Generic estimation problems for robotic navigation

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ARS4

Robotic navigation

- Navigation is a field of study that focuses on the process of monitoring and controlling the movement of a mobile platform from one place to another.
- For a mobile robot, the main objective is to reach a given goal while avoiding obstacles.
- In this course, navigation is the simultaneous estimation of the state of the robot and of the dynamic environment.
  - The vehicle must determine its own location (in absolute and with respect to a map),
  - Localize and track the others objects (vehicles, pedestrians),
  - Characterize its environment and improve its map as appropriate.

Estimation

- Estimation is the process of inferring the value of a quantity of interest from indirect, inaccurate and uncertain observations.
- In estimation theory, two approaches are generally considered:
  - The probabilistic approach assumes that the measured data is random with probability distribution dependent on the parameters or variables of interest,
  - The set-membership approach assumes that the measured data vector belongs to a set which depends on the parameter vector.

Multi-sensor fusion

- Multi-sensor fusion is the process of combing information from a number of different sources to provide a robust and complete description of an environment or process of interest.
- Multi-sensor fusion can also refer to estimation problems with more information than unknowns in which one seeks to take advantage of all available information.
- Information means here
  - Measurements,
  - Relationships (like observation or evolution models),
  - Knowledge of the various random factors (noises or disturbances)
  - Prior knowledge.

Information can be

- Inaccurate,
- Uncertain,
- Complementary,
- Redundant,
- Contradictory (in conflict),
- Abnormal (i.e. an outlier that not matches the model that one has)
- Incomplete (partial knowledge).

The goal of multi-sensor fusion is to

- Detect consistent and inconsistent data,
- Merge the data that are consistent,
- Reject outliers (and sometimes identify them),
- Provide confidence indicators on which decisions can be made.

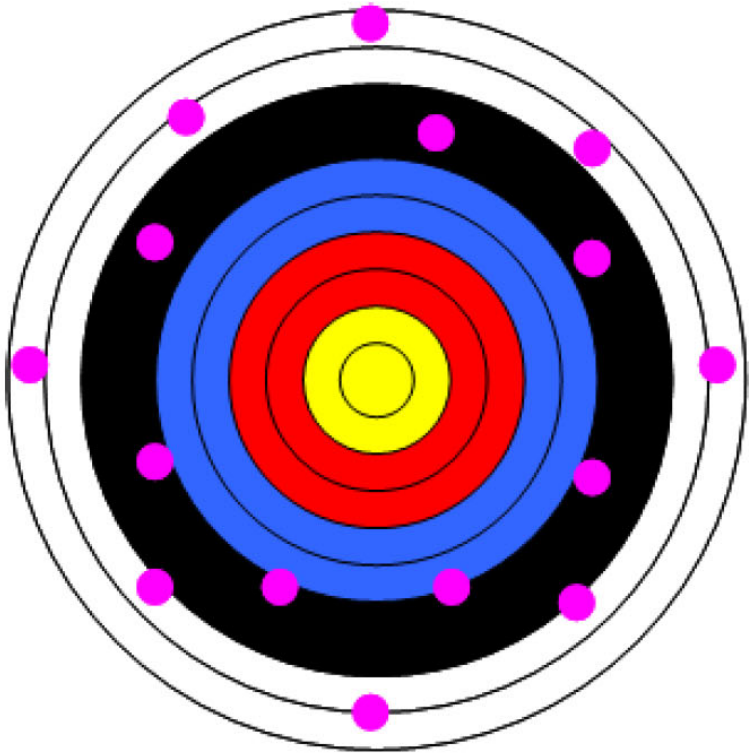
Tracking

- Tracking is the estimation of the state of a moving object based on exteroceptive measurements. It can be done using one or more sensors at fixed locations or on moving platforms.
- In this course, the sensors are attached to the mobile robot that has to track by itself the moving objects in its surrounding.

