



Multi-sensor Fusion: Introduction

Multi-sensor Fusion- Introduction

- 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



Sight
Smell
Touch
Hearing
Taste



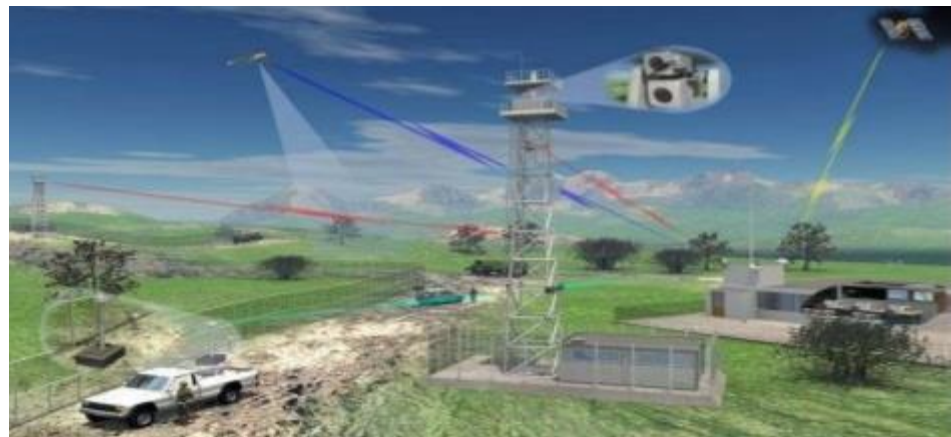
Advantages of Multi-sensor fusion

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).

