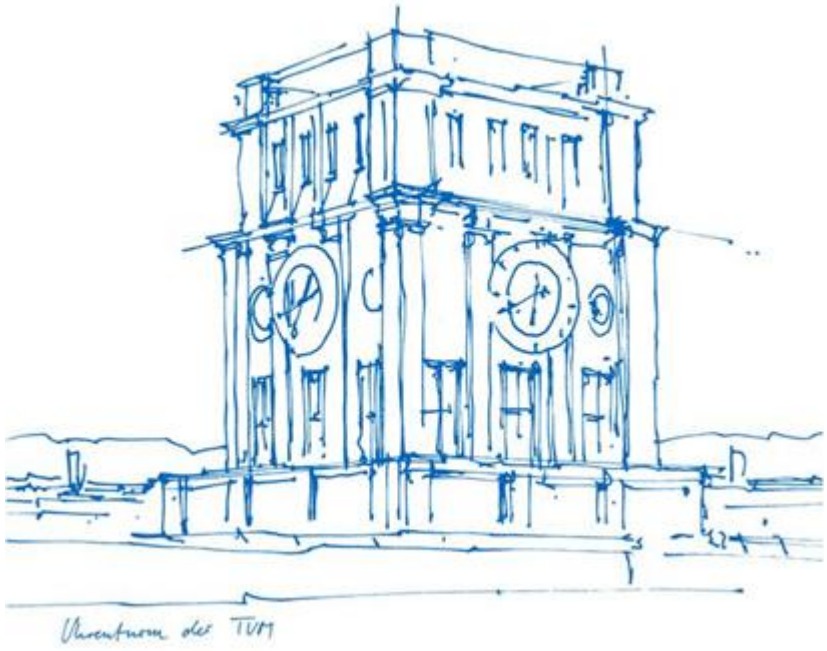
Chair for Cognitive Systems
Department of Electrical and Computer Engineering
Technische Universität München

Introduction Lab Humanoid RoboCup: Final Presentation

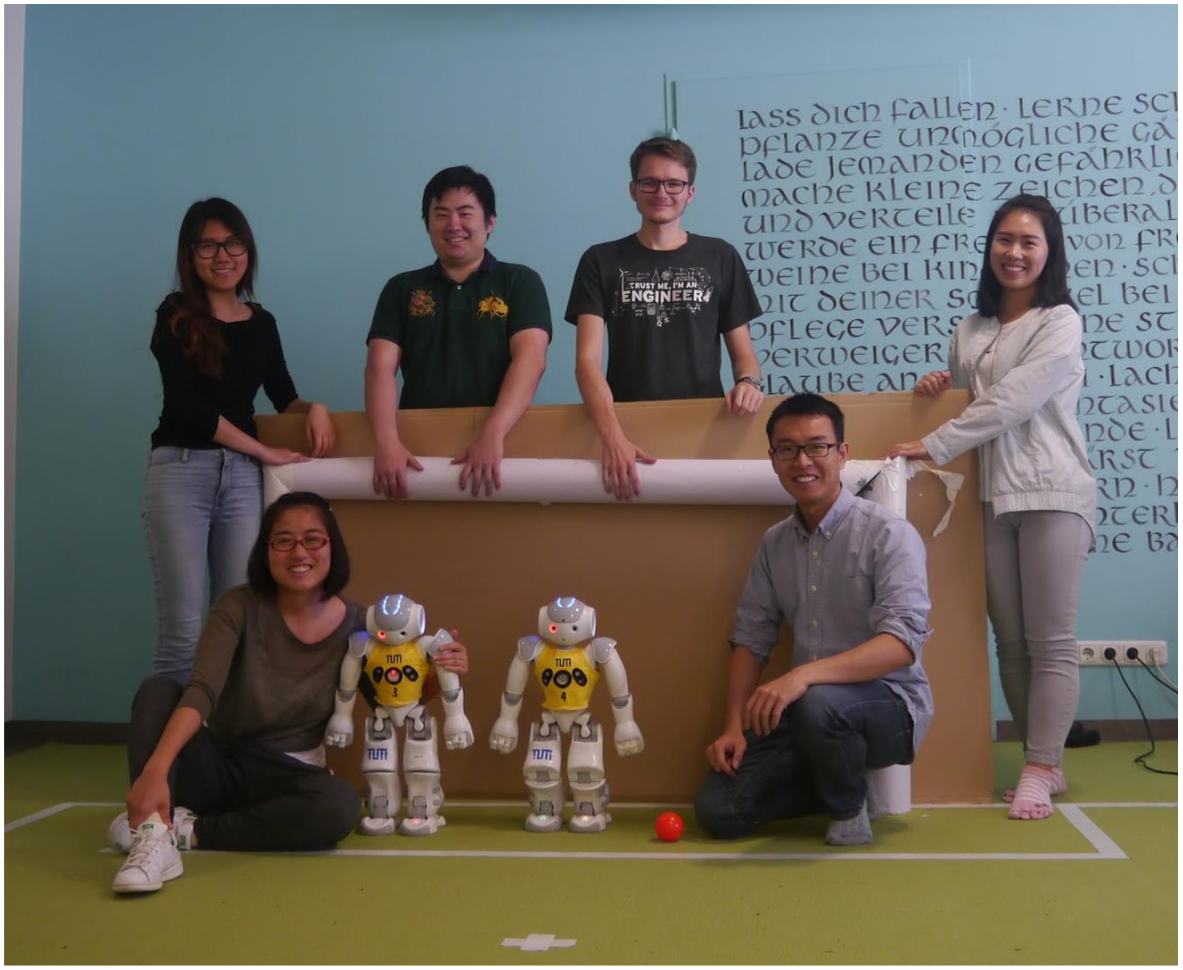
Supervisor: Mohsen Kaboli

Institute for Cognitive Systems
Technical University of Munich

Munich, July 24th, 2017



Yellow Team



Minkai Hu
Fabian Kreutmayr
Jingjie Jiang

Tianming Qiu
Zhiyi Li
Yao Rong

What is the RoboCup?

- RoboCup is robotics competition
- The World Cup takes place every year
- Participants are research team from all over the world
- 2016’s champion is “BHuman” from the University of Bremen
- 2017’s tournament is taking place from 27th to 30th July in Nagoya, Japan

What are the objectives?

- **Push development in several research fields:**
  - Humanoid locomotion
  - Computer vision
  - Machine learning
  - And much more

- **Strengthen connections and exchange between universities and other research centers**

- **The vision:** By 2050, a team of fully autonomous robots should beat the Soccer World Champions

Semester Projects

Improvement of Kicking Process

- Kick Methods
- Foot Selection
- Alignment to Goal
- Area-based Alignment

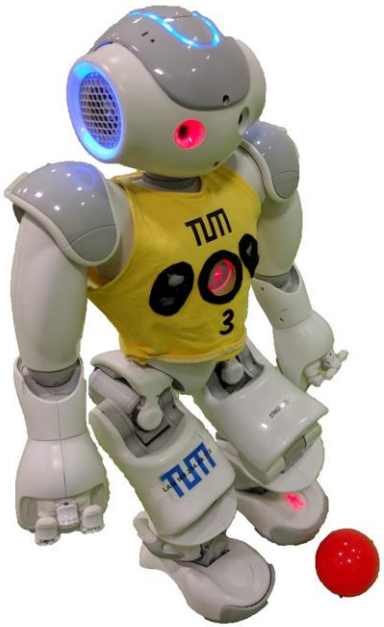
Improvement of Localization

- Penalty Mark Perception
- Vertical Line Perception
- Visual Odometry

Semester Projects

Improvement of Kicking Process

- **Kick Methods**
- Foot Selection
- Alignment to Goal
- Area-based Alignment



Kick Methods - Ground Truth

Kick Methods

Why improve the kick?

Current state:

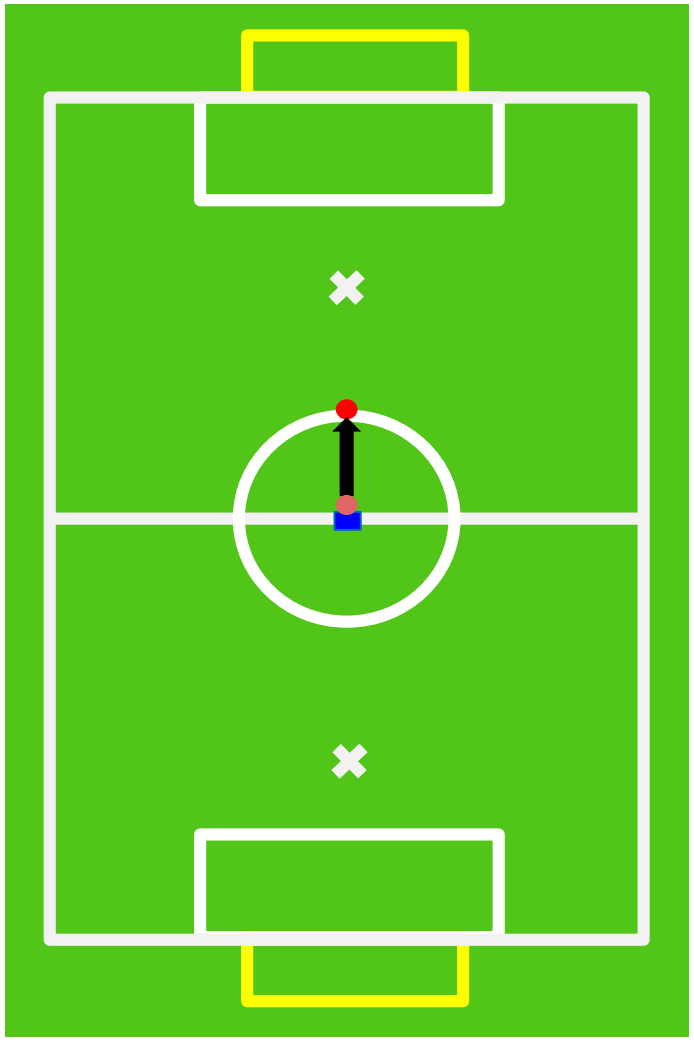
- NAO aligns behind the ball and kicks the ball weakly to the goal
- No variability
- Easy to intercept

Nao

Ball position

Previous ball position

Current kick



Kick Methods

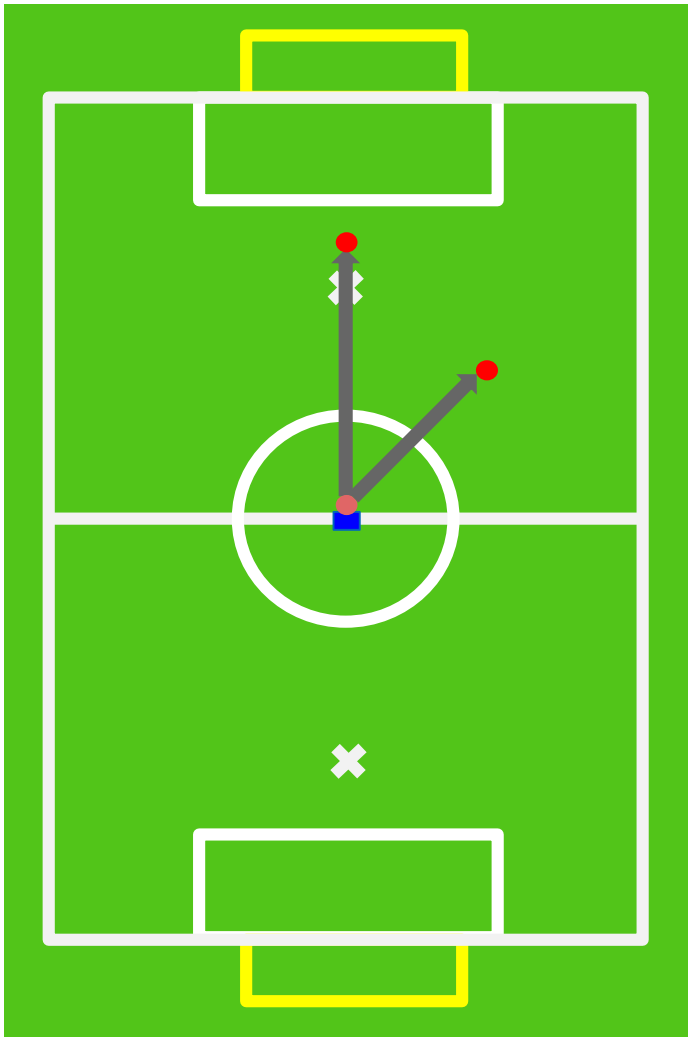
- **Improvements:**
  - Adding different kicking methods
    - Stronger/weaker kick
    - Angled kick
- **Advantage:**
  - Stronger kick increases chances to score
  - Angled kick is more difficult to defend against