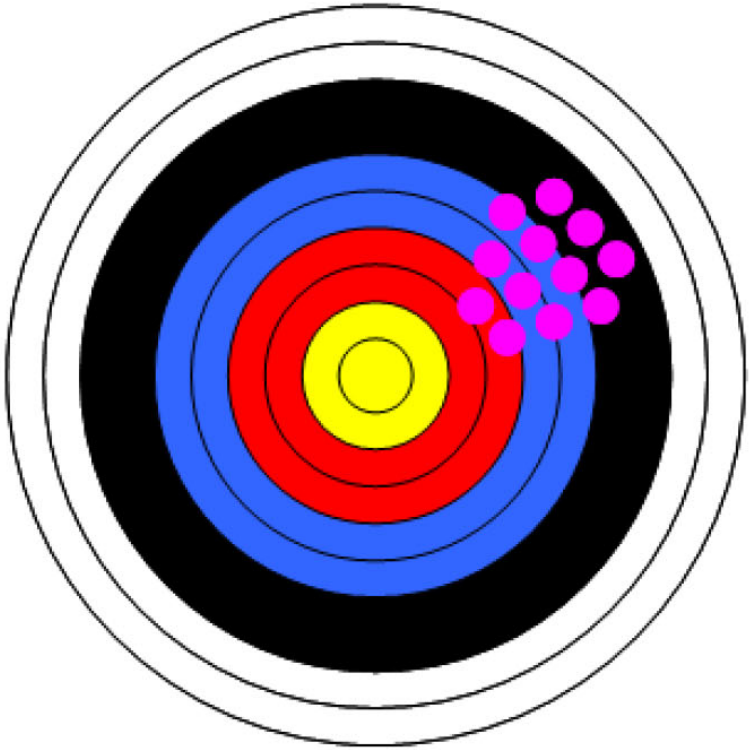
Accuracy

- According to ISO 5725-1, accuracy consists of
  - Trueness
    - proximity of measurement results to the true value
  - Precision
    - repeatability or reproducibility of the measurement).

Accuracy (exactitude)



Justesse **Trueness**
ISO/DIS 3534-2



Fidélité **Precision**
ISO/DIS 3534-2

Inaccuracy and uncertainty

- In data fusion (low level)
  - Inaccuracy = uncertainty
- In information fusion (high level)
  - Uncertainty is a different concept from inaccuracy
  - Uncertainty is linked to the confidence one has in a proposal to be true. Higher the uncertainty, lower the trueness of the proposal.
- Examples:
  - “Paul is approximately 18 years old.”
    - The age of Paul is inaccurate,
    - The fact that Paul is of the age of majority is uncertain.
  - Consider an observer who tries to detect and track targets.
    - The actual existence of each target is uncertain,
    - Each track is followed with inaccuracy.

