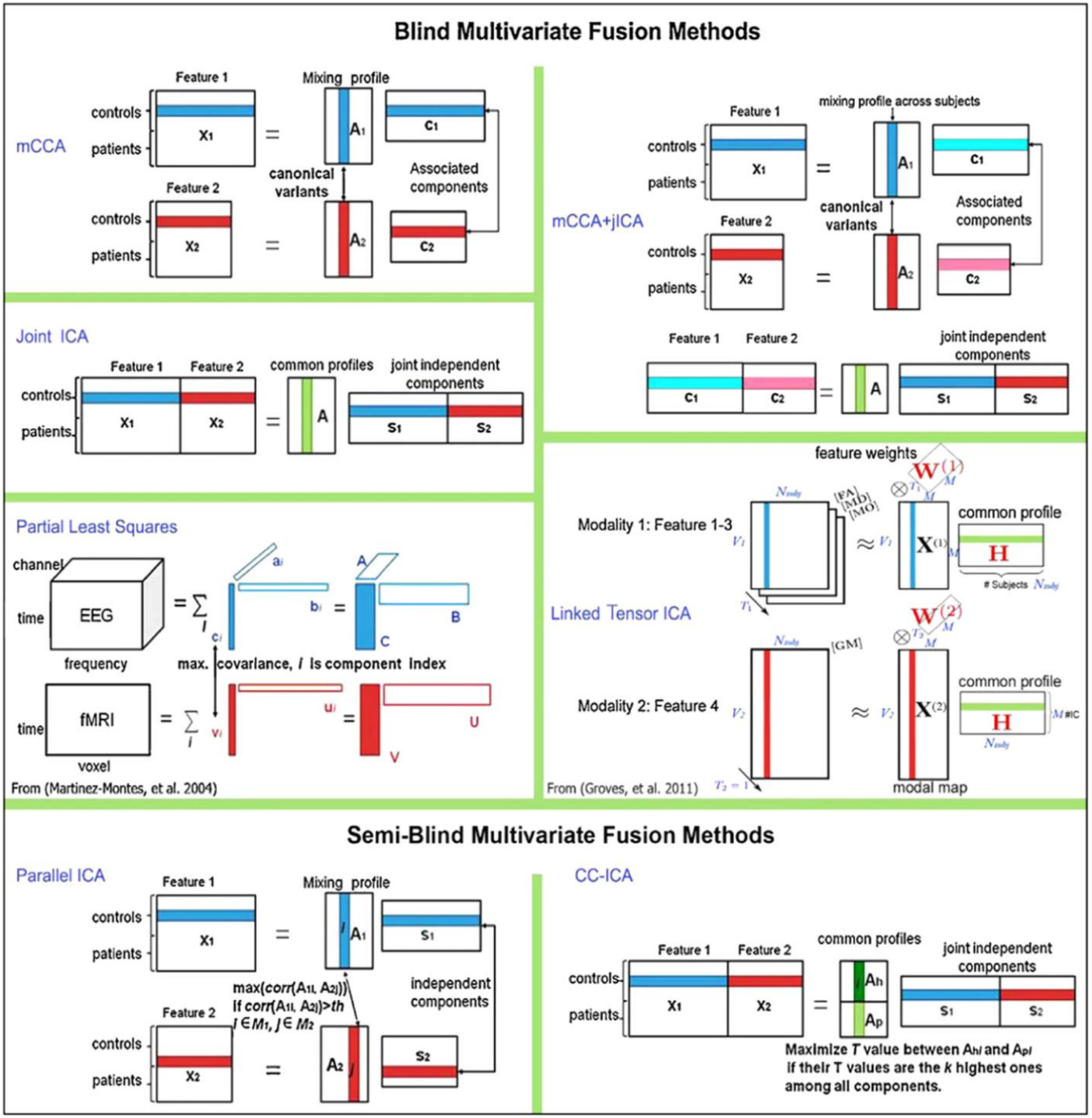
    one modality constrains another modality
  - ✓ symmetric data fusion

    all modalities are analyzed jointly

Doi: 10.1177/1550059418782093



DOI: 10.1016/j.bpsc.2015.12.005


Blind Multivariate Fusion Methods
mCCA
Feature 1
controls
patients
X1
Mixing profile
A1
C1
canonical variants
Associated components
Feature 2
X2
A2
C2
mCCA+jICA
mixing profile across subjects
Joint ICA
common profiles
joint independent components
A
S1
S2
Partial Least Squares
channel
time
EEG
frequency
fMRI
voxel
max. covariance, i is component index
From (Martinez-Montes, et al. 2004)
feature weights
Modality 1: Feature 1-3
common profile
H
Subjects
Linked Tensor ICA
Modality 2: Feature 4
[GM]
modal map
From (Groves, et al. 2011)
Semi-Blind Multivariate Fusion Methods
Parallel ICA
max(corr(A1i, A2j))
If corr(A1i, A2j)>th
i ∈ M1, j ∈ M2
independent components
CC-ICA
Ah
Ap
Maximize T value between Ahi and Api
if their T values are the k highest ones
among all components.

frontiers in Neuroinformatics

TECHNOLOGY REPORT
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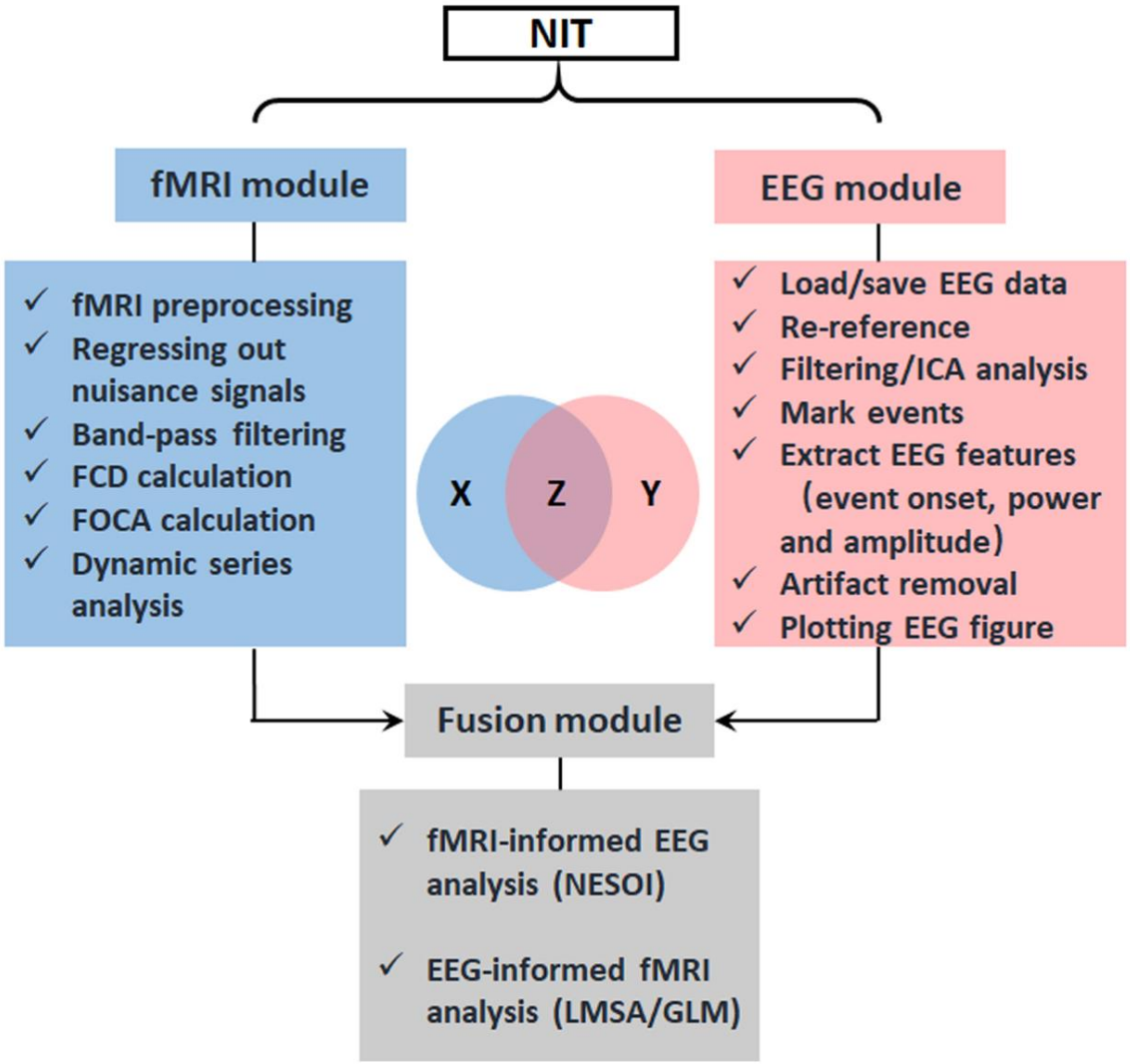
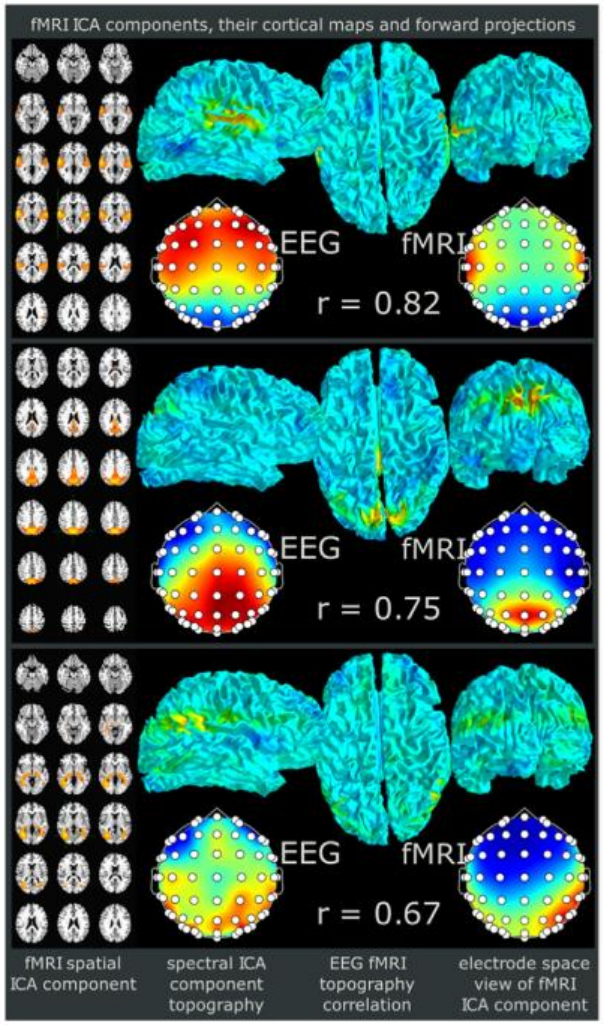
Neuroscience Information Toolbox: An Open Source Toolbox for EEG–fMRI Multimodal Fusion Analysis

