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Multi-sensor Fusion: Introduction

Multi-sensor Fusion- Introduction

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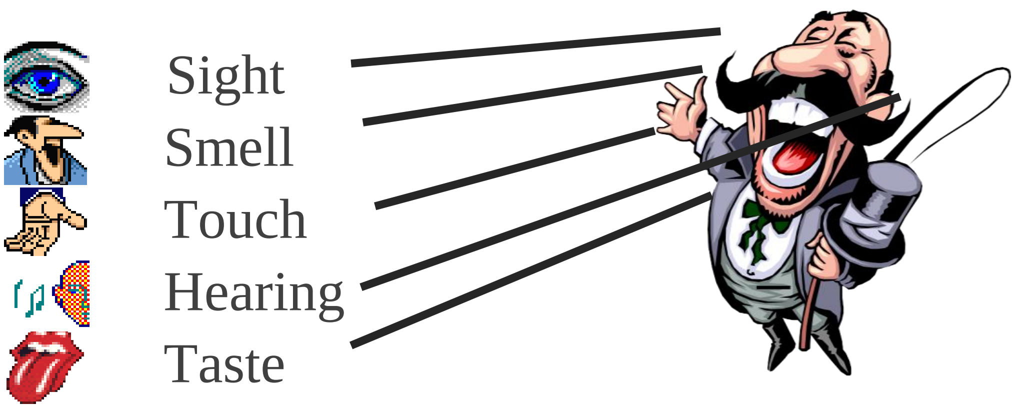
- Process of **combining data or information from various sensors to provide a robust and complete description** of an process of interest

Goal:

- To obtain a better understanding of some phenomenon introduce or enhance intelligence and system control functions

Human brain: Multi-sensor fusion



Advantages of Multi-sensor fusion

MDF provides following advantages over a single sensor :

- Improves accuracy
- Improves availability
- Reduces uncertainty
- Supports effective decision making
- Reduces transmission energy requirement as less data to be transmitted (thus increasing network battery lifetime).

