DREIS: DJI Event on DRONES in RESEARCH and ENERGY INDUSTRIAL APPLICATIONS

UAV and Multimodal Image Analysis for Power Line Monitoring

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Outline

- Introduction
- Context: SCIADRO project
- Inspection of aerial power lines
- Multipath data transmission
- Conclusions & future work

Introduction
- many is better than one -
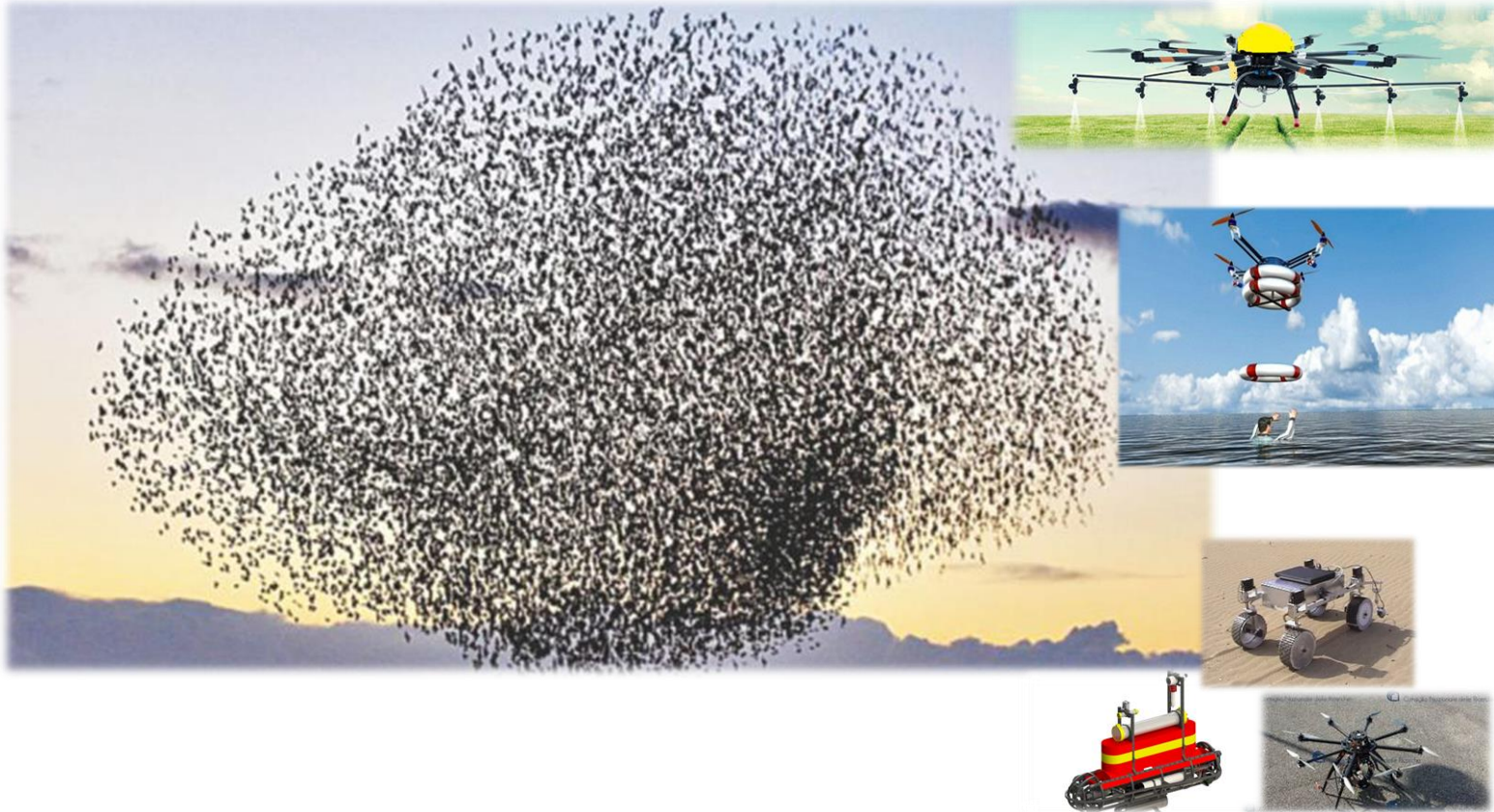
coverage of vast areas in less time

faster search & rescue (SAR) operations

multimodal swarms

Introduction
- the SCIADRO (UAV swarm) research project -

Co-funded by the Tuscany region, Italy, the SCIADRO project aims at developing the enabling technologies for the use of a coordinated drone swarm in civilian scenarios.

GOALS: environmental monitoring, first response to natural disasters, monitoring of social events, safety inspection of public utility grids or other critical infrastructures.

