

# Embedded Solution for Person Identification and Tracking with a Robot

## Master in Telecommunication Engineering

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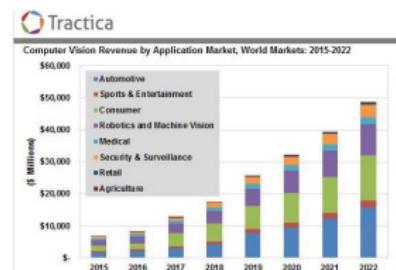
## 3 Results

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Strong evolution in computer vision research and development.

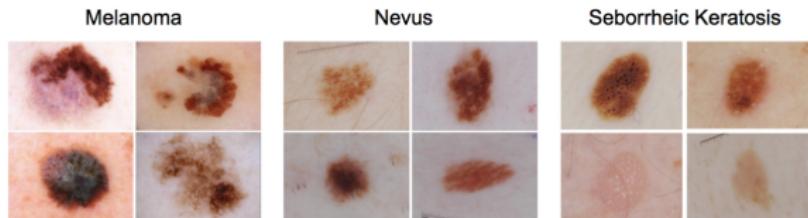
Notable spreading of *deep learning* techniques on computer vision: CNNs (*Convolutional Neural Networks*).

## Motivation I

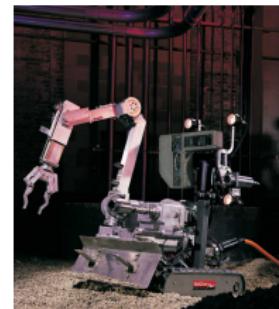


Multiple applications:

- Autonomous driving
- Medical diagnosis
- Surveillance



## Motivation II



Powerful applications in robotics as well:

- Remote inspections on hazardousness
- Precision surgery
- Social robotics



# Objectives

Main goal: Autonomous robot that robustly follows a person.

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# Objectives

Main goal: **Autonomous robot that robustly follows a person.**  
Subgoals:

- Implement a real-time person following behavior on affordable hardware.
- Use only robust CNNs for the inference tasks.
- Enhance the robustness combining the CNNs with optical tracking.



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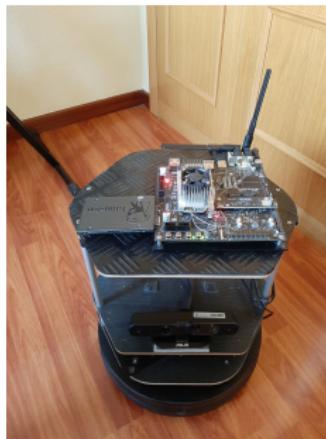
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## Hardware



- NVIDIA Jetson TX2
- Turtlebot2
- ASUS Xtion Pro Live

## Software



- Python 3.7
- ROS Melodic Morenia
- TensorFlow
- TensorRT

# Embedded Solution for Person Identification and Tracking with a Robot

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## Design

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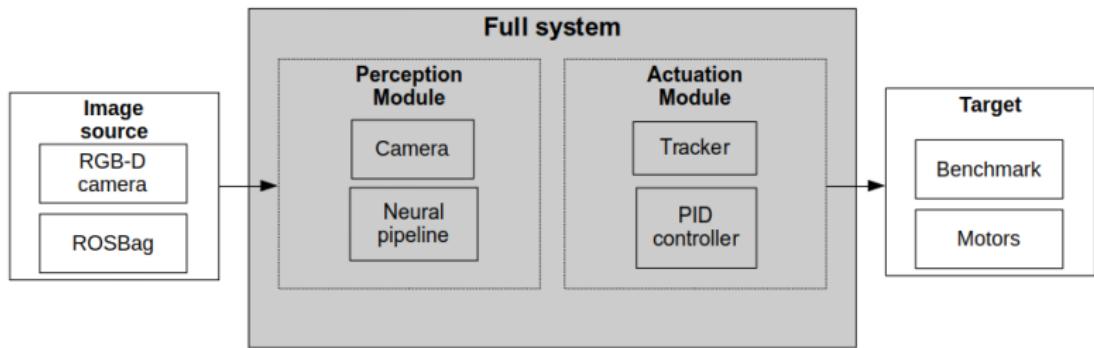
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# Perception Module I

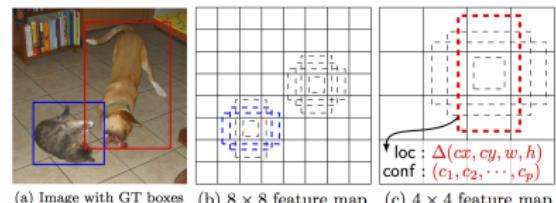
## Tasks to address:

- Person detection.
- Face detection.
- Face recognition.

