

In the name of Allah

Data Fusion: A new Bayesian approach to Scientific Image Fusion

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Data Fusion Concepts

Definition and Concept

- Human and animals use combination of multiple senses.
- Data Fusion is the theory, techniques and tools used for combining data derived from different sensors, into a common representational format.
- Data fusion problems deal with determining the best procedure for combining the multi-sensor data inputs.
- The **goal** is to improve the quality of the information and knowledge discovery, so that the result would have more information than the case when data sources were used individually.

Multi-sensor Data Fusion System

Three basic configurations:

- **Complementary:** The sensors do not directly depend on each other, but can be combined in order to give a more complete image of the phenomenon under observation.
 - **help to resolve the problem of *incompleteness*.**
- **Competitive.** Each sensor delivers an independent measurement of the same property.
 - **reduce the effects of uncertain and erroneous measurements.**
- **Cooperative.** It uses the information provided by two, or more, independent sensors to derive information that would not be available from the single sensors.

Complementary Data Fusion System: Example

*Multispectral Bilateral Video Fusion for night vision imagery**

- An infra-red (IR) image provides a bright and relatively low-noise view of a dark environment.
- IR image is difficult to interpret due to inconsistencies with the corresponding visible-spectrum image.
- A visible video input can be enhanced using information from a registered IR video input.

Original RGB



Histogram-stretch RGB



Original IR



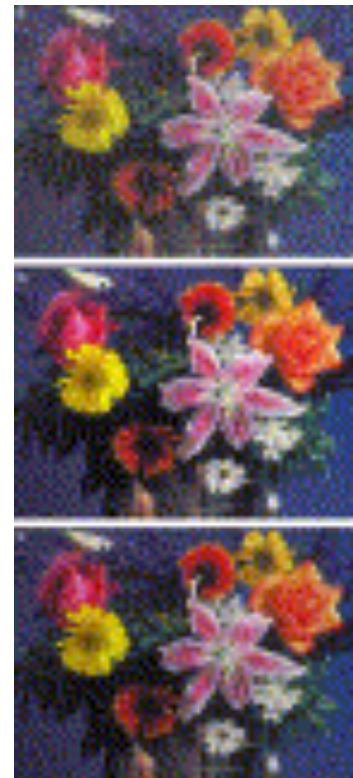
Fusion result



* By Bennett, Mason, and McMillan (2007)

Competitive Data Fusion System: Example

Noise suppression by competitive fusion of
several noisy inputs.