Example 1: Military applications

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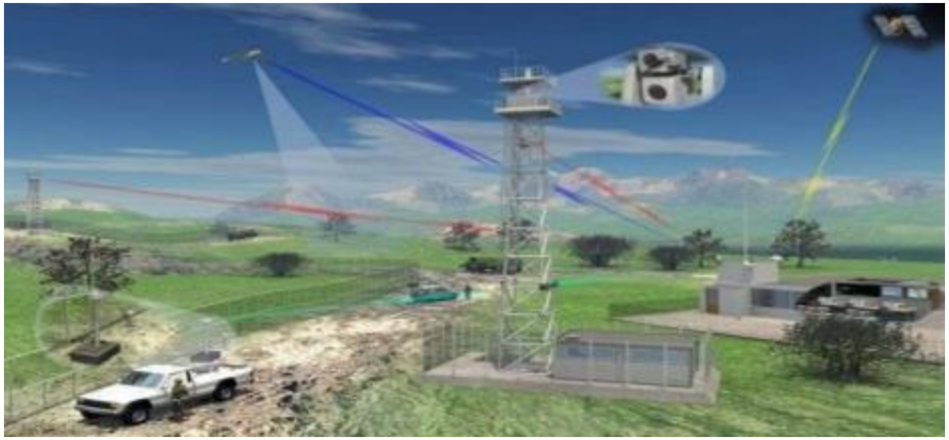
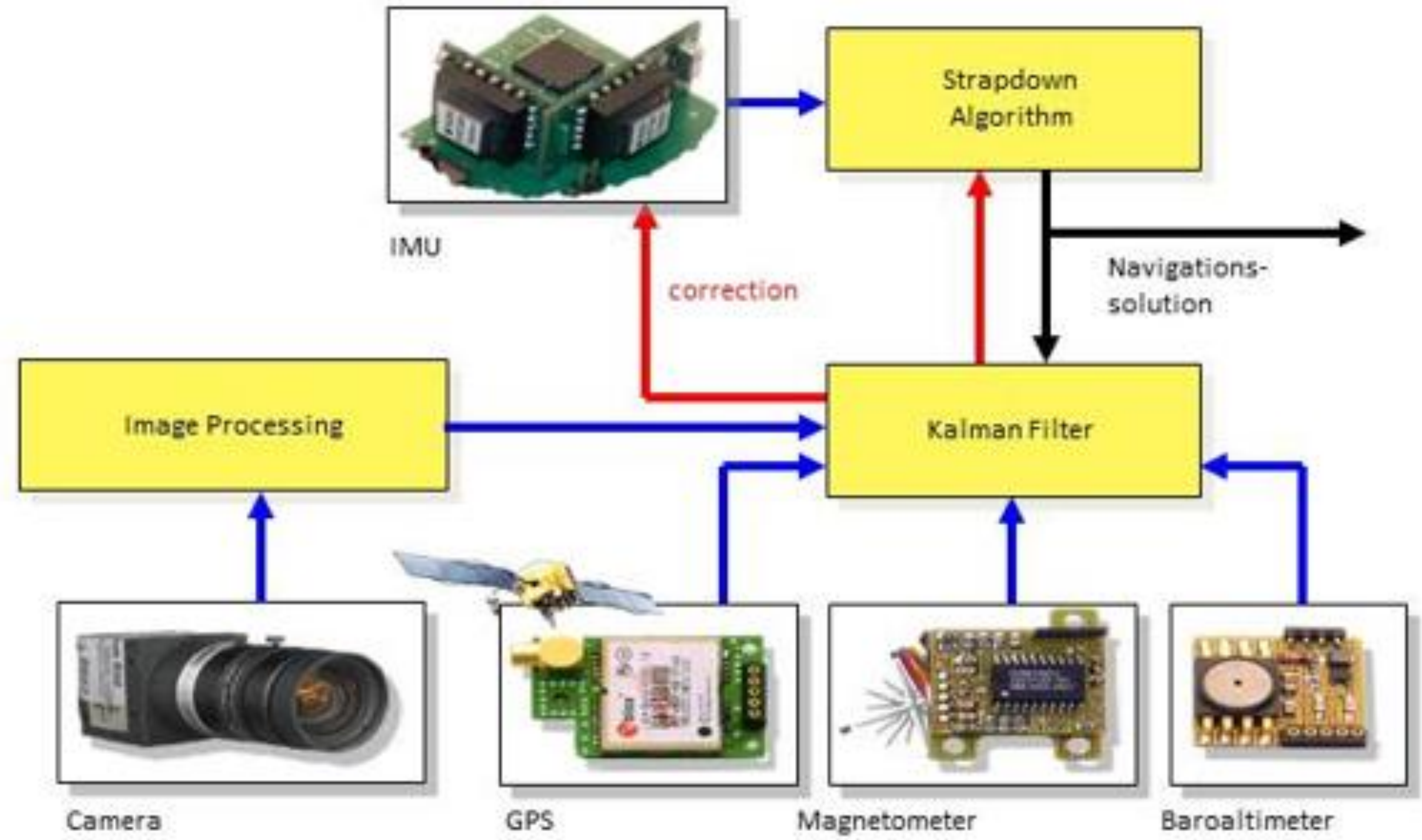
- Detection, location , tracking and identification of military entities.
- **Sensors**: radar, sonar, infrared, synthetic aperture radar (SAR), electro-optic imaging sensors etc.
- Complex problem
- Large number and types of sensors and targets
- Size of the surveillance volume
- Real-time operational requirements
- Signal propagation difficulties



Example 2: Navigation

- Smart Auto navigation of vehicle (based on sensor fusion on sensor data from camera, gps etc.)



