

Sensor Signal Processing

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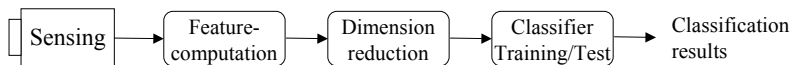
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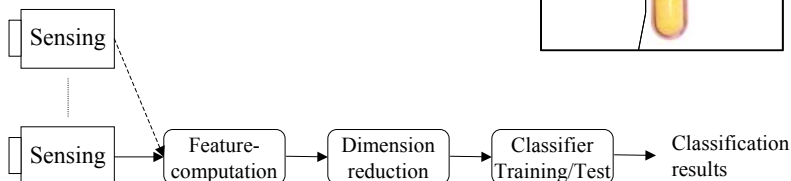
Motivation

Sensor Signal Processing Sensor Fusion

- The current treatment regarded only a **single source of sensorial information** for the design of the recognition system
- Examples from the lab are **grey-value sensor** (camera) or a **microphone**



- If the information is sufficient in the available modality, recognition performance will be satisfiable
- To **improve selectivity**, **(cross)-sensitivity**, and **stability**, **multi sensing** is applied

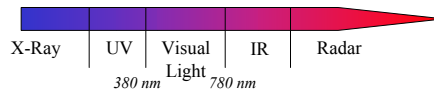
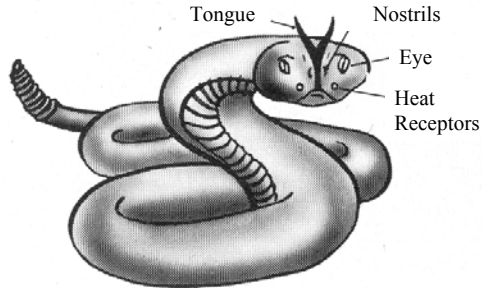
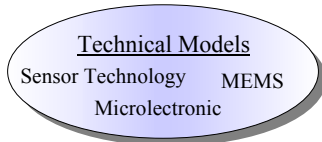
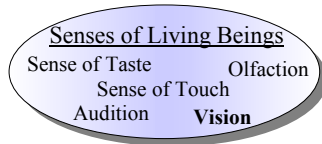


Sensor Signal Processing

Sensor Fusion

Motivation

- Additional sensor information, e.g., **color**, **3D**, **NIR**, **FIR** or general **hyperspectral information** can be **added and fused** in an architecture
- Exploitation of Bio-Inspiration, e.g., rattle-snake night vision



Most Complex Sense: **Vision**

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Sensor Signal Processing

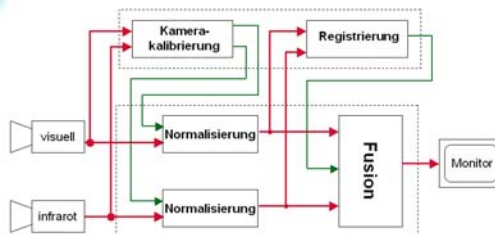
Sensor Fusion

Motivation

- Fusion more and more adapted by consumer applications:



Night-Vision in Automotive Applications*:



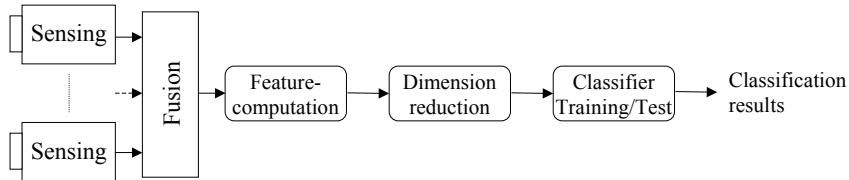
- Information unique to visual/IR domain
- Appropriate sensor fusion required
- Embedded real-time capable solution mandatory

*Courtesy BMW AG, Munich, T. Weidner, H. Hahn

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Sensor-Level Fusion

- On the most basic level, **raw sensor information** is **fused** before computation of features and higher-level recognition processes:

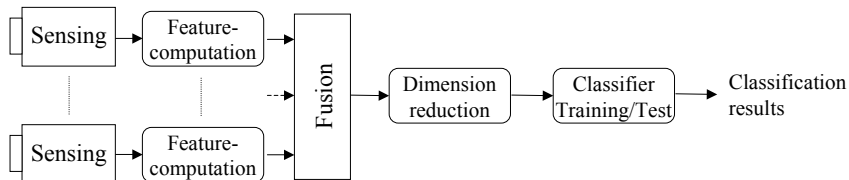


- Basic preprocessing and/or normalization can take place before fusion
- Fusion result commonly is again a structure of the same organization, than the original acquired sensor data
- In the case of **image processing**, quasi *retinotopic* processing returns an **image as fusion result**
- Individual **channel resolution might not match**, e.g., 3D-dimension is commonly much less than grey-value resolution
- Under this constraint **fusion** takes commonly place as, e.g., a **weighted** or scaled **addition** of the sources