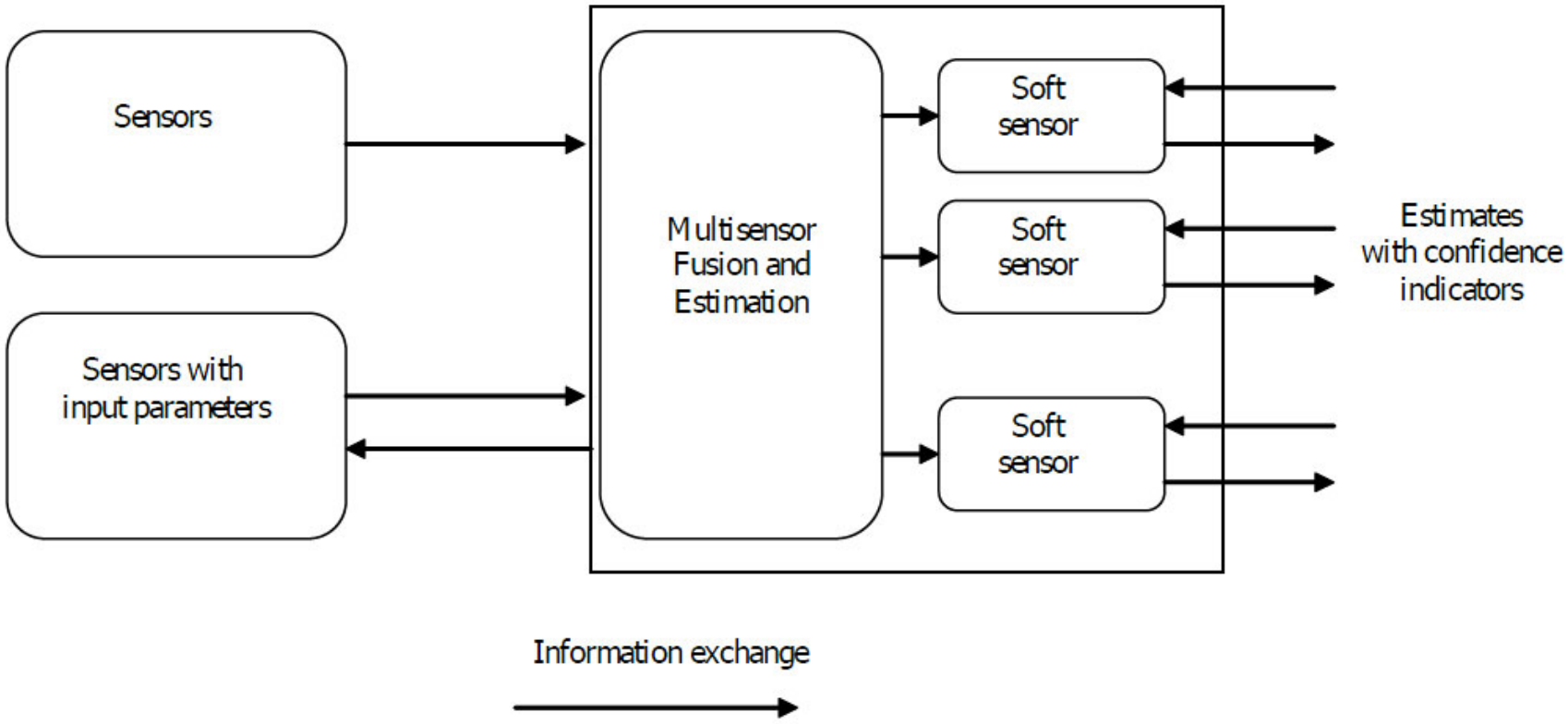
Inaccuracy and uncertainty in information fusion

- The frame of discernment is discrete
- Example
  - color of balls $\Theta = \{\text{red}, \text{green}, \text{blue}, \text{black}, \text{yellow}\}$
  - A first system says I have detected a “blue or black ball” with a confidence of 60%
  - A second one I have detected a “red or blue or black ball” with a confidence of 90%
- The first one is more accurate but less certain than the second one

Integrity

- Integrity is a measure of the trust that can be placed by a client application in the correctness of the information supplied by a positioning system.
- Integrity includes the ability of the system to provide timely warnings to users when the system should not be used for navigation.
- Integrity is also defined as the ability to get reliable confidence information associated with a result.
- When the variable to estimate is continuous a confidence domain is characterized.
  - The Integrity Risk (IR) associated to a confidence domain is the probability that the estimate to be outside of this domain.