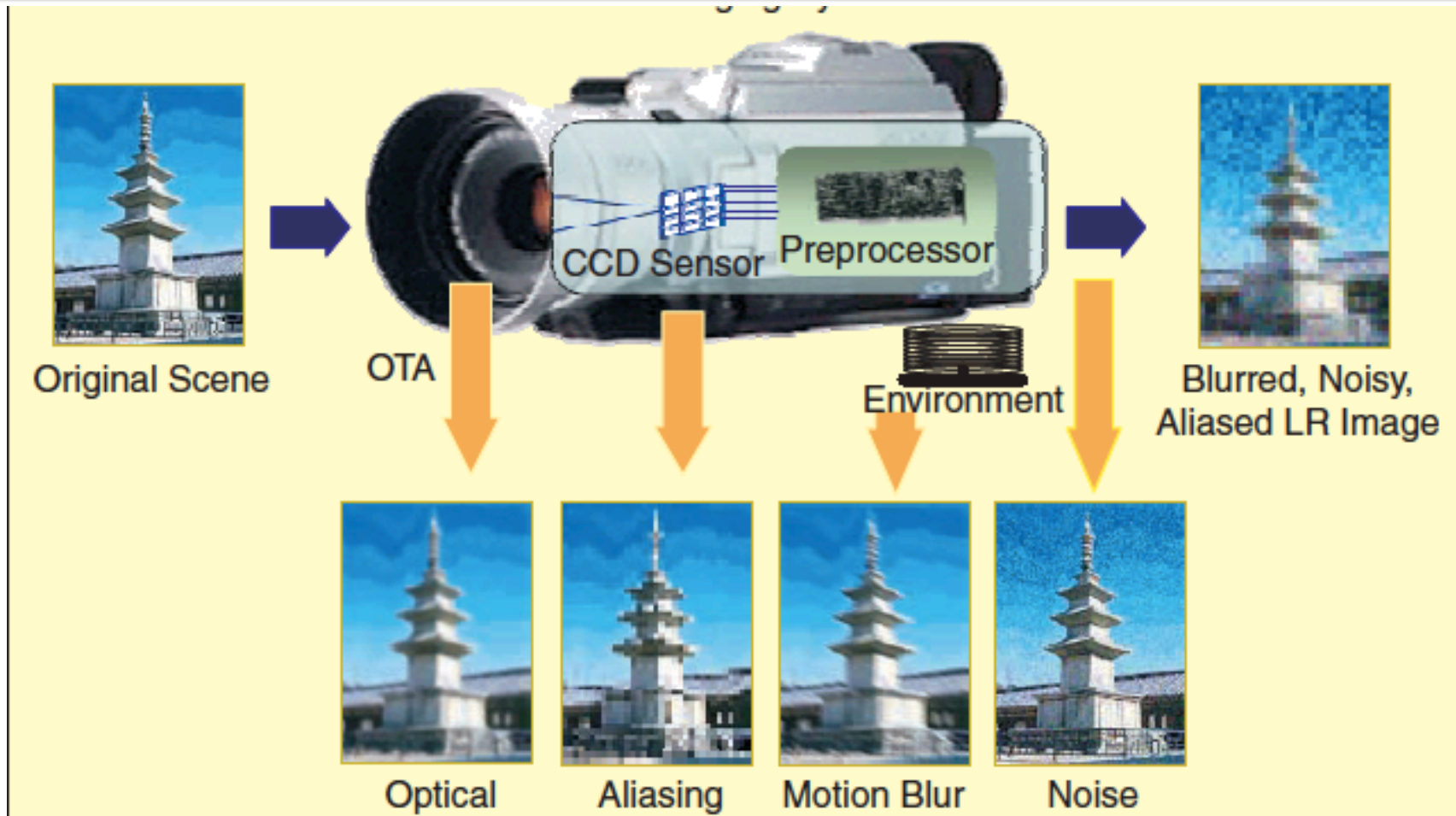


Cooperative Data Fusion System: Example

Super Resolution:

- *Cooperatively* fuse together two or more images of the same scene and taken by the same sensor but from slightly different viewing angles.
- The result is a new image which has higher spatial resolution than any of the input images.

Cooperative Data Fusion: Super Resolution



Park, Park, Kang (2003)

Types of Fusion:

Fusion Across Sensors

A number of sensors nominally measure the same property.

- **Example 1:** a number of temperature sensors measuring the temperature of an object.
- **Example 2: Flood Forecasting**
 - Fusing measurements of the
 - ground-based rain gauges, and
 - a weather radar system.



Types of Fusion:

Fusion Across Attributes

A number of sensors measure different quantities associated with the same experimental situation.

- **Example 1:** Multi-Modal Biometric Systems



Voice Signal



Palm Print



Ear Shape



Iris Image

Types of Fusion:

Fusion Across Attributes

■ Example 2: Fire Detection

- Urban-Rural Interface : zones where forest and rural lands interface with homes, other buildings and infrastructures.
- Detection and monitoring of a fire is very important. Different sensors to detect fire:
 - Temperature
 - Humidity
 - Vision