Objectives:

- developing **sensors** to monitor the presence of potential pollutants within surveyed environments;

- achieving **computer vision techniques and algorithms** which can detect complex objects and extract information on local anomalies which might affect them;

- developing suitable logics and algorithms which can effectively **organize and guide the** overall **swarm** motion and actions during a mission;

- studying, developing and demonstrating **network architectures and protocols** which can allow communication among multiple drones within a swarm

- increasing communication **reliability** towards the ground segment and reducing the *Size, Weight and Power* (SWaP) requirements of the in-flight radio-communication equipment.

Application: 2D/3D inspection of aerial power lines (1/2)
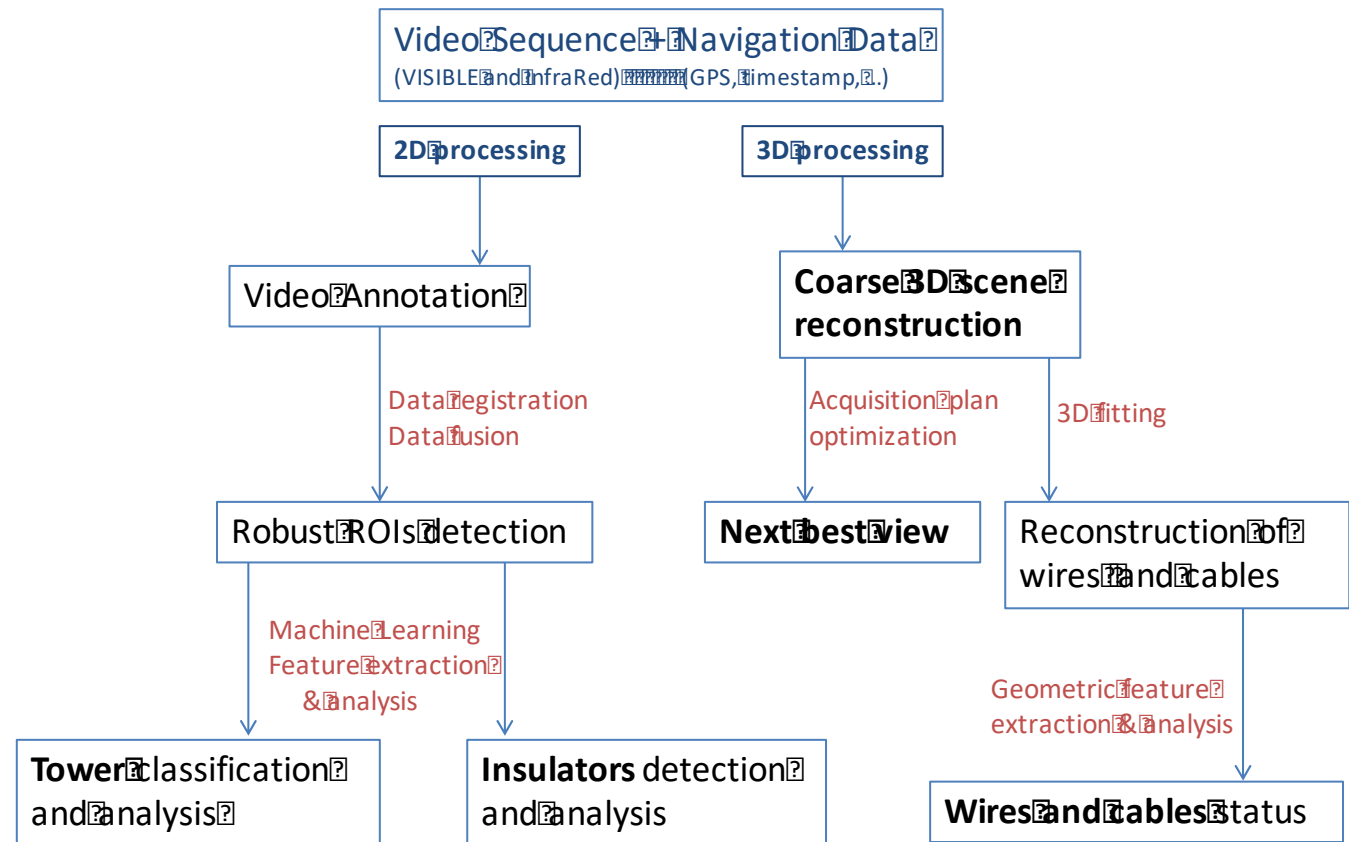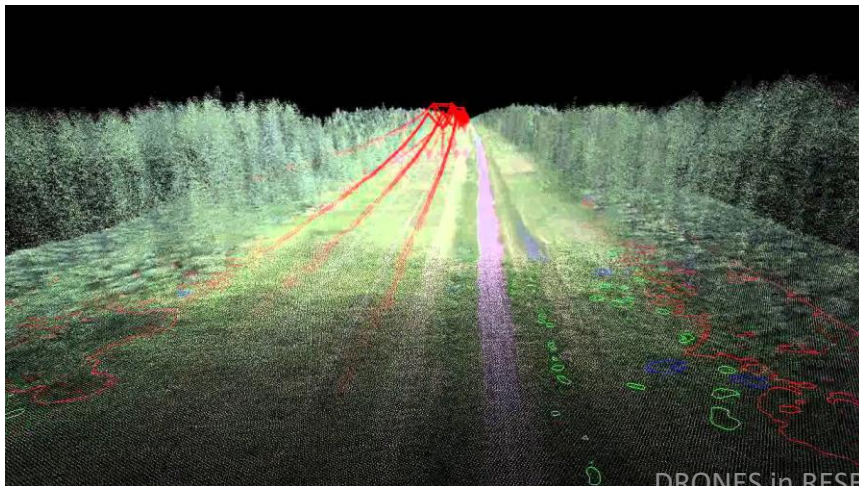
Necessary set of actions:

1. detection of wires and cables

2. analysis of wires and cables

3. detection and classification of electric towers

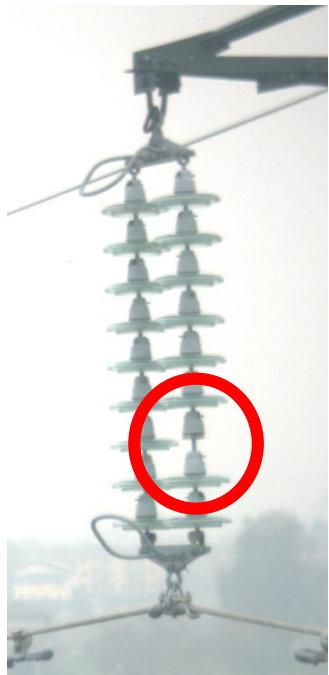4. analysis of tower components (insulators, hanging points)

2D/3D inspection of aerial power lines (2/2)

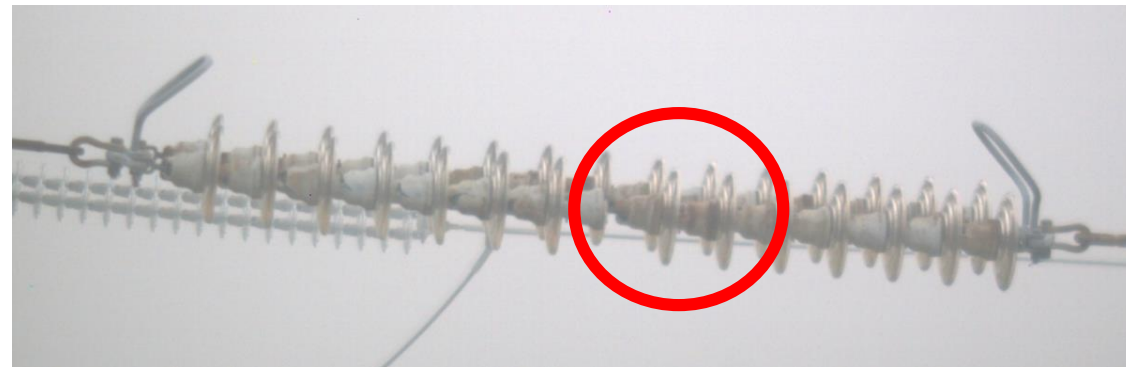Swarm equipped with different payloads:

- Infrared Cameras
- RGB cameras
- 3D scanners (LiDAR devices)

Video Sequence + Navigation Data
(VISIBLE and InfraRed)   (GPS, timestamp, ...)

2D processing   **3D processing**

Video Annotation

Coarse 3D scene reconstruction

Data registration
Data fusion

Acquisition plan optimization

3D fitting

Robust ROIs detection

Next best view

Reconstruction of wires and cables

Machine Learning
Feature extraction
& analysis

Geometric feature extraction & analysis

Tower classification and analysis

Insulators detection and analysis

Wires and cables status
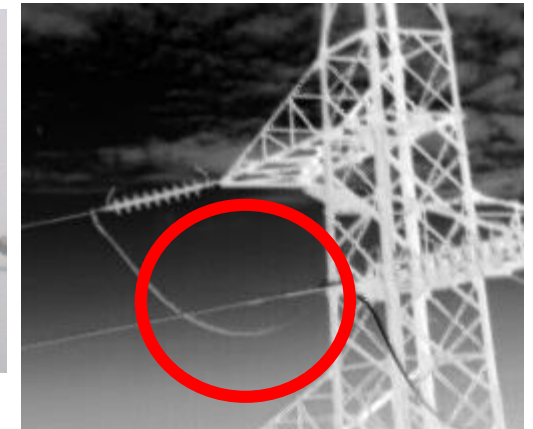
2D inspection of aerial power lines

Rust and missing insulator

Infiascatura

Missing insulator #1

Strefolatura – Broken strands

2D inspection of aerial power lines
Example: object detection pipeline

UAV Video Stream

Object detection

Objects of interest detected

Example: insulator detector detects Regions of Interest (ROI)