## Perception Module II

One devoted neural network for solving each task.

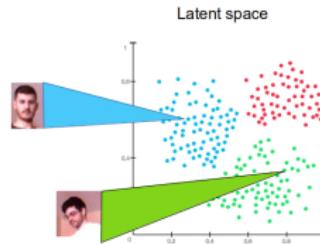
- **Person detection:** object detection CNNs: YOLOv3, SSD.



- **Face detection:** specific face detection CNN: faced.



- **Face recognition:** face encoder to latent  $\mathbb{R}^{128}$  space: FaceNet.



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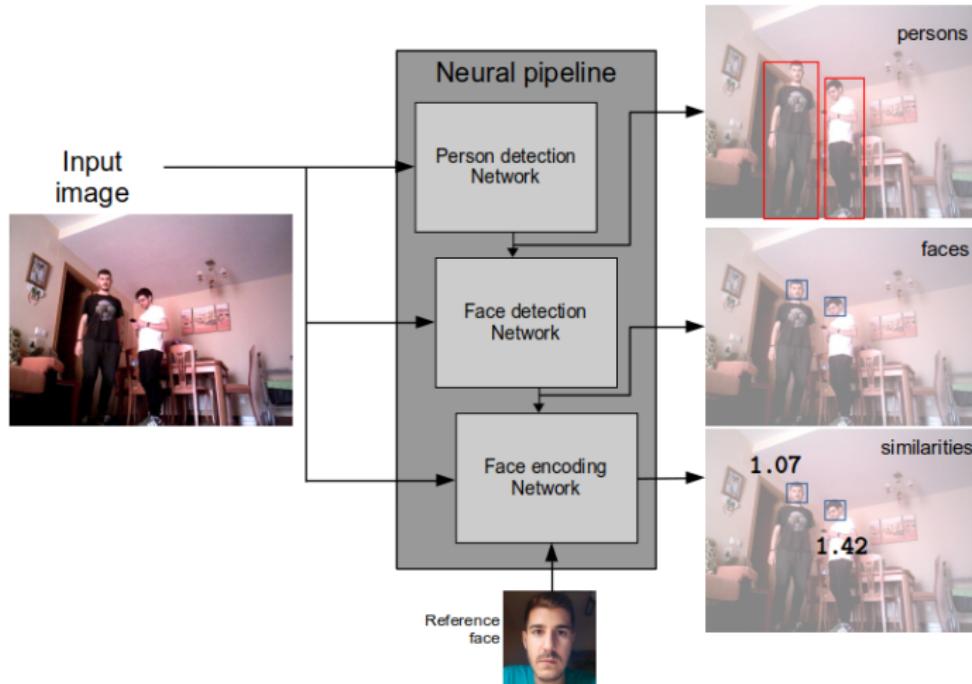
Actuation Module

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# Perception Module III

TensorRT used to optimize the networks across the neural pipeline.



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# Actuation Module I

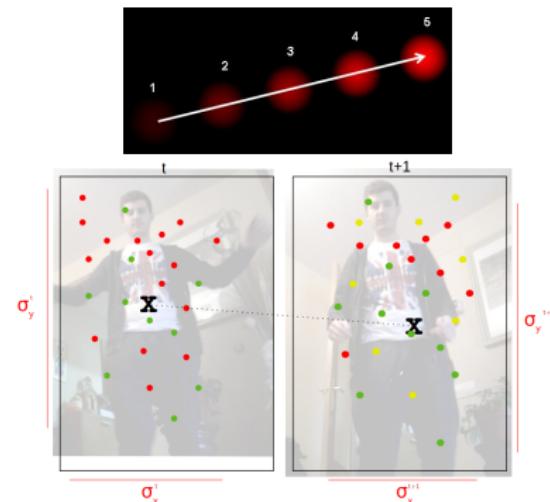
## Tasks to address:

- Track the persons.
- Move the robot.

