UAV Infrastructure Inspection summary

V. Mygdalis, Prof. Ioannis Pitas
Aristotle University of Thessaloniki
pitas@csd.auth.gr
www.aiia.csd.auth.gr
Version 3.3.1

Artificial Intelligence & Information Analysis Lab

Infrastructure inspection applications

- Aerial robots with different characteristics must be integrated for:
  1. Long range and local very accurate inspection of the infrastructure.
  2. Maintenance activities based on aerial manipulation involving force interactions.
  3. Aerial co-working safely and efficiently helping human workers in inspection and maintenance.

UAV Infrastructure Inspection

- **Overview**
- Sensors
- Visual analysis
- Drone operations

Technical objectives

- Cognitive functionalities for aerial robots including ***perception based on novel sensors*** such as event cameras and data fusion techniques, learning, reactivity, fast on-line planning, and teaming.
- Cognitive safe aerial robotic co-workers capable of ***physical interaction with people***.
- ***Cognitive aerial manipulation*** capabilities, including manipulation while flying, while holding with one limb, and while hanging or perching to improve accuracy and develop greater forces.
- Aerial platforms with ***morphing capabilities***, including morphing between flight configurations, and between flying and ground locomotion, to save energy and perform a very accurate inspection.

Long range inspection of power lines

Helicopter inspection of power lines

Safe local manipulation interventions

- Examples:
  - Installing anti-birds systems.
  - Cleaning isolator in power lines.

Installing anti-birds systems

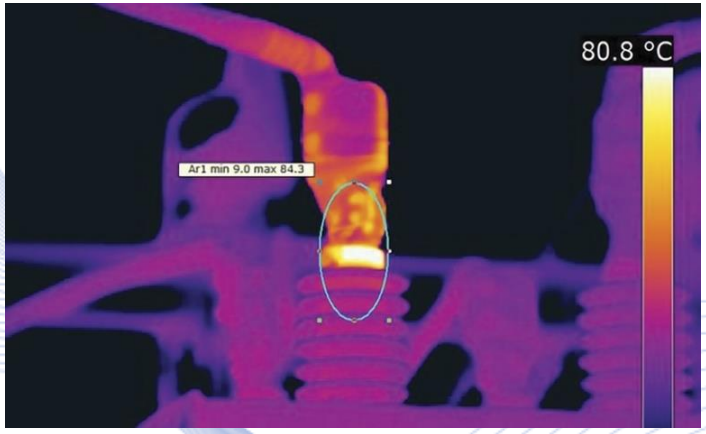
- National regulation (a few years ago) enforces their installation every 5-10 m.
- (De-)installation is performed by work at height on a basket.
- Dangerous, slow and costly.
- The electrical lines has to be without voltage, resulting in money loss.

Co-working activities

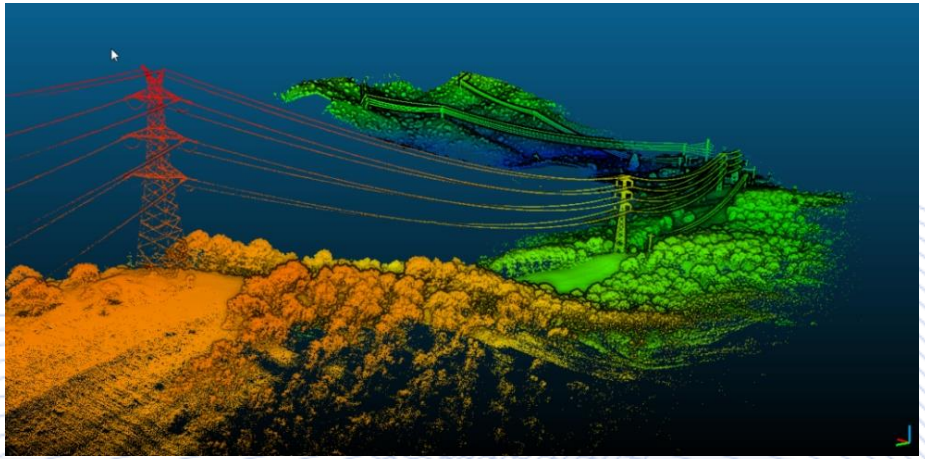
Infrastructure Inspection

- Overview
- **Sensors**
- Visual analysis
- Drone operations

Types of inspection



Thermography

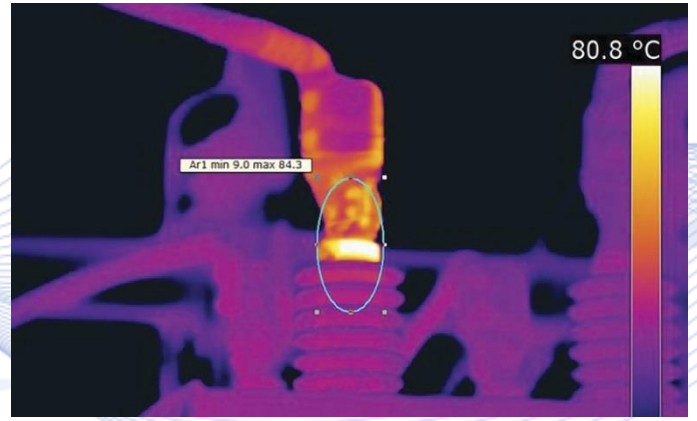


3D mapping (LIDAR)

Camera & video

Thermography

- Detection of hot spots in the electrical tower: cramps and connections
- To perform thermography, the speed of a fixed wing UAV is limited to 50-60 km/h.