Nao

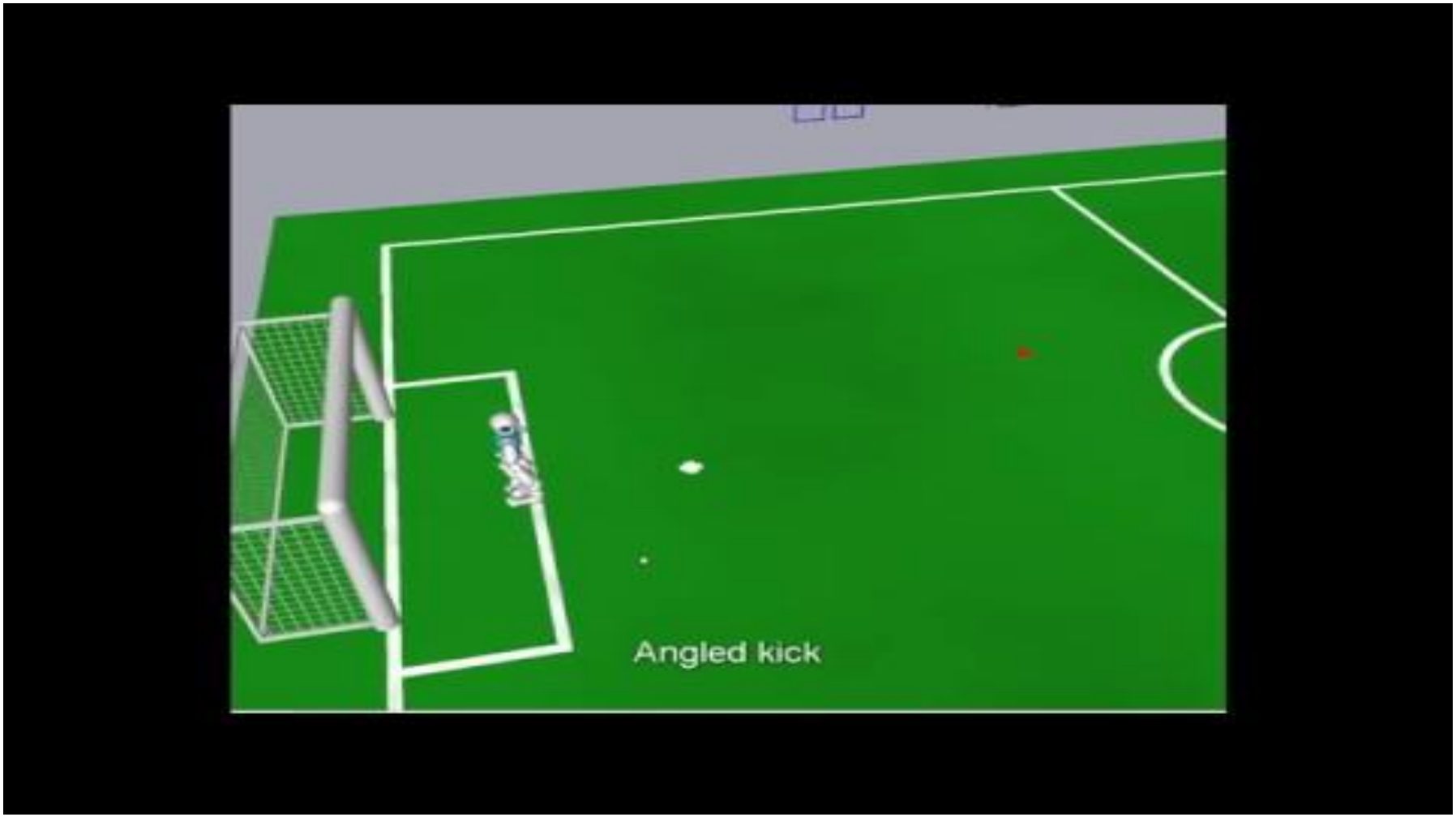
Ball position

Previous ball position

New kicks



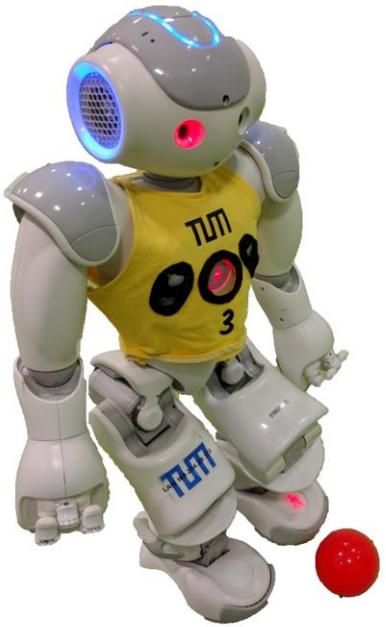
Kick Methods - Video



Semester Projects

Improvement of Kicking Process

- Kick Methods
- **Foot Selection**
- Alignment to Goal
- Area-based Alignment



Foot Selection - Ground Truth

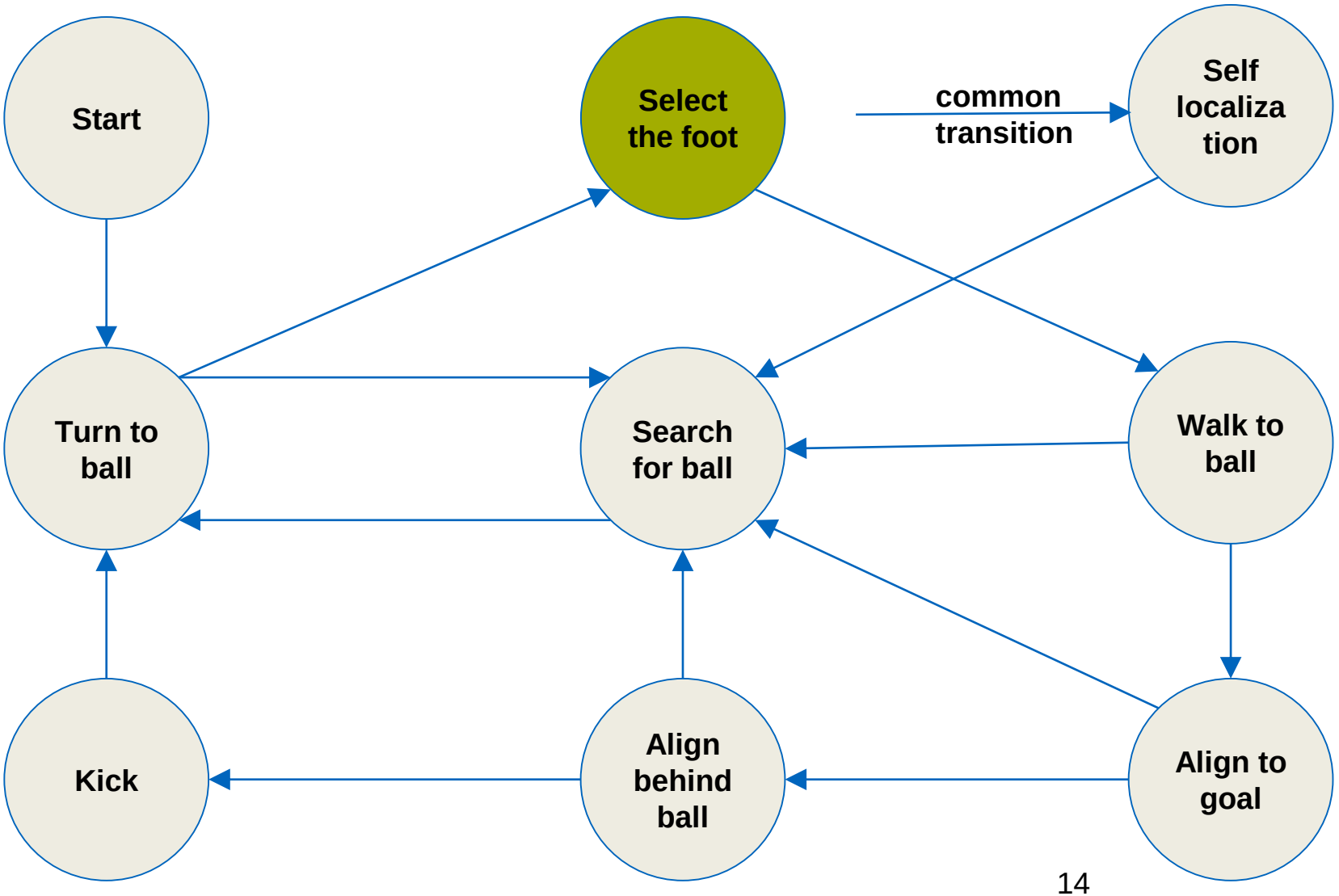
Foot Selection - Ground Truth

- **Problem:**
  - NAO kicks ball always with the left foot → needs long time for aligning behind the ball

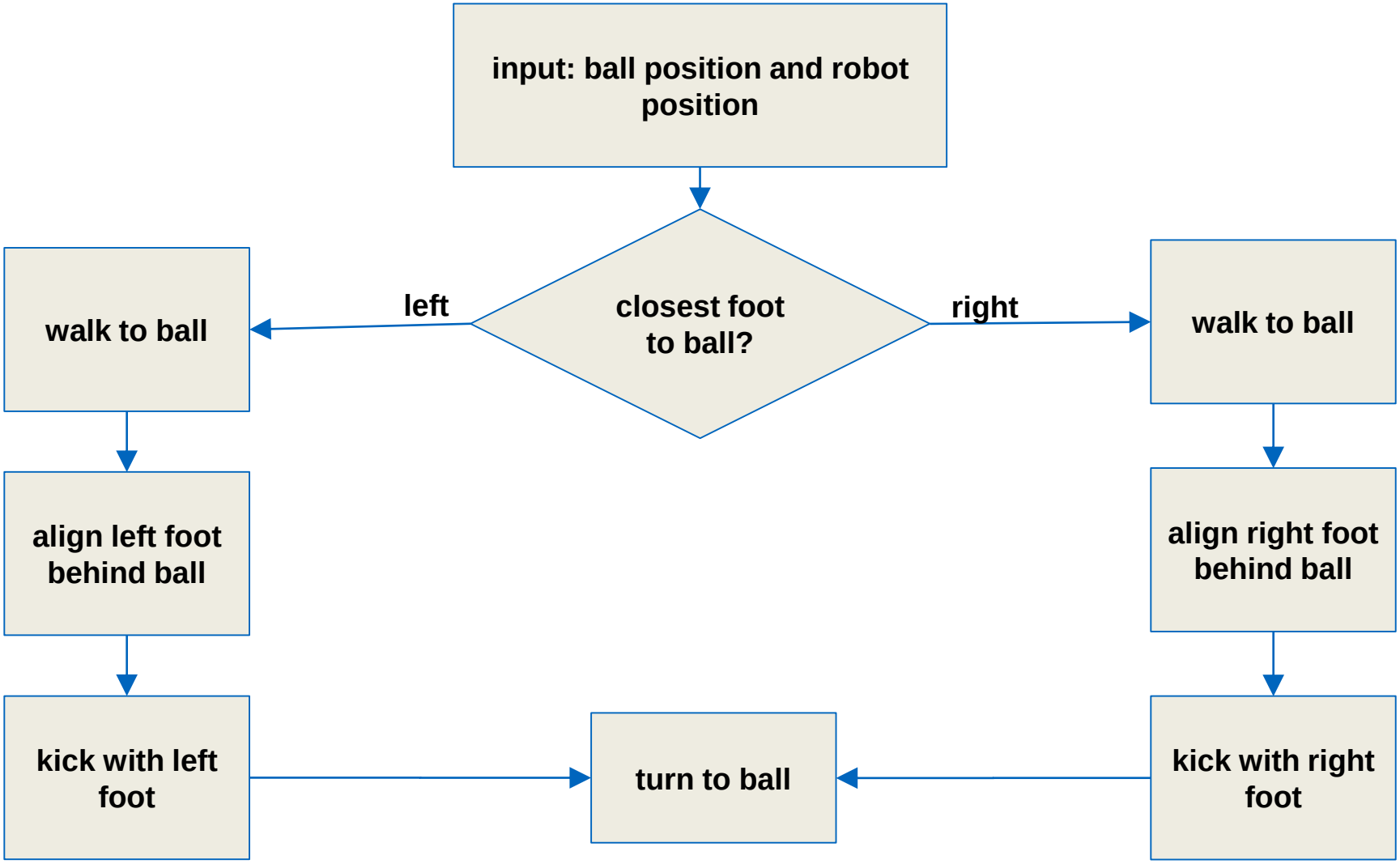
- **Solution:**
  - Introduce a method where NAO decides to kick with left or right foot
  - Choose foot that is closer to the ball