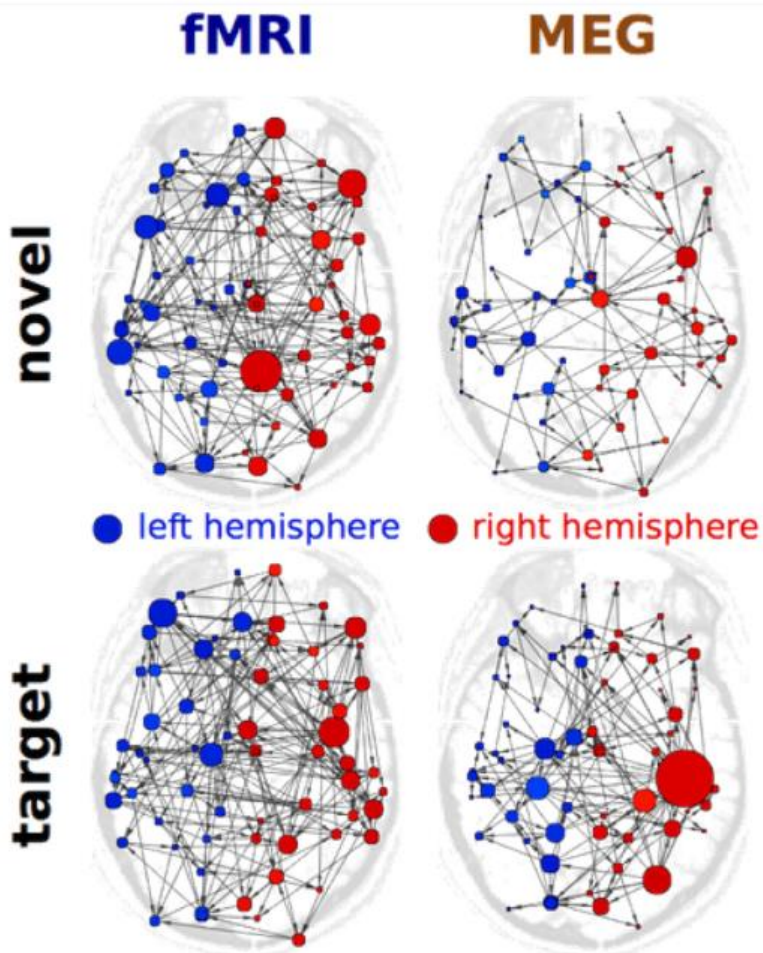
Li Dong[1,2], Cheng Luo[1,2]*, Xiaobo Liu[1,2], Sisi Jiang[1,2], Fali Li[1,2], Hongshuo Feng[2], Jianfu Li[1,2], Diankun Gong[1,2] and Dezhong Yao[1,2]**



DOI: 10.3389/fninf.2018.00056

Brain networks extracted from EEG and fMRI



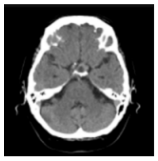
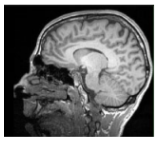
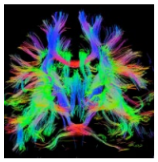
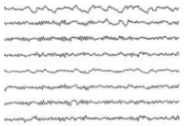
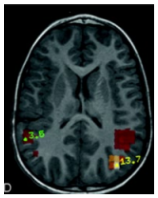
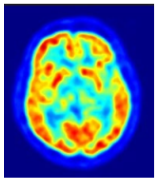


Advantages and Limitations of Neuroimaging Techniques

- fMRI measures the hemodynamic response related to neural activity in the brain dynamically
- sMRI provides information about the tissue type of the brain [gray matter (GM), white matter (WM), cerebrospinal fluid (CSF)
- DTI can additionally provide information on structural connectivity among brain networks.
- EEG measures brain electrical activity

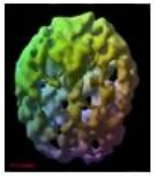
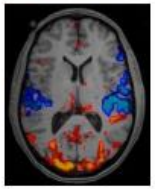
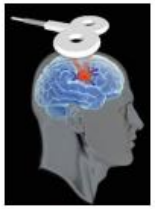
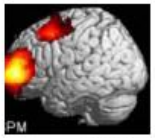
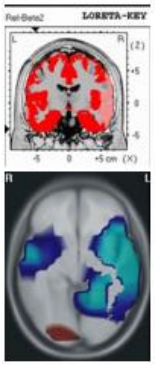
DOI: 10.1177/1550059418782093

Advantages and Limitations of Neuroimaging Techniques

Methods		Measurement Provided	Temporal Resolution	Spatial Resolution	Advantages	Limitations
	CT	Brain structures	Minutes	0.5-1 mm	High spatial resolution	Radiation Low contrast Low temporal resolution
	MRI	Brain structures (eg, white matter, gray matter, and cerebrospinal fluid)	Minutes to hours	1-2 mm	High spatial resolution No radiation	Low temporal resolution Relatively low sensitivity High cost Long scanning time
	DTI	Fiber tracks	Minutes	2.5 mm	High spatial resolution	Limited information for GM
	EEG	Brain activity	Milliseconds	>10 mm	High temporal resolution No radiation Low cost Portable Widely available Fewer motion artefacts	Low spatial resolution Does not measure activity below the cortex
	MEG	Brain magnetic activity	Milliseconds	>5 mm	High temporal resolution Medium spatial resolution	Low spatial resolution Not portable Limited availability High cost
	PET	Perfusion Metabolism Neurotransmitter dynamics	Seconds to minutes	4-10 mm	Fewer motion artifacts High sensitivity	Low spatial and temporal resolution Limited availability Radiation High cost Not portable