Object classification

Object of interest classified

Bad

Normal

Example: a classifiers takes in input detected insulators ROI and assign class labels, such as *rust, no rust, missing disk, deformed*
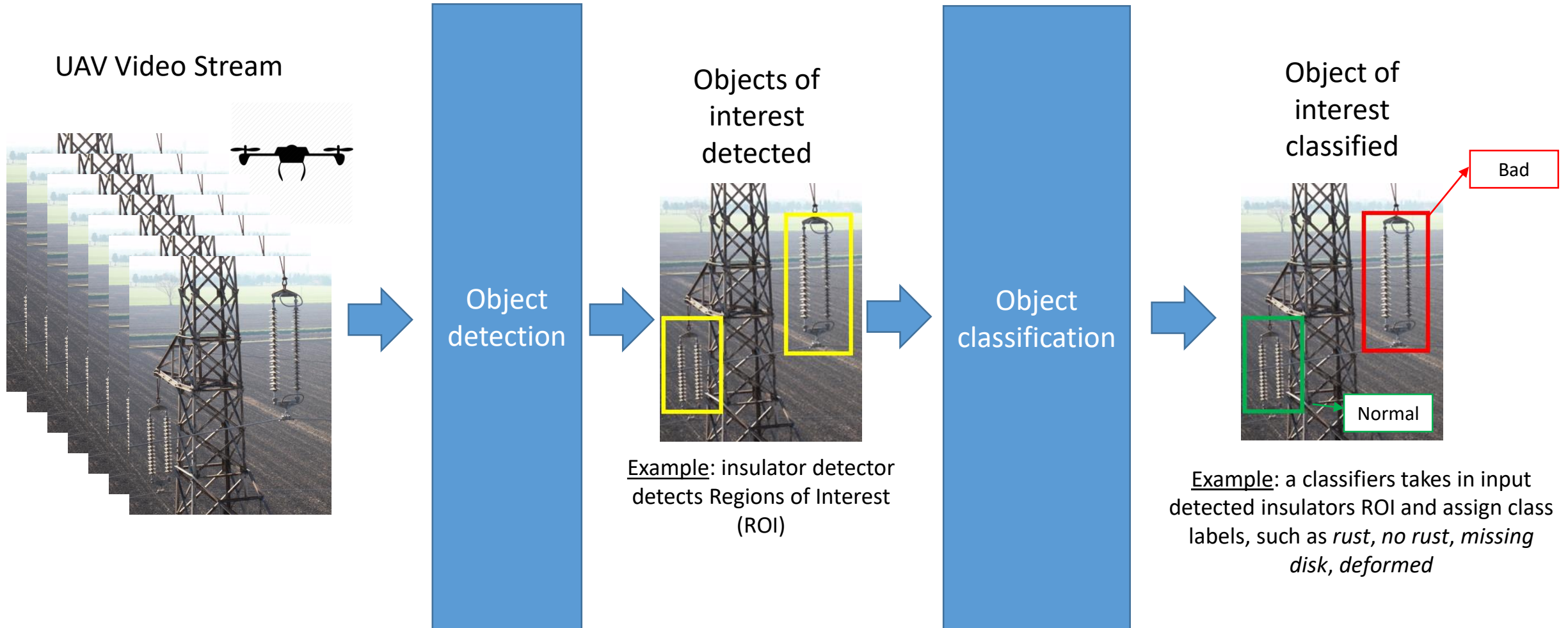
2D inspection of aerial power lines: Example – Current results using Deep Learning

- Used 2 Convolutional Neural Network (CNN - Deep Learning)
  1. Detection: State of the art R-CNN trained for insulator detection
  2. Classification
     - New CNN trained on only 2 classes (Rust / No Rust)
       - Train accuracy = 100.0%
       - Validation accuracy = 90% (N=110)
       - Final test accuracy = 97% (N=110)

  - Encouraging results
    - Good performance, suitable for on board processing
  - But:
    - Limited dataset
      - Need more data and examples from several sites to perform proper validation
      - Interest in incrementing the number of classes to detect also missing parts and other faults
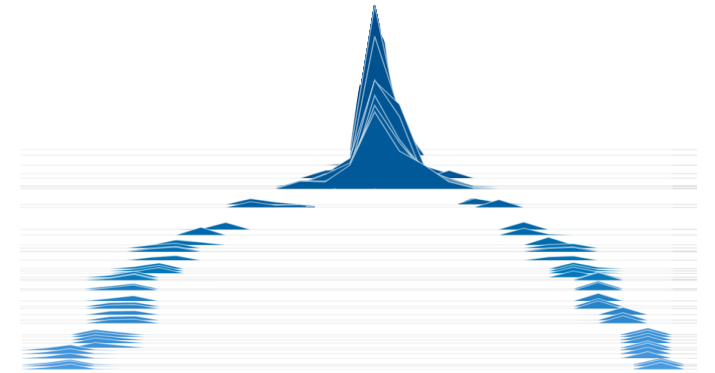
2D inspection of aerial power lines:
# *Wire detection and thermal analysis*