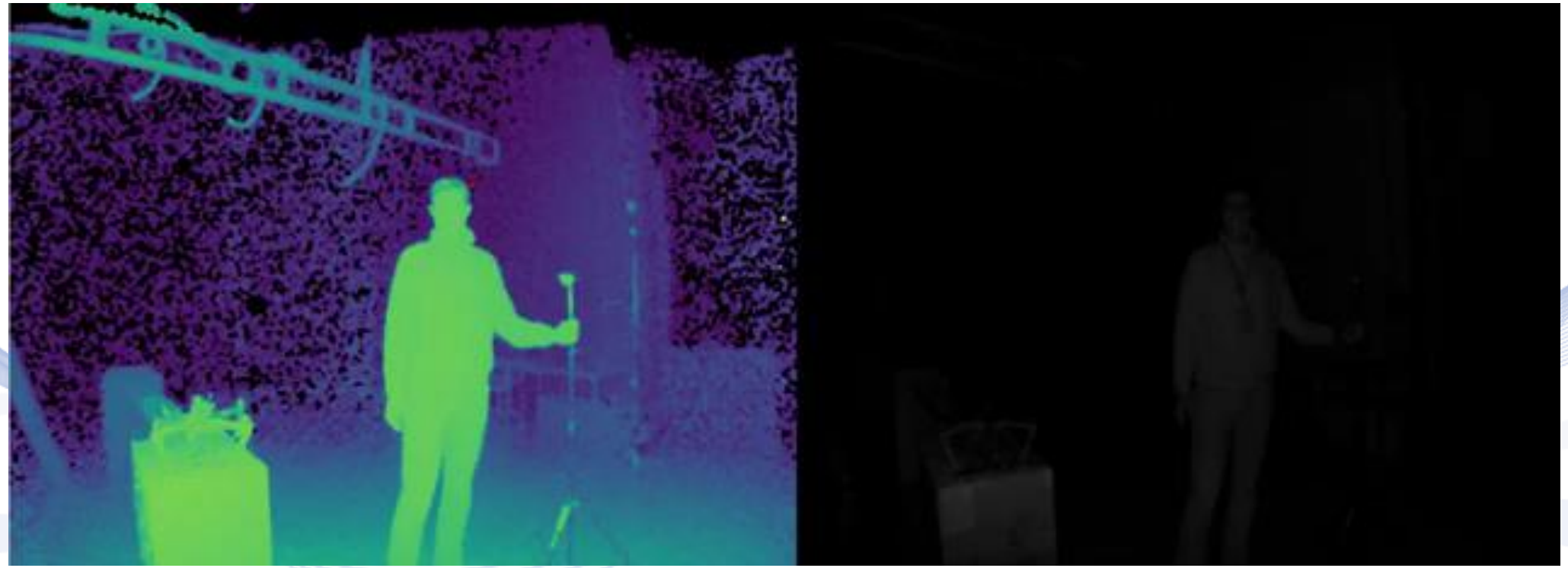


3D LIDAR

- Precise 3D mapping (with cm level accuracy and precision)
- No speed limitation on the manned helicopter
- A 3D map is constructed to:
  - Detection of obstacles close to power lines.
  - Measurement of vegetation around power lines.
  - Checking distance when crossing power lines.
  - Once the 3D map is obtained, a classifier algorithm (and also checked and adjusted by a technician) is used.
  - Afterwards, distances and other measurements are performed to develop the inspection report.

3D VGA Time-of-Flight camera

- A camera for human gesture recognition, object avoidance in close distance, landing and taking-off.



Indoor Tests, February 2021, Terabee facilities

Event cameras - motivation

Latency & Motion blur.

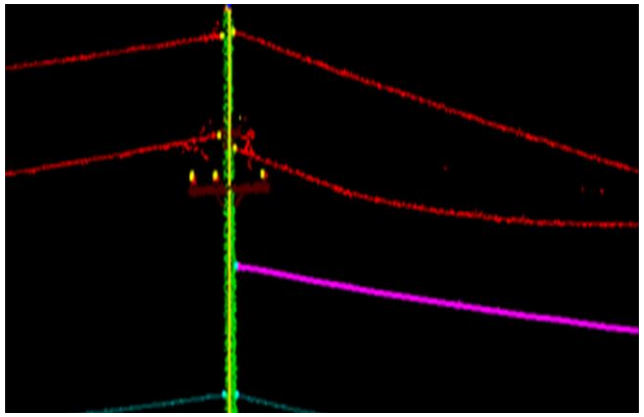
Dynamic Range.

Infrastructure Inspection

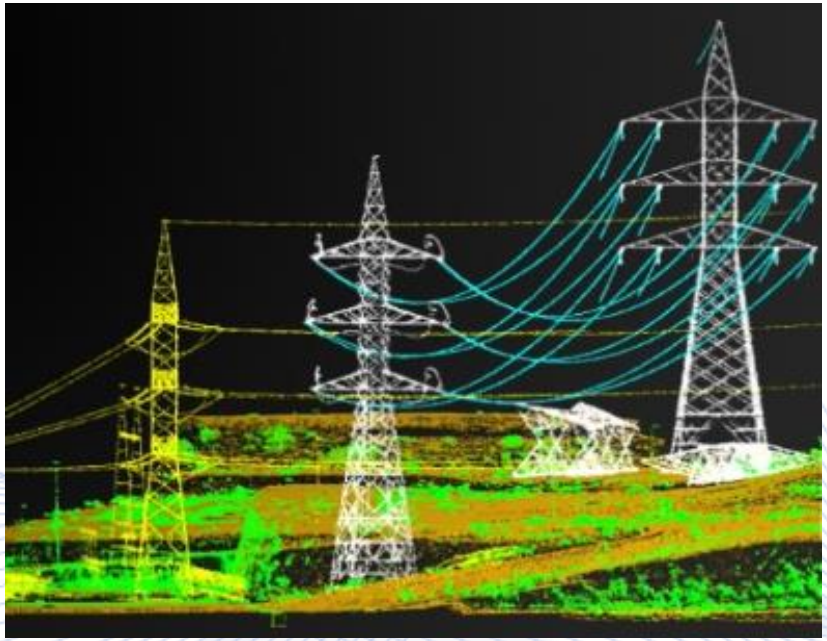
- Overview
- Sensors
- **Visual analysis**
- Drone operations

Research tasks

- Semantic 3D world mapping.
- Learning methods for object detection/tracking of electric lines, rods, etc.
- Human-drone interaction:
  - Gesture drone control.
  - Body posture estimation.
  - Human action recognition.
  - Facial pose estimation.