https://www.ite.kit.edu/english/datenfusion.php

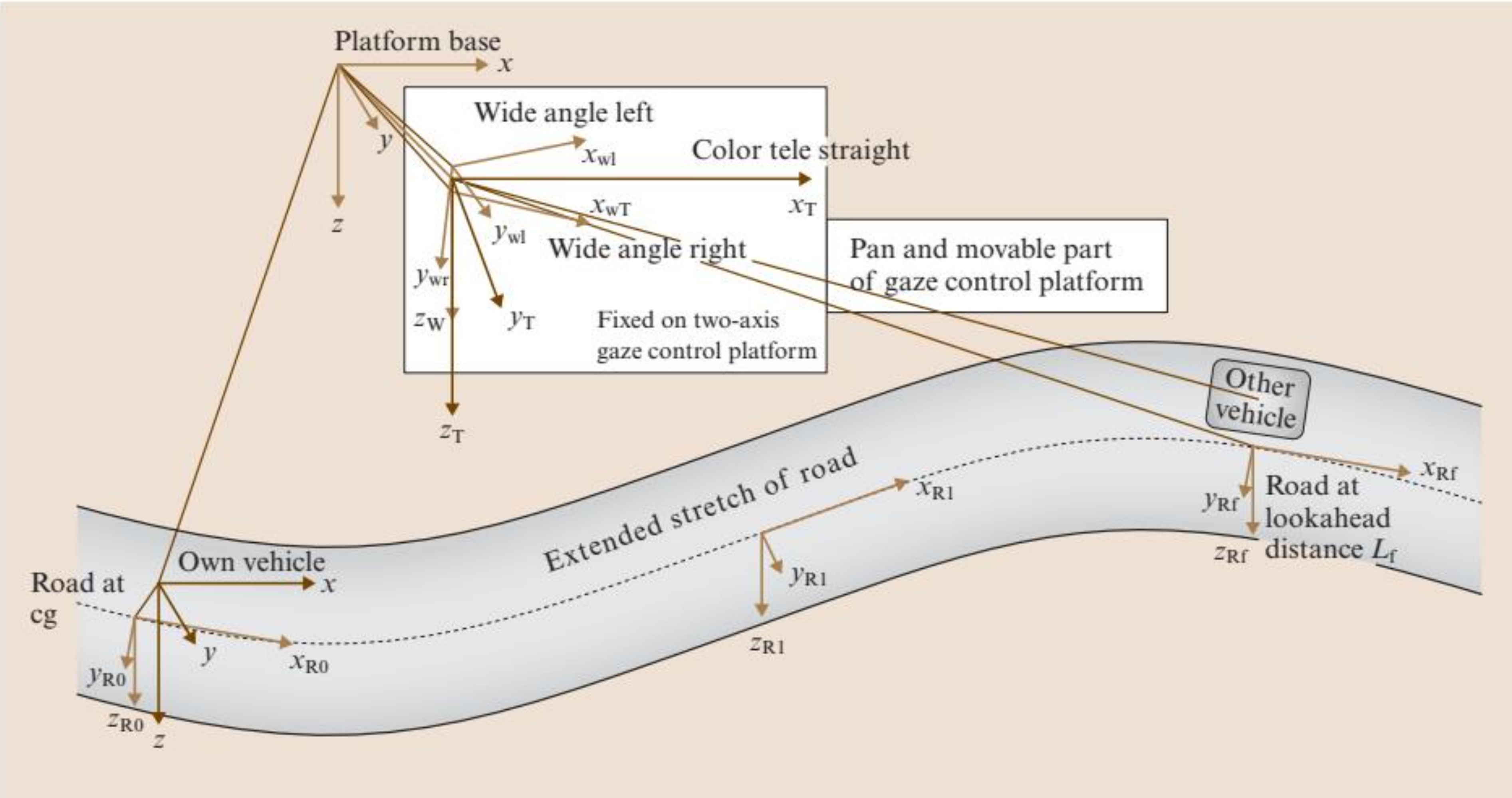
Case Study: Navigation

First fully autonomous vehicle on German autobahn

The first vehicle to drive fully autonomously on the German autobahn for 20 km and at speeds up to 96 km/h

Vehicle road scene

- Information from inertial and vision sensors is combined to produce a road scene