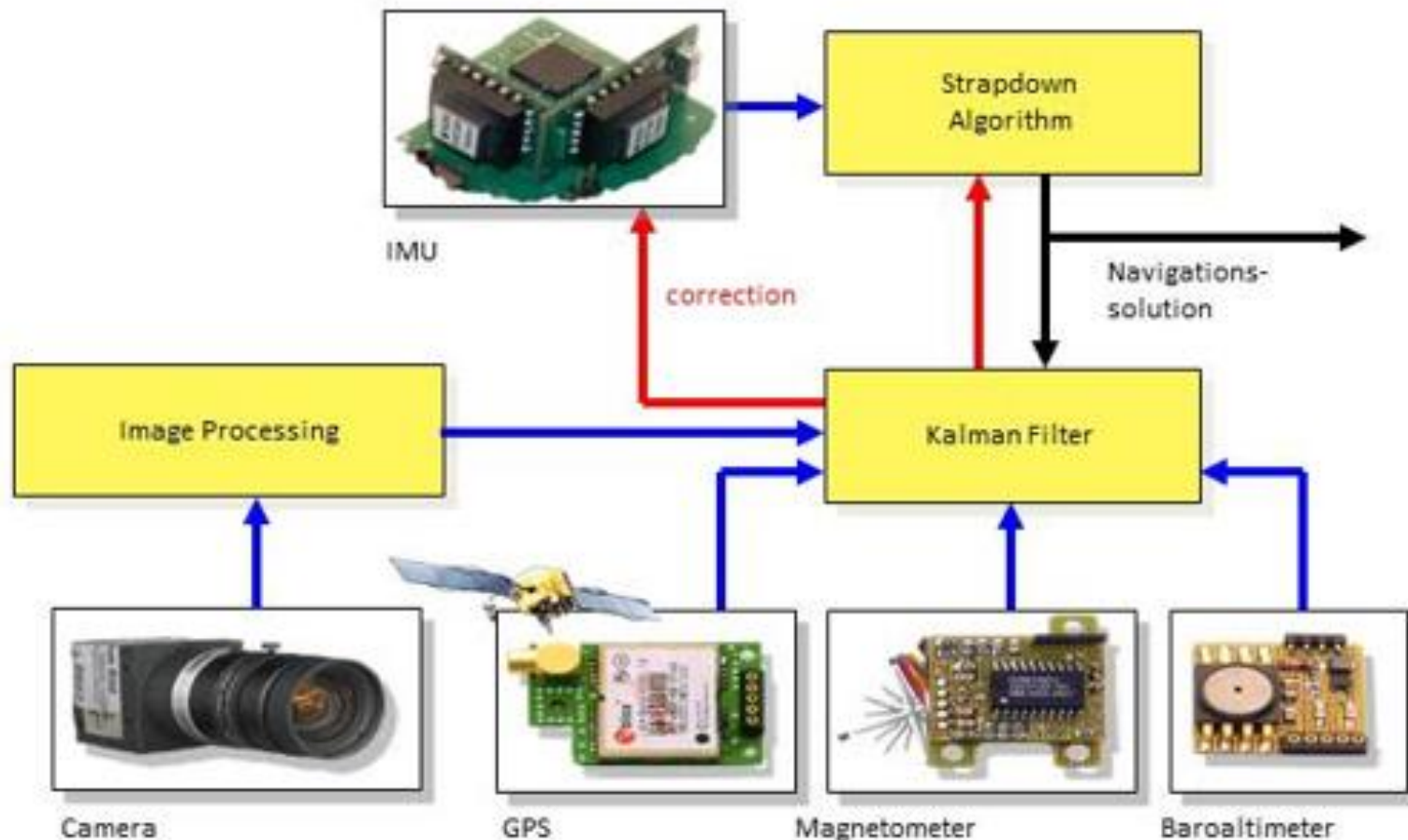
Example 1: Military applications

- 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.)