- **Advantage:**
  - Save time during alignment process → NAO is more competitive

Foot Selection - State Machine



Foot Selection - Flow Chart

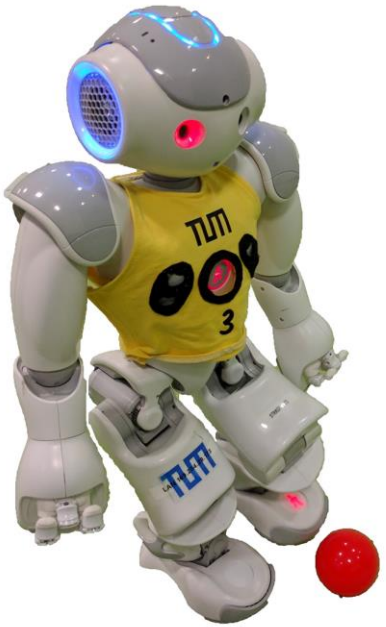


Foot Selection - Video

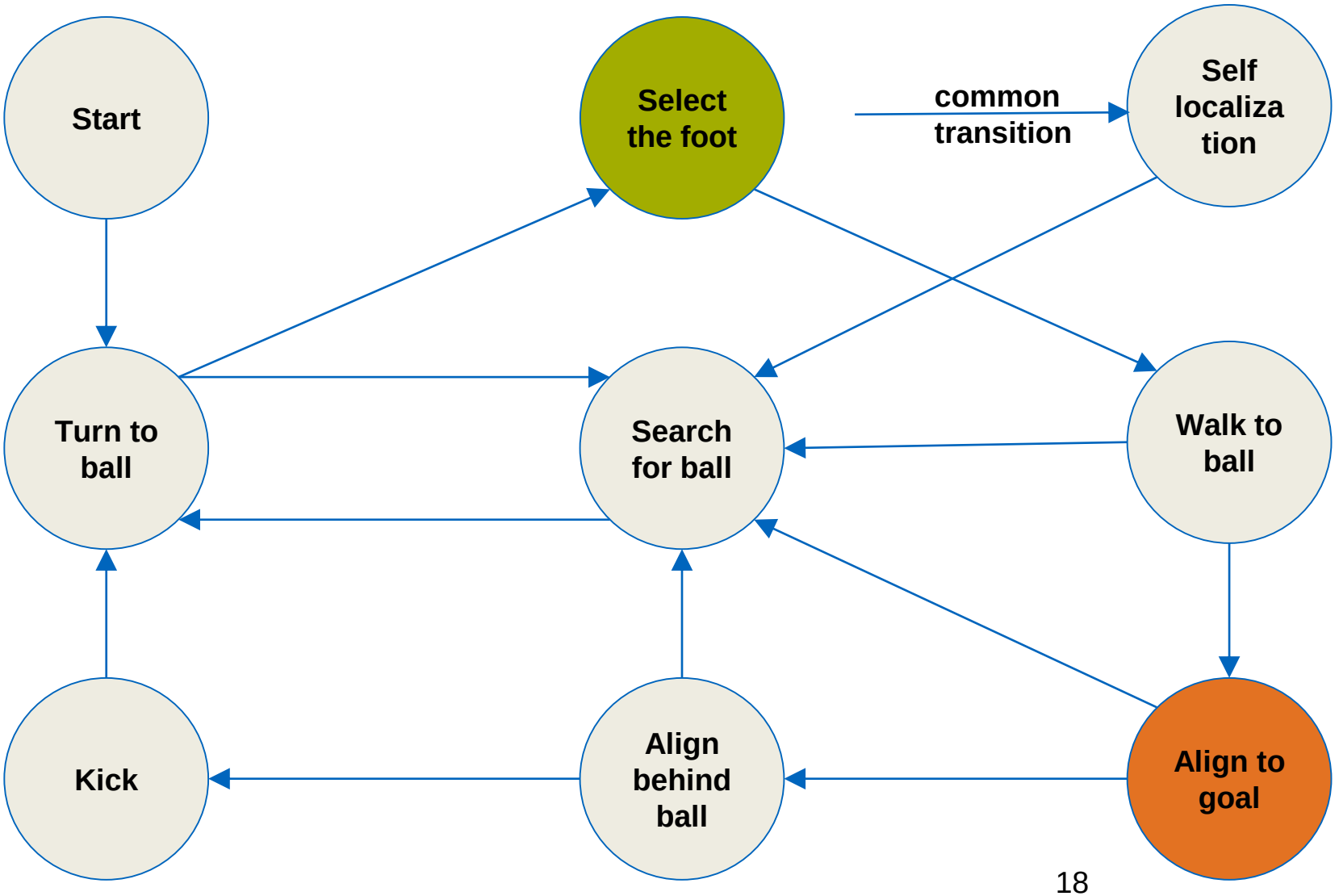
Semester Projects

Improvement of Kicking Process

- Kick Methods
- Foot Selection
- **Alignment to Goal**
- Area-based Alignment



Alignment to Goal- State Maschine

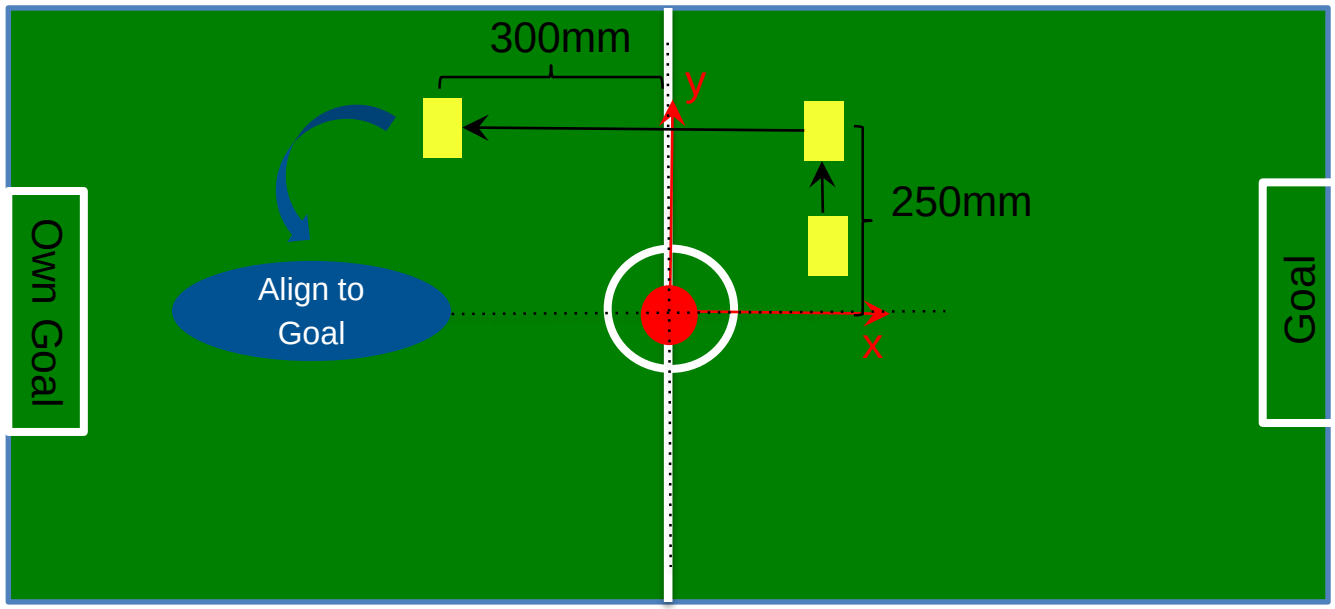


Alignment to Goal – State of the Art

- Problem when robot is between ball and goal
  - Kick to own goal
  - Unable to score