Vehicle sensing hardware

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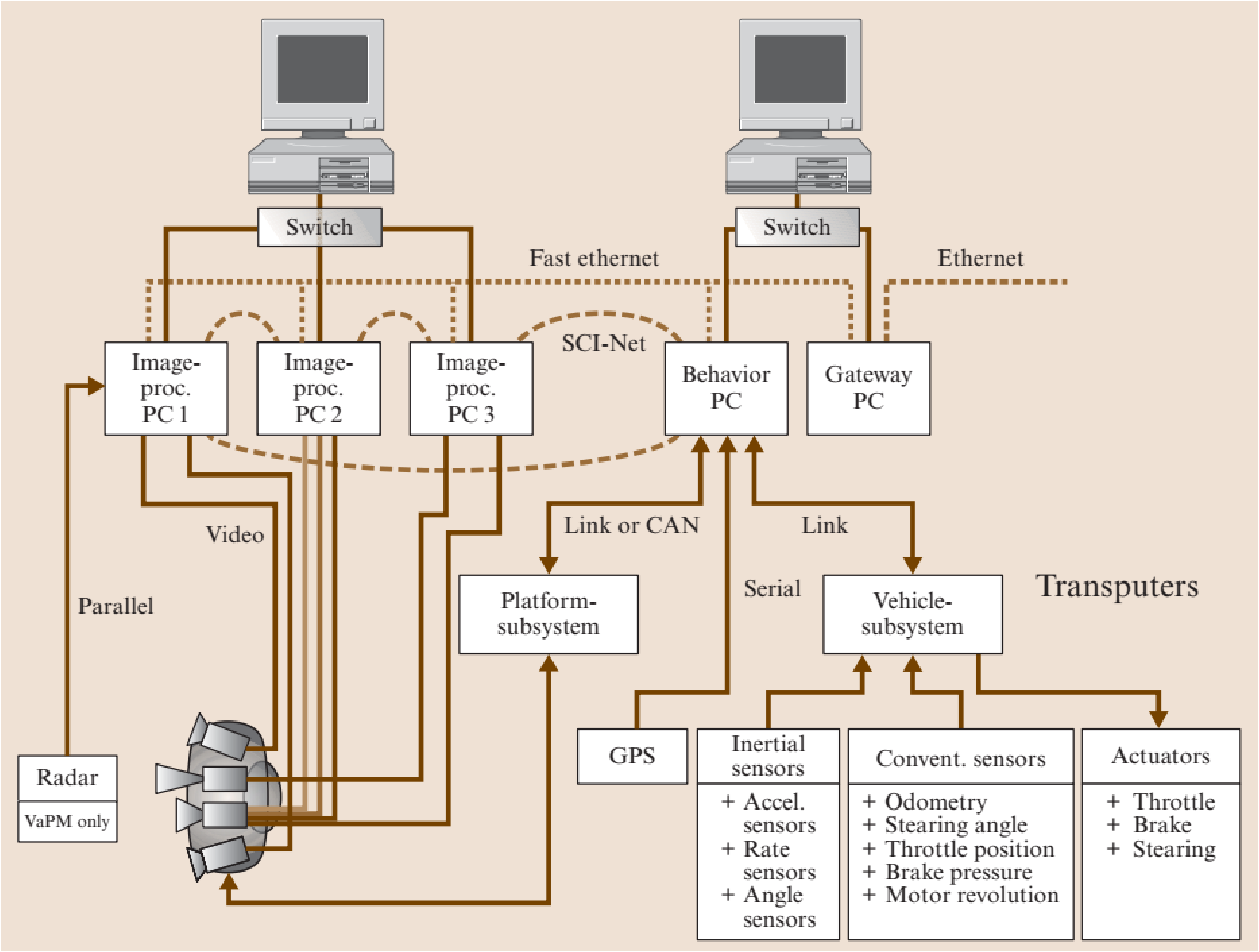
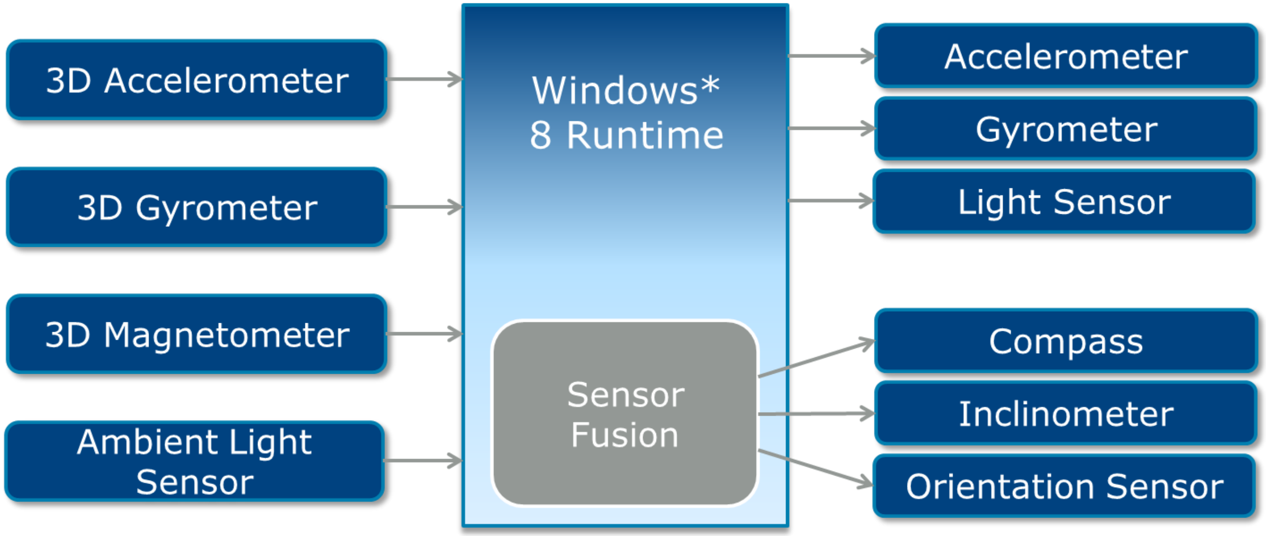