Case Study: Navigation



BITS Pilani

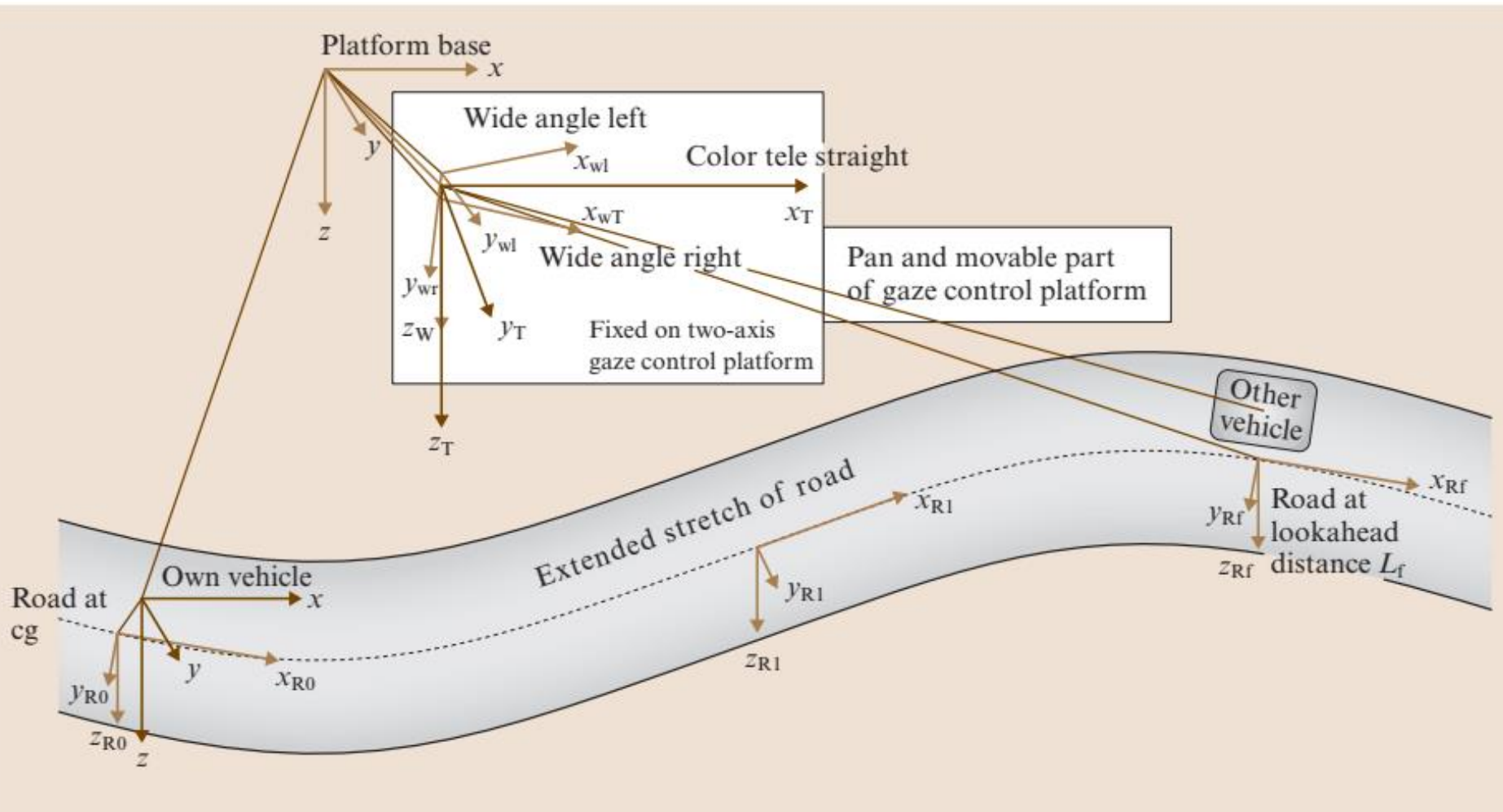


First fully autonomous vehicle on German autobahn

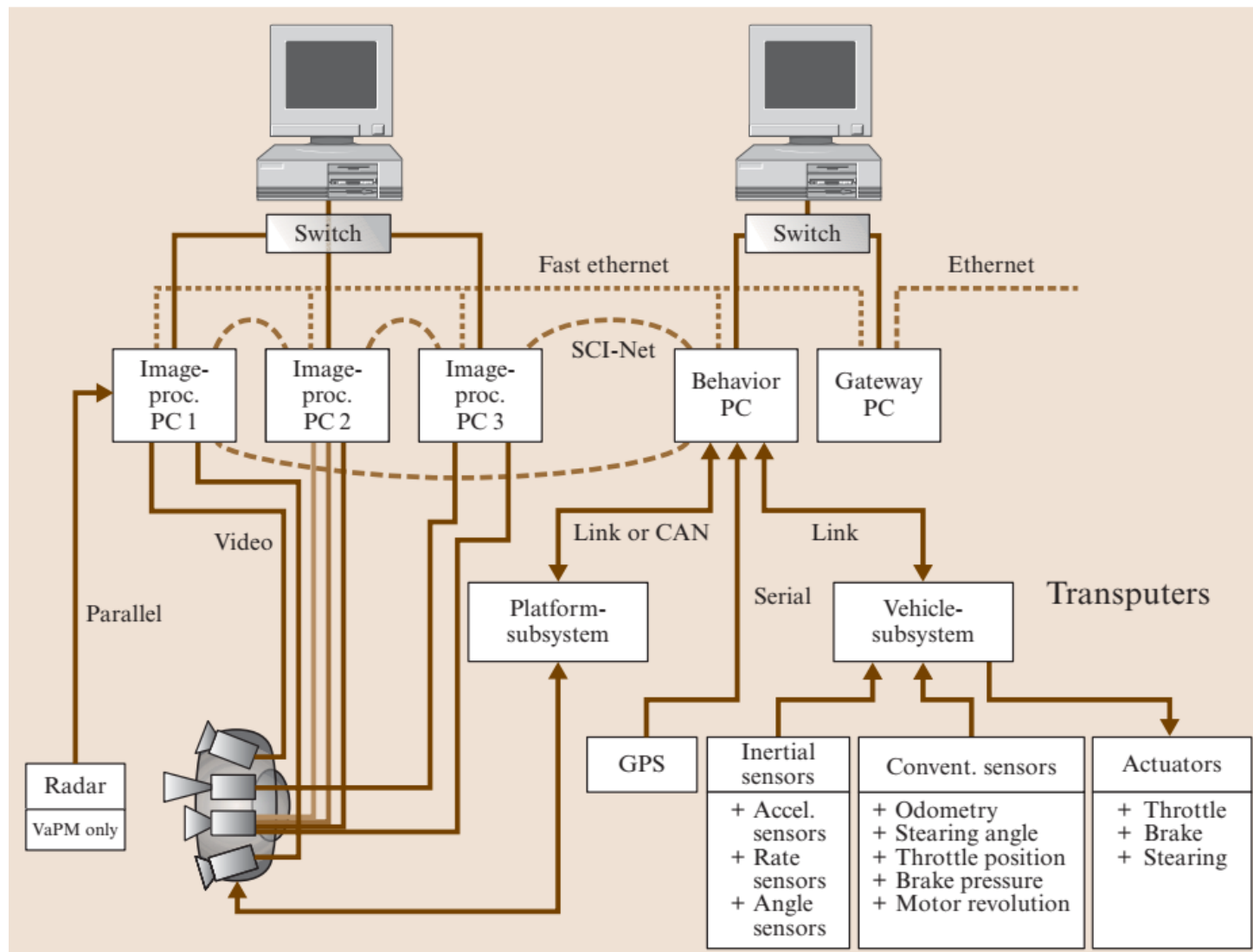
The first vehicle to drive fully autonomously on the German autobahn for 20 km and at speeds up to 96 km/h