Semantic 3D World Mapping



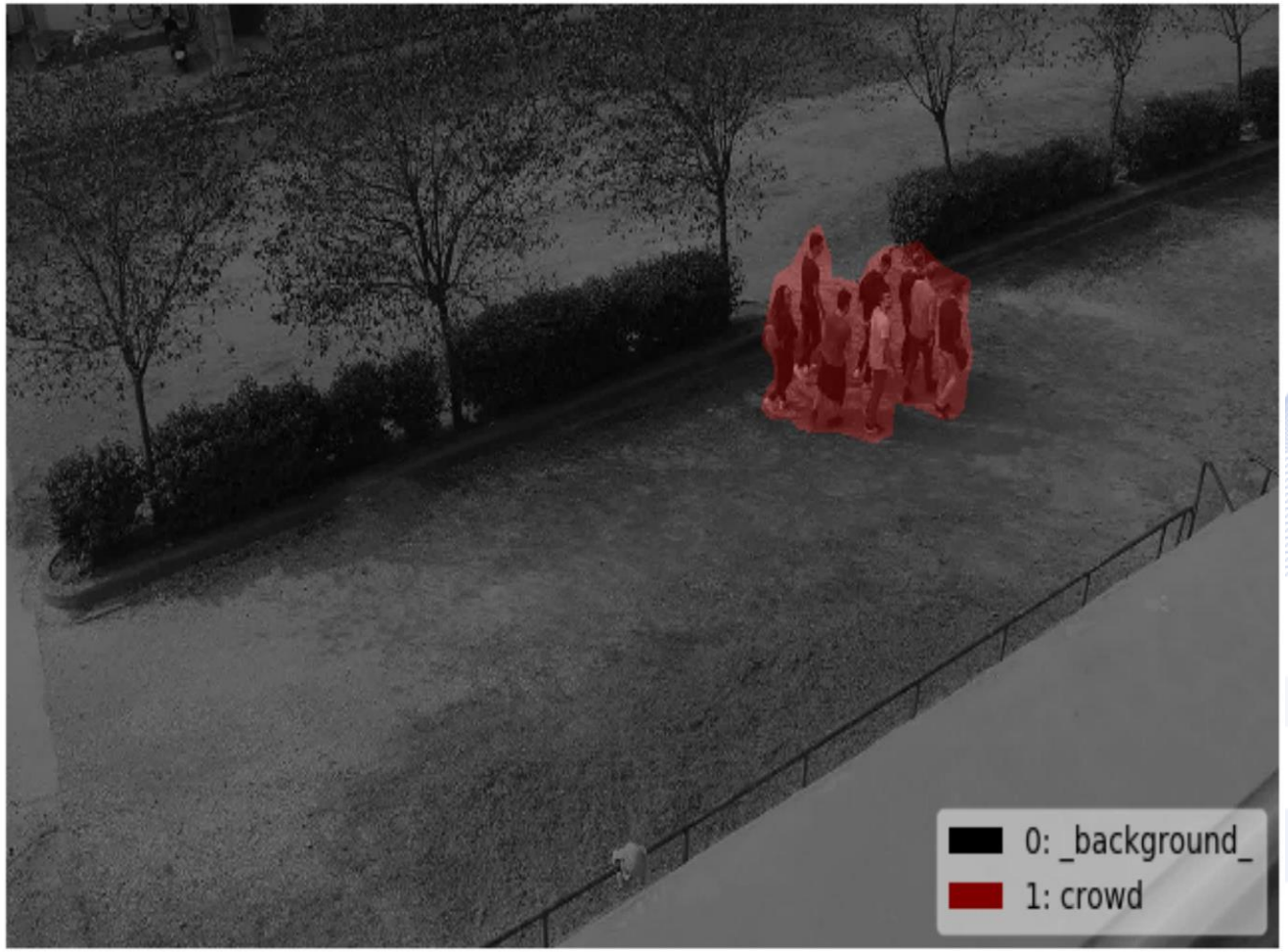
Geometric modeling of the 3D world.

Semantic 3D World Mapping

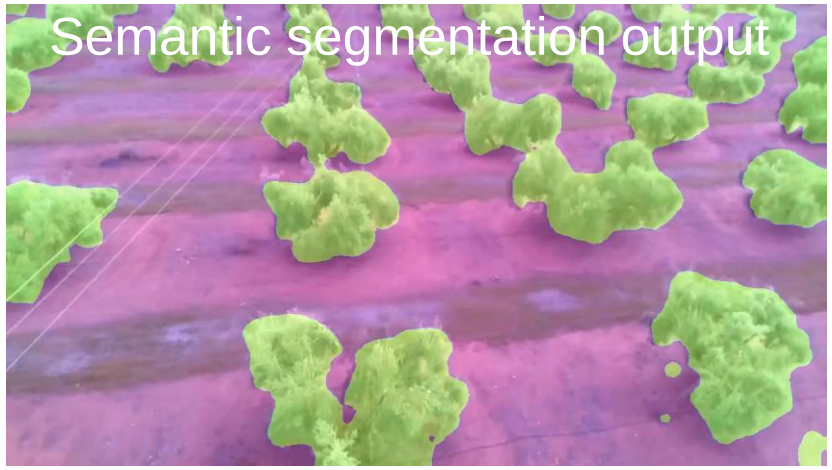
- ***Semantic image segmentation***:
  - Segment low/high vegetation regions, roads.

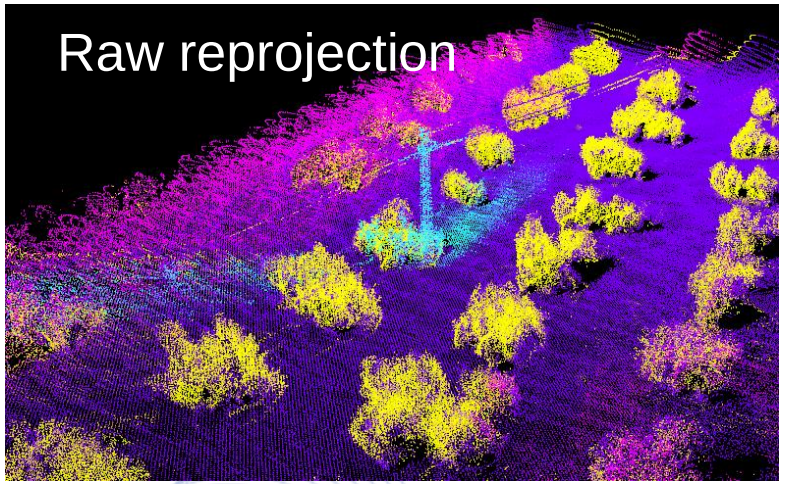
Semantic 3D World Mapping

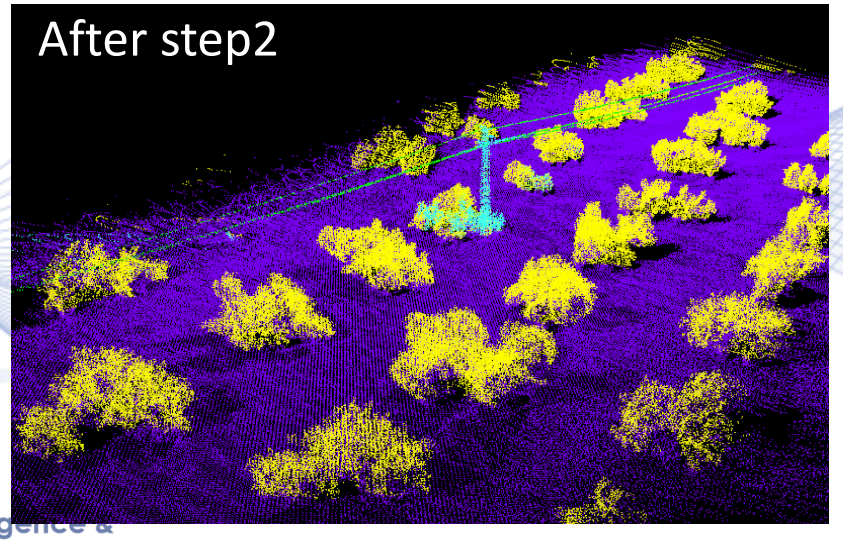
- ***Semantic image segmentation:***
  - Crowd detection and localization.