DOI: 10.1177/1550059418782093

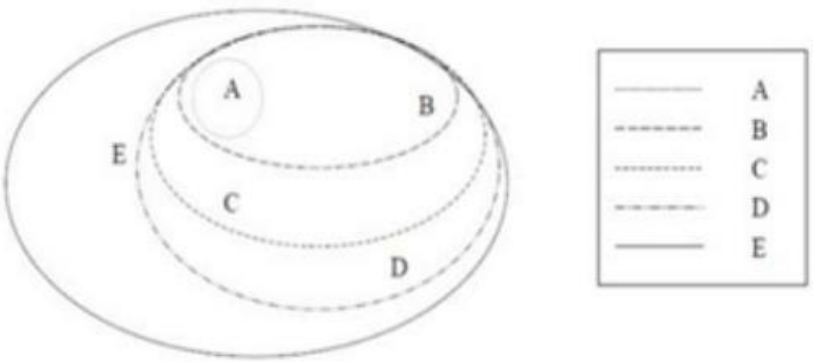
Advantages and Limitations of Neuroimaging Techniques

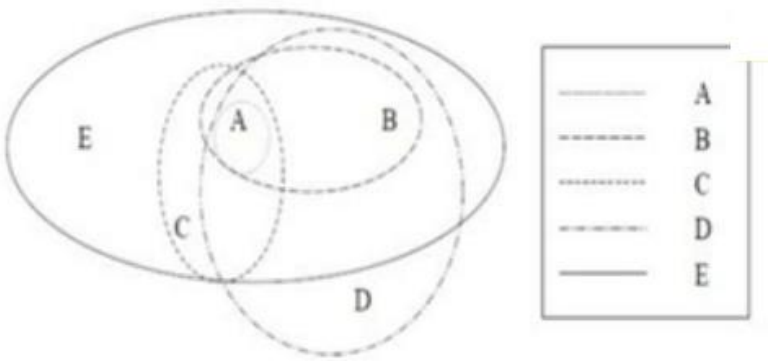
Methods		Measurement Provided	Temporal Resolution	Spatial Resolution	Advantages	Limitations
	SPECT	Perfusion Metabolism Neurotransmitter dynamics	Minutes	8-15 mm	High sensitivity Lower cost than PET Higher availability than PET	Low spatial and temporal resolution Lower sensitivity than PET
	fMRI	Hemodynamic activity	Seconds	< 3 mm	High spatial resolution No radiation Widely available	Not portable Low temporal resolution Sensitive to motion artefacts
	TMS[a]	Focal brain activity	Milliseconds to seconds	45-90 mm	No radiation Portable Can stimulate lesions	Spatial and temporal resolution dependent on other parameters Has some risks (eg, seizures, damage brain cells)
	NIRS	Fluctuations in cerebral metabolism during neural activity	Seconds	> 5 mm	Medium temporal resolution Low cost Portable	Low spatial resolution
	LORETA/VARETA	Brain electric/magnetic activity	Milliseconds	5-7 mm	High estimation accuracy of the current density and location Low error rate High time resolution VARETA imposes different amounts of spatial smoothness for different types of generators. VARETA eliminate ghost solutions and minimize the diffuse allocation of variance	Low spatial resolution when compared with that of an fMRI or PET scan Need some algorithms for spatial blurring In LORETA, regularization parameter is a constant

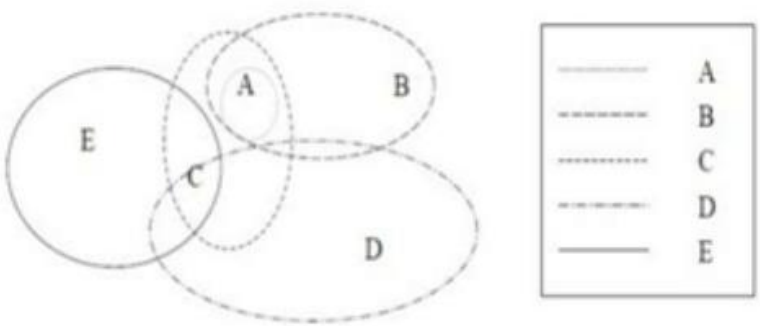
General data fusion methods

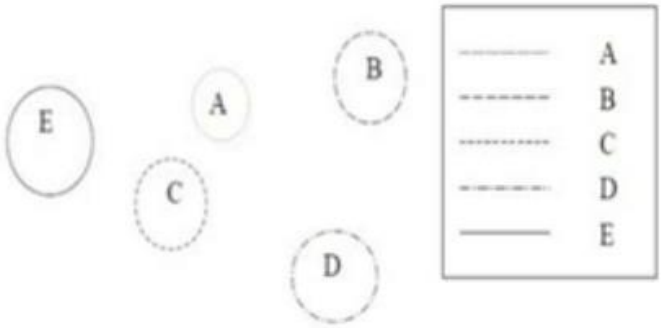
- Bayesian network (interference)
- Dempster-Shafer evidential theory
- Kalman filter
- Extended Kalman filter (EKF)
- Particle filters
- Fuzzy logic
- Artificial neural networks (ANN)
- Knowledge based expert systems
- Monte Carlo (MC) methods

Dempster-Shafer evidential theory









General data fusion methods

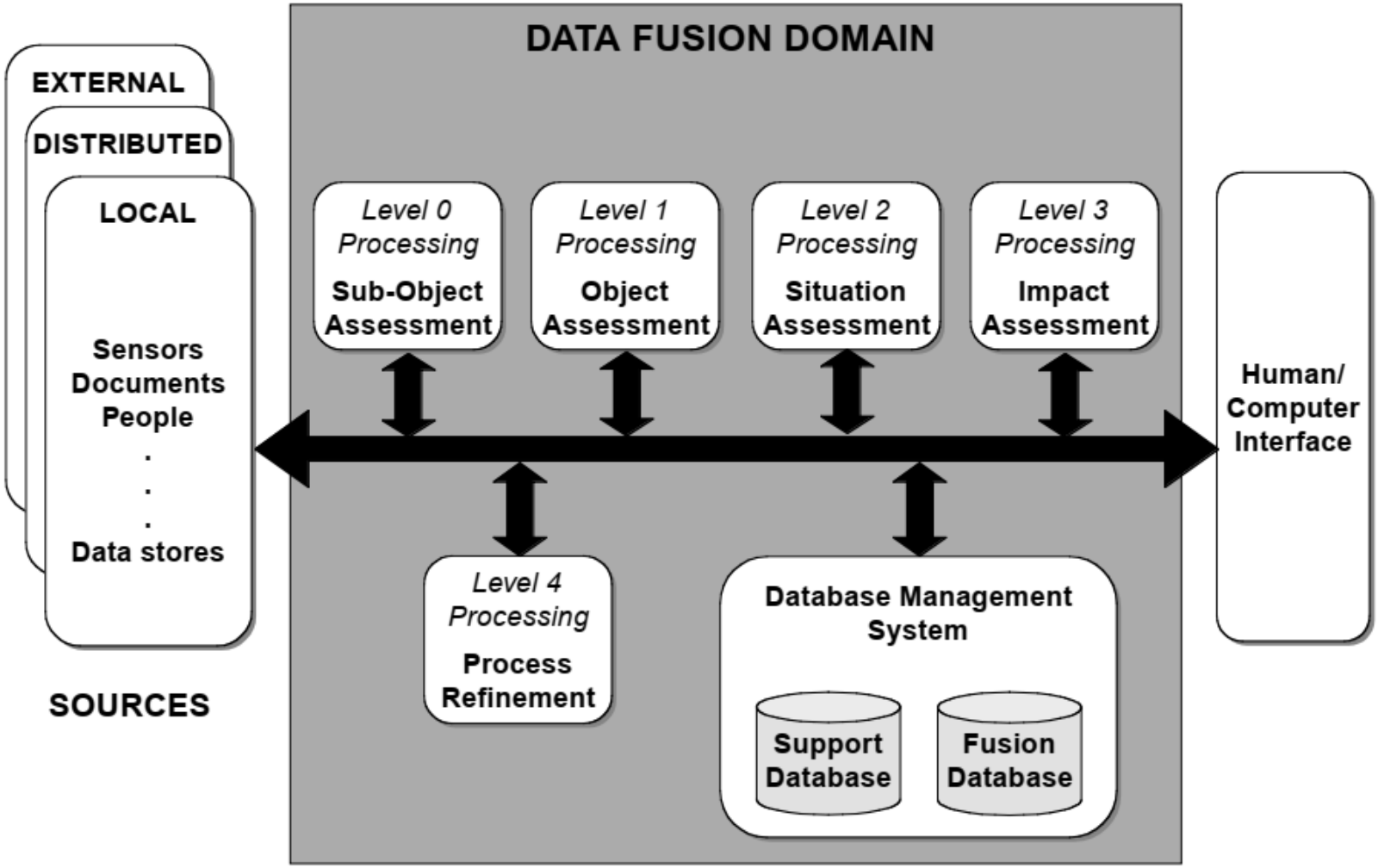
- The Bayesian and Dempster–Shafer approaches belong to the class of feature-based parametric algorithms. They directly map parametric data (e.g., features) into a declaration of identity. Physical models are not used.
- Artificial neural networks belong to the class of feature-based information theoretic techniques that transform or map parametric data into an identity declaration. No attempt is made to directly model the stochastic aspects of the observables.