Vehicle road scene

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



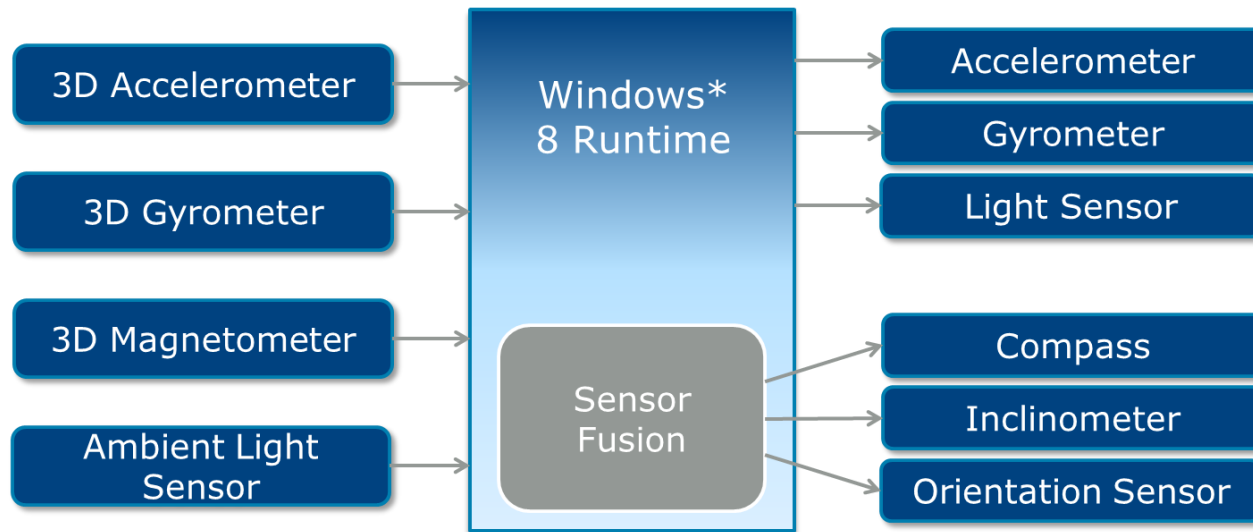
Vehicle sensing hardware



Example 3: Motion application

Applications:

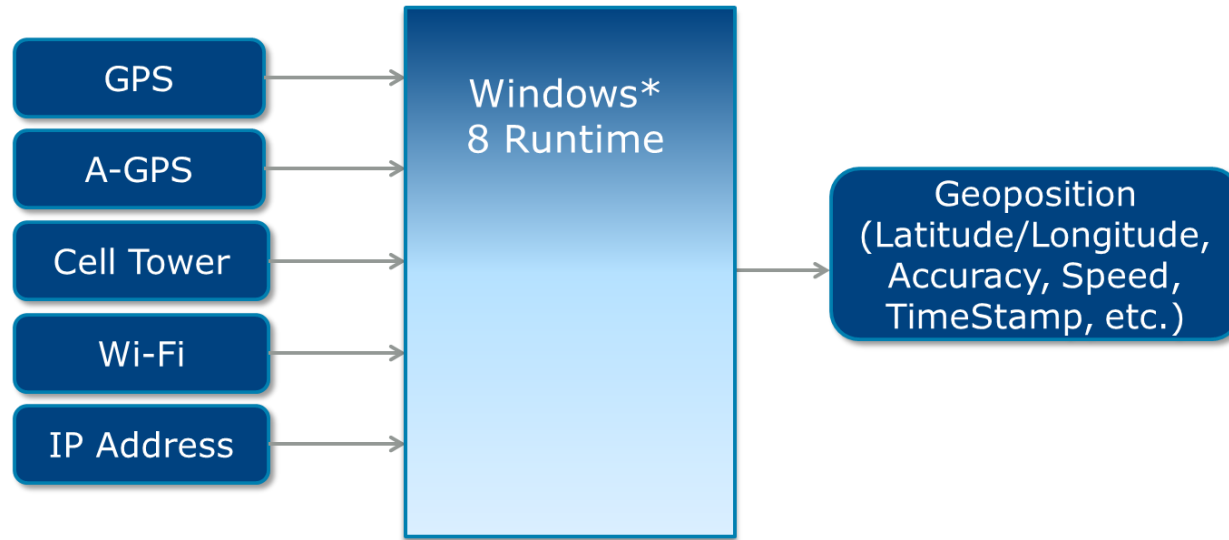
- Augmented Reality
- Games
- Orientation
- Pedometer
- Navigation
- Remotely-controlled Devices
- Biofeedback