Soft sensors



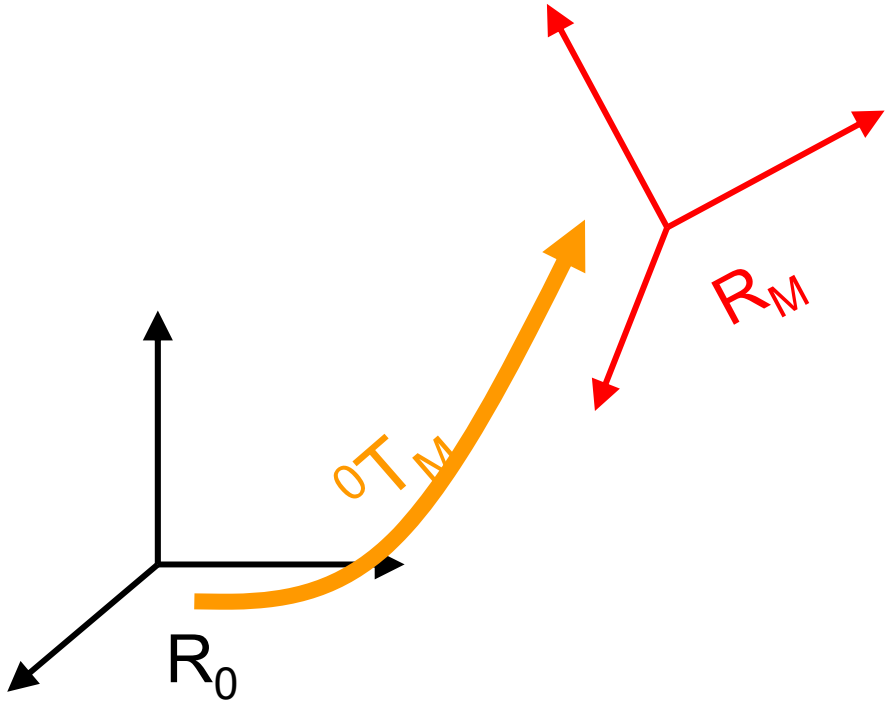
Main categories of estimation and data fusion problems

- Estimation and multi-sensor data fusion can be viewed as schemes for information extraction and combination based on measurements.
- They are usually classify into the following categories depending of the nature of the considered variable:
  - A parameter i.e. a time-invariant quantity (a scalar or a vector)
  - The state of a dynamic system (usually a vector), which evolves in time according to a stochastic equation

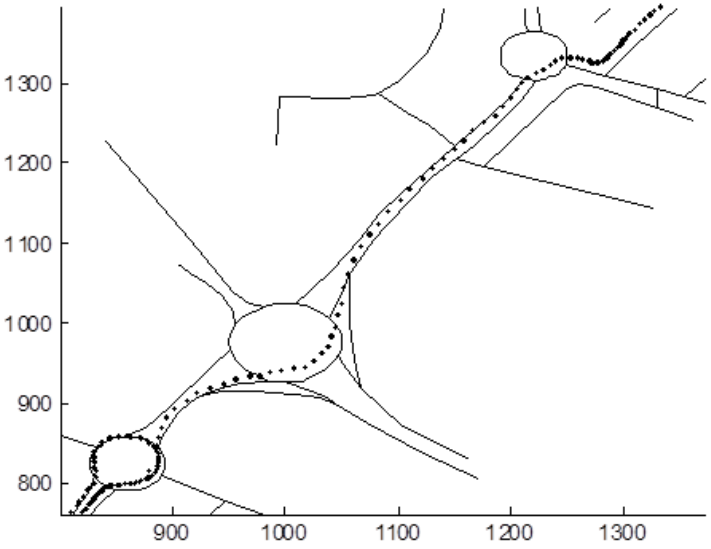
Classical navigation problems in robotics