General data fusion methods

- Fuzzy logic and knowledge-based expert systems are examples of cognitive-based approaches that attempt to emulate and automate the decision-making processes used by human analysts.
- The Kalman filter and its nonlinear-motion counterparts are examples of physical models since the kinematics of the objects being tracked are modeled. Physical models replicate object discriminators—in this case, position, velocity, and sometimes acceleration—that are easily observable or calculable.

- **Input:** sensor data from multiple sensors
- **Process:** combining data
- **Goal:** to get better and/or more reliable data

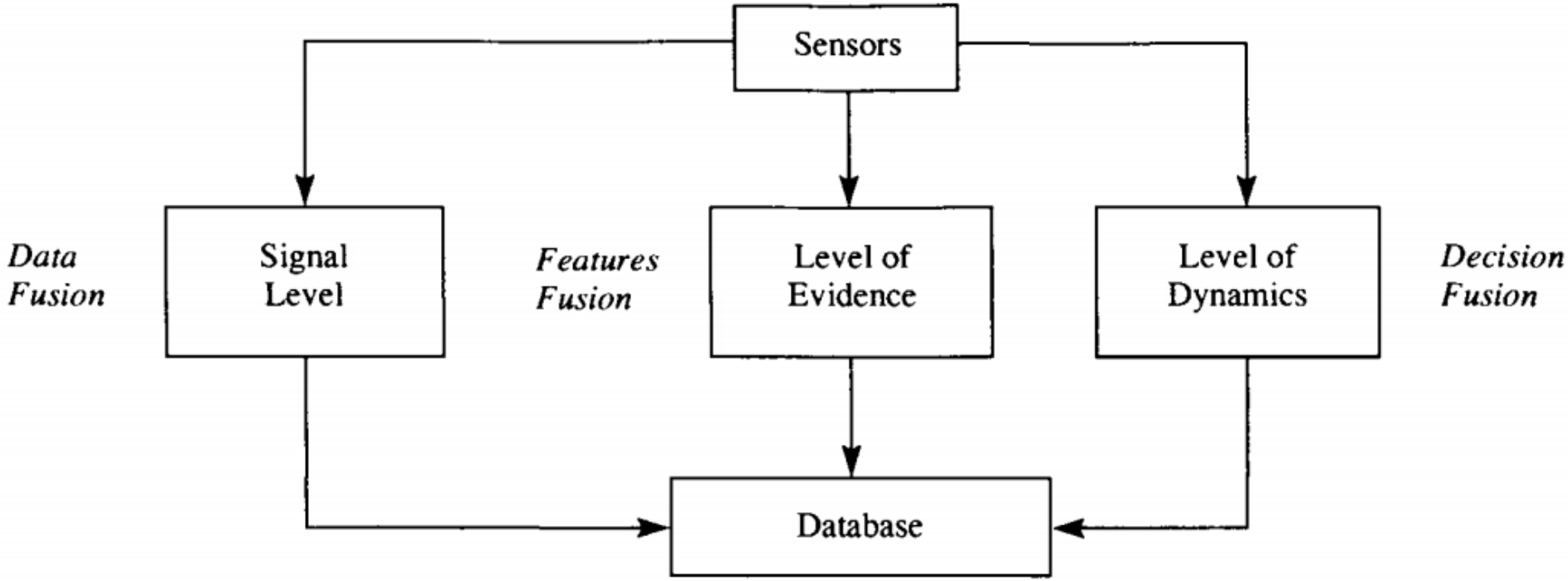
Revised JDL data fusion model (1998)



A three-level fusion paradigm

- **Signal level fusion**, where data correlation takes place through learning due to the lack of a mathematical model describing the phenomenon being measured.
- **Evidence level fusion**, where data is combined at different levels of inference based on a statistical model and the assessment required by the user (e.g. decision making or hypothesis testing).
- **Dynamics level fusion**, where the fusion of data is done with the aid of an existing mathematical model.

A three-level fusion paradigm



Data fusion techniques

- **Data association (Raw data level)**
  - **Kalman Filtering**
  - **Figure of Merit**
  - **Gating**
- **State estimation (Feature data level)**
  - **Bayesian Theory**
  - **Dempster-Shafer**
  - **Neural Networks**
  - **Clustering Algorithms**
  - **Template Methods**
- **Decision fusion level**
  - **Fuzzy Logic**
  - **Genetics Algorithms**
  - **Expert Systems**
  - **Blackboard Systems**

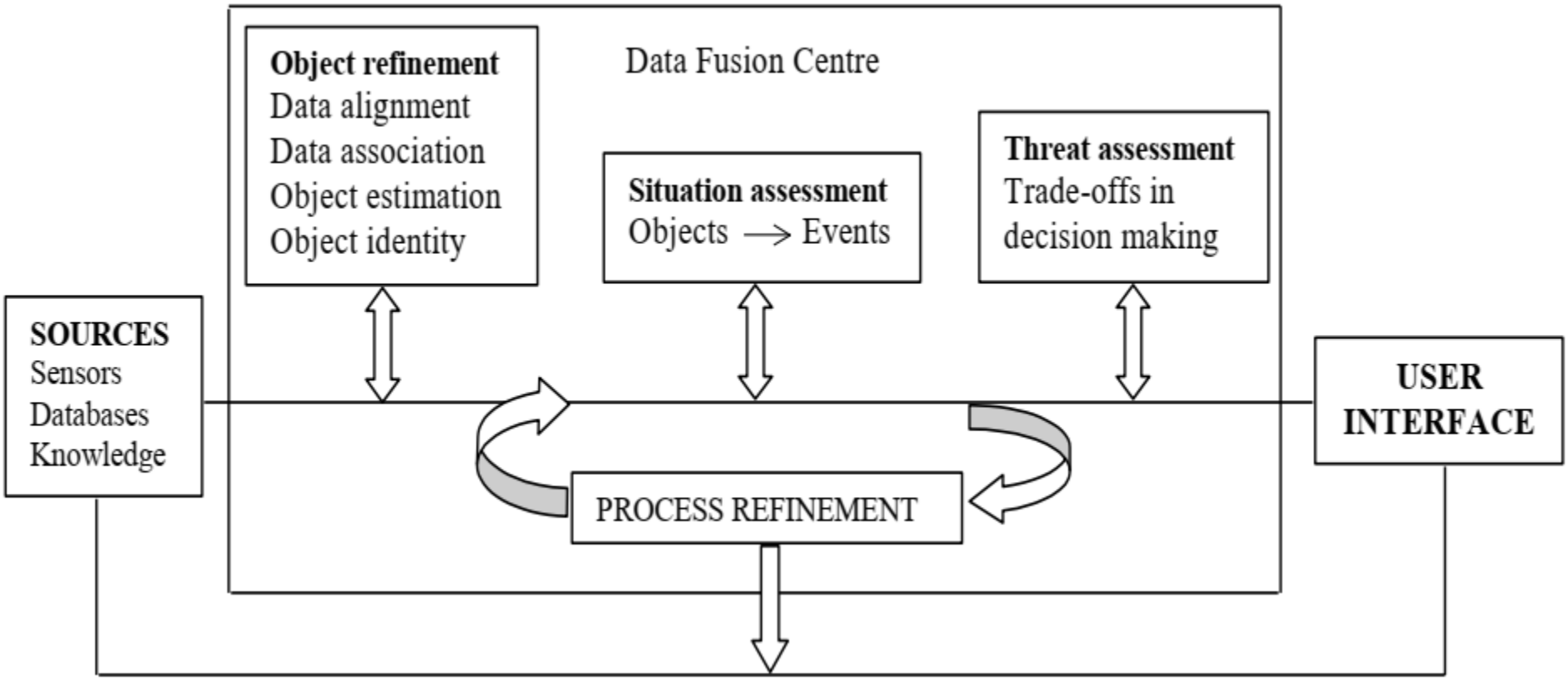
A number of things need to be considered when defining the type of fusion algorithm used and level at which fusion will occur. These include:

- How are the sensors distributed?
- What are the format, type and accuracy of the collected data?
- What is the nature of the sensors used?
- What is the resolution of the sensors used?
- What is the computational capability at the sensors?

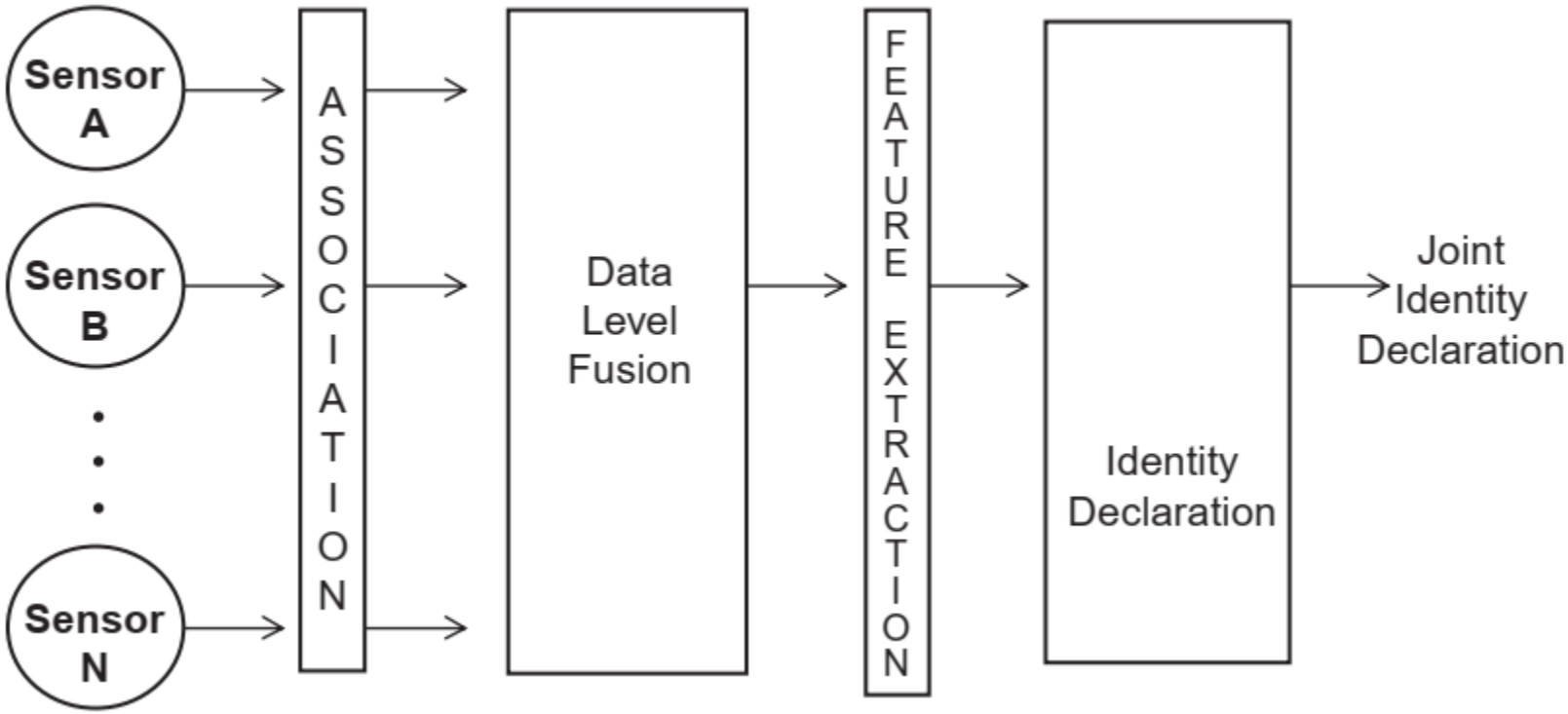
Joint Directors of Laboratories (JDL)

- Level 1, object refinement
- Level 2, situation assessment
- Level 3, threat/impact assessment
- Level 4, Process Refinement

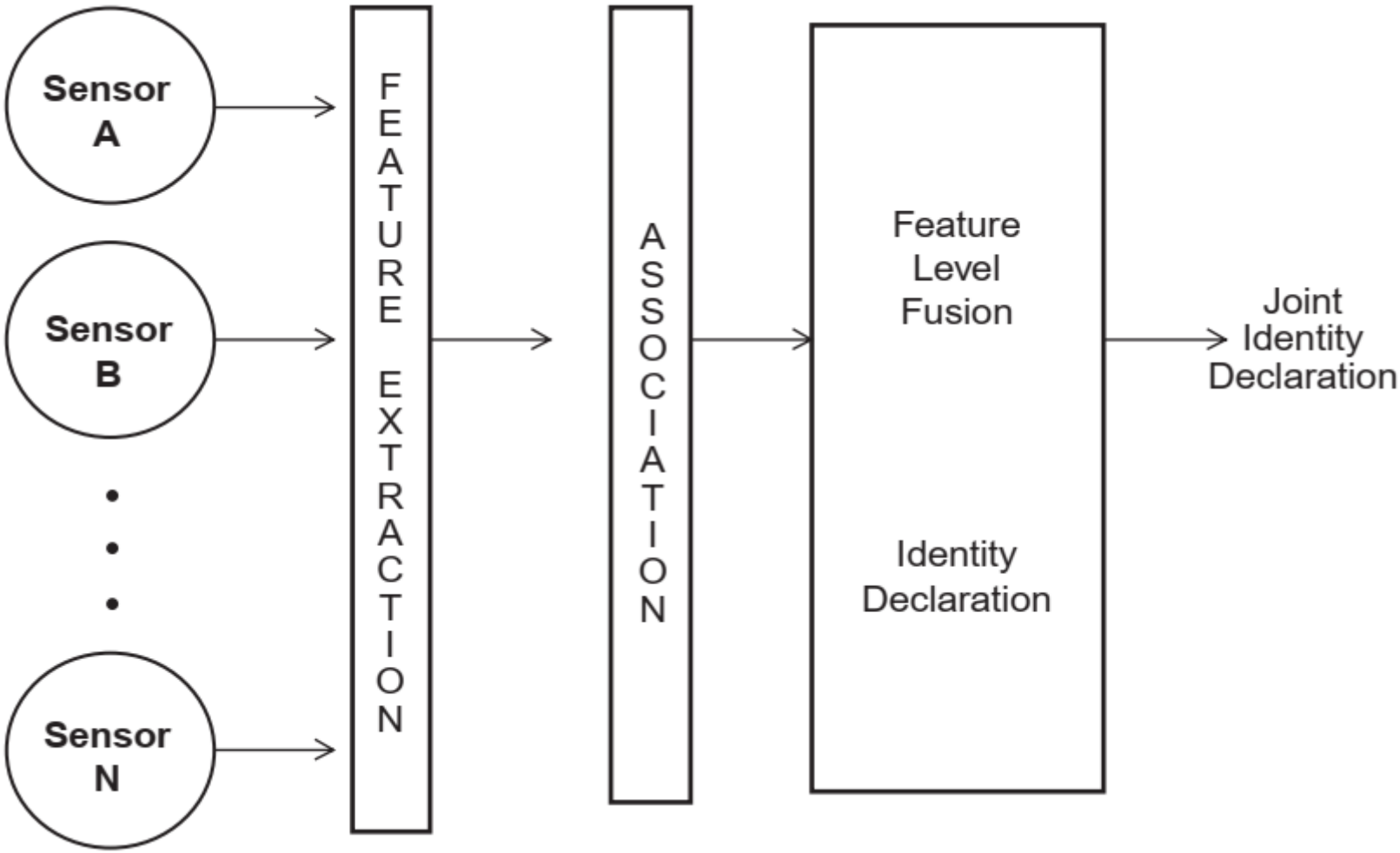
Joint Directors of Laboratories (JDL)