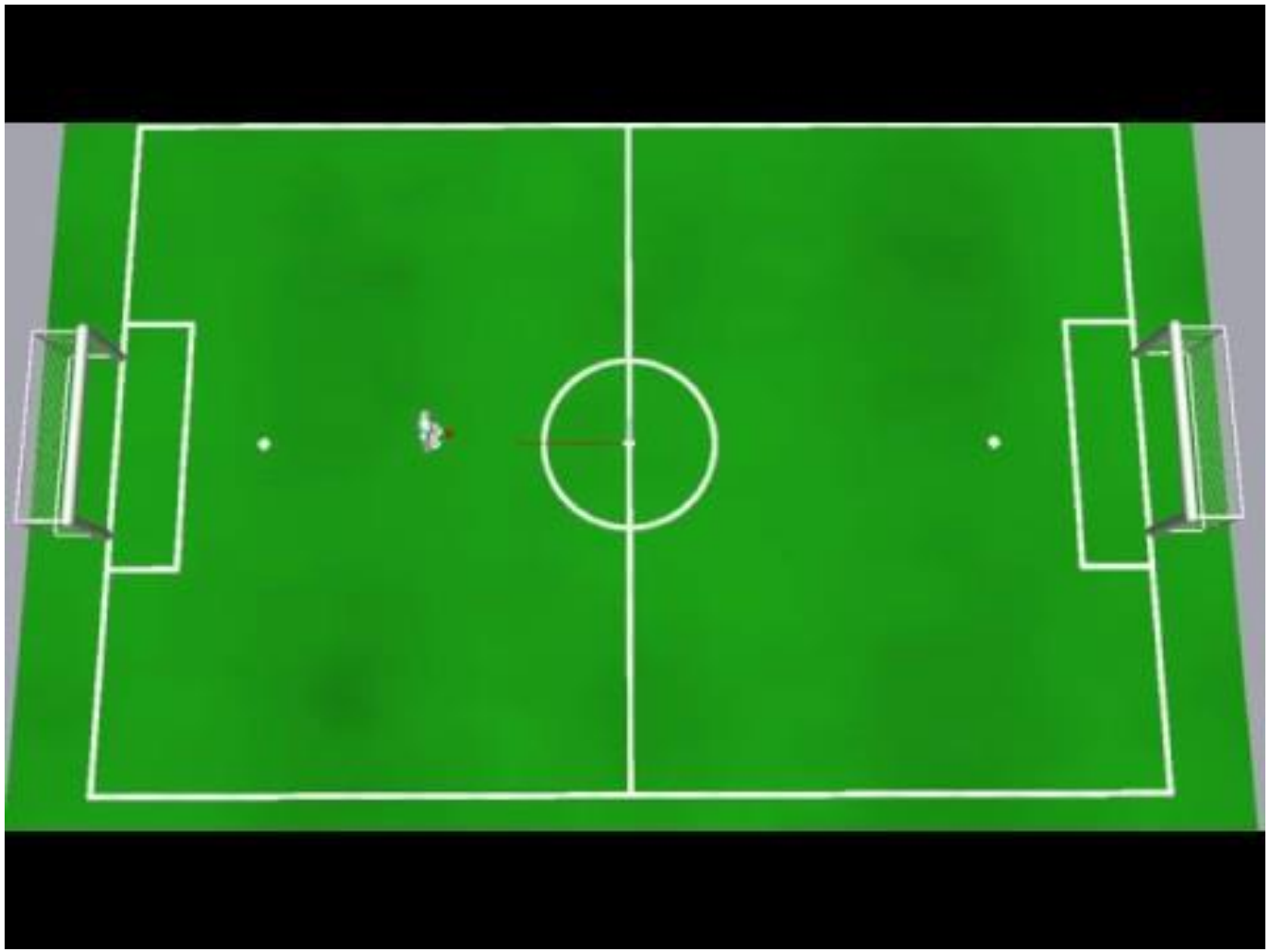
Align to goal

Proposed Solution



- Advantage
  - \+ Guarantee for kicking to goal

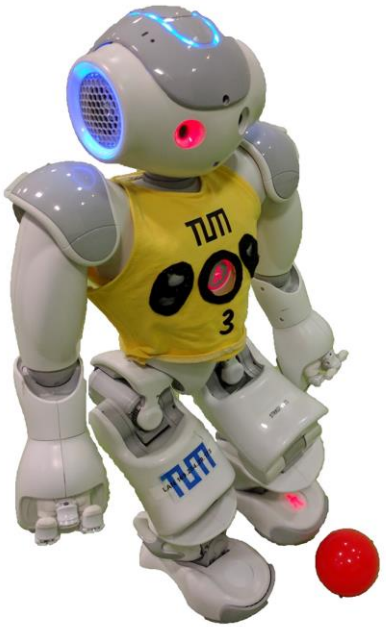
Improved Alignment to Goal – Video



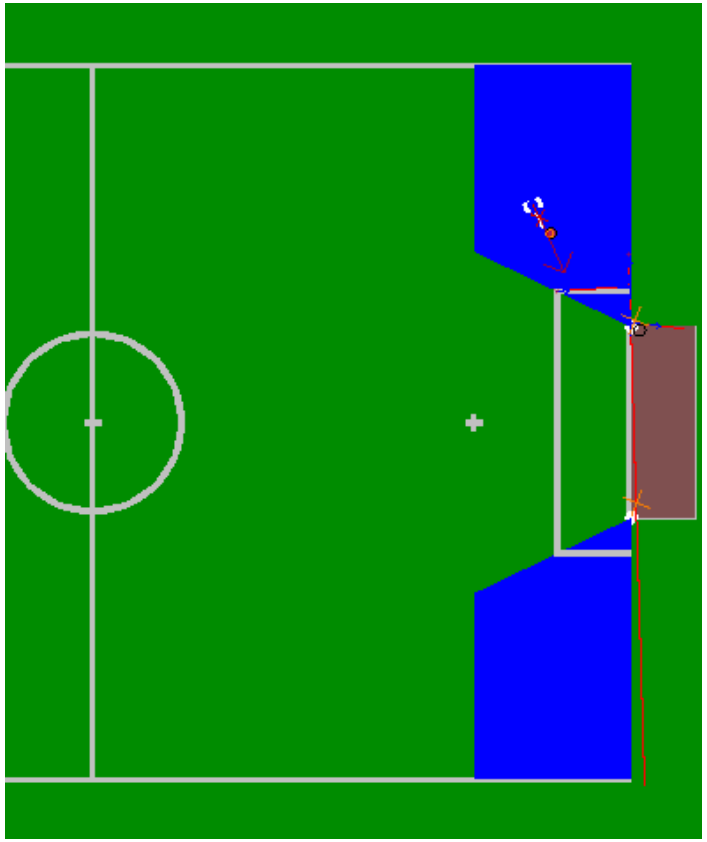
Semester Projects

Improvement of Kicking Process

- Kick Methods
- Foot Selection
- Alignment to Goal
- **Area-based Alignment**



Area-based Alignment – State of the Art

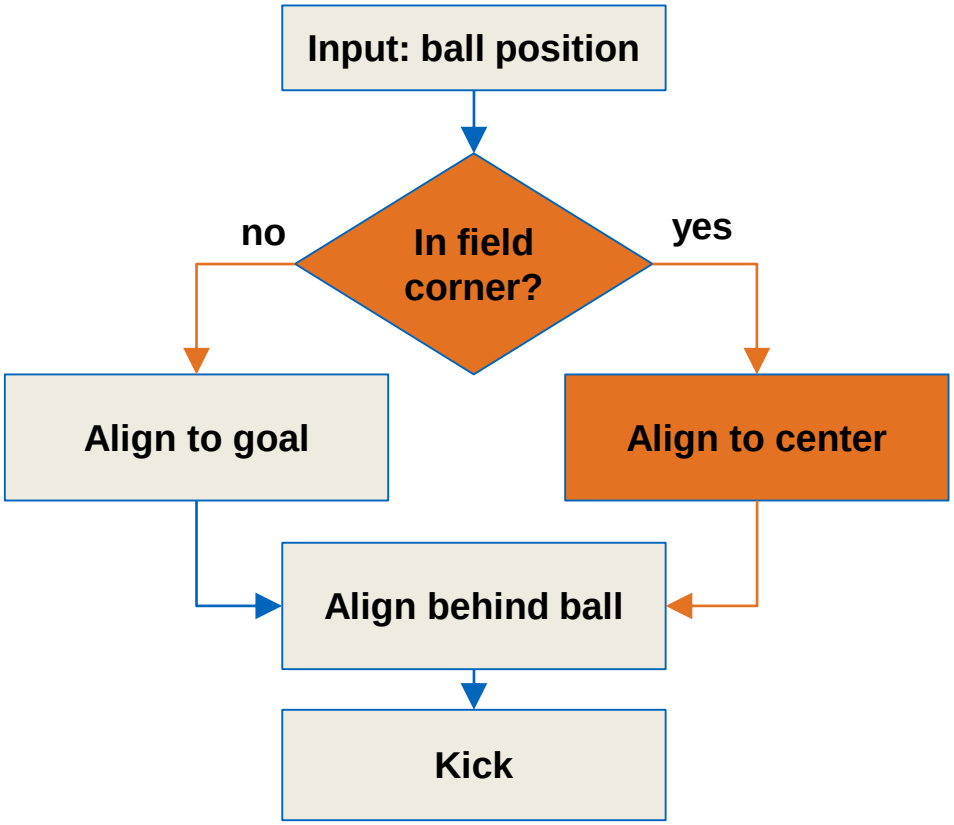


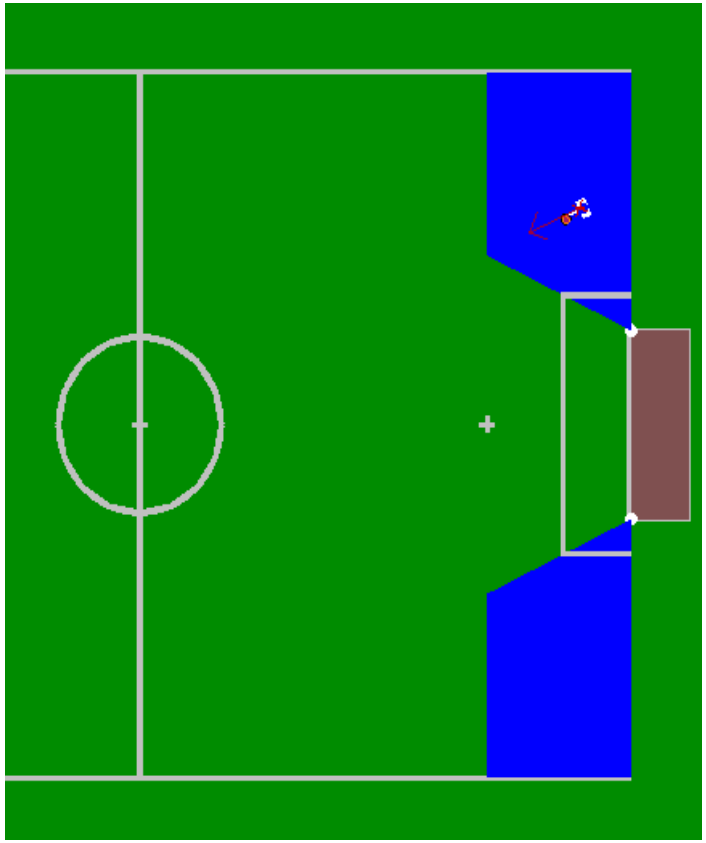
Adapted from [1]

- Problem in field corner
  - Low possibility of scoring

[1] ETH, 2014, Semester Project ‘Robocup: A Framework for Passing’, https://drive.google.com/file/d/0B_tMocQbHqQuOUMteFpELUxMaHM/view

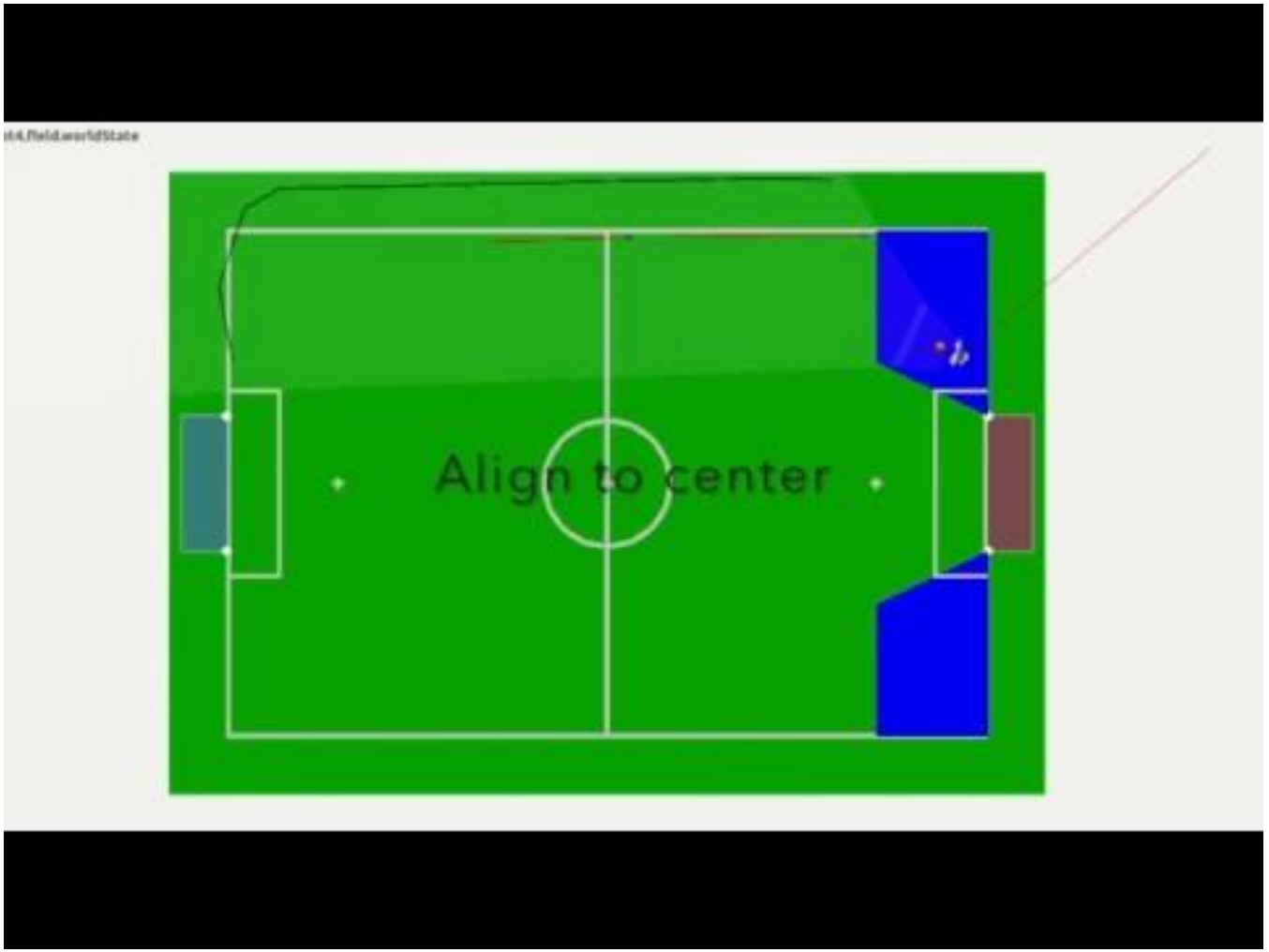
Proposed Solution



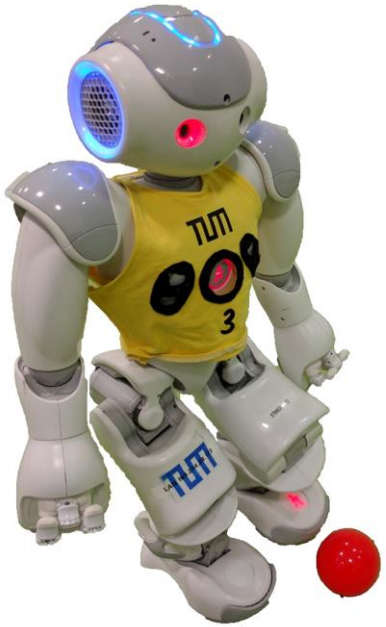


- Advantage
  - \+ Higher possibility of scoring
  - \+ Foundation of passing strategy