Localization

- Global Localization
  - Known beacons
  - Unknown pose
- Dead-Reckoning

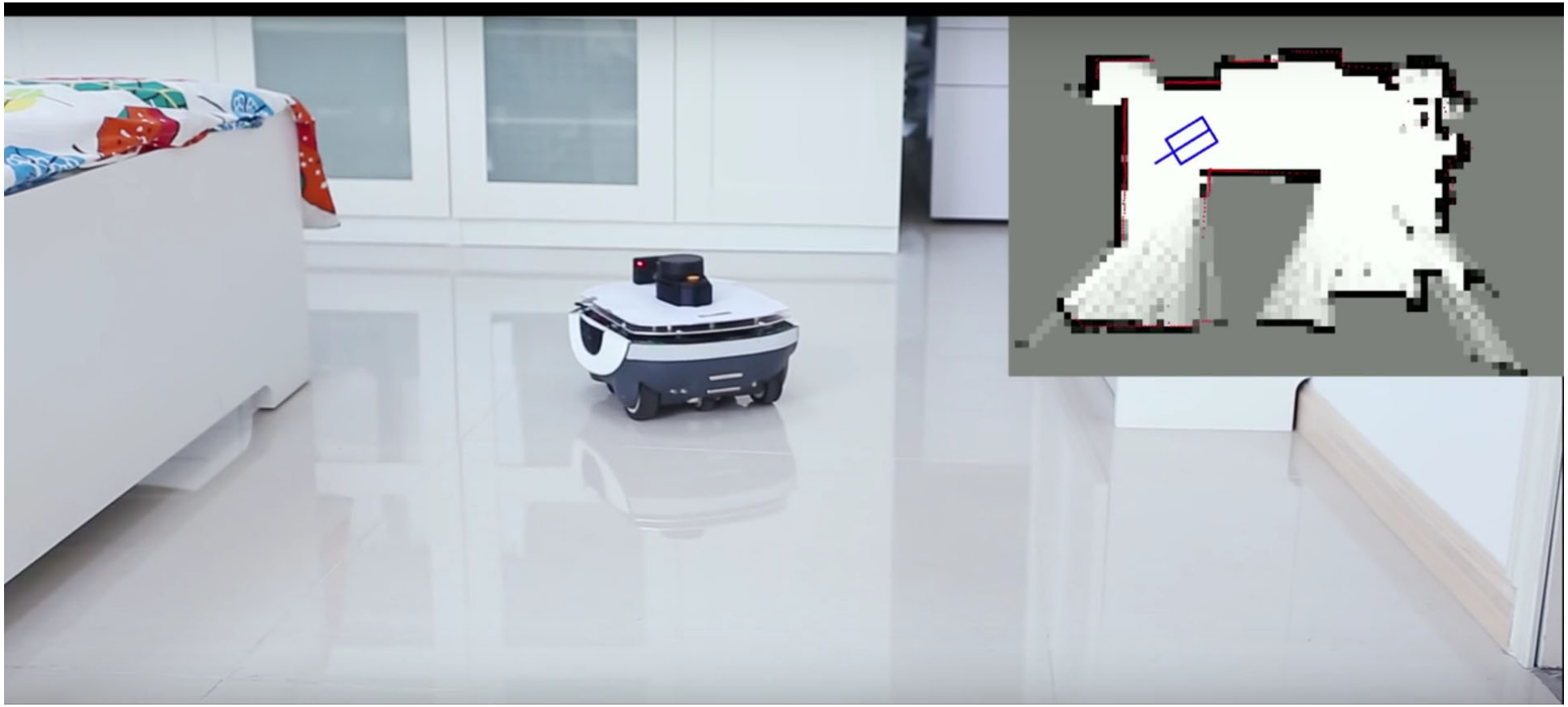


- Localization on a map
  - Map-Matching



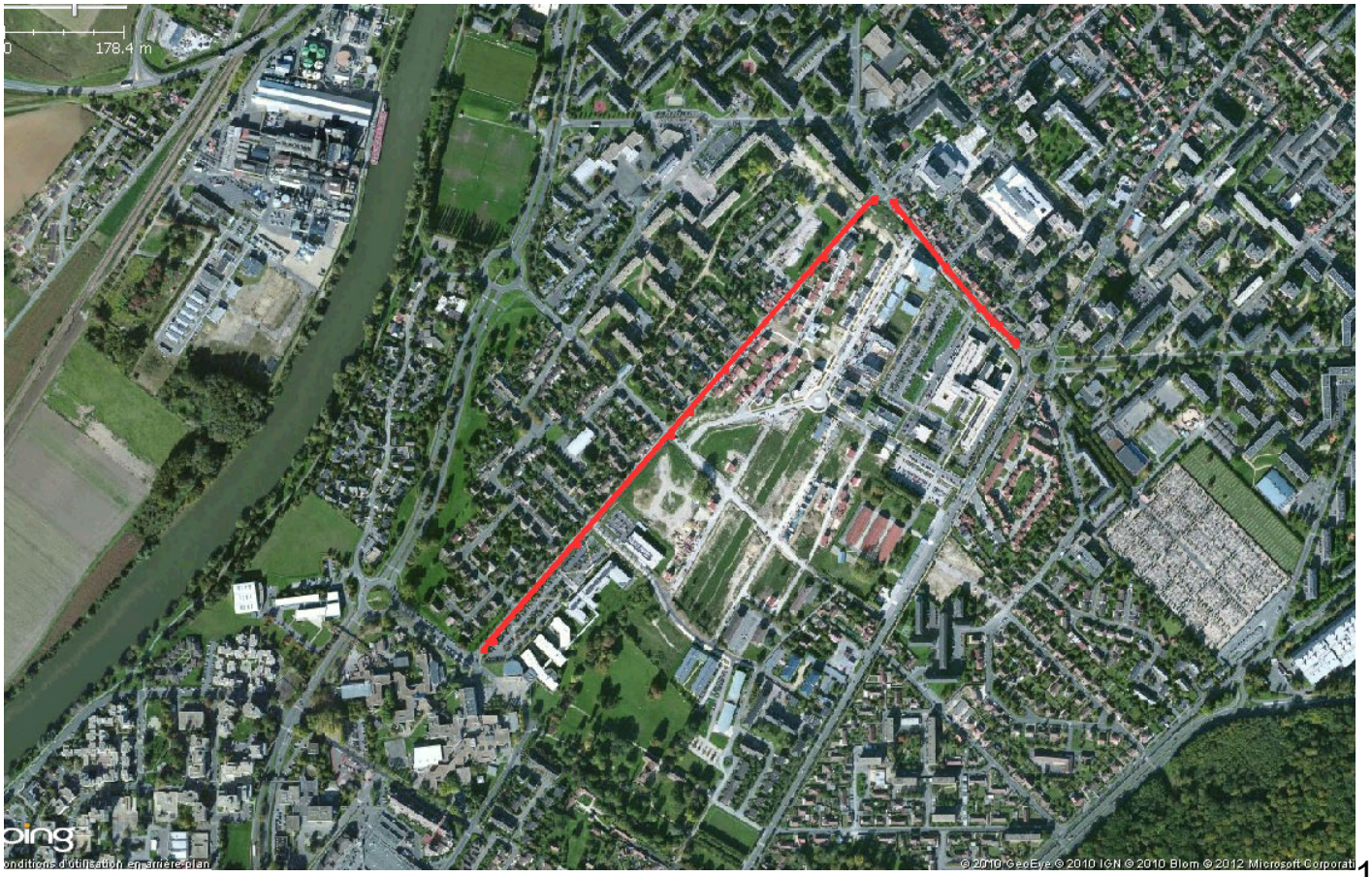
SLAM

- Simultaneous localization and mapping



Mapping knowing the pose
Mobile Mapping

- Mapping of static elements
- Example: lane markings at UTC



Moving objects tracking (MOT)