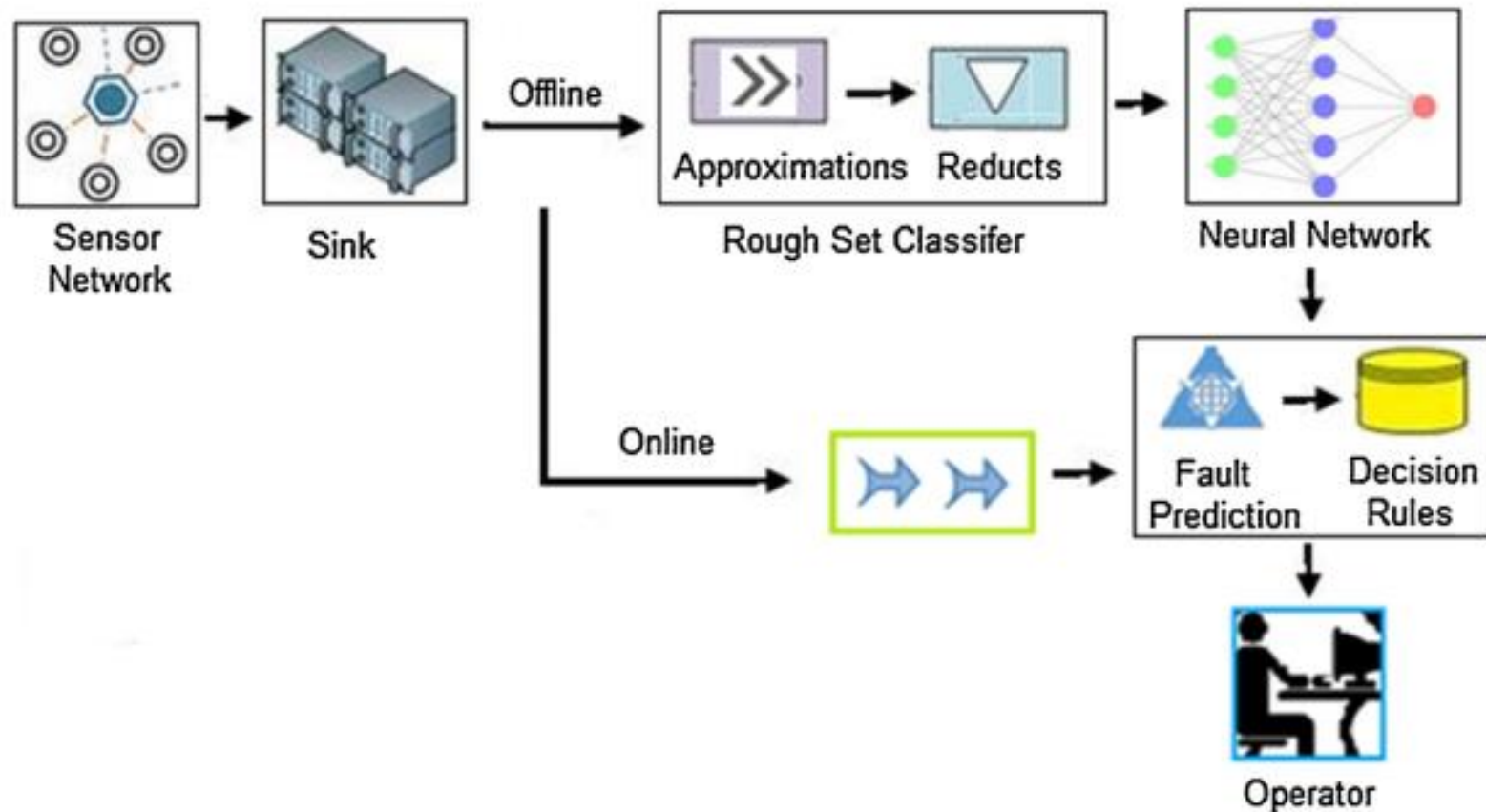
Example 4: Location detection

Applications:

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



Example 5: Water pollution monitoring



Sarvesh Rawat a*, Surabhi Rawat “Multi-sensor data fusion by a hybrid methodology – comparative study”
Elsevier 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)

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)

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)

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.

