Embedded Solution for Person Identification and Tracking with a Robot

Master in Telecommunication Engineering

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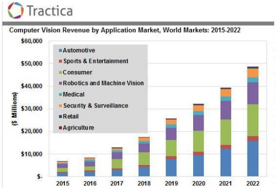
Motivation I

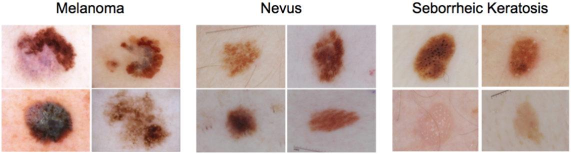
Strong evolution in computer vision research and development.

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

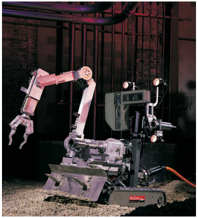


Multiple applications:

- 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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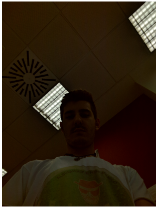
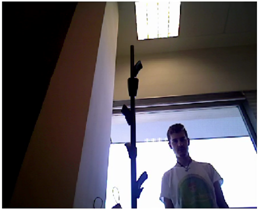
Subgoals:

- 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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Resources

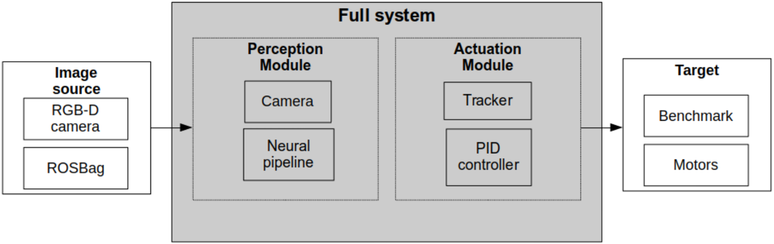
Hardware

- NVIDIA Jetson TX2
- Turtlebot2
- ASUS Xtion Pro Live

Software

- Python 3.7
- ROS Melodic Morenia
- TensorFlow
- TensorRT

Design


Full system
Image source
RGB-D camera
ROSBag
Perception Module
Camera
Neural pipeline
Actuation Module
Tracker
PID controller
Target
Benchmark
Motors

Perception Module I

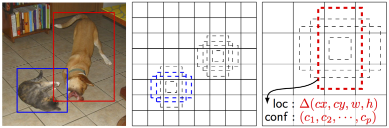
Tasks to address:

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

Perception Module II

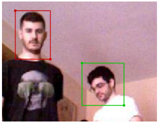
One devoted neural network for solving each task.

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

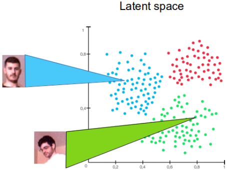


(a) Image with GT boxes (b) 8×8 feature map (c) 4×4 feature map

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

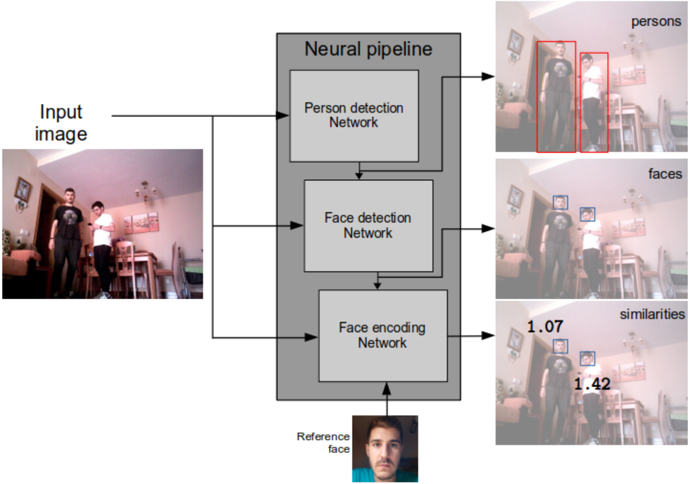


- **Face recognition:** face encoder to latent $\mathbb{R}^{128}$ space: FaceNet.



Perception Module III

TensorRT used to optimize the networks across the neural pipeline.



Actuation Module I

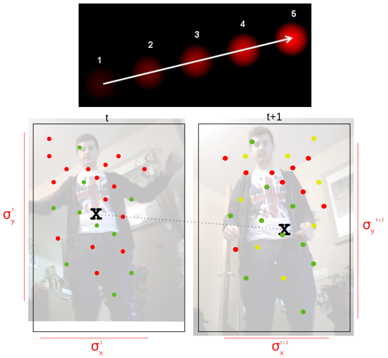
Tasks to address:

- Track the persons.
- Move the robot.

Actuation Module II

Person tracker:

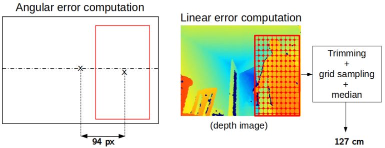
- Based on optical flow estimation (Lucas-Kanade).
- Shift and transform the bounding box.
- *Patience* for alleviating occlusions.