- In the mobile frame
- Detecting, localizing and tracking moving objects

Pedestrian detection and recognition

utc
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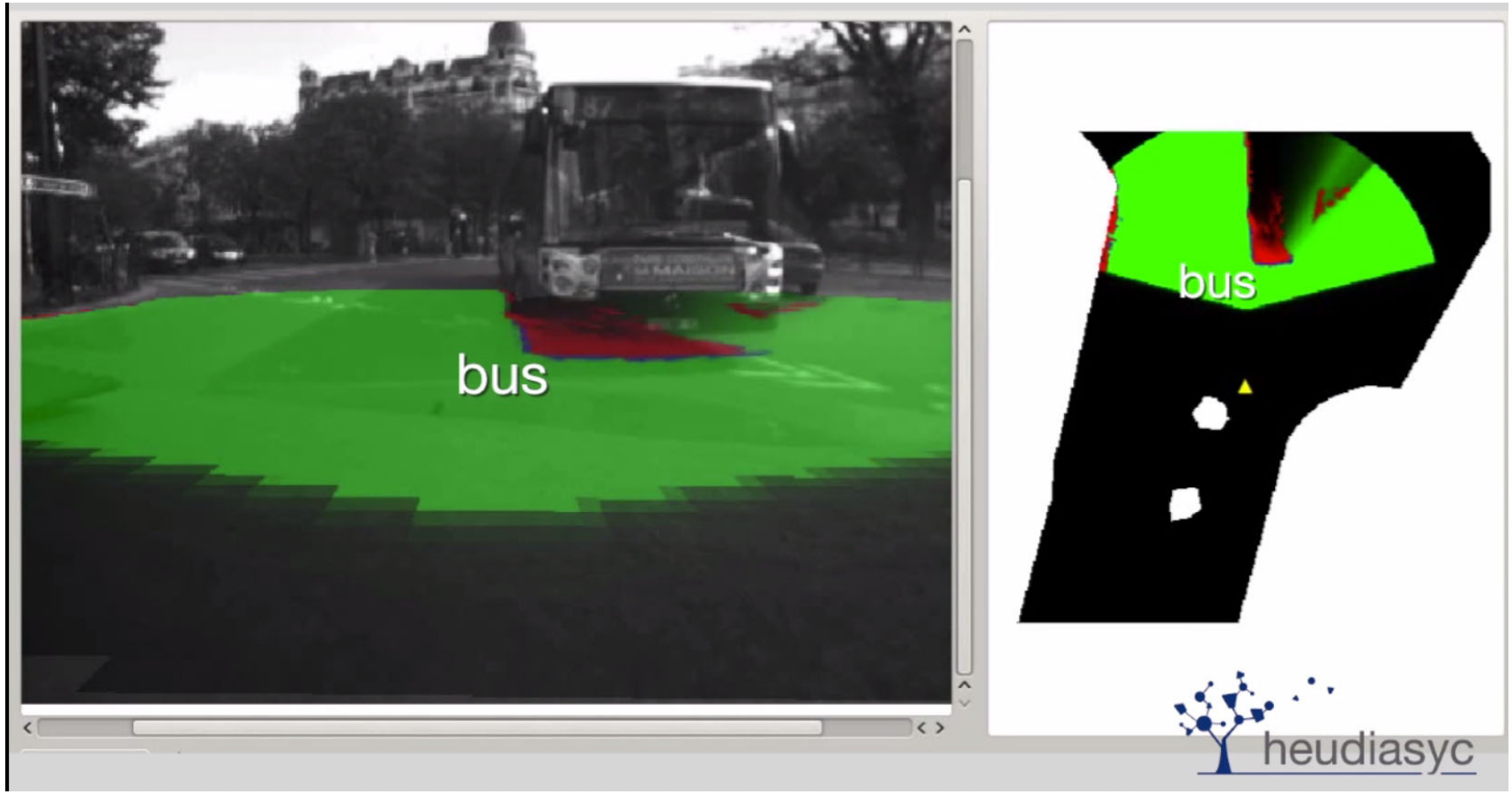
Compiègne

Drivable space determination



SLAMMOT

- SLAM + Mobile Objects