# Actuation Module II

## Person tracker:

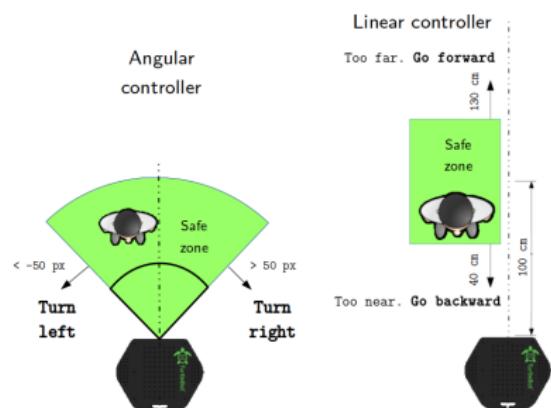
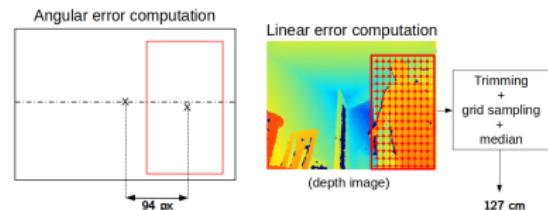
- Based on optical flow estimation (Lucas-Kanade).
- Shift and transform the bounding box.
- Patience for alleviating occlusions.



# Actuation Module III

## PID Controllers:

- Closed-loop control system.
- One per degree of freedom.
- Reactive responses.
- Safe zones for smooth response.



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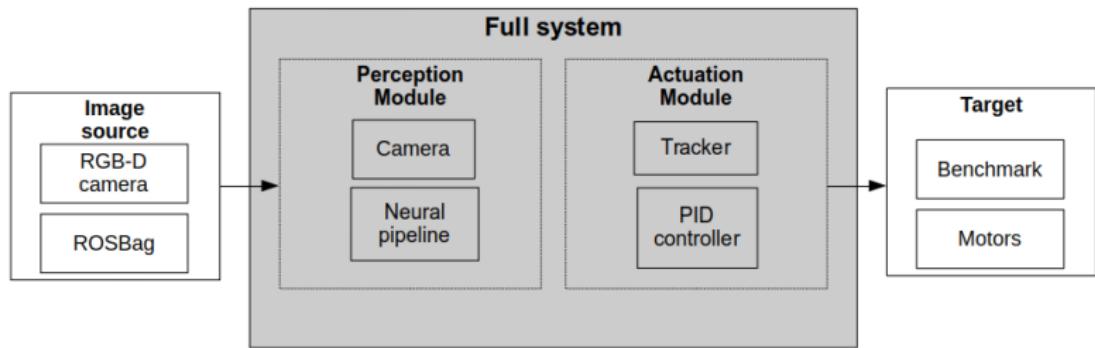
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# Design summary



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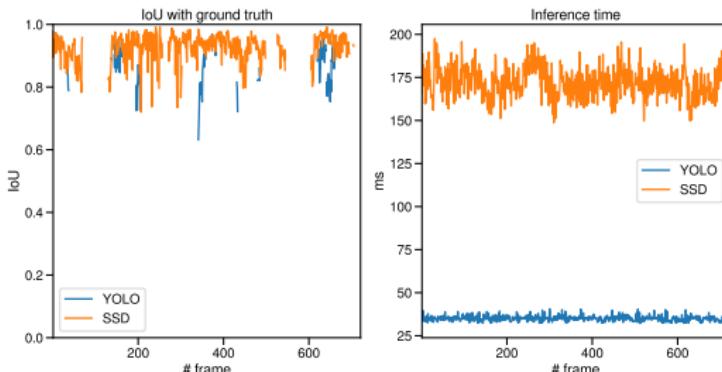
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# Person detection