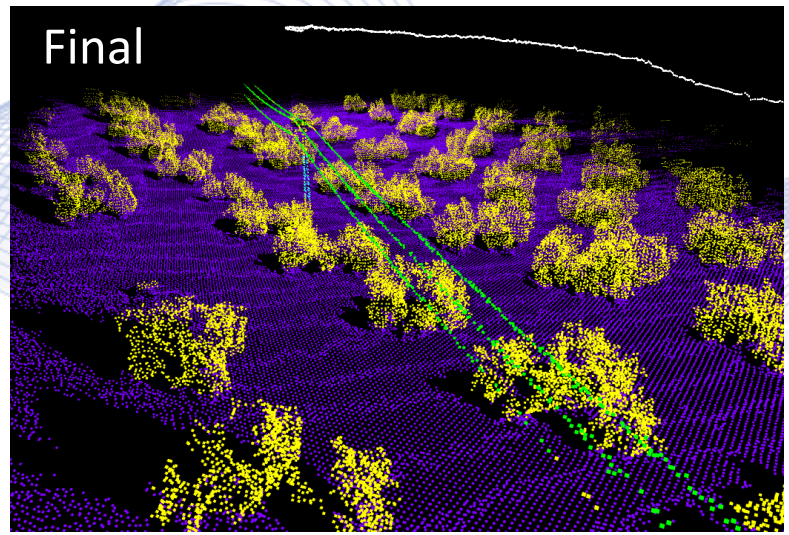


Semantic 3D World Mapping

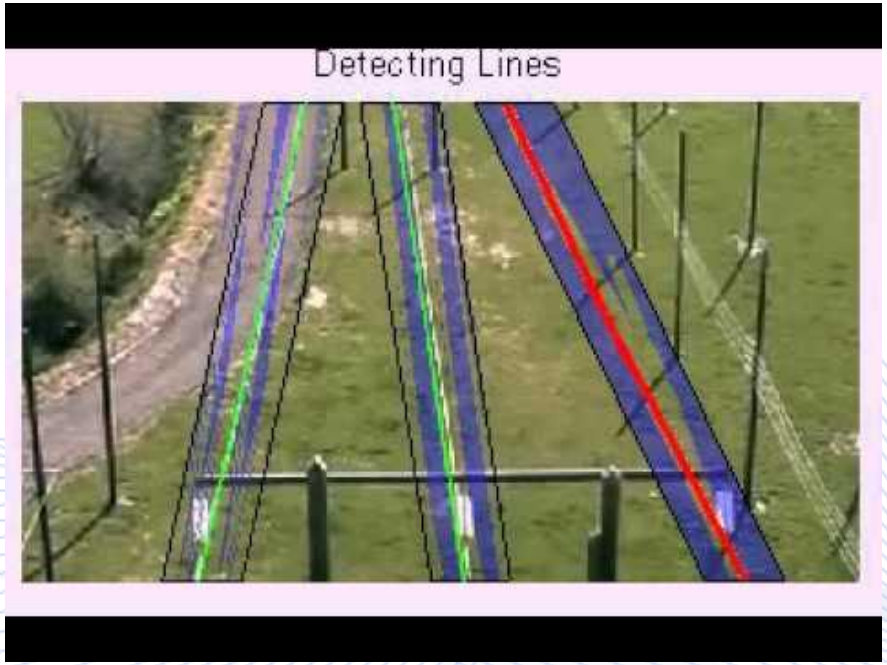








Object detection and tracking



Deep learning for power line detection and tracking.

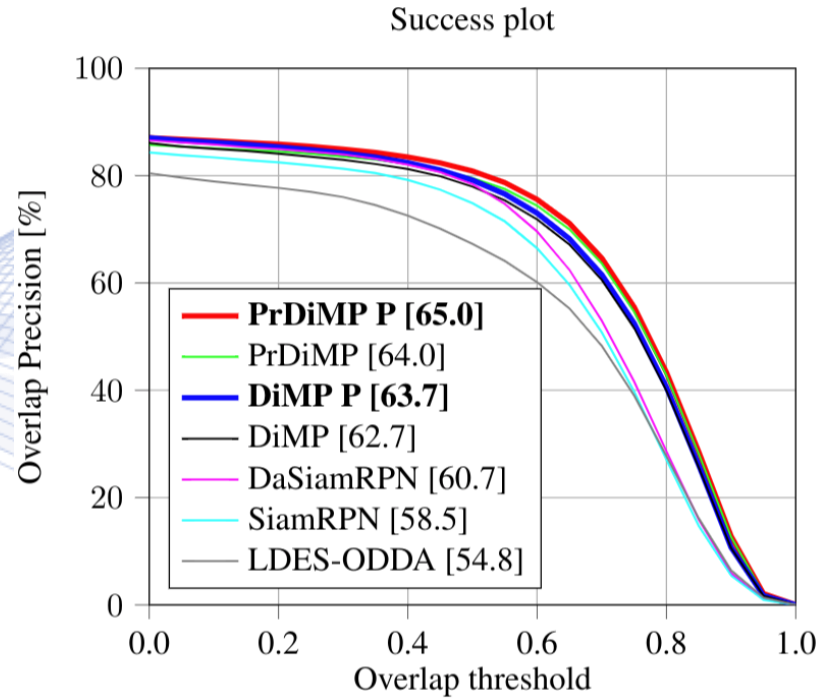
Object detection and tracking

- ENDESA dataset (17K images, insulators, dumpers, towers).
- SoA detector evaluation (Single-Shot-MultiBox-Detector (SSD), You-Only-Look-Once v4 (YOLOv4), Detection-Transformer (DETR).
- Proposed approach: Content-specific image queries (based on DETR)