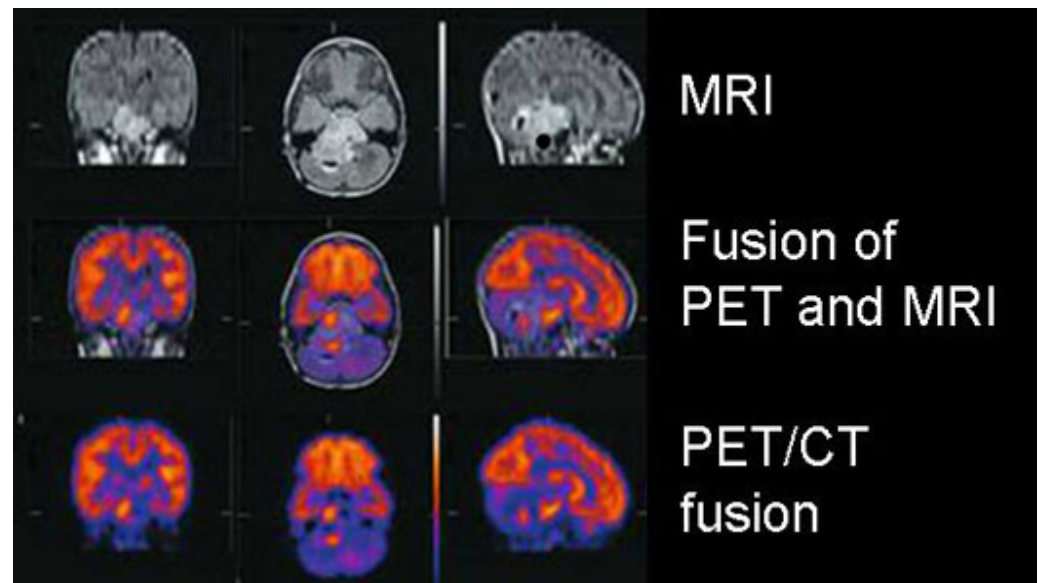
Types of Fusion:

Fusion Across Domain

A number of sensors measure the same attribute over a number of different ranges or domains.

- **Example:** Multi-Modal Medical Imaging

- **MRI:** soft tissue
- **CT** scan: skeleton or bone information
- **PET** scan: functional or physiological information



captured from Image Analysis Lab at the Boston's Children Hospital

Types of Fusion:

Fusion Across Time

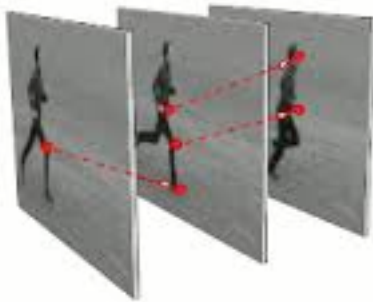
Current measurements are fused with historical information.