Example 3: Motion application

Applications:

- Augmented Reality
- Games
- Orientation
- Pedometer
- Navigation
- Remotely-controlled Devices
- Biofeedback



https://software.intel.com/en-us/articles/using-sensors-and-location-data-for-cutting-edge-user-experiences-in-mobile-applications

Example 4: Location detection

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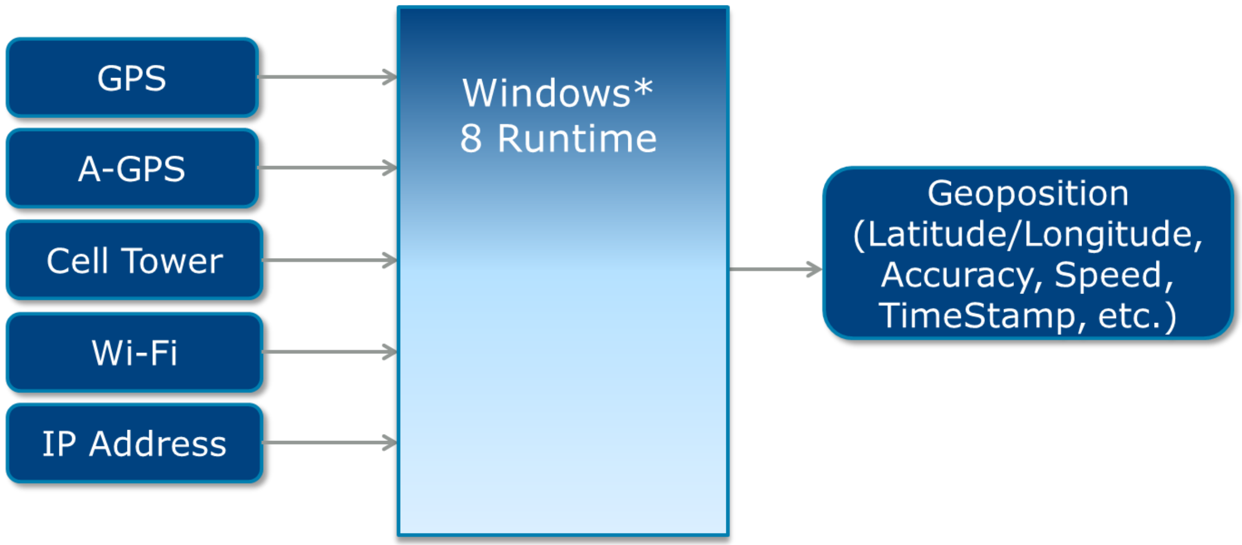
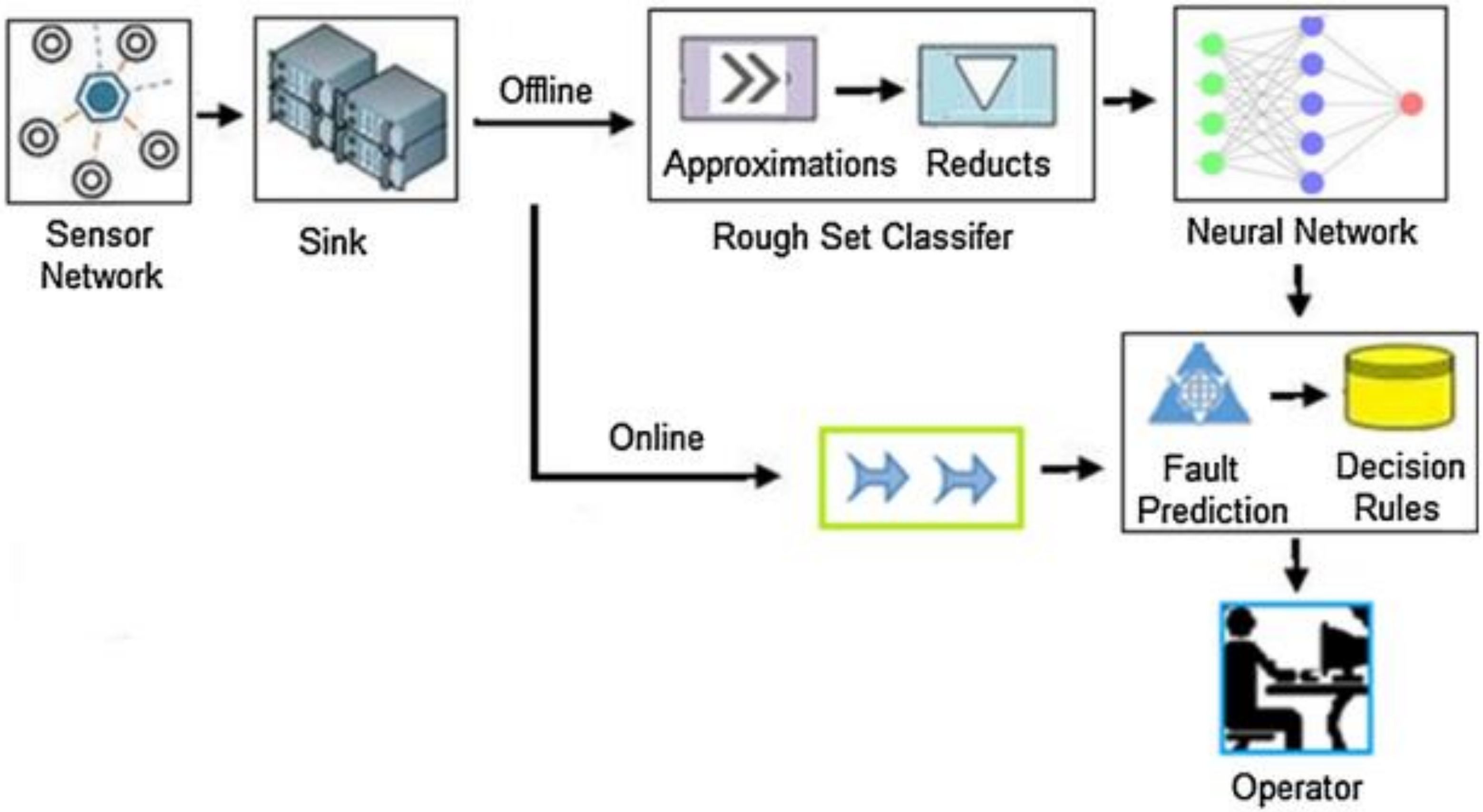
Applications:

- Search for Points of Interest (POIs)
- Geotagging ? adding location information to files such photos
- Games ? Geocaching
- Outdoors and fitness
- Pedestrian or vehicle navigation



https://software.intel.com/en-us/articles/using-sensors-and-location-data-for-cutting-edge-user-experiences-in-mobile-applications

Example 5: Water pollution monitoring



Sarvesh Rawat a,*, Surabhi Rawat “Multi-sensor data fusion by a hybrid methodology – comparative study” Elseiver Computers in Industry 75 (2016) 27–34

Challenges in MDF (Multi sensor data fusion)

Many challenges primarily arising from :

- sensor **data** to be fused
- **Imperfections** in sensor data
- **diversity** of the sensor technologies
- nature of the **application** environment

Challenges in MDF (Multi sensor data fusion)

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Data imperfection:

Some **inaccuracy** in the sensor data from one of the inputs can produce completely different result

Outliers and spurious data:

One needs to accommodate/ identify outliers and check if they are right values or due to sensor fault

Static vs. dynamic phenomena:

- the phenomenon under observation may be time-invariant or varying with time. In the latter case, it **may be necessary for the data fusion algorithm to incorporate a recent history of measurements into the fusion process**.

Challenges in MDF (Multi sensor data fusion)

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Conflicting data:

- At times different sensors may give inputs indicating different conclusion

Data modality:

- The data may be coming from **different kind of sensors like audio, visual** etc. , fusing which is a challenge.

Data alignment

- One needs to account/ be careful of the **calibration error** induced by individual sensor nodes.

Challenges in MDF (Multi sensor data fusion)

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Processing framework:

- data fusion processing can be performed in a **centralized or decentralized manner**.

Operational timing:

- the area covered by sensors may span a vast environment composed of different aspects varying in different rates. Also, in the case of homogeneous sensors, the operation frequency of the sensors may be different. A well-designed data fusion **method should incorporate multiple time scales** in order to deal with such timing variations in data. In distributed fusion settings, different parts of the data may **traverse different routes** before reaching the fusion center, which may cause **out of-sequence arrival of data**. This issue needs to be handled properly, especially in real-time applications, to avoid potential performance degradation.

Fusion architectures

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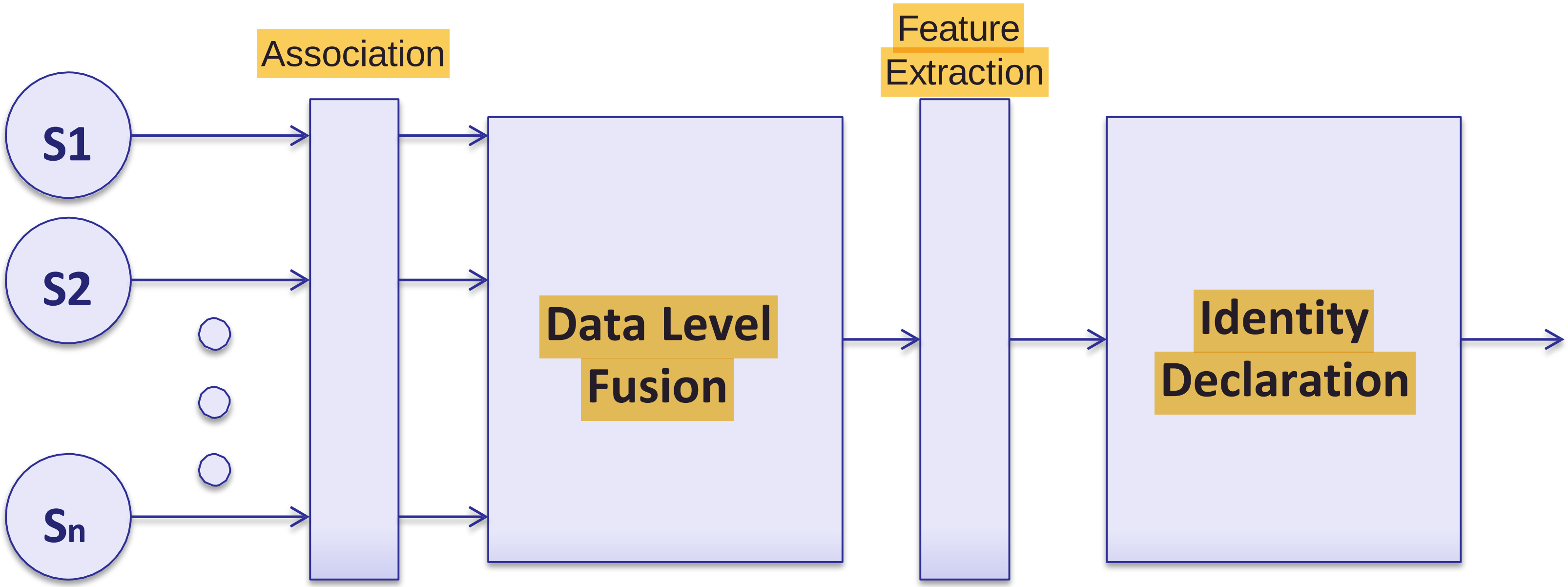
Data fusion can be categorized into 3 main classes based on the level of data abstraction used for fusion :