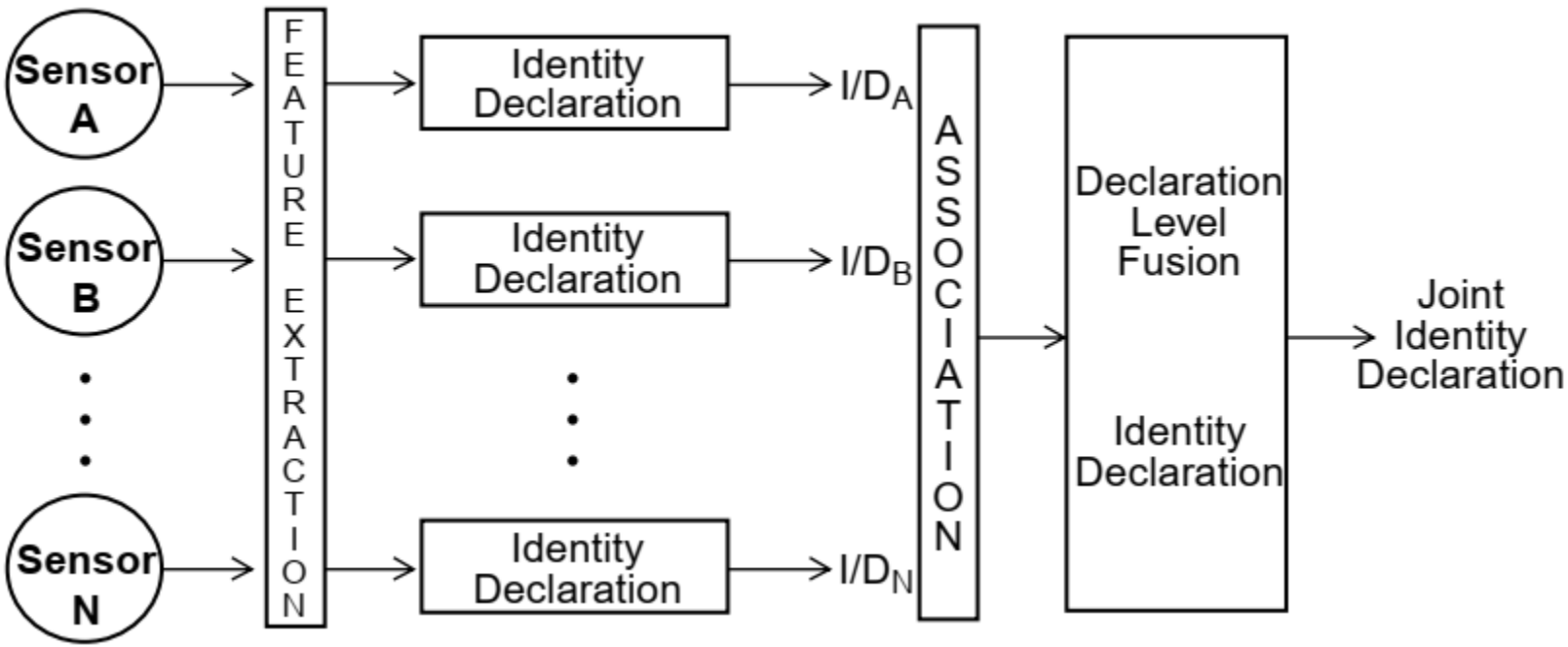
Three Processing Architectures:
a) Direct fusion of sensor data



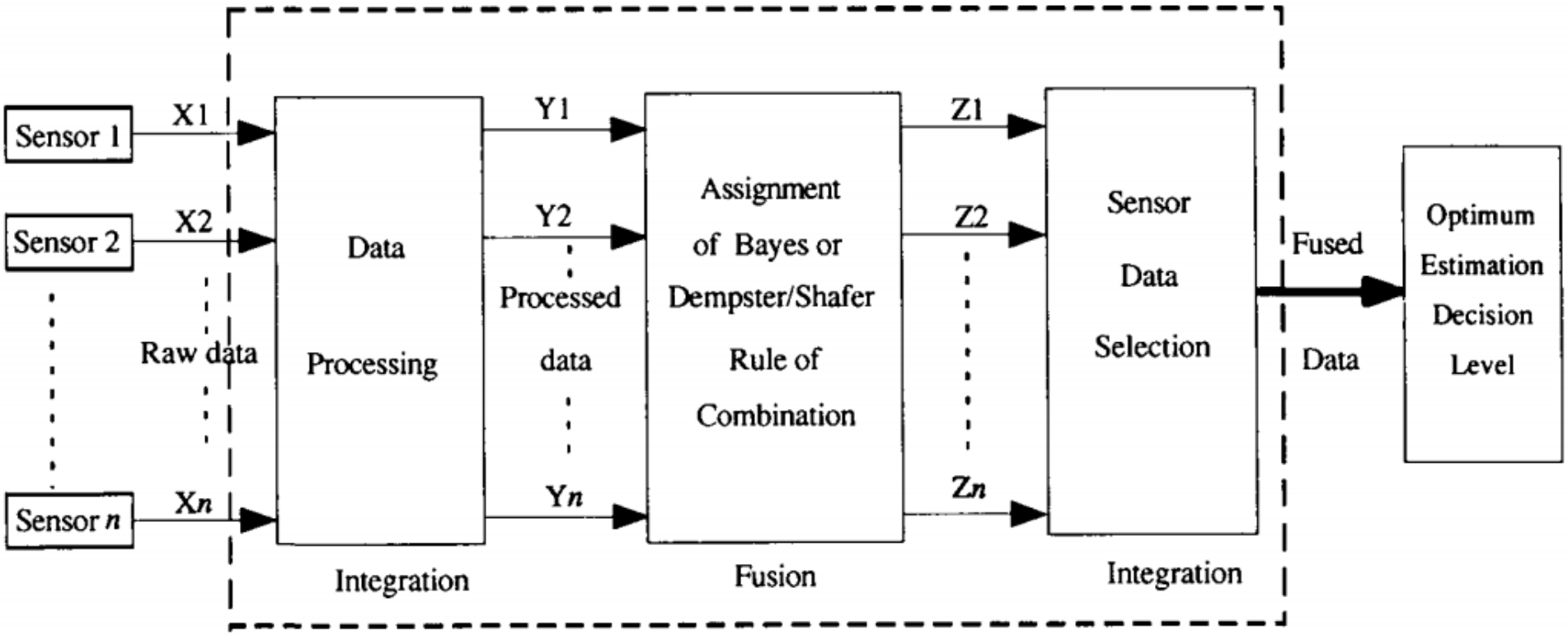
b) Representation of sensor data via feature vectors and subsequent fusion of the feature vectors



c) Processing of each sensor to achieve high-level inferences or decisions that are subsequently combined