Visible Images:

- Image Enhancement
- Edge detection (canny edge detection with threshold adjustment)
- Hough Transform
- Mask generation
  - Identification of clusters of peaks corresponding to nearly parallel lines
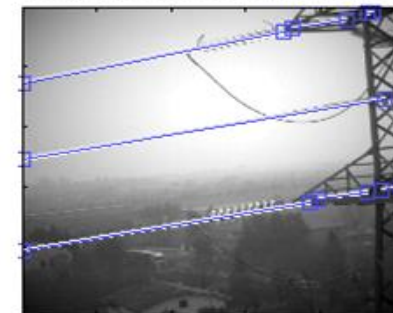
Infrared Image:

- Cables inspection and fault detection
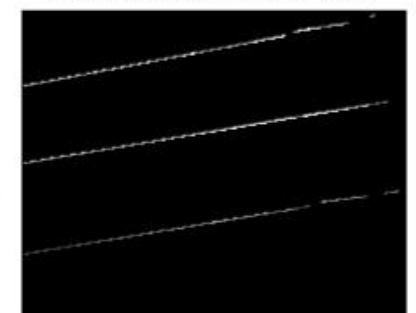
On Larger perspective:

- Image registration both visible and Infrared images
- Fully automatic algorithm
- Fast algorithm
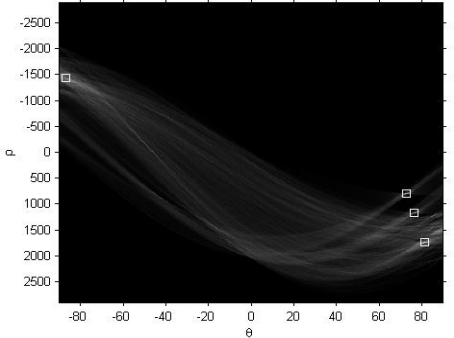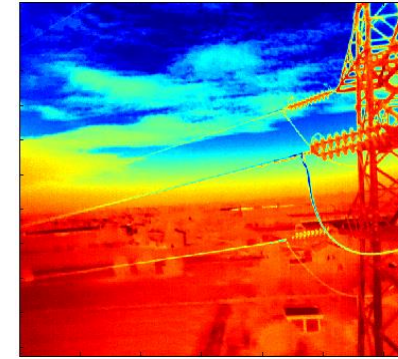
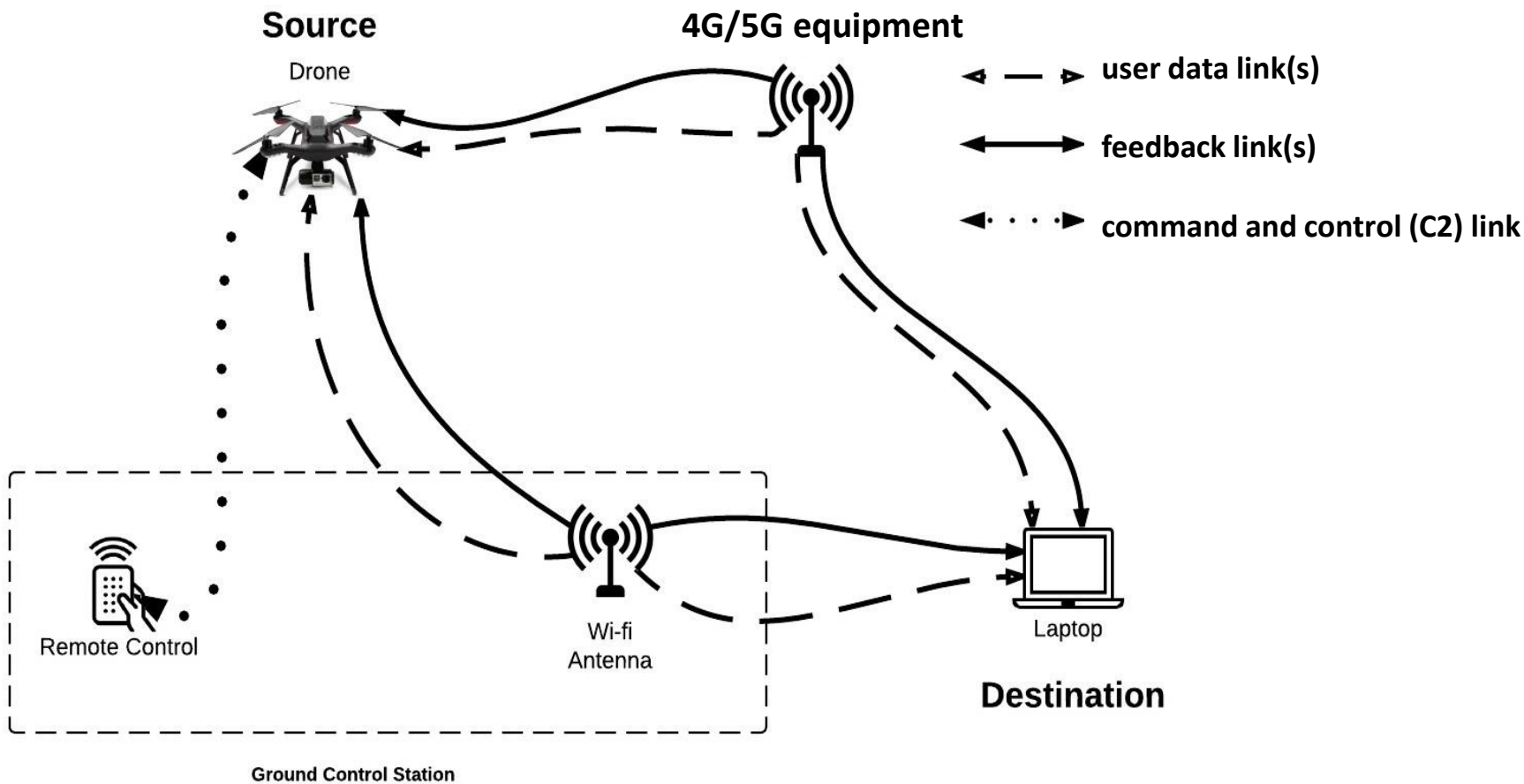Hough trasform detection in Images