- Measurement Fusion (Sensor data Fusion)
- Feature-level Fusion
- Decision-level Fusion (High-level data Fusion)

Measurement Fusion

- Direct fusion of sensor data
- The sensors measuring the **same physical phenomena** are required.



Feature level Fusion

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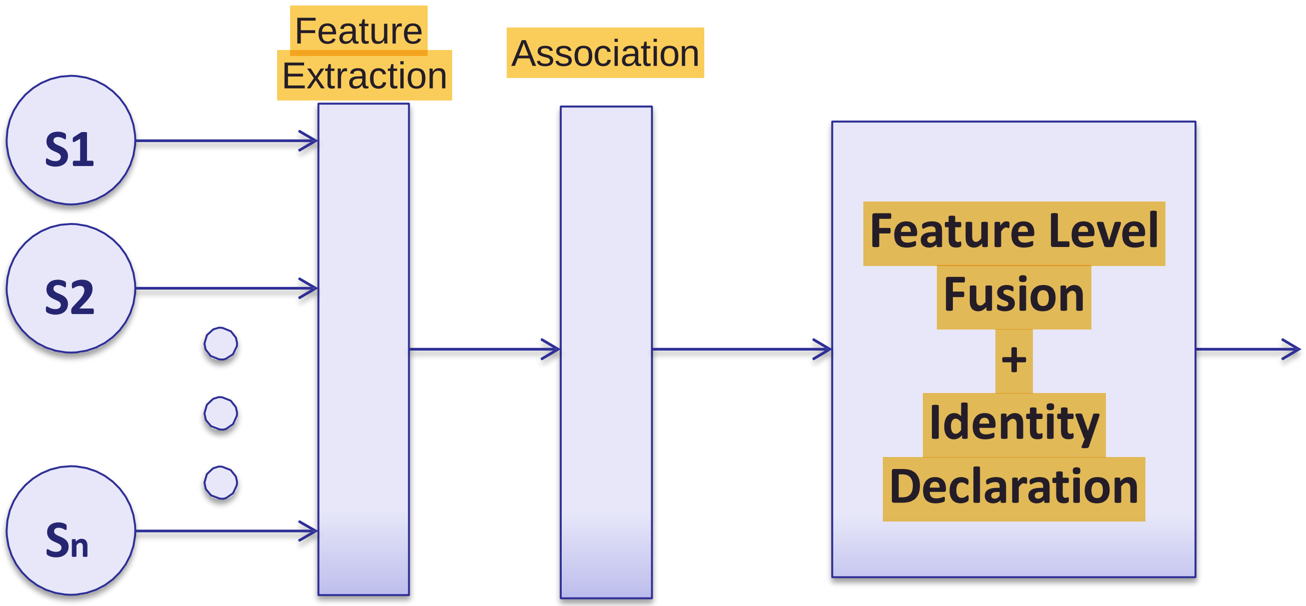
- Involves the extraction of representative features from sensor data
- Features are combined into a single concatenated feature vector that is an input to a fusion node



Decision-level Fusion

- Each sensor has made a preliminary determination of an entity's location, attributes and identity before combining