- **Example 1 :**

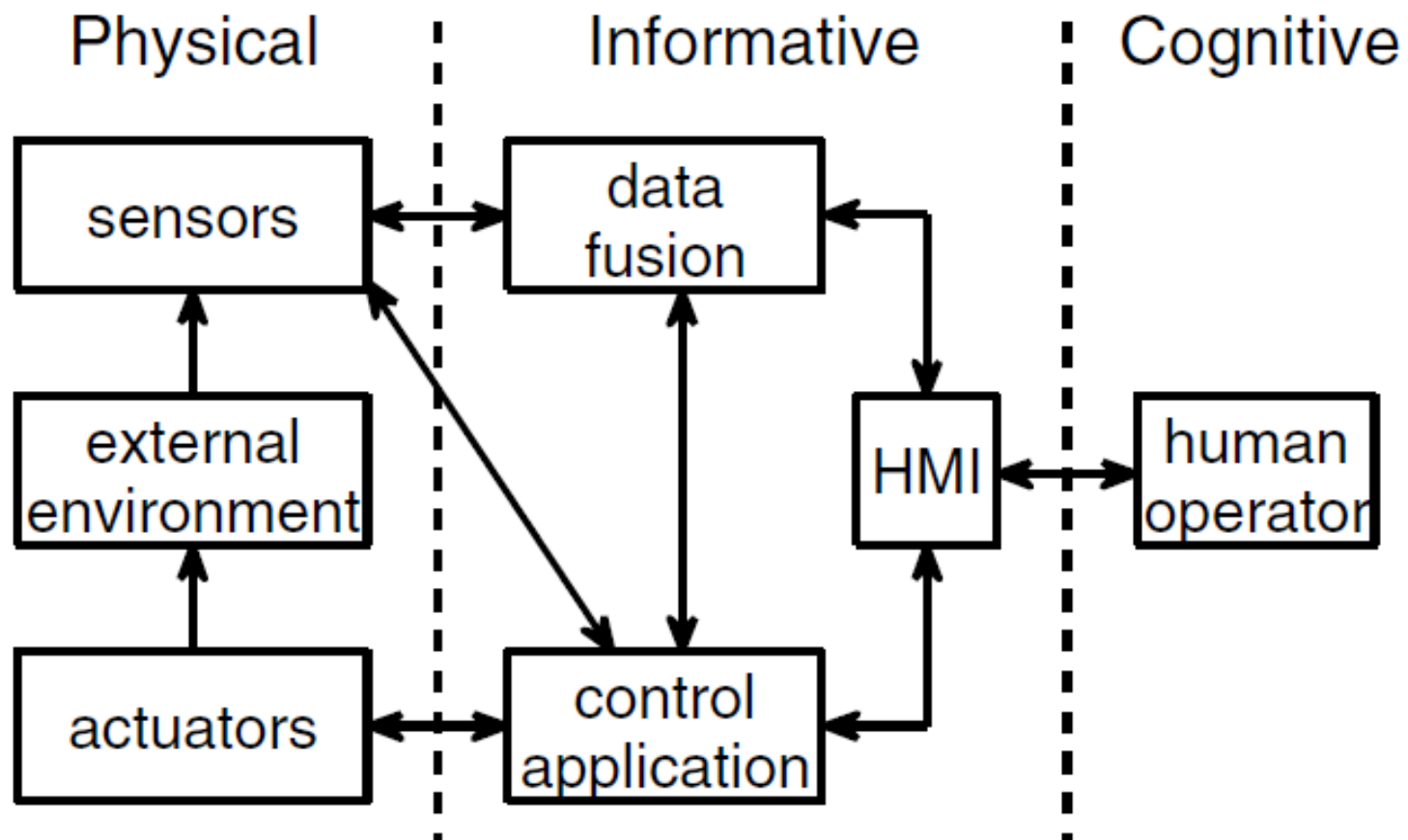
Speech Recognition System



- **Example 2:** Human Action Recognition System



Multi-Sensor Data Fusion System



Physical Domain: Hardware

- Contains the sensor modules physically interacts with the external environment.
- Each module contains a *sensor model*.
- Each *sensor model* contains the *description* of the measurements made by the sensor.
- If we want to change the external environment, then the physical domain will contain actuators, which are able to modify the external environment.

Informative Domain: Software

It contains three blocks

- **data fusion block**
 - constructed as an autonomous network of “fusion” modules,
 - responsible for combining all the sensor data into the form of “environmental image”.
- **control application/resource management**
 - responsible for all decisions which are made on the basis of the environmental image.
- **human-machine interface (HMI)**

Cognitive Domain: Human User

- In many applications the human user is the final arbiter or decision maker.
- The cognitive domain is responsible to transfer all the information to the human user into a form which is intuitively usable by the user for his decision-making process.

Basic Requirements of a Fusion Methodology

- **Transformation:** transferring the information stemming from heterogeneous sources into a common mathematical description; this step makes them compatible.
- **Fusion:** superposition of the transformed information.
- **Focusing:** concentrating the pooled information in order to derive specific statements for the problem at hand.