Detected power lines in Images

Multipath techniques for real-time video streaming

scenario: high throughput multimedia applications involving UAV (swarms)

➤Robustness
  ➤FEC
  ➤Interleaving
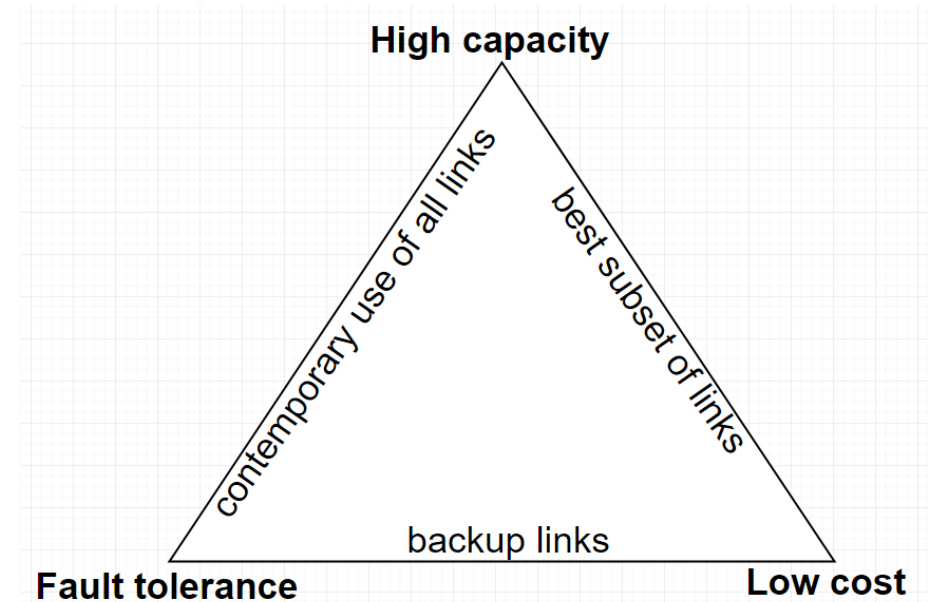 ➤multihoming
➤Delay
  ➤multihoming

Multipath techniques for real-time video streaming

scenario: high throughput multimedia applications involving UAV (swarms)

- **multihoming**: multiple IP addresses per host (multiple network interfaces)