Functional model for a data fusion process

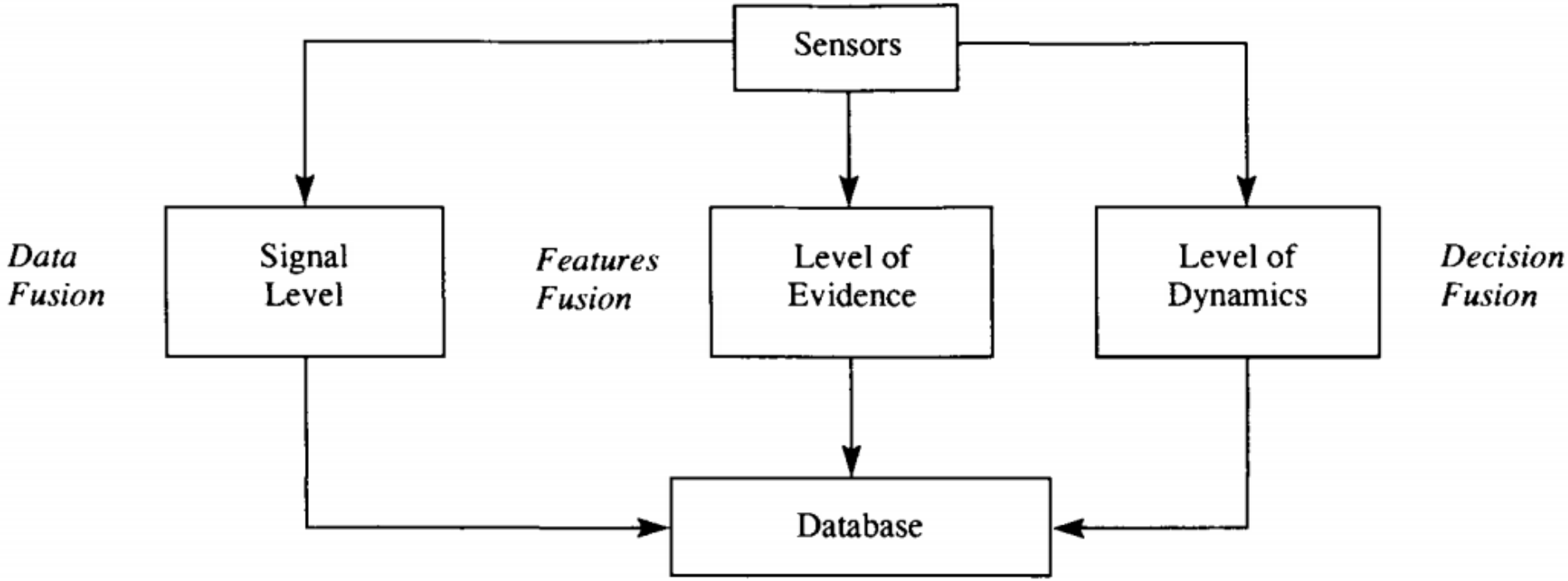


Multisensor data integration and fusion centre

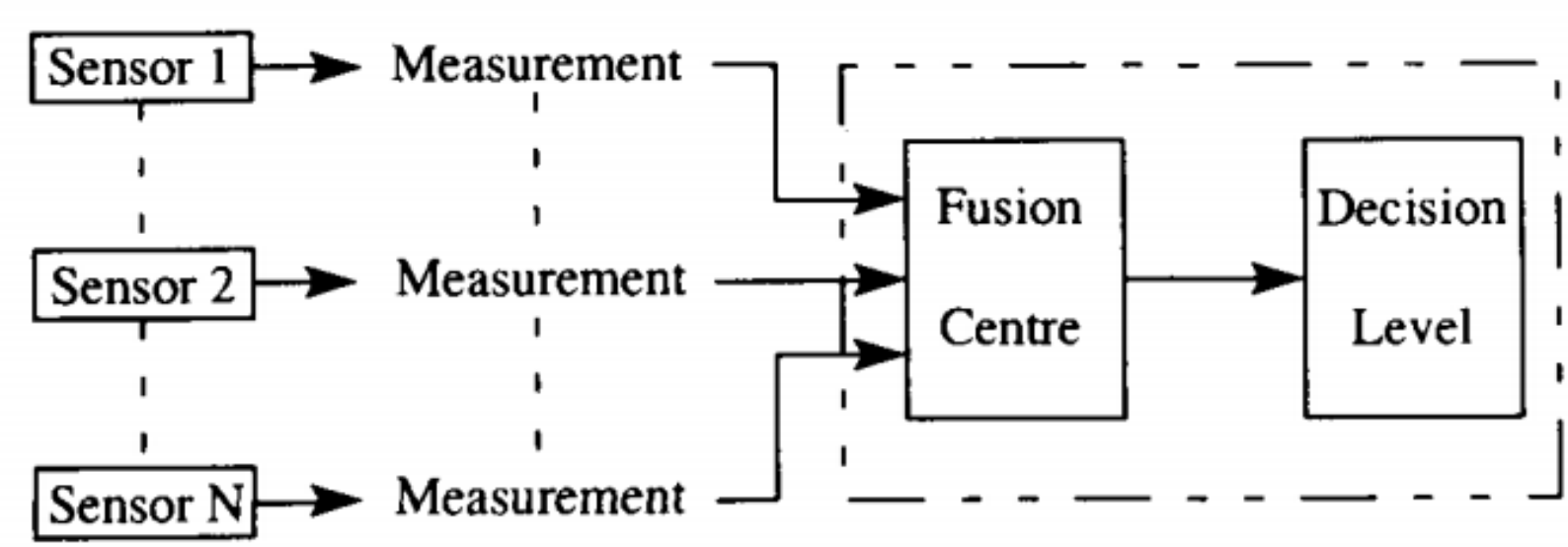
A three-level fusion paradigm

- **Signal level fusion**, where data correlation takes place through learning due to the lack of a mathematical model describing the phenomenon being measured.
- **Evidence level fusion**, where data is combined at different levels of inference based on a statistical model and the assessment required by the user (e.g. decision making or hypothesis testing).
- **Dynamics level fusion**, where the fusion of data is done with the aid of an existing mathematical model.