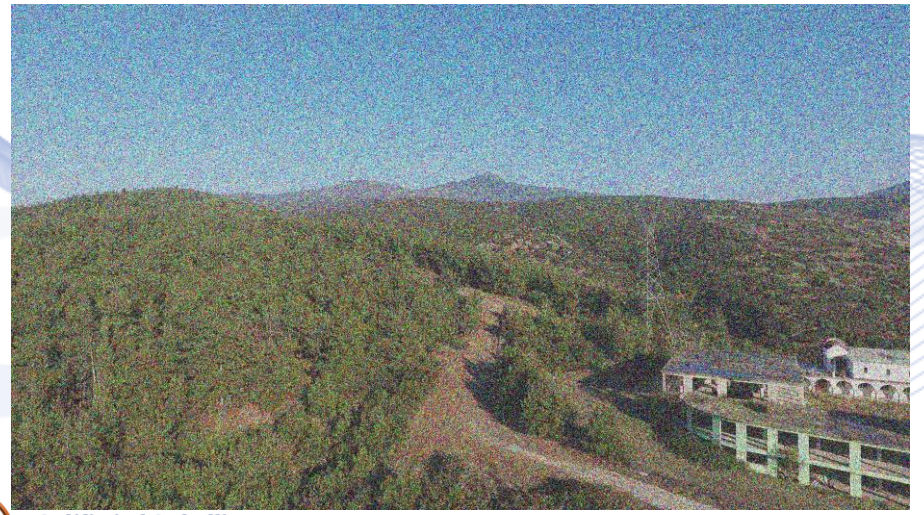
Model	FPS 2080 / Jetson	AP	AP_{50}
YOLO v4 CSPDarknet53	96/26	41.6	83.5
SSD Mobilenet v2	126/17	50.1	82.1
SSD Inception v2	84/13	48.7	80.0
SSD Resnet50	40/9	52.3	79.8
DETR Resnet50	35/8	52.4	83.1
Ours Resnet50	35/8	**53.9**	**83.9**

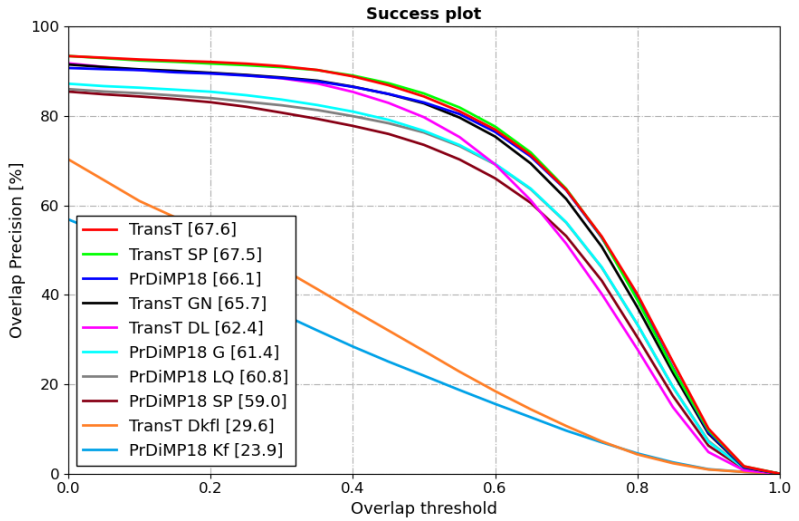
Online tracking model adaptation

- Online tracking model updating is typically addressed as a regression problem.
- An **adversarial optimization scheme**
- **Generator** is assigned to the tracking model producing response maps.
- **Discriminator** network is trained to identify if the tracker response maps produced by the generator belong to the target distribution, or not.