- **multipath**: contemporary use of the several network paths between sender and receiver
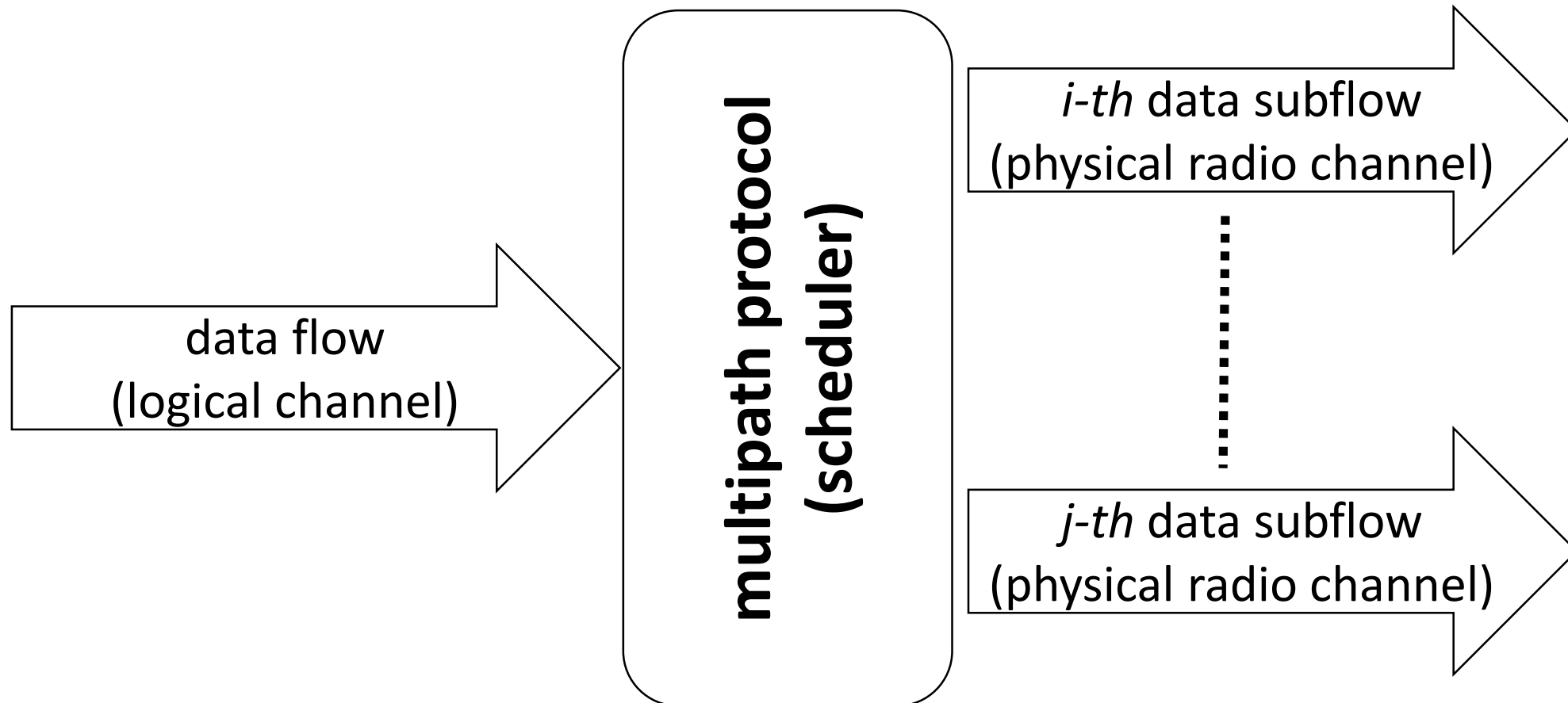
WHY?

- *redundancy*: if a link fails, backup ones can be activated

- *performance*: the whole set (or a subset) of links can be used at the same time

- *cost:* a set of low-cost links can provide a performance level comparable to using an expensive one
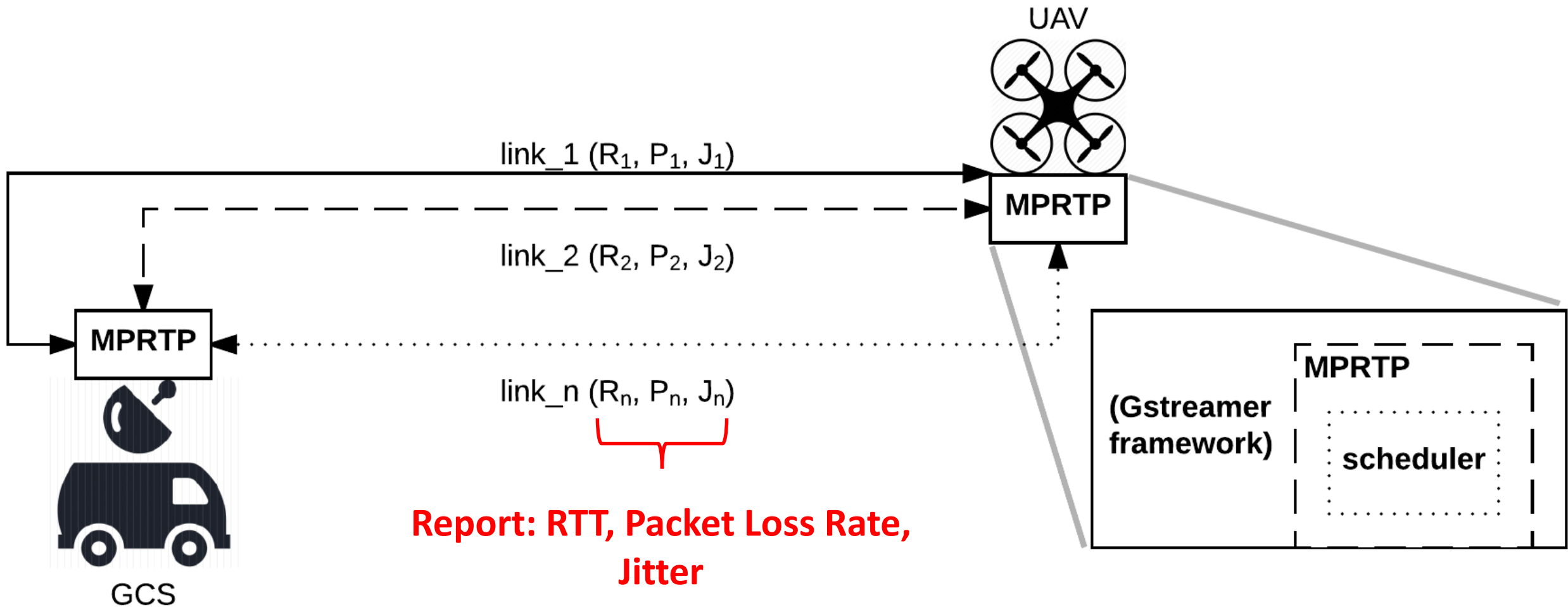