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Feature-Level Fusion

- On the next level, **feature information** computed for the individual channels **fused** before higher-level recognition processes:

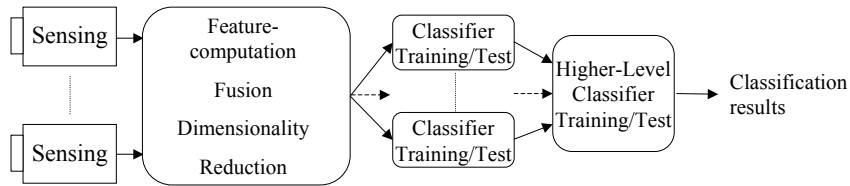


- **Straightforward** fusion **concatenates feature vectors**
- Weighting schemes or similar operations feasible, correspond to DR !
- **Fusion** of features can take place for **complete registrations**, e.g., images, or for **subregions/windows** (**micro classification**)
- Neglecting salient DR, the fused (concatenated) feature vector is handed-on towards the classifier
- Color image registration is one simple example, where every **color channel** can serve separately for **same/different** feature computation

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Decision-Level Fusion

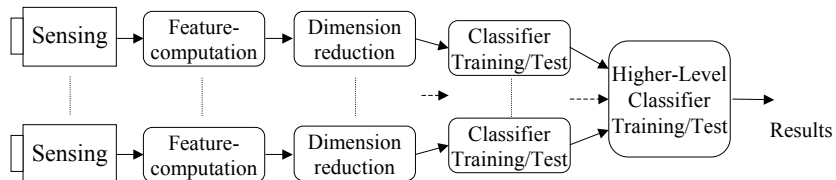
- On the following level, **decision information** computed from individual classifiers can be **fused** to obtain more robust higher-level recognition



- The individual performance differences of classifiers was discussed
- Intuitively: **combination of several classifiers** should **improve results**
- **Hierarchical classification** can be applied, employing **multiple classifier** models fed by **identical feature** data
- Individual decisions are fused for final decision making, e.g., by **voting** or **pdf fusion** (s. NDS/NLS)
- The master classifier receives $k \cdot L$ pdf inputs of k slave classifiers
- Hierarchy expansion: expert classifiers for **pair/groupwise** class separation

Decision-Level Fusion

- The **decision-level fusion** process can be extended by generalizing from **identical to individual features** per classifier in the hierarchy:

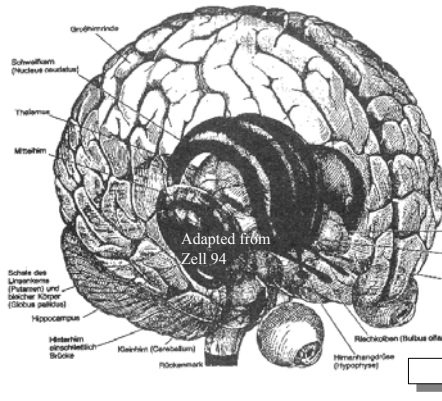


- Each slave classifier now receives different (reduced) features
- In **RCE systems**, **basic & fast feature computation** sufficient for most decisions was applied; hard cases report as **ambiguous** and **invoke** more **extensive feature computation** and **hierarchical decision making**
- **Homogeneous or heterogeneous slave classifiers** can be employed
- Higher-level decision making by voting or pdf exploitation fuses the individual information channels
- **Slave classifiers** could **recursively** be **hierarchical classifiers** themselves

Sensor Signal Processing Sensor Fusion

Summary

- Nature makes wide-spread use of diverse sensors and fusion

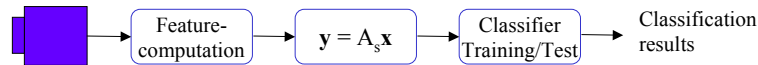


Example by functions of human visual system:

- Saccades (Ocular motorics)
- Stereo vision
- Colour vision
- Motion detection/estimation
- Invariant feature extraction (Hyper columns)
- Figure/ground separation
- Gestalt theory

Recognition, Understanding, Acting

- Technical cognition systems still mostly nutshell models of bio-evidence:



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Sensor Signal Processing Sensor Fusion

Summary

- The chapter gave a survey of basic concepts of multisensor fusion
- The topic has been well-visited for many decades, in particular due to massive military interest for satellite and aerial image analysis
- For reconnaissance purposes, the fusion of visible range, IR, and radar where in particular regarded and fusion methods developed
- Currently, hyperspectral sensors add much power to the approach
- More and more commercial, non-military applications benefit from the gathered experience, e.g., night vision in automotive applications
- Fusion techniques are not limited to compatible sensor organisation, e.g., visual and auditory data can be fused for speech recognition by fusing lip reading from image data and speech data processing results
- This chapter just scratched the surface

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