Aalto University
School of Electrical
Engineering

ELEC-E8740 — Basics of Sensor Fusion
Introduction to the project work

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Before we begin

- Sign up for a team. A team of max. **three** members are allowed.
- Deadline for signing up is **November 14, 2020**.
- Link: https://mycourses.aalto.fi/mod/choicegroup/view.php?id=651037
- Project instruction:
  https://mycourses.aalto.fi/pluginfile.php/1380370/mod_resource/content/3/project_guide.p
- Make sure to check for updates in
  https://mycourses.aalto.fi/course/view.php?id=28638&section=4
- Data will be available after signing up. Link:
  https://mycourses.aalto.fi/course/view.php?id=28638&section=4
- Demo: https://mycourses.aalto.fi/mod/page/view.php?id=651876

Objective

- The aim of this project is to develop an algorithm for tracking an autonomous robot (DiddyBorg) by using a set of sensors.
- Sensors available: IMU, infra red detector, a motor controller, and a camera module.
- Track predefined lines (black) in a confined space.
- All handled by Raspberry PI.

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Part I

- Derivation of the sensor model: IMU and Camera system.
- Estimation of the model parameters $\rightarrow$ this includes calibration.

Part II

- Localization using camera measurements.

Part III

- Tracking using IMU only
- Tracking using both IMU and Camera.

Tasks

No.	Task	Notes
Part I		
1	Static IMU experiment	Check the static bias and the covariance.
2	IMU calibration	Determine the gain and the bias of the accelerometers, gyroscope, etc.
3	Camera module calibration	Determine the focal length and bias.
4	Motor control	Determine the speed of the robot.
Part II		
5	Localization	Estimate the position and attitude of the robot.
Part III		
6	Tracking with IMU	Develop a tracking algorithm.
7	Tracking with IMU and camera	Develop a tracking algorithm.

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Reports

- Intermediate report
  (DL: Monday, 30th November, 2020, 12:00)
- Final submission
  (DL: Monday, 11th January, 2021, 12:00)

Intermediate report

- Specify team number and members
- A brief description of the robot and sensor models.
- Explanatory data analysis of the log files.
- Plans to implement Part II (localization) and Part III (tracking) algorithms.

Final report

- Specify team number and members.
- An abstract.
- A brief introduction to the project and the problem that you are solving.
- Derivation of the model.
- Calibration procedures that are used (if any).
- Methods: a description of the estimation method(s) used for parameter estimation, validation, and tracking.
- Results.
- Conclusions and/or a summary.
- References (if applicable).

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Grading criteria

- Part I: Grade max. 1 (Pass)
- Part II: Grade max. 3
- Part III: Grade max. 5

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IMU

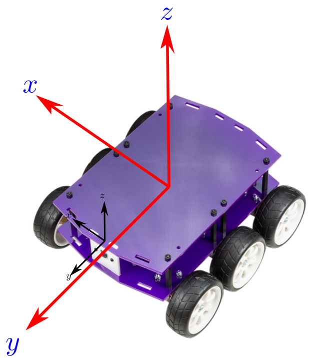

Figure: Illustration of the robot and camera coordinate systems given by the right hand axis rule. Notice the camera coordinate system is parallel to the robot coordinate system

Measurement Model: Camera

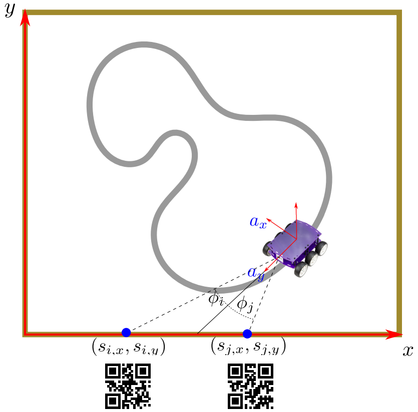

Figure: Illustration of the global coordinate system, QR-codes with known positions in global coordinate, and the robot local acceleration. When the robot camera heads to the *y* axis, the global angle of the robot equal to zero.

Measurement Model: Camera

For each QR-codes:

$$
\begin{aligned}
d_i &= \sqrt{(x_c - x_i)^2 + (y_c - y_i)^2} \\
\phi_i &= \arctan((x_c - x_i)/(y_i - y_c)) - \psi
\end{aligned}
$$

The distance d_i and direction of QR-codes from robot y axis ϕ_i can be determined by

$$
\begin{aligned}
\phi_i &= \arctan(\frac{c_{x,i}}{F}), \\
d_i &= \frac{H_o F}{h_i}.
\end{aligned}
$$

Measurement Model: Camera

Therefore

$$\begin{aligned}
c_{x,i} =& F \cdot \tan(\arctan((x_c - x_i)/(y_i - y_c)) - \psi), \\
h_i =& \frac{H_o F}{\sqrt{(x_c - x_i)^2 + (y_c - y_i)^2}}, \\
\mathbf{y} =& \mathbf{h}(\mathbf{x}).
\end{aligned}$$

H_o is the height of QR-codes, and F is the focal length of the lens in *pixel*.

Dead-reckoning

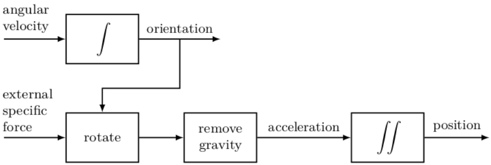

Figure: Schematic illustration of dead-reckoning, where the accelerometer and gyroscope measurements are integrated to position and orientation.

Tracking

First use IMU only, then after that use also the camera.
Also, consider the timestamp.

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Demonstration (2min)

https://mycourses.aalto.fi/mod/resource/view.php?id=651871