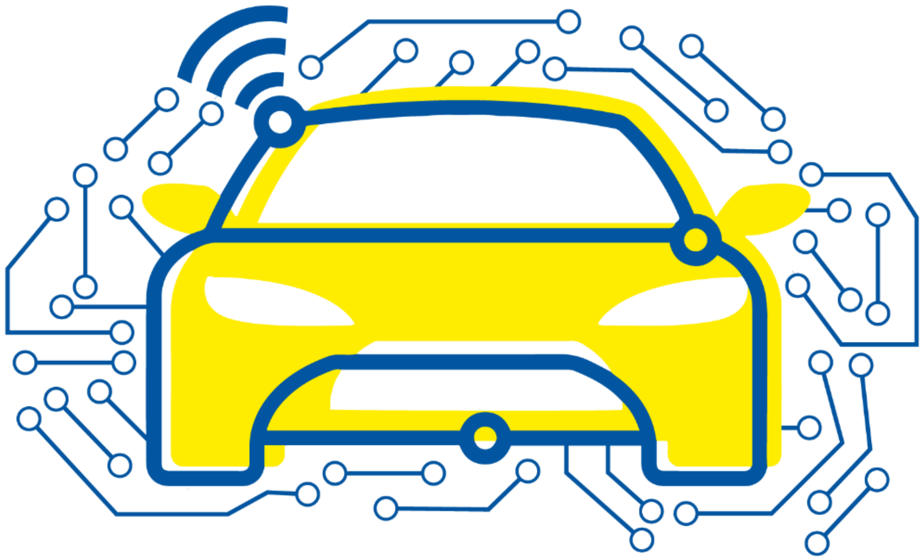
Automated and Connected Driving Challenges

Section 3 – Object Fusion and Tracking

Object Association



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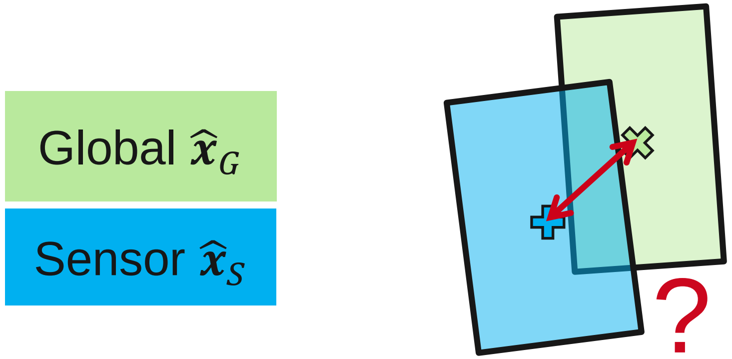
Object Fusion and Tracking

Object Association



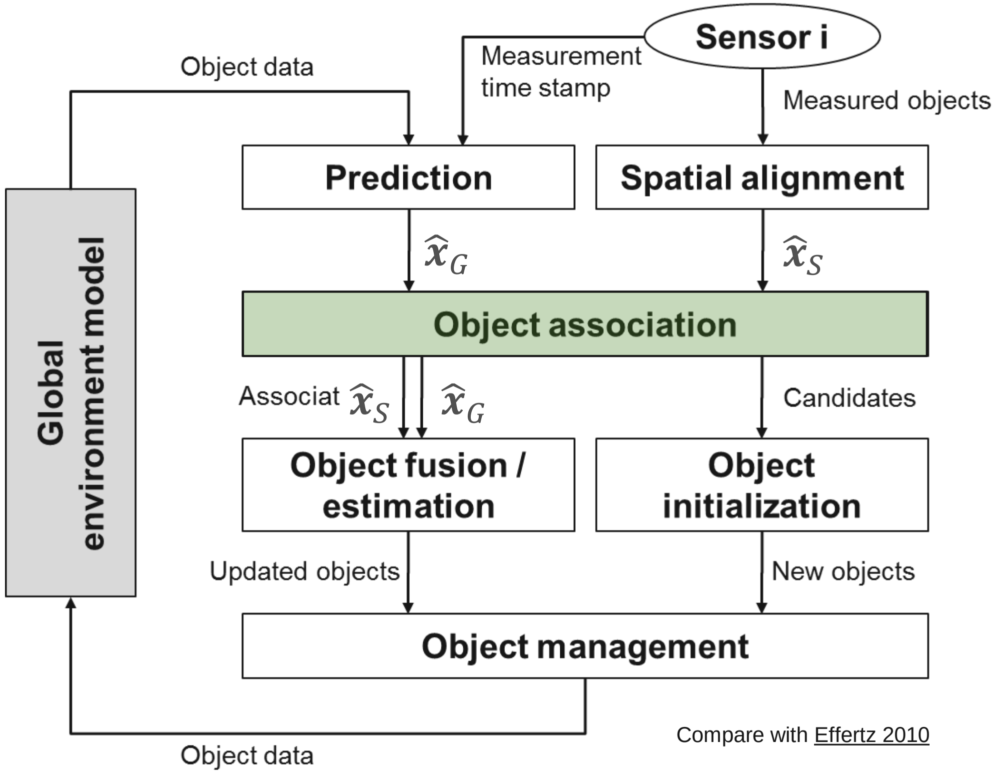
Does the sensor-level object actually belong to the global object?