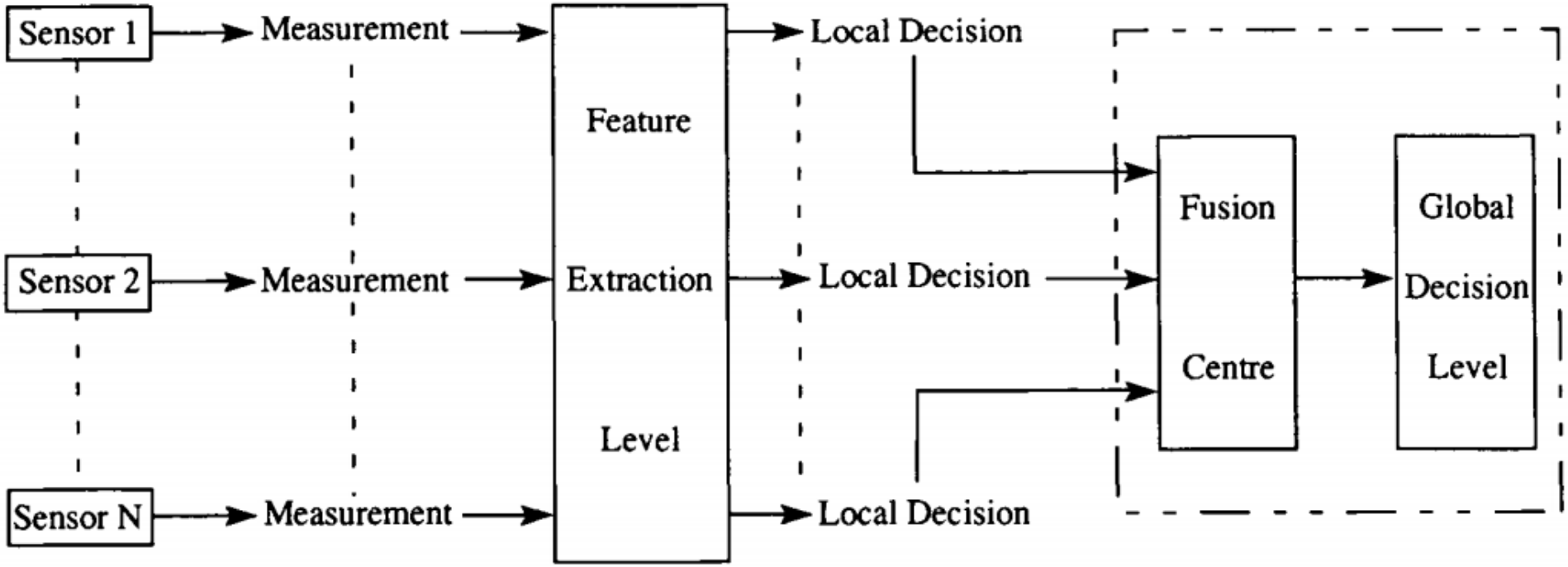
A three-level fusion paradigm



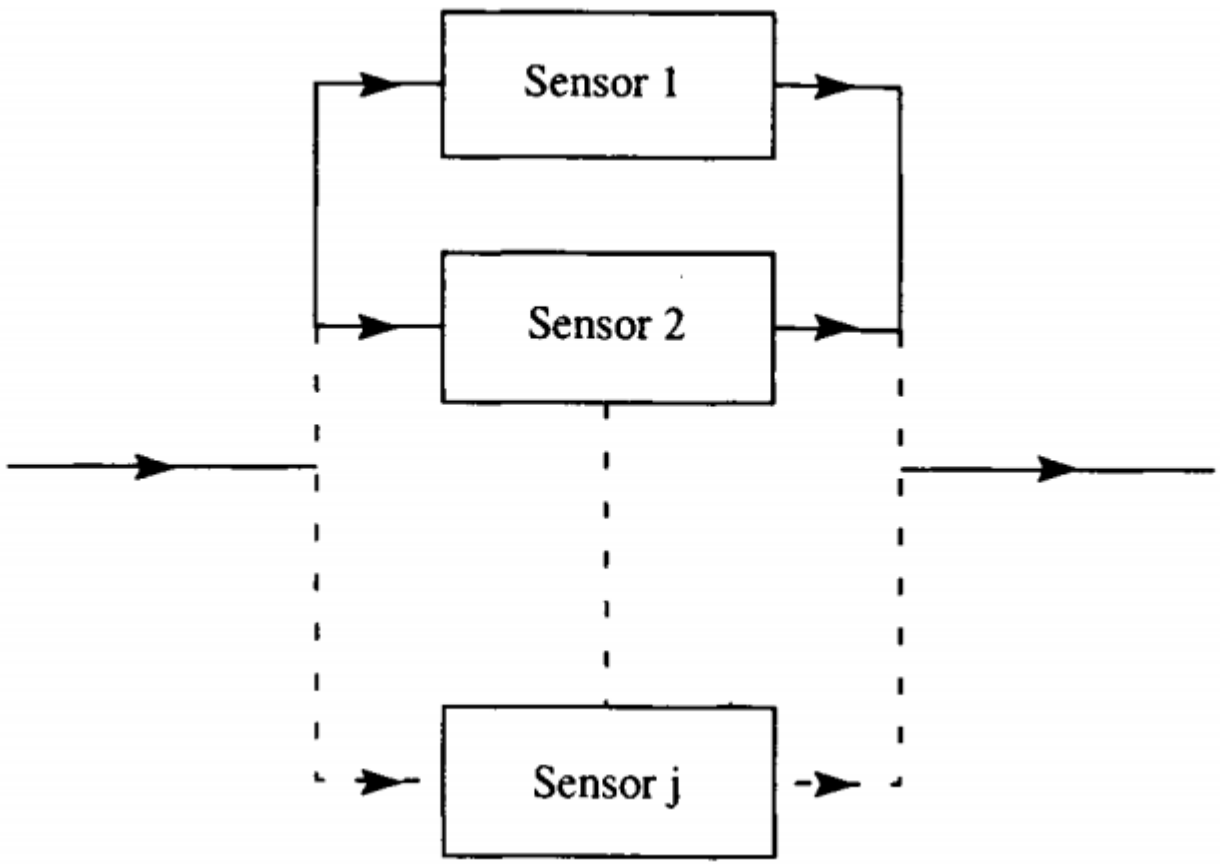
Centralized signal detection system



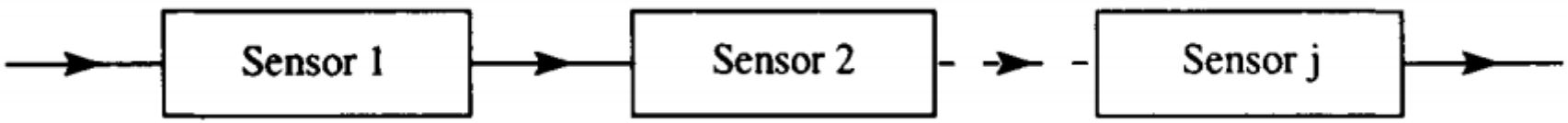
Distributed (decentralized) signal detection system



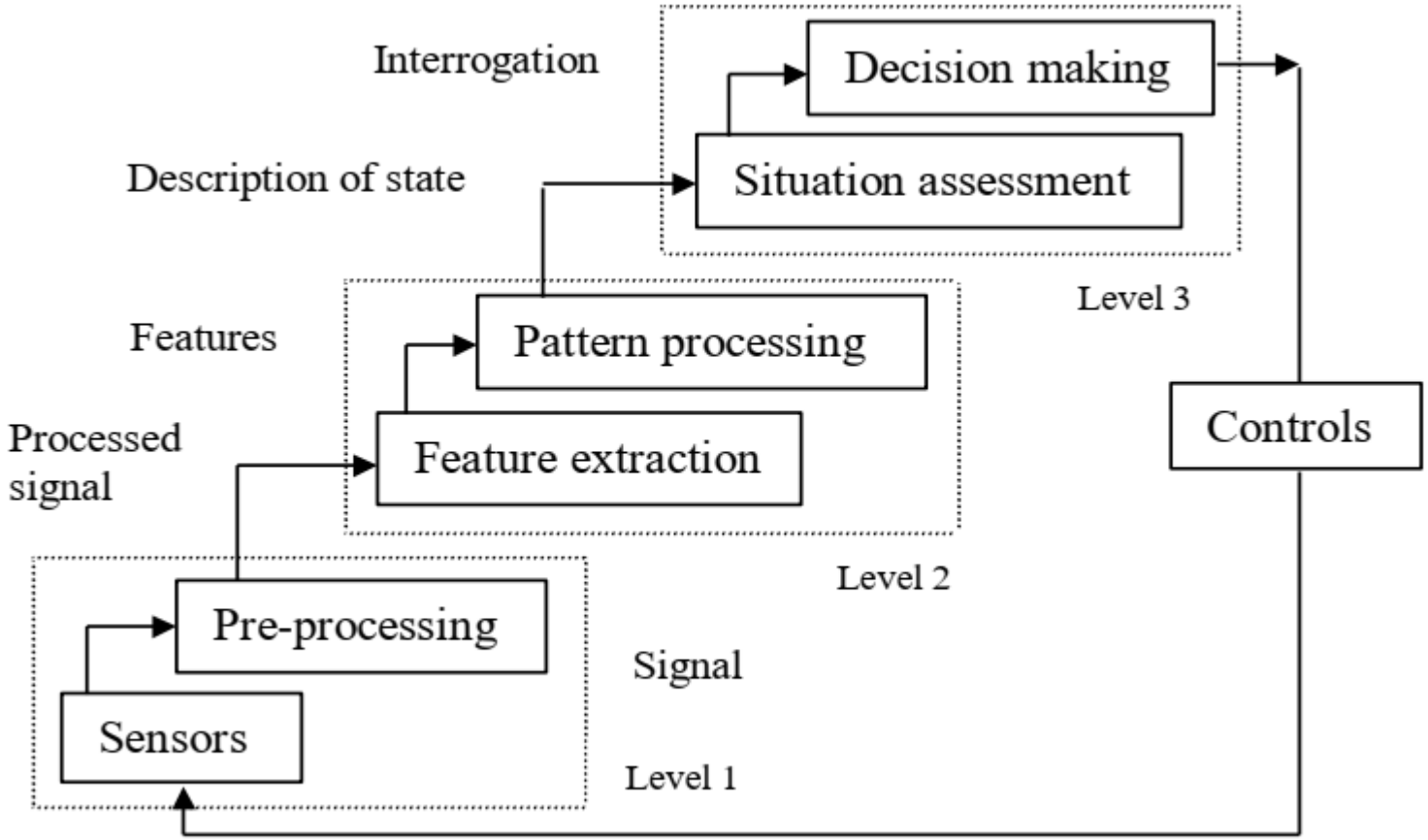
Parallel multi-sensor suite



Serial multi-sensor suite



Waterfall model



The End

Thank you for your Attention!

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