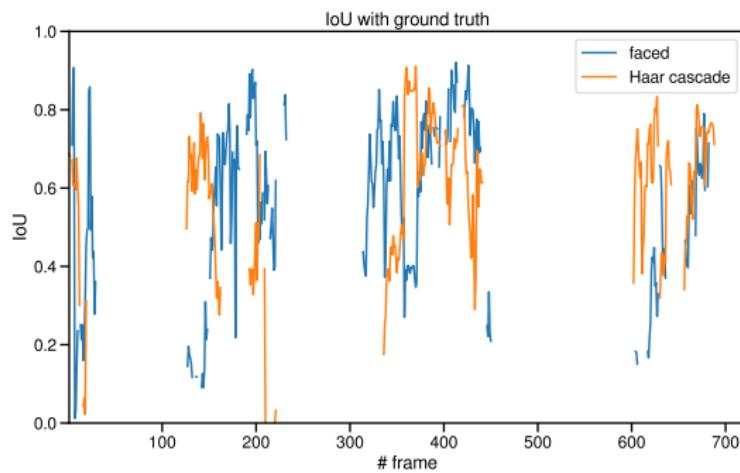
## Precision and inference time: SSD vs. YOLOv3 tiny



	YOLO	SSD
IoU	$0.858 \pm 0.068$	$0.926 \pm 0.044$
Inf. time (ms)	$35.003 \pm 1.503$	$172.237 \pm 8.791$
Frames with detection	123 (17.06%)	533 (73.93%)

# Face detection

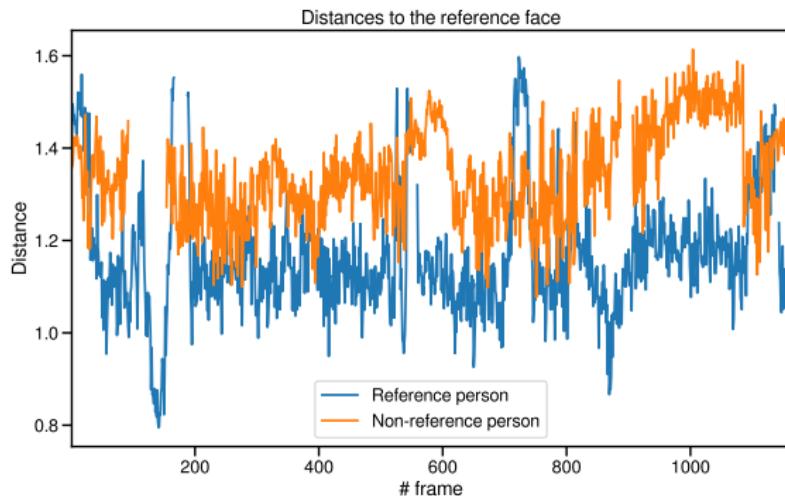
Precision: neural detector (`faced`) vs Haar-features classifier.



	haar	faced
IoU	0.579 ± 0.202	0.559 ± 0.221
Frames with detection	248 (34.40%)	266 (36.89%)

# Face recognition

Distance between two faces and the reference face.



	Ref. person	Non-ref. person
IoU	$1.160 \pm 0.128$	$1.344 \pm 0.102$

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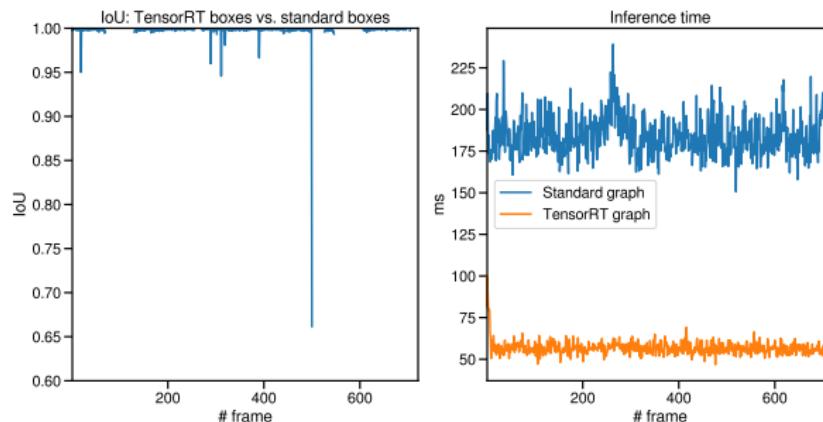
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# TensorRT Optimizations

Loss in precision and inference time.



	Original graph	TensorRT graph
Inference time (ms)	$184.477 \pm 11.827$	$56.769 \pm 4.148$
IoU with original graph	-	$0.997 \pm 0.015$

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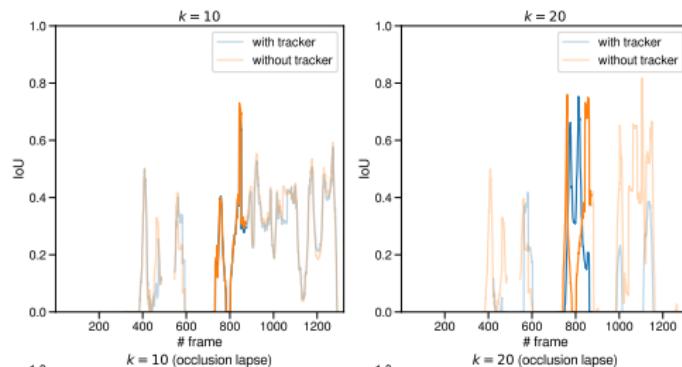
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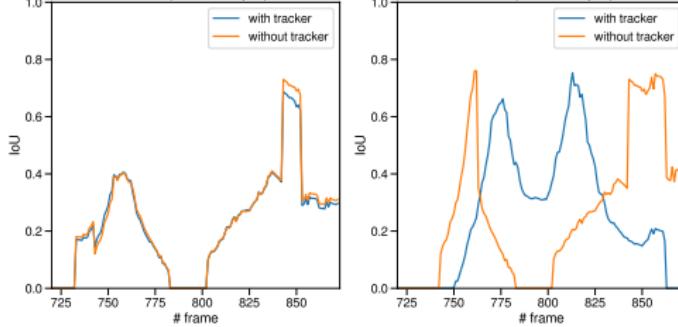
# Motion tracker

## Gain in robustness to occlusions using the tracker.

IoU with ground truth



$k = 10$  (occlusion lapse)



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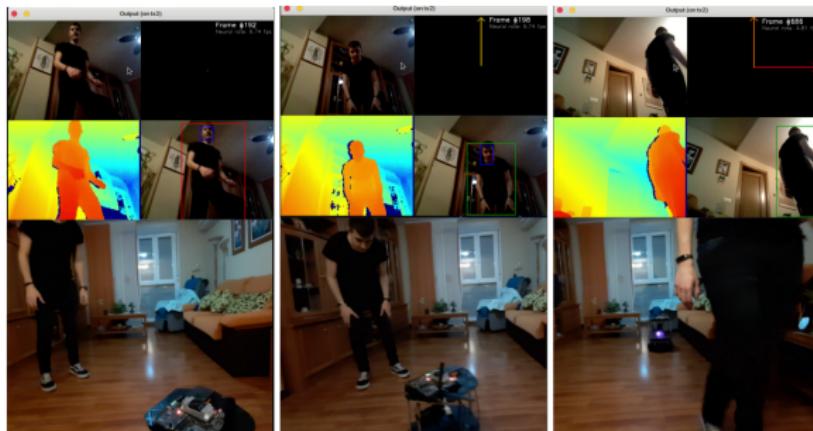
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# Full system

Following the person.



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Accomplishment of the outlined objectives:

- ✓ Real-time following behavior.
- ✓ Affordable/educational hardware.

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Accomplishment of the outlined objectives:

- ✓ Real-time following behavior.
- ✓ Affordable/educational hardware.
- ✓ Robust detection relying on deep learning.

# Conclusions I

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Accomplishment of the outlined objectives:

- ✓ Real-time following behavior.
- ✓ Affordable/educational hardware.
- ✓ Robust detection relying on deep learning.
- ✓ Enhanced softness using an optical tracker.

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Main drawbacks found:

- ✗ Lighting affected by the camera position.

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# Conclusions II

Main drawbacks found:

- ✖ Lighting affected by the camera position.
- ✖ Persons crossing each other may be confounded.

## Conclusions II

Main drawbacks found:

- ✖ Lighting affected by the camera position.
- ✖ Persons crossing each other may be confounded.
- ✖ Collisions with obstacles may occur.

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Future lines to address:

- Sensor fusion to enhance the perception.

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Future lines to address:

- Sensor fusion to enhance the perception.
- Probabilistic tracker to model trajectories.

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Future lines to address:

- Sensor fusion to enhance the perception.
- Probabilistic tracker to model trajectories.
- Navigation algorithms for obstacle avoidance.

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