- Difficult in case of multiple objects per list

→ Association criterions:

  - Method 1: Object overlap must be bigger than a threshold
  - Method 2: Object distance must be smaller than a threshold

→ Introduce **Intersection over Union** IoU and **Mahalanobis distance** $d_{G,S}$ as association measures



Compare with Effertz 2010

Object Fusion and Tracking

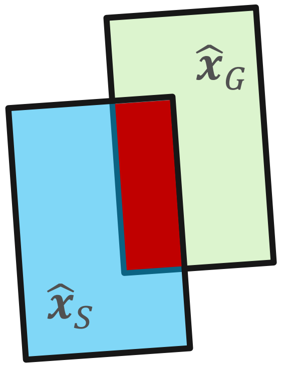
Object Association

Intersection over Union

$IoU = \frac{A_{intersection}}{A_{union}}$	**Intersection over Uníon**, with …
$A_{intersection}$	Overlapping area of the bounding boxes
$A_{union} =$ $A_G + A_s - A_{intersection}$	Combined area of both bounding boxes
$K_{threshold}$	Association threshold

Simplifications:

- Only consider the bounding boxes in the x-y plane
- Assume that the axes of all objects are aligned



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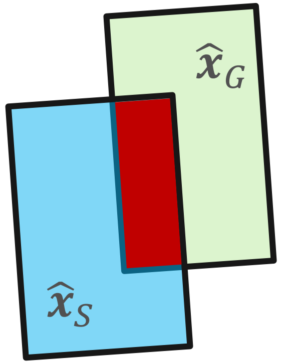
$A_{intersection}$	Overlapping area of the bounding boxes
$A_{union} =$ $A_G + A_s - A_{intersection}$	Combined area of both bounding boxes
$K_{threshold}$	Association threshold

If $IoU > IoU_{threshold}$, the sensor-level object $\hat{\boldsymbol{x}}_S$ and the global object $\hat{\boldsymbol{x}}_G$ actually belong to each other.

Note: In the code, we also have to account for non overlapping objects

Simplifications:

- Only consider the bounding boxes in the x-y plane
- Assume that the axes of all objects are aligned



Object Fusion and Tracking

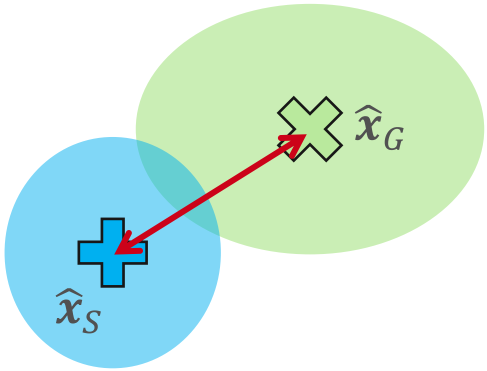
Object Association

Mahalanobis distance:

"How many error standard deviations are the two objects away from each other?"

$$d_{G,S} = \sqrt{\boldsymbol{\Delta\tilde{x}}^T \, \boldsymbol{S}_{S,G}^{-1} \boldsymbol{\Delta\tilde{x}}}$$

Mahalanobis distance, with …



Object Fusion and Tracking

Object Association

Mahalanobis distance:

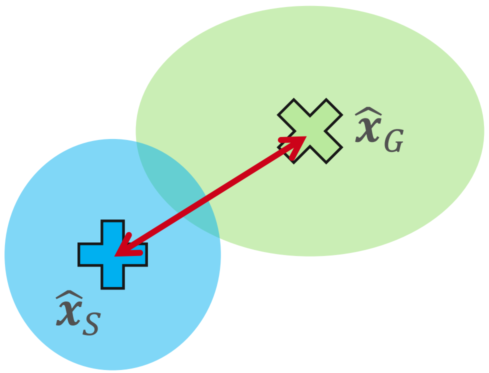
"How many error standard deviations are the two objects away from each other?"

$d_{G,S} = \sqrt{\boldsymbol{\Delta\tilde{x}}^T \, \boldsymbol{S}_{S,G}^{-1} \boldsymbol{\Delta\tilde{x}}}$	**Mahalanobis distance**, with …
$\boldsymbol{\Delta\tilde{x}} = \boldsymbol{H}(\boldsymbol{\hat{x}}_S - \boldsymbol{\hat{x}}_G)$	Differences between object states in x and y positions

Simplification:
Only compute Mahalanobis distance in x-y-plane:

$$\begin{array}{cc} & \begin{array}{cccccccccc} x & y & z & v_x & v_y & a_x & a_y & l & w & h \end{array} \\ \boldsymbol{H} = & \begin{bmatrix} 1 & 0 & 0 & & & & & & & \\ 0 & 1 & 0 & \ldots & & & & & & \end{bmatrix} \end{array}$$

$\boldsymbol{H}$ maps a full state vector onto the x-y-plane by discarding all other values



Object Fusion and Tracking

Object Association

Mahalanobis distance:

"How many error standard deviations are the two objects away from each other?"

$d_{G,S} = \sqrt{\Delta\tilde{\boldsymbol{x}}^T \, \boldsymbol{S}_{S,G}^{-1} \Delta\tilde{\boldsymbol{x}}}$	**Mahalanobis distance**, with …
$\Delta\tilde{\boldsymbol{x}} = \boldsymbol{H}(\hat{\boldsymbol{x}}_S - \hat{\boldsymbol{x}}_G)$	Differences between object states in x and y positions
$\boldsymbol{S}_{S,G} = \boldsymbol{H}(\boldsymbol{P}_S + \boldsymbol{P}_G)\boldsymbol{H}^T$	Error covariance matrix of these differences, also only in x and y positions

Simplification:
Only compute Mahalanobis distance in x-y-plane:

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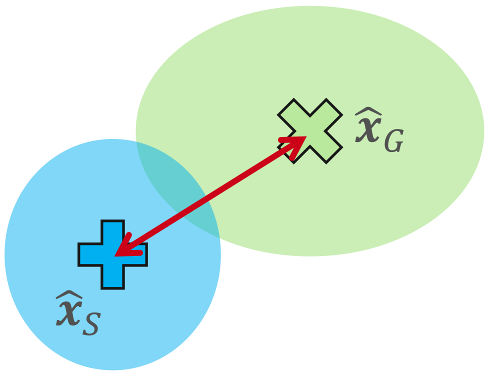

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$\boldsymbol{\Delta\tilde{x}} = \boldsymbol{H}(\boldsymbol{\hat{x}}_S - \boldsymbol{\hat{x}}_G)$	Differences between object states in x and y positions
$\boldsymbol{S}_{S,G} = \boldsymbol{H}(\boldsymbol{P}_S + \boldsymbol{P}_G)\boldsymbol{H}^T$	Error covariance matrix of these differences, also only in x and y positions
$K_{threshold}$	Association threshold

If $d_{G,S} < K_{threshold}$, the sensor-level object $\boldsymbol{\hat{x}}_S$ and the global object $\boldsymbol{\hat{x}}_G$ actually belong to each other.

Simplification:
Only compute Mahalanobis distance in x-y-plane:

$$\begin{array}{cc} & \begin{array}{cccccccccc} x & y & z & v_x & v_y & a_x & a_y & l & w & h \end{array} \\ \boldsymbol{H} = & \begin{bmatrix} 1 & 0 & 0 & & & & & & & \\ 0 & 1 & 0 & \dots & & & & & & \end{bmatrix} \end{array}$$

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