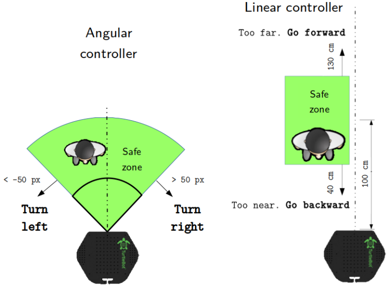


Actuation Module III

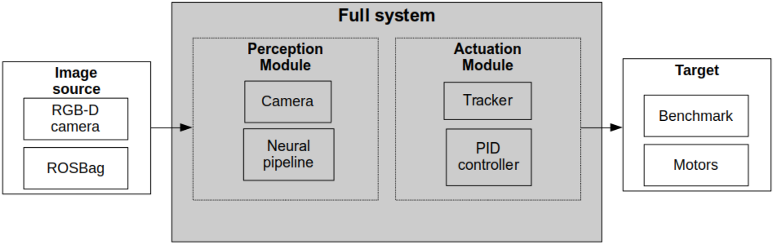
PID Controllers:

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





Design summary



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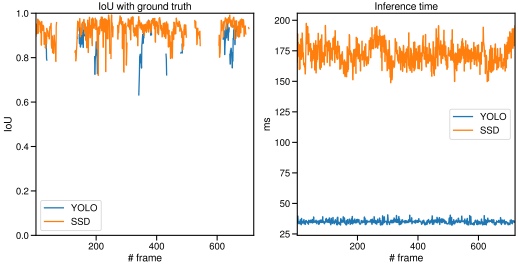
Person detection

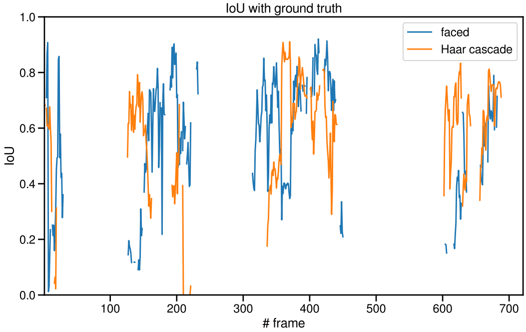
Precision and inference time: SSD vs. YOLOv3 tiny



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

Face detection

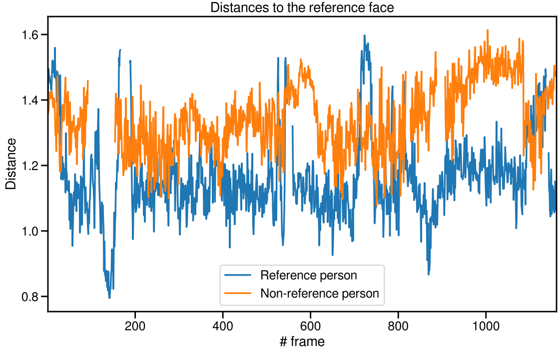
Precision: neural detector (`faced`) vs Haar-features classifier.



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

Face recognition

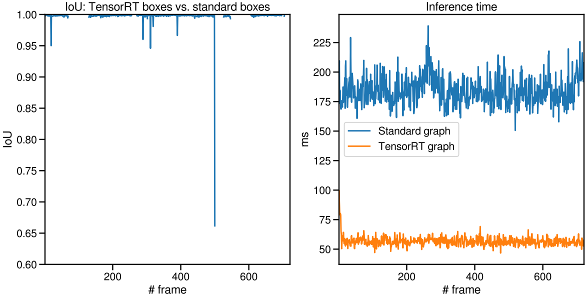
Distance between two faces and the reference face.



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

TensorRT Optimizations

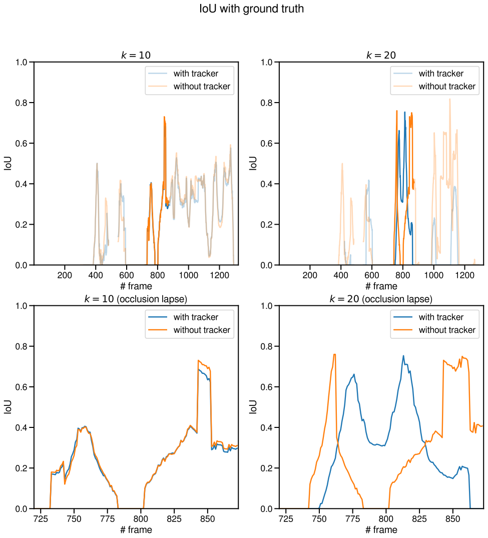
Loss in precision and inference time.



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

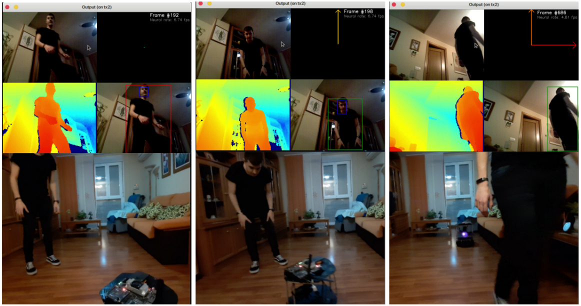
Motion tracker

Gain in robustness to occlusions using the tracker.



Full system

Following the person.



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Conclusions I

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.
- ✔ Enhanced softness using an optical tracker.

Conclusions II

Main drawbacks found:

- ✖ Lighting affected by the camera position.

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- ✖ Persons crossing each other may be confounded.

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- ✖ Persons crossing each other may be confounded.
- ✖ Collisions with obstacles may occur.

Conclusions III

Future lines to address:

- Sensor fusion to enhance the perception.

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- 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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