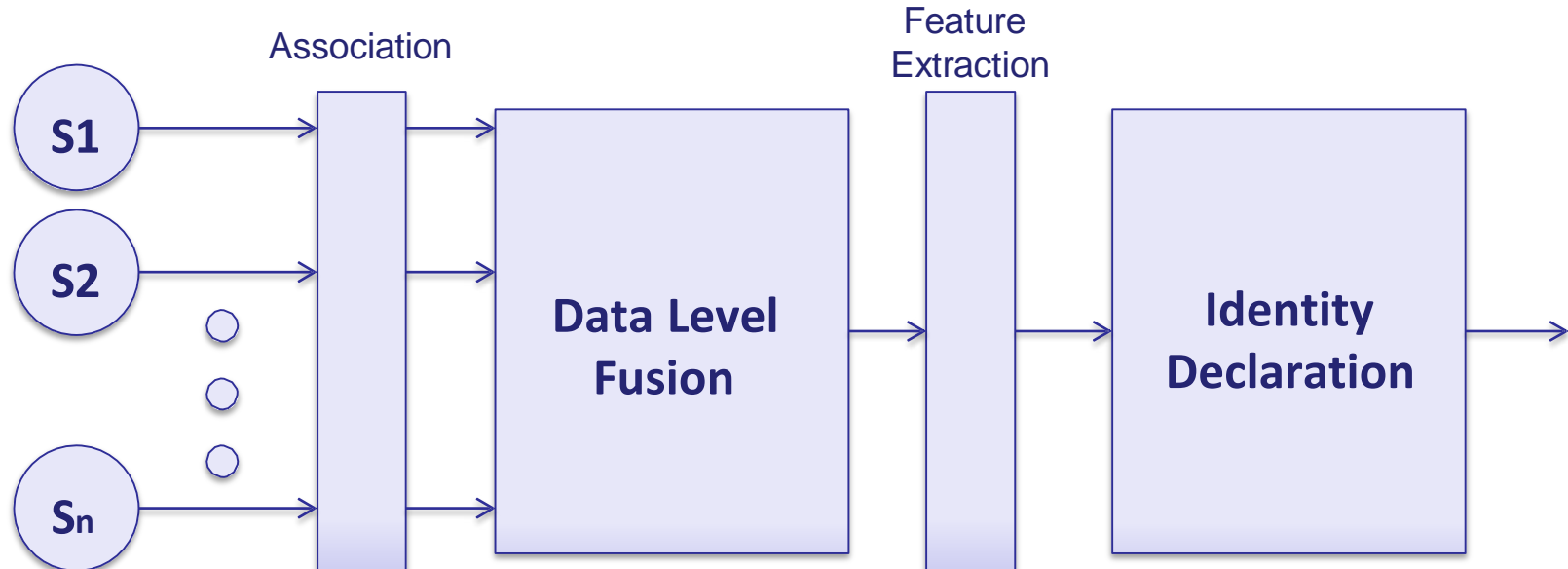
Fusion architectures

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)**

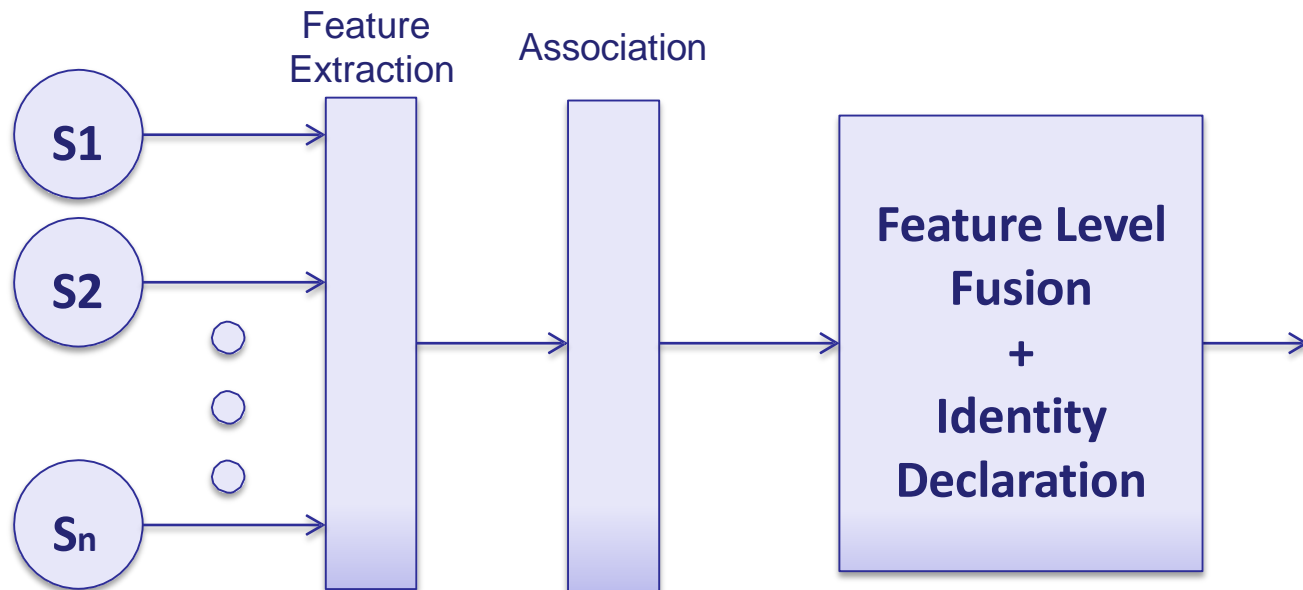
Measurement Fusion

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



Feature level Fusion

- 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