High capacity

contemporary use of all links

best subset of links

backup links

Fault tolerance

Low cost

Multipath techniques for real-time video streaming

scenario: high throughput multimedia applications involving UAV (swarms)

data flow
(logical channel)

**multipath protocol
(scheduler)**

i-th data subflow
(physical radio channel)

j-th data subflow
(physical radio channel)

Multipath techniques for real-time video streaming

UAV

link_1 (R_1, P_1, J_1)

link_2 (R_2, P_2, J_2)

link_n (R_n, P_n, J_n)

MPRTP

MPRTP

Report: RTT, Packet Loss Rate, Jitter

GCS

(Gstreamer framework)
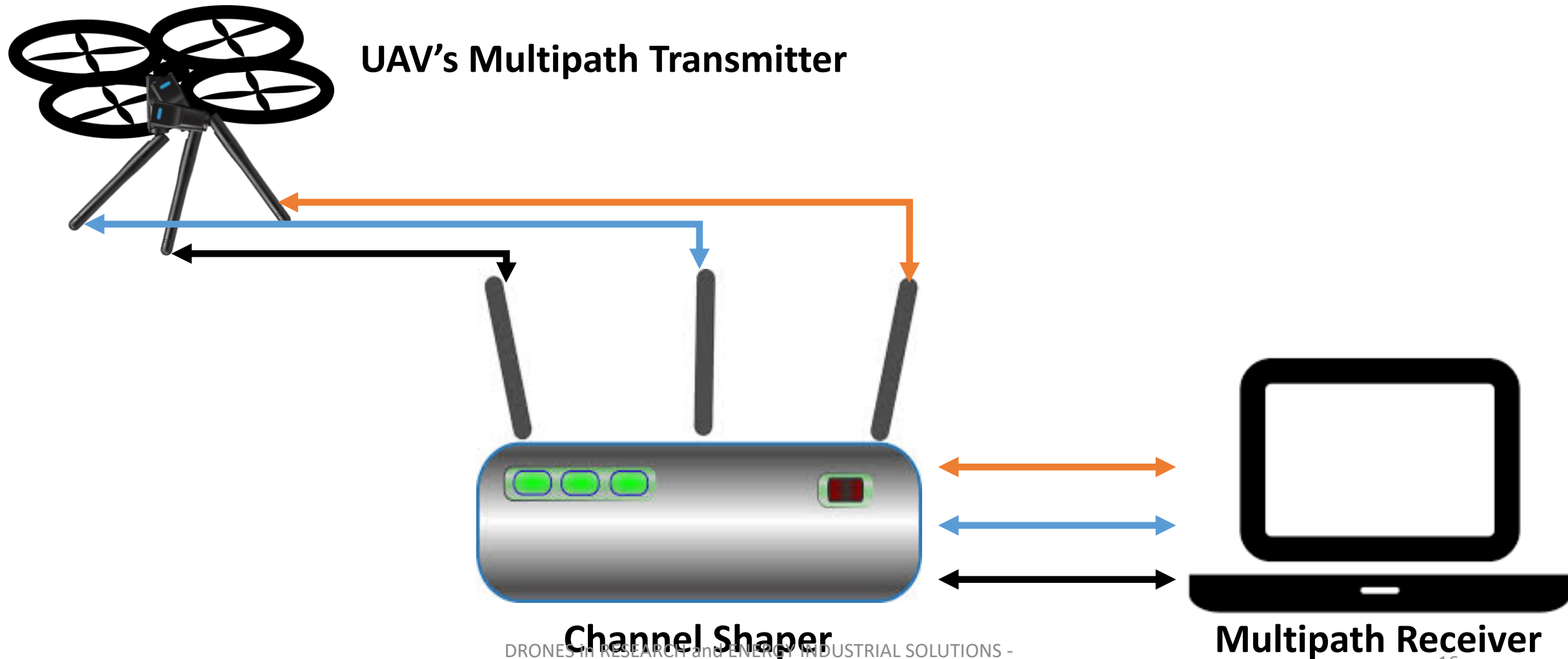
MPRTP

scheduler

Multipath techniques for real-time video streaming