Area-based Alignment – Video



Semester Projects



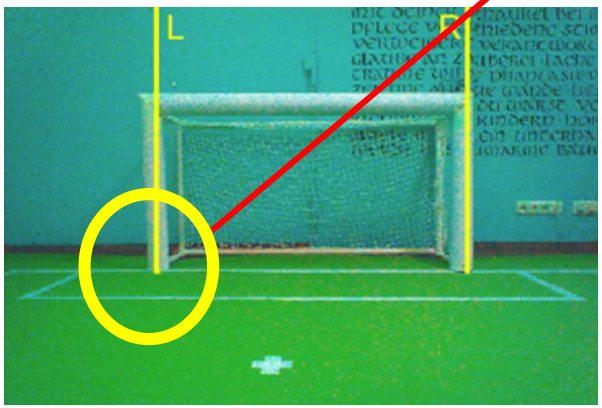
Improvement of Localization

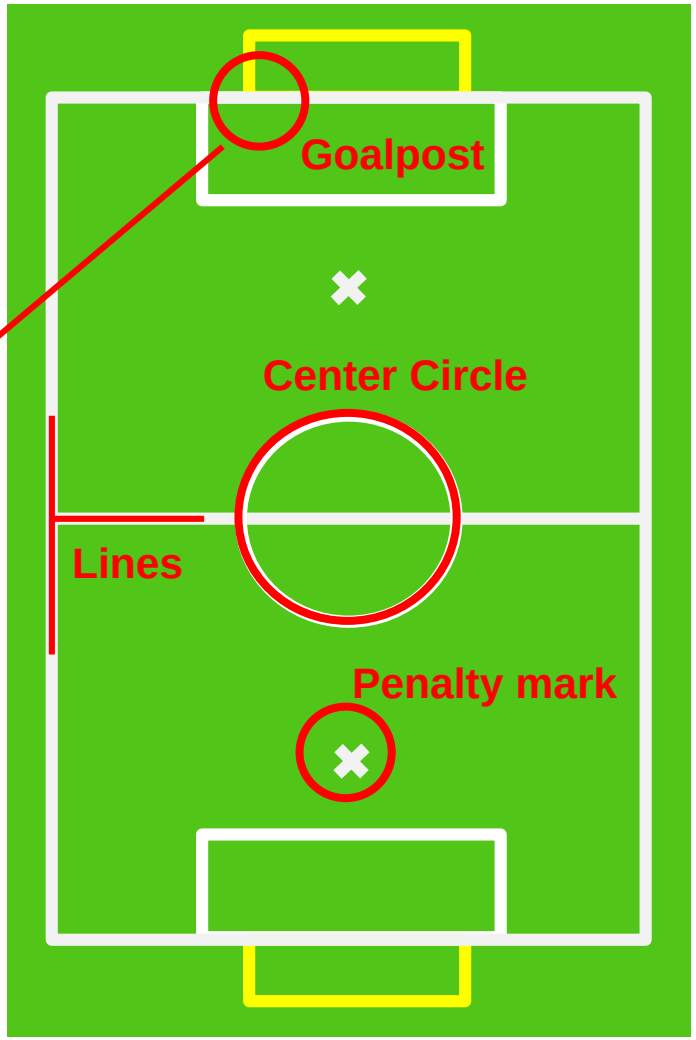
- Penalty Mark Perception
- Vertical Line Perception
- Visual Odometry

Localization: Problem Statement

What is RoboCup localization problem?

- **Given?**
  - Map of field (with landmark coordinate)
  - Sequence of camera measurements





Localization: Problem Statement

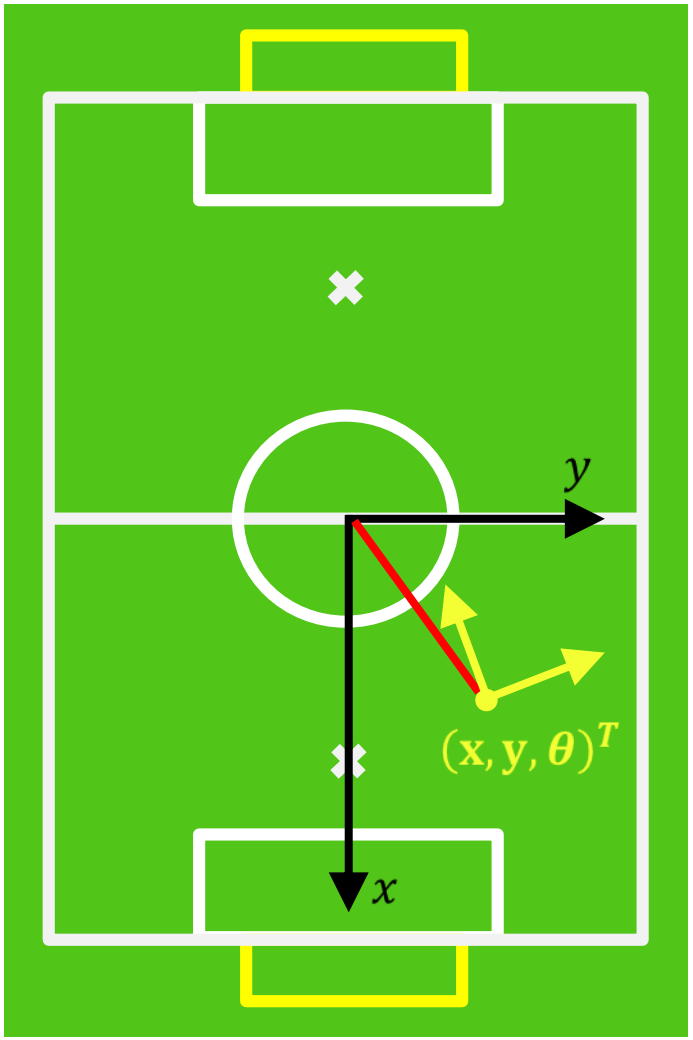
What is RoboCup localization problem?

- **Given?**

  - Map of field
  - Sequence of camera measurements

- **Wanted?**

  - Robot 2D location and pose: $(x, y, \theta)^T$



Localization: Problem Statement

What is RoboCup localization problem?

- **Given?**

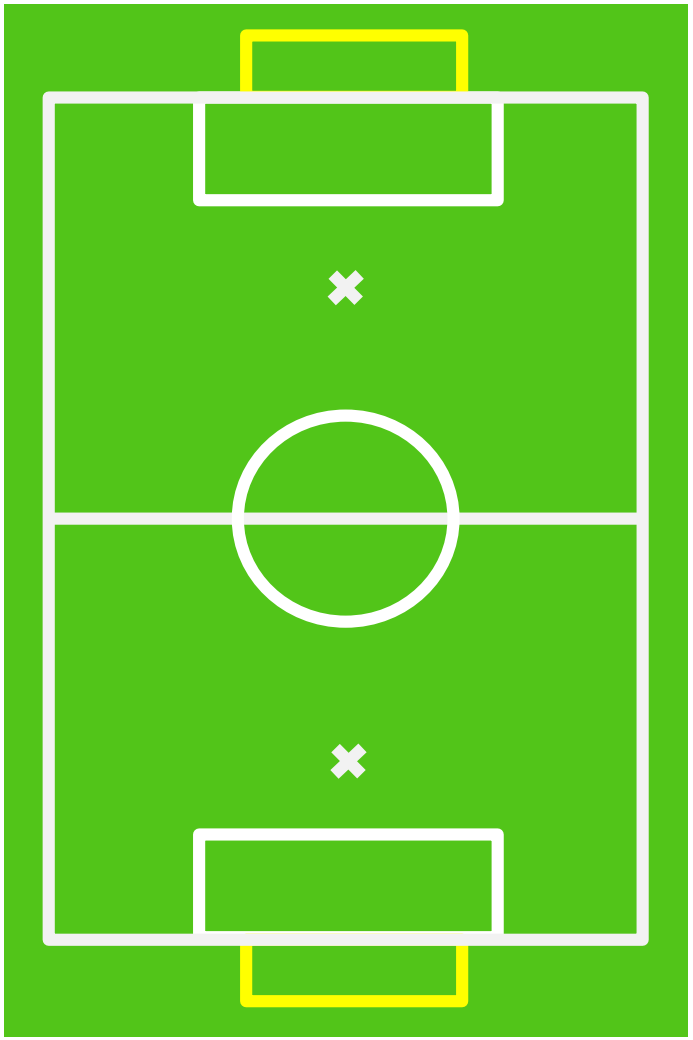
  - Map of field
  - Sequence of camera measurements

- **Wanted?**

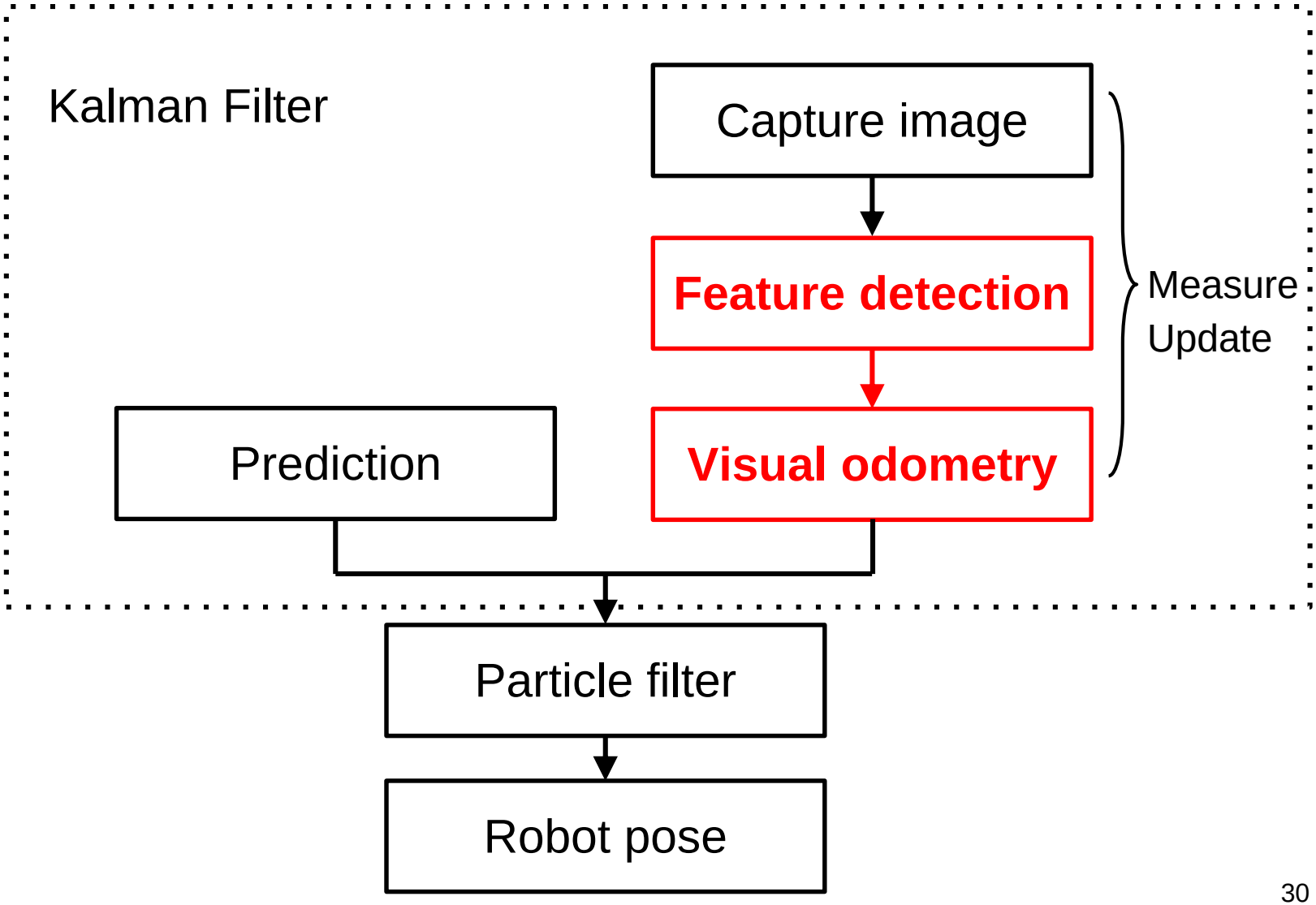
  - Robot 2D location and pose: $(x, y, \theta)^T$

- **Method?**

  - Unscented Kalman Filter + Particle filter



Localization: Motivation



Localization: Current Problems

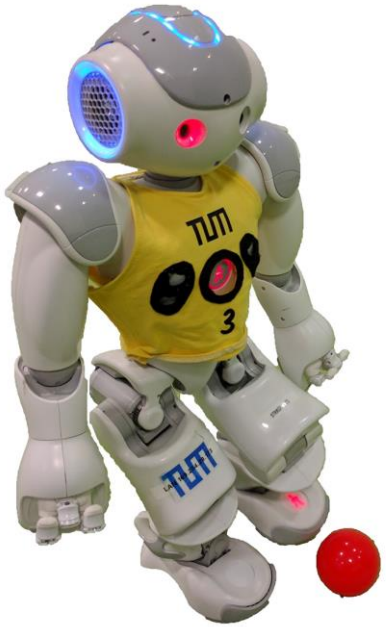
Feature detection

Visual odometry

- Ignore the good penalty mark
- Poor vertical line perception

- Inaccurate pose calculation caused by ignoring robot's walking noise

Semester Projects



Improvement of Localization

- **Penalty Mark Perception**
- Vertical Line Perception
- Visual Odometry

Penalty Mark Perception

Motivation

1. What is the Penalty Mark?

   - Appearance: cross

   - Location: in front of each penalty area

1. Why using the Penalty Mark?

   - special feature

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Penalty Mark Perception

Current Method

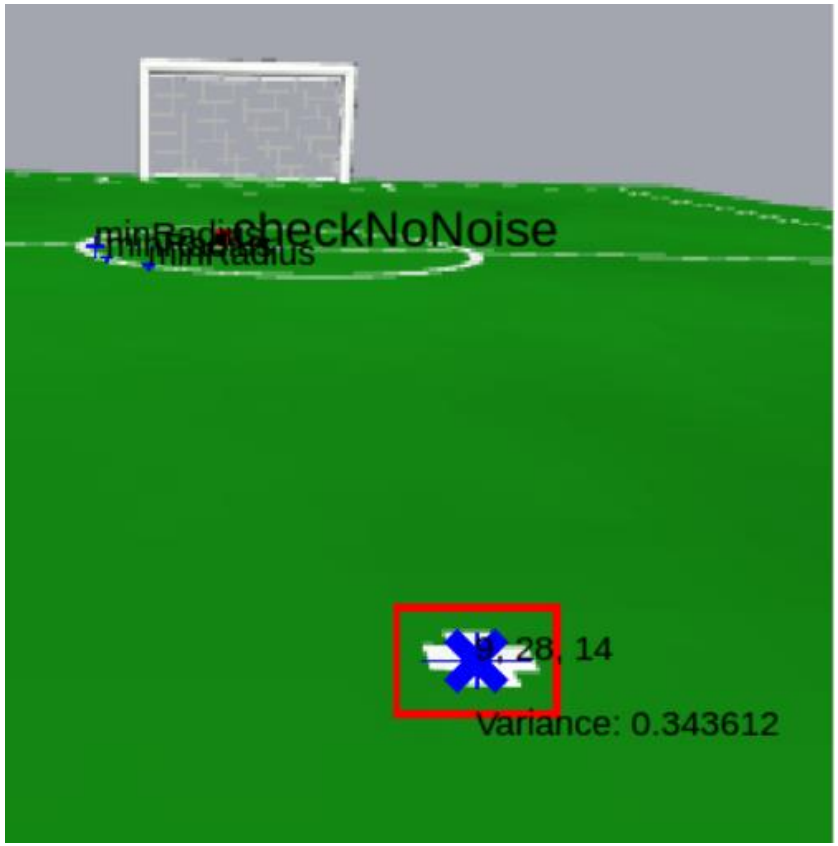
Criterion 1: distance from observer

Criterion 2: distance from field border

Criterion 3: variance

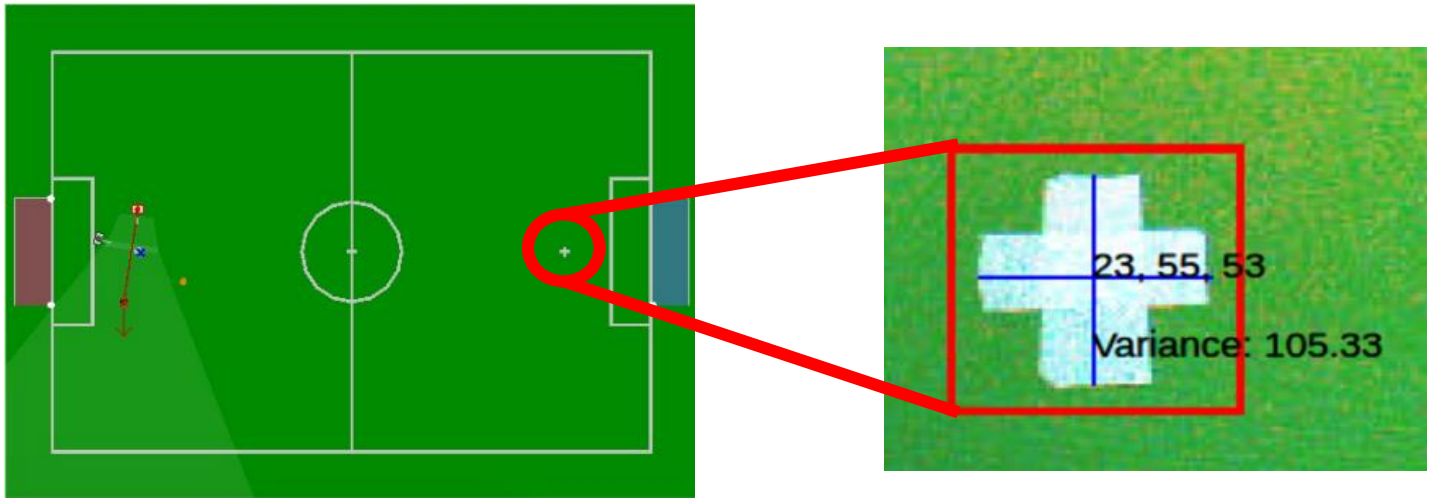
Criterion 4: size

Criterion 5: enough green area around



Penalty Mark Perception

Current Problem



Good penalty mark cannot be selected!

Test No.	1	2	3	4	5	6	7
Variance	-0.33697	-0.661187	12.9169	-0.69982	44.29901	-0.485818	0.190308

Negative variance!

Penalty Mark Perception

Method

Welford's method [2]

$$M_n = M_{n-1} + (x_n - \bar{x}_{n-1})(x_n - \bar{x}_n) \qquad \text{with } \sum_{i=1}^{n}(x_i - \bar{x}_n)^2 = M_n$$

$$\text{Variance} = \frac{M_n}{n-1}$$

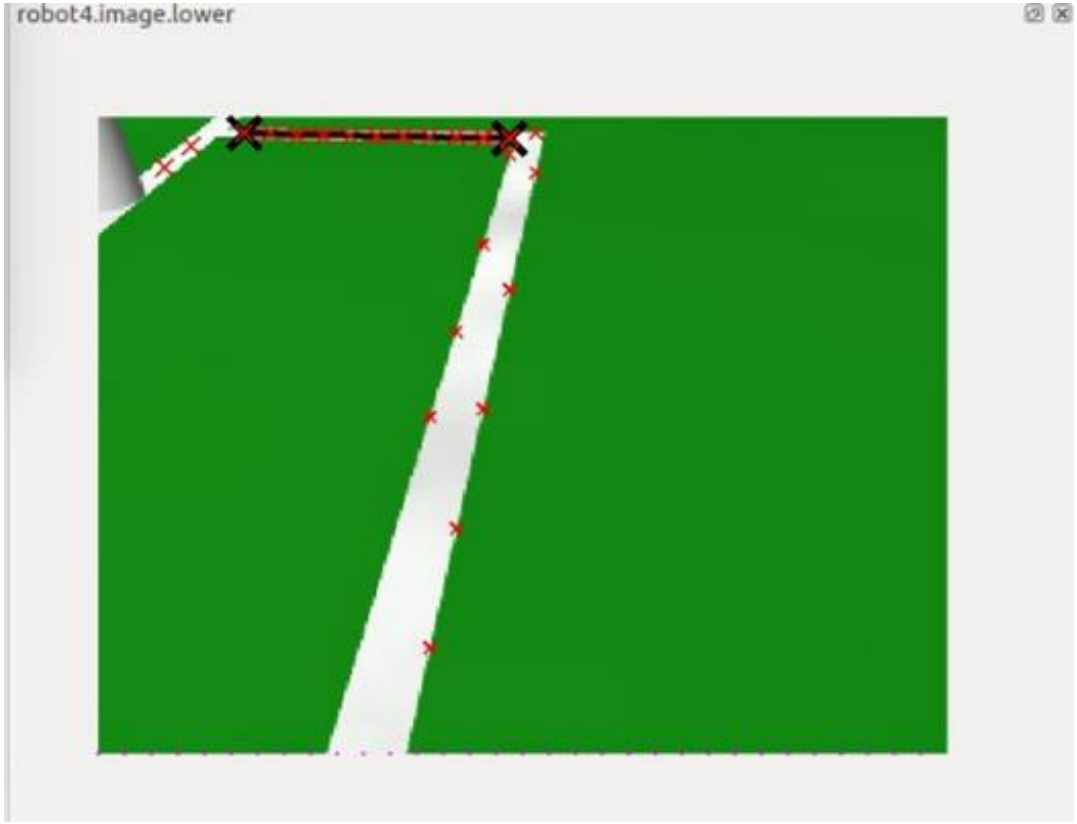
Achievement and evaluation

Test No.	1	2	3	4	5	6	7
Current Variance	-0.33697	-0.661187	12.9169	-0.69982	44.29901	-0.485818	0.190308
Standard Variance	0.10183	0.103699	18.0895	6.03105	19.0168	12.2954	0.101453
Improved Variance	0.2572	0.2486	0.2526	0.251778	0.3914	0.3966	0.24897

[2] Donald E. Knuth (1998). *The Art of Computer Programming*, volume 2: *Seminumerical Algorithms*, 3rd edn., p. 232. Boston: Addison-Wesley.

Penalty Area Perception

Poor vertical line perception!



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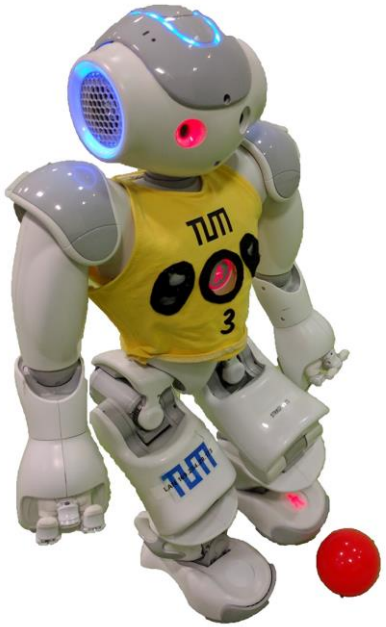
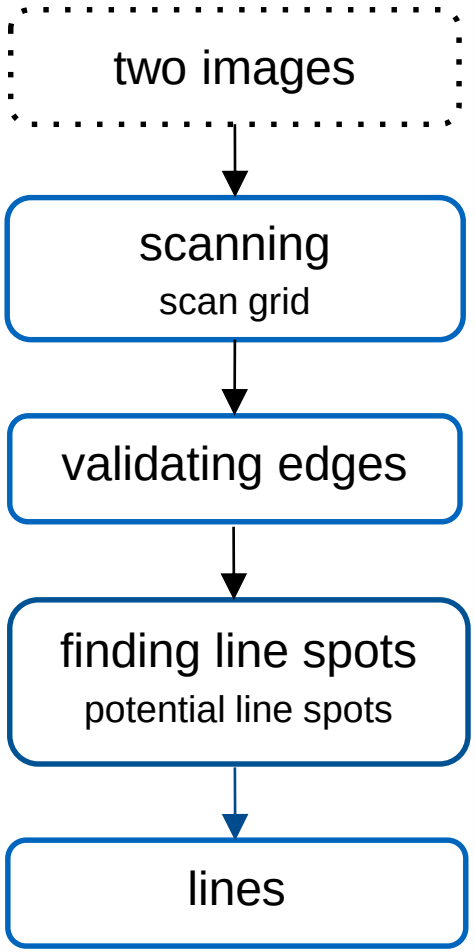
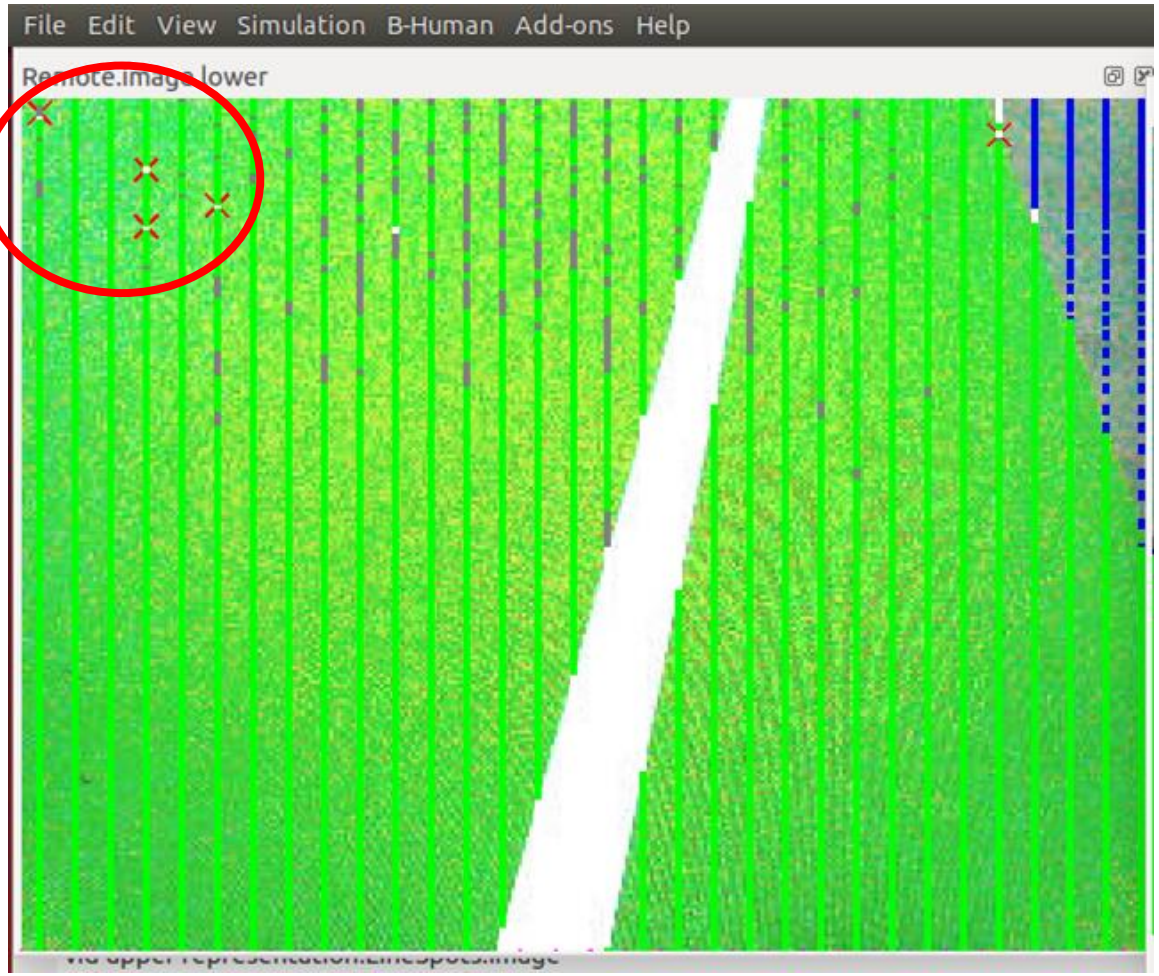


Improvement of Localization

- Penalty Mark Perception
- **Vertical Line Perception**
- Visual Odometry

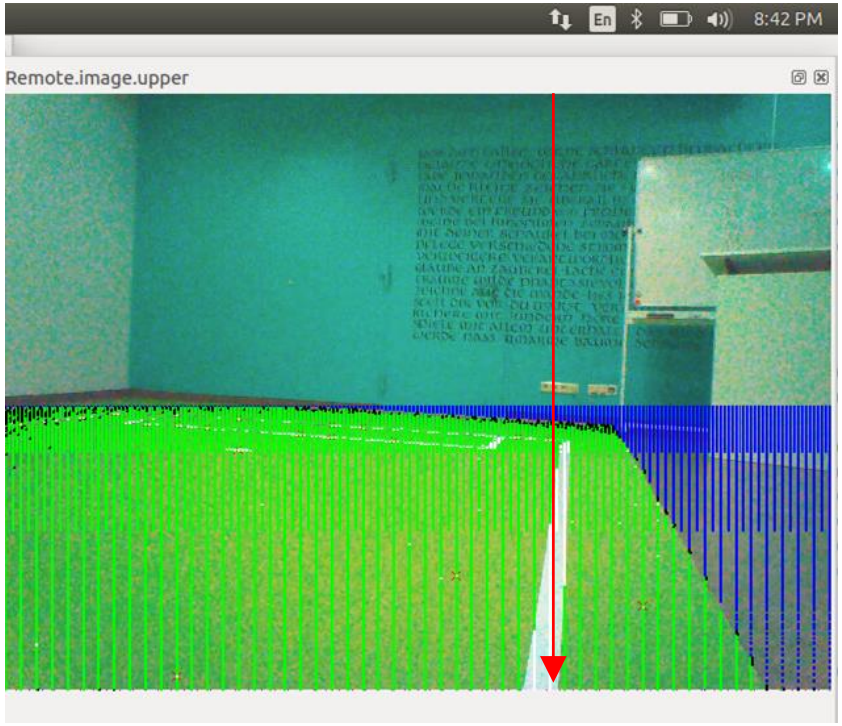
Line Perception





Line Perception

- two images
- **scanning**
  - scan grid
- validating edges
- finding line spots
  - potential line spots
- lines



increase the scanning rate to get more segments

Line Perception

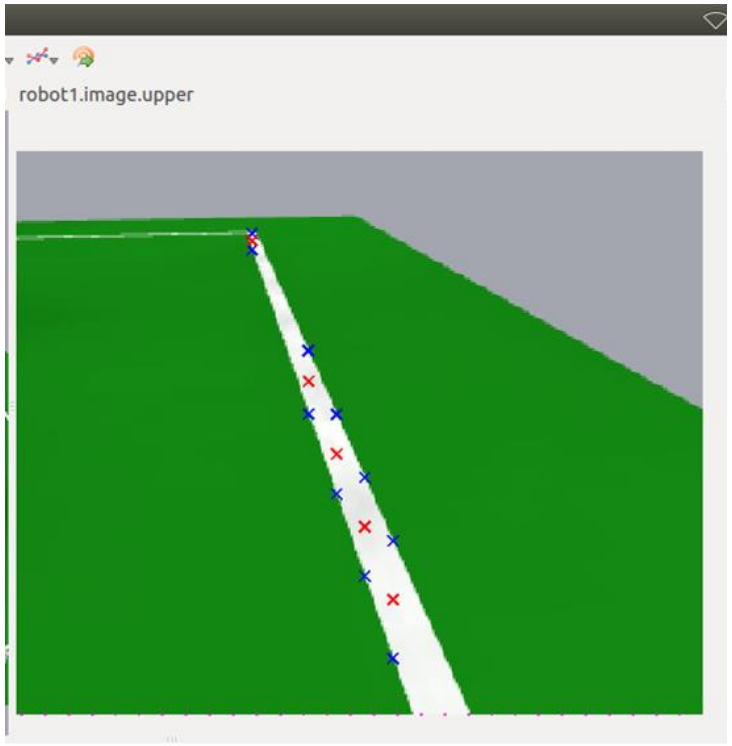
two images

scanning
scan grid

validating edges

finding line spots
potential line spots

lines



red: potential line spots
blue: line edges

set the threshold for the distance between two edges → potential line spot

Line Perception

two images

scanning
scan grid

validating edges

finding line spots
potential line spots

lines

potential line from abandoned line spots.

?

Line Perception

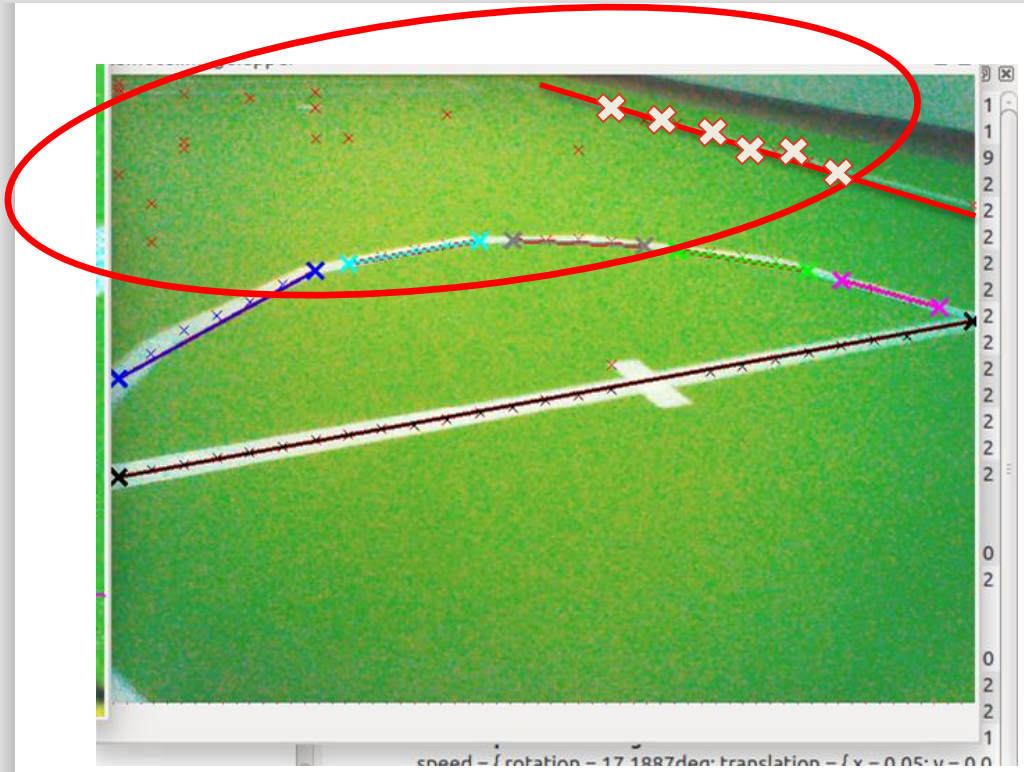
two images

scanning
scan grid

validating edges

finding line spots
potential line spots

lines



RANSAC
potential line from abandoned line spots.

Line Perception

two images

scanning
scan grid

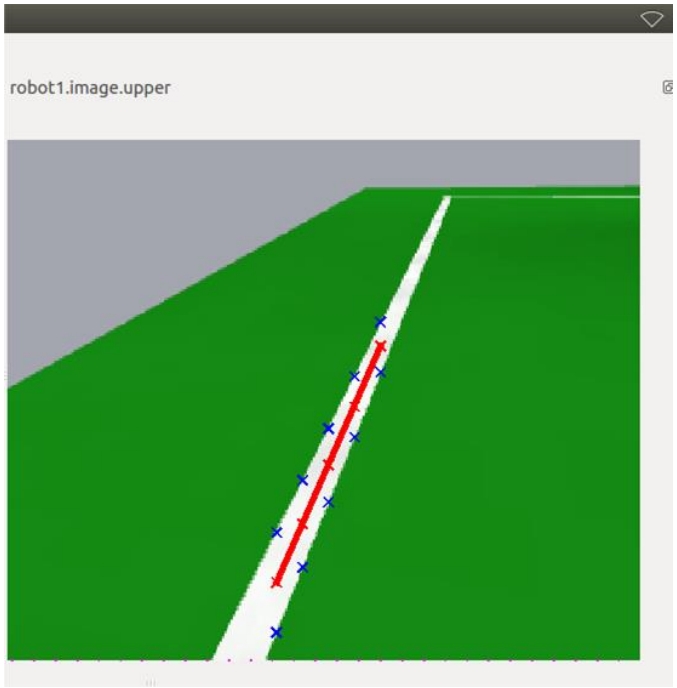
validating edges

finding line spots
potential line spots

lines

$y = a + bx$

b too large ✖



connect the first and last spot in the same cluster

Line Perception

Results:

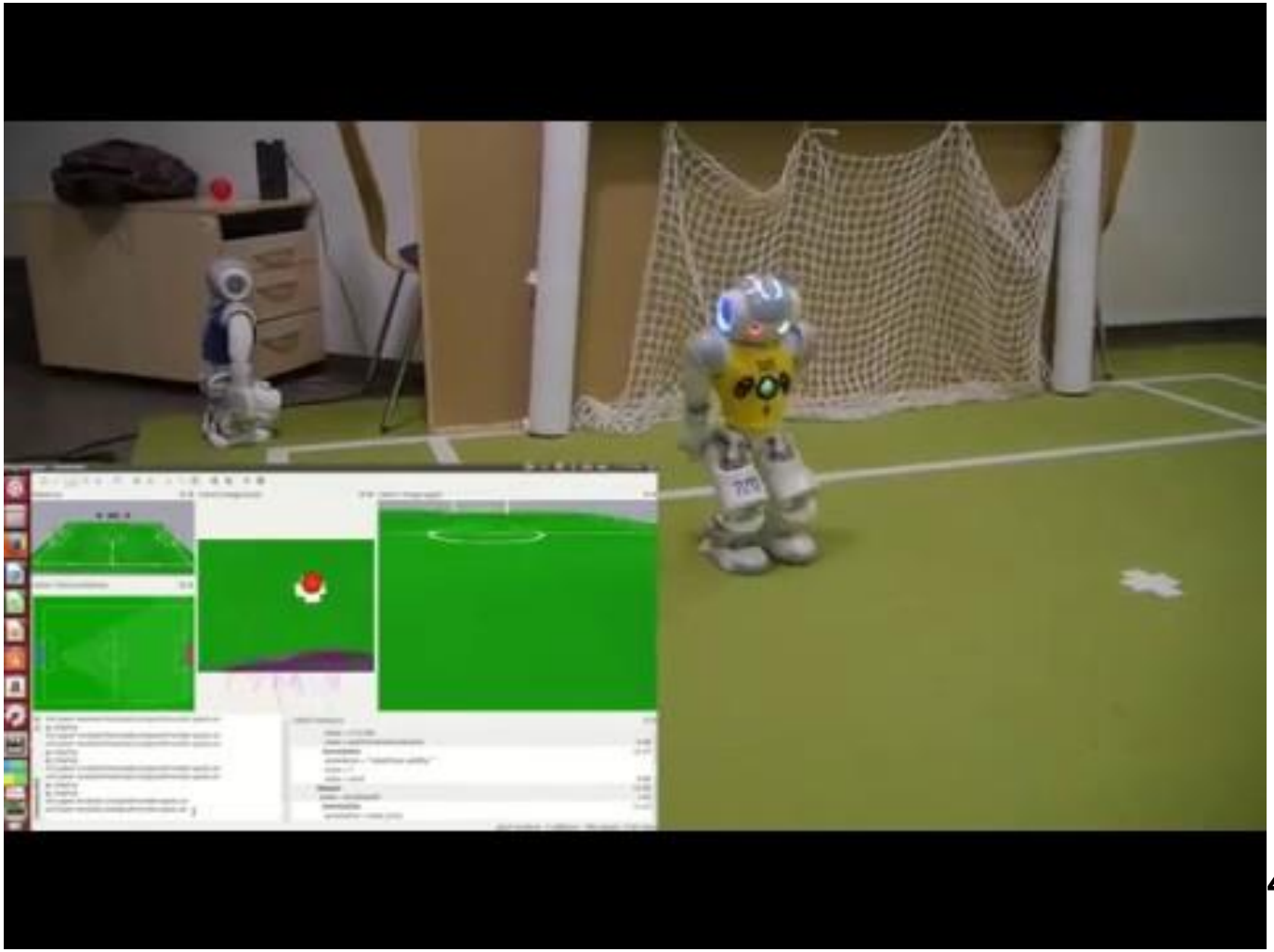
1. Extended line perception range: large slope

2. Detected line spots increased about 2 times (experimental value)

3. The best time consume to finish self-localization: 1’40’’

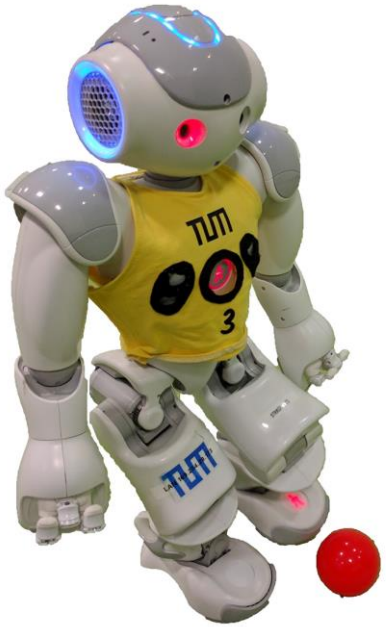
Result

Test day: July 14th, 2017; 17:00-18:00 pm; Cloudy.



4x

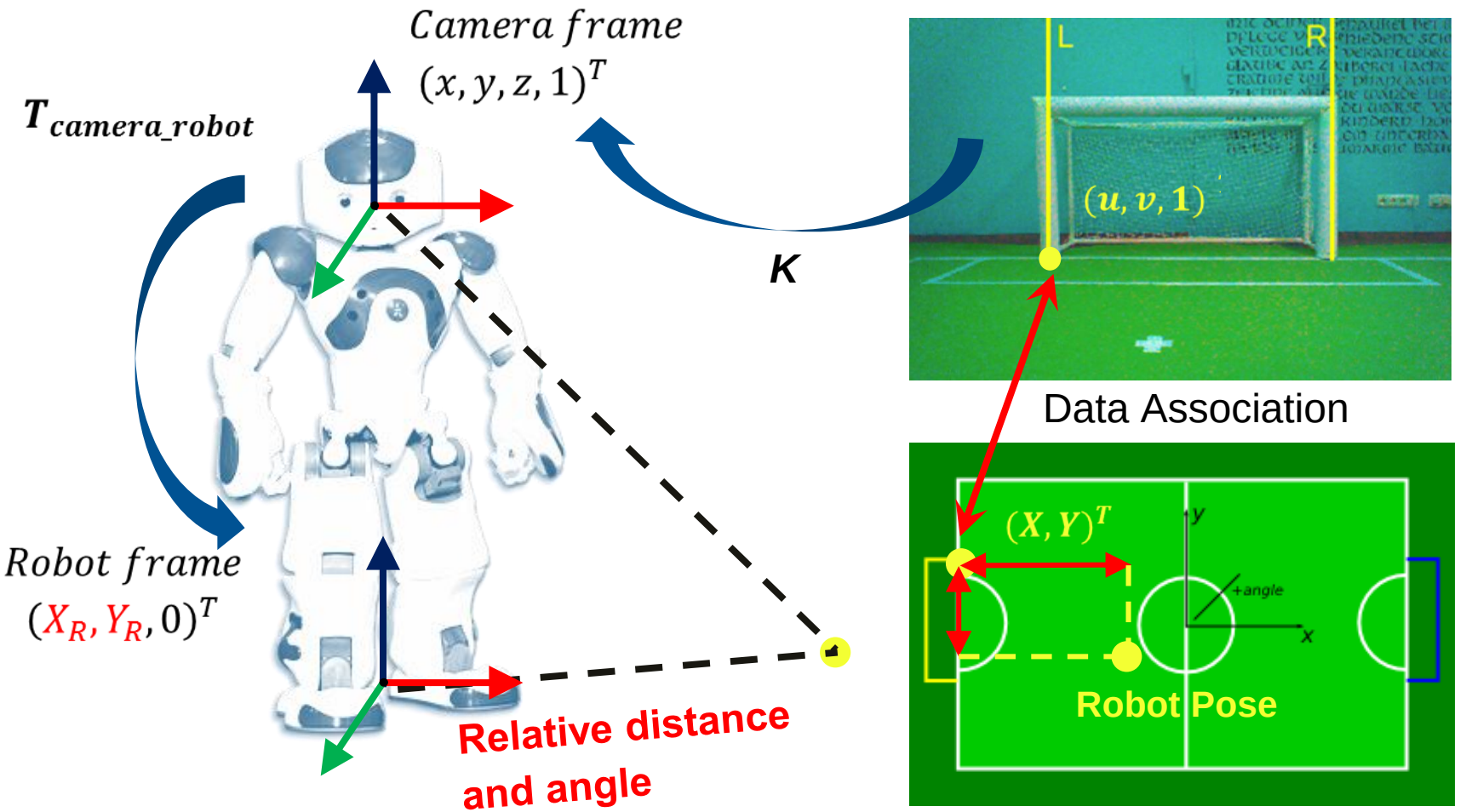
Semester Projects



Improvement of Localization

- Penalty Mark Perception
- Vertical Line Perception
- **Visual Odometry**

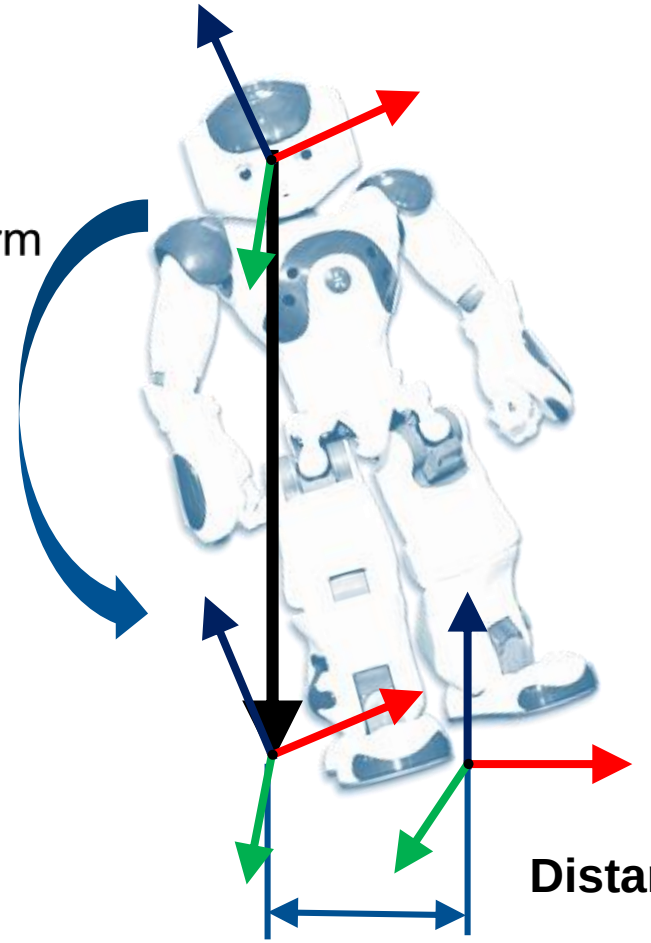
Visual Odometry: current method



Visual Odometry: Current Problem

A constant transform

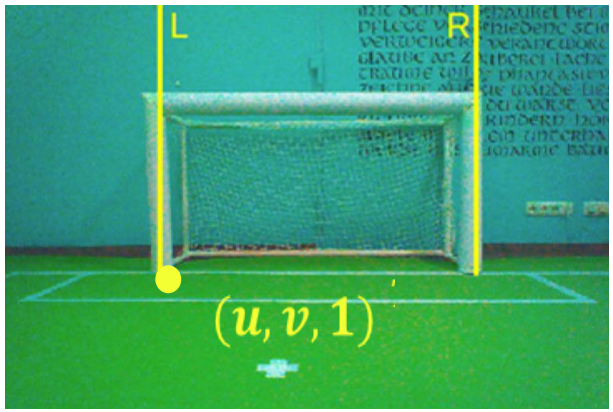
T_{camera_robot}

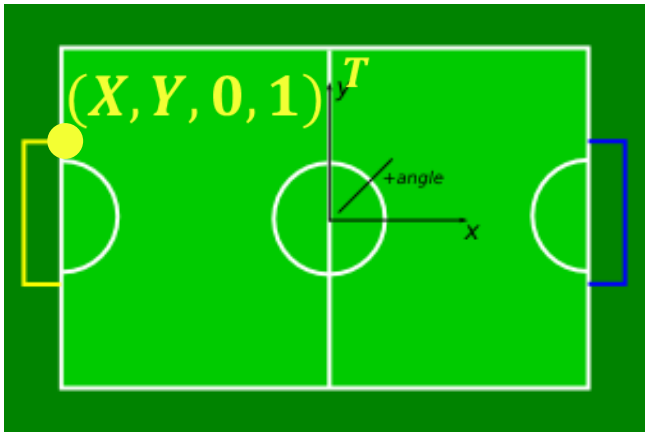


Real Robot base coordinate

Distance Error

Visual Odometry: PnP Pose Estimation[3]





$$\underbrace{T_{image\_field}}_{\text{Which we can calculate}} = \underbrace{K \cdot T_{camera\_robot}}_{\text{Known}} \cdot \underbrace{T_{robot\_field}}_{\text{Which we want to know}}$$

[3]: Simon Flueckiger, Self-Localization on NAO robots based on external features: PnP pose estimation, 2016, Computer Vision Lab, ETH Zuerich

Visual Odometry: PnP Pose Estimation[3]

$$\underbrace{\boldsymbol{T}_{image\_field}}_{\text{Which we can calculate}} = \underbrace{\boldsymbol{K}}_{\text{Known}} \cdot \boldsymbol{T}_{camera\_robot} \cdot \underbrace{\boldsymbol{T}_{robot\_field}}_{\text{Which we want to know}}$$

$$\boldsymbol{T}_{robot\_field} = [\boldsymbol{R} \quad \boldsymbol{T}] = \begin{bmatrix} cos\,\alpha & sin\,\alpha & 0 & T_x \\ -sin\,\alpha & cos\,\alpha & 0 & T_y \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

- 4 unkowns
- 2 pairs of correspondences $(u, v, 1)^T \leftrightarrow (X, Y, 0,1)^T$
- P2P Estimation

[3]: Simon Flueckiger, Self-Localization on NAO robots based on external features: PnP pose estimation, 2016, Computer Vision Lab, ETH Zuerich

Visual Odometry: Result

Visual Odometry: Evaluation

	Advantages	Disadvantages
Current method	• Quick, easy • Only need one pair correspondence	• Walking noise
PnP estimate method	• More accurate	• Complex calculation

Conclusions & Future Work:

Kicking Process

Achievements:

- Advanced kicking methods
- Kicking with both feet
- More improved alignment process

Future Work:

- Add more kicking methods
- Introduce strategies for passing and dribbling

Localization

Achievements:

- More robust penalty mark and line perception
- Eliminate pose estimation approximation error

Future Work:

- Scan grid in both vertical and horizontal directions
- Get a more adequate noise model