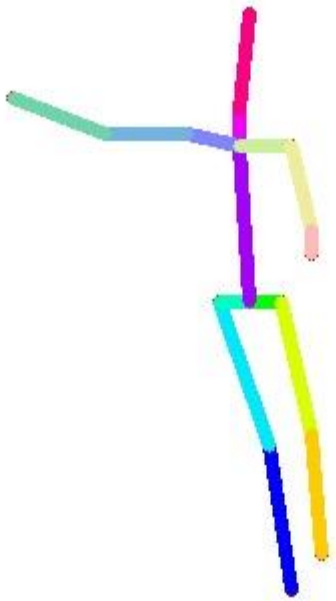


Robustness 2D Visual Object Tracking



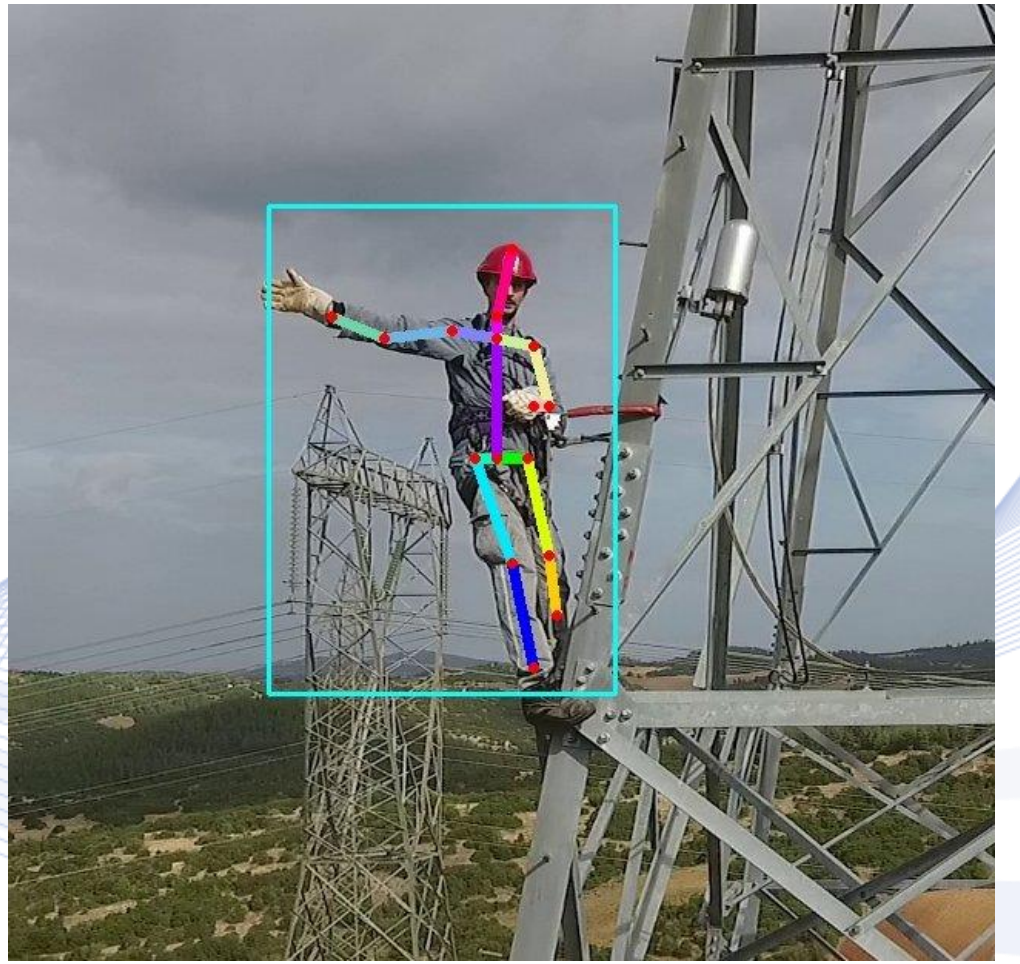


Human posture estimation



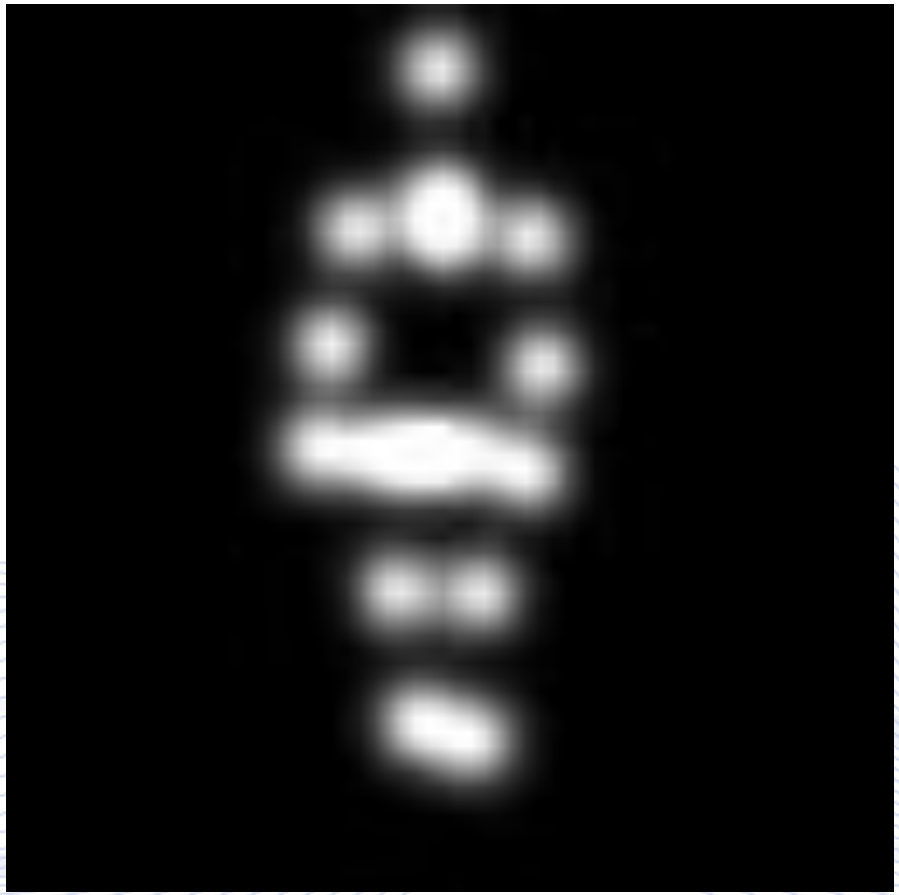
a) Original image; b) Body joints heatmap; c) Human posture estimation.

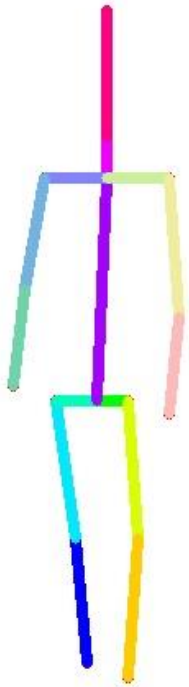
Human posture estimation



Human posture estimation.

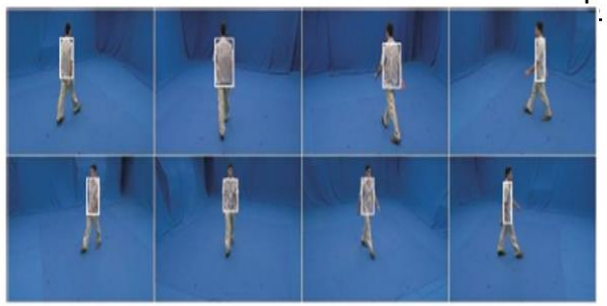
Human posture estimation



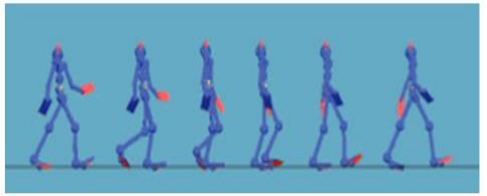


a) Original image; b) Body joints heatmap; c) Human posture estimation.

Human action recognition

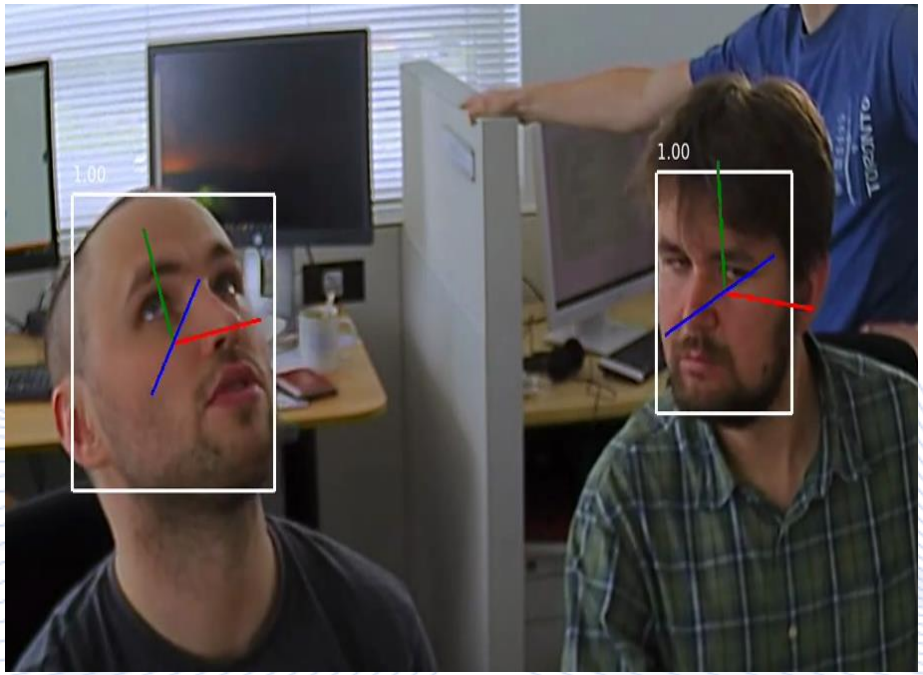


walk



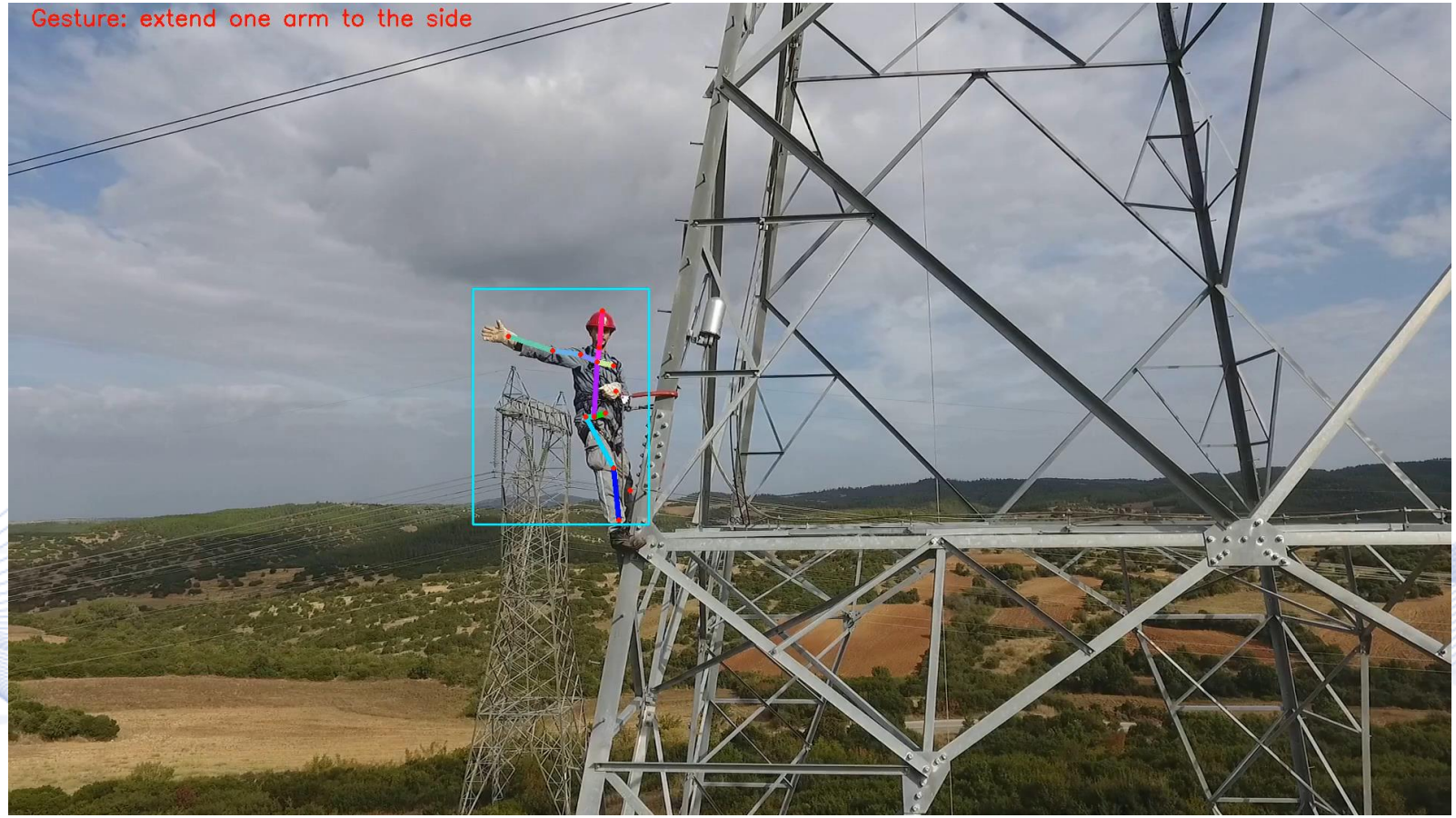
walk

Human pose estimation



Facial pose estimation.

Human posture – gesture recognition



Coordination of a Heterogeneous Team of ACWs

- 3 main ACW activities:
- Safety-ACW - equipped with a surveillance camera (blue).
- Inspection-ACW – inspection sensor (red).
- Physical-ACW - equipped with a manipulator to provide tools required by workers

Infrastructure Inspection

- Overview
- Sensors
- Visual analysis
- **Drone operations**

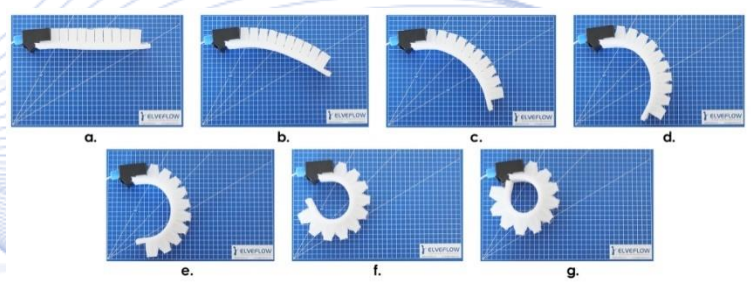
Autonomous landing

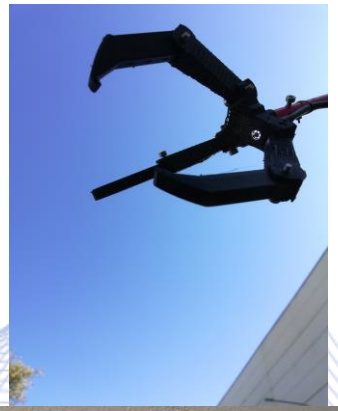
Autonomous perching

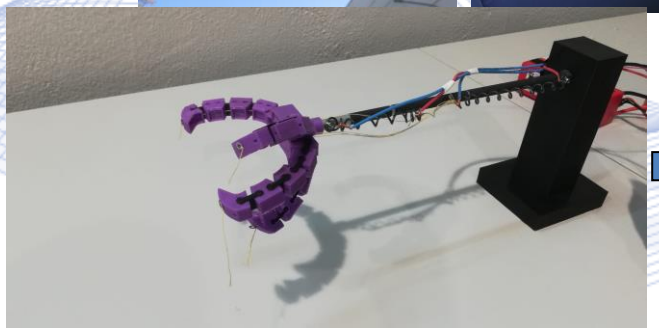
- Sensor fusion to exploit synergies:
- Perching steps:
- Preparation
  - Multi-sensor detection & tracking of perching candidates
    - LIDAR
- Fast approach to perching zone
  - Multi-sensor Visual Servoing:
    - event cameras
- Short distance approach & perching
- Multi-sensor Visual Servoing.

End-effectors for holding/grabbing

- Bio-inspired actuators for compliant co-working and close range inspection.



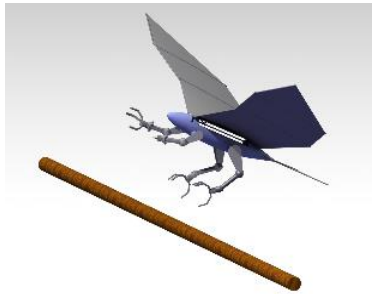


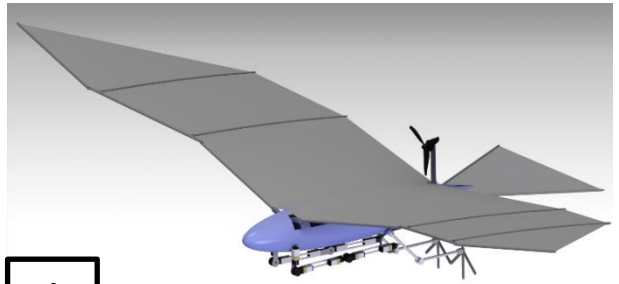


Manipulation while holding/perching

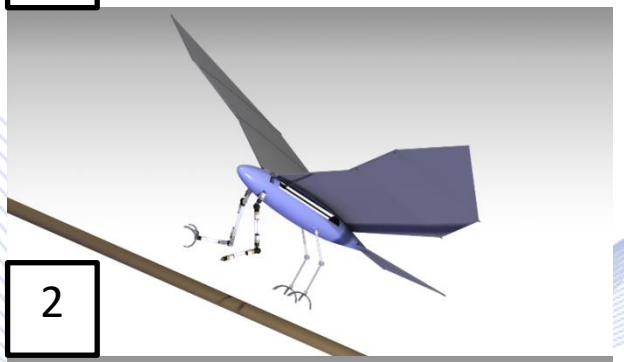
Morphing

- ***Flapped wing*** to fixed wing.
- Fixed to rotary.
- ***Ornithopters*** can potentially achieve better efficiency, maneuverability and safety.

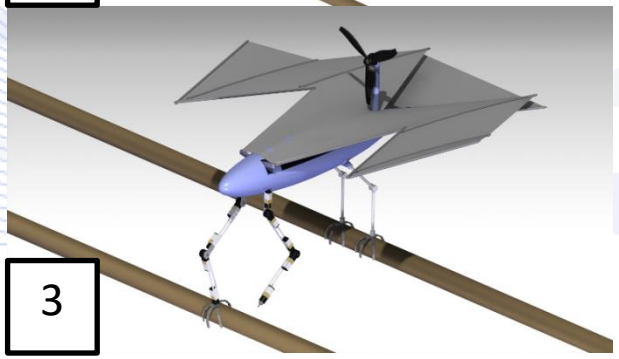




1



2



3

Simulations

Bibliography

[PIT2021] I. Pitas, “Computer vision”, Createspace/Amazon, in press.
[PIT2017] I. Pitas, “Digital video processing and analysis ” , China Machine Press, 2017 (in Chinese).
[PIT2013] I. Pitas, “Digital Video and Television ” , Createspace/Amazon, 2013.
[NIK2000] N. Nikolaidis and I. Pitas, 3D Image Processing Algorithms, J. Wiley, 2000.
[PIT2000] I. Pitas, “Digital Image Processing Algorithms and Applications”, J. Wiley, 2000.

Bibliography

[PIT2021] I. Pitas, “Optimal multidimensional cyclic convolution algorithms for deep learning and computer vision applications”, in Proceedings of the International Conference on Autonomous Systems (ICAS), 2021

[KAR2021] I. Karakostas, V. Mygdalis, and I. Pitas,“Adversarial optimization scheme for online tracking model adaptation in autonomous systems”, ICIP (special session on Autonomous Vehicle Vision), 2021

[KAR2020] I. Karakostas, I. Mademlis, N.Nikolaidis and I.Pitas, "Shot Type Constraints in UAV Cinematography for Autonomous Target Tracking", Elsevier Information Sciences, vol. 506, pp. 273-294, 2020

[KAR2019] I. Karakostas, V. Mygdalis, A.Tefas and I.Pitas, "On Detecting and Handling Target Occlusions in Correlation-filter-based 2D Tracking" in Proceedings of the 27th European Signal Processing Conference (EUSIPCO), A Coruna, Spain, September 2-6, 2019

[NOU2019a] P. Nousi, A.Tefas and I.Pitas, "Deep Convolutional Feature Histograms for Visual Object Tracking" in Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Brighton, UK, 2019

Bibliography

[NOT2019b] P. Nousi, D. Triantafyllidou, A.Tefas and I.Pitas, "Joint Lightweight Object Tracking and Detection for Unmanned Vehicles" in Proceedings of the IEEE International Conference on Image Processing (ICIP), Taipei, Taiwan, September 22-25, 2019.

[PAP2019] C. Papaioannidis and I.Pitas, "3D Object Pose Estimation using Multi-Objective Quaternion Learning", IEEE Transactions on Circuits and Systems for Video Technology, 2019.

[PAPAD2021] Papadopoulos, Sotirios, I. Mademlis and I. Pitas, “Semantic Image Segmentation Guided by Scene Geometry”, in Proceedings of the International Conference on Autonomous Systems (ICAS)*, 2021*.

[PAP2021] C. Papaioannidis, I. Mademlis and I. Pitas, “Autonomous UAV Safety by Visual Human Crowd Detection Using Multi-Task Deep Neural Networks”, ICRA, 2021.

[PIT2021] I. Pitas, “Optimal multidimensional cyclic convolution algorithms for deep learning and computer vision applications”, in Proceedings of the International Conference on Autonomous Systems (ICAS), 2021

[PER2018] Perera, Asanka G., Yee Wei Law, and Javaan Chahl. "UAV-GESTURE: A dataset for UAV control and gesture recognition." *Proceedings of the European Conference on Computer Vision (ECCV)*. 2018.

Bibliography

[NOM2019] P. Nousi, I. Mademlis, I. Karakostas, A.Tefas and I.Pitas, "Embedded UAV Real-time Visual Object Detection and Tracking" in Proceedings of the IEEE International Conference on Real-time Computing and Robotics 2019 (RCAR2019), Irkutsk, Russia, 2019

[BOC2020] A. Bochkovskiy, CY Wang and HY M. Liao. “YOLOv4: Optimal Speed and Accuracy of Object Detection”. arXiv, 2020.

[DIET2021] A.Dietsche, G.Cioffi, J.Hidalgo-Carrió, D. Scaramuzza Autonomous Persistent Power line Tracking using Events, IROS 2021

[LIU2016] Liu, Wei, et al. "SSD: Single Shot Multibox Detector." European Conference on Computer Vision. 2016.

[NIC2020] C. Nicolas, et al. "End-to-End Object Detection with Transformers." arXiv preprint arXiv:2005.12872 (2020).

[SHA2019] A. Shahroudy, J. Liu, T. Ng and G. Wang, "NTU RGB+D: A Large Scale Dataset for 3D Human Activity Analysis," 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Las Vegas, NV, 2016, pp. 1010-1019.

Q & A

Thank you very much for your attention!

More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

Contact: Prof. I. Pitas
pitas@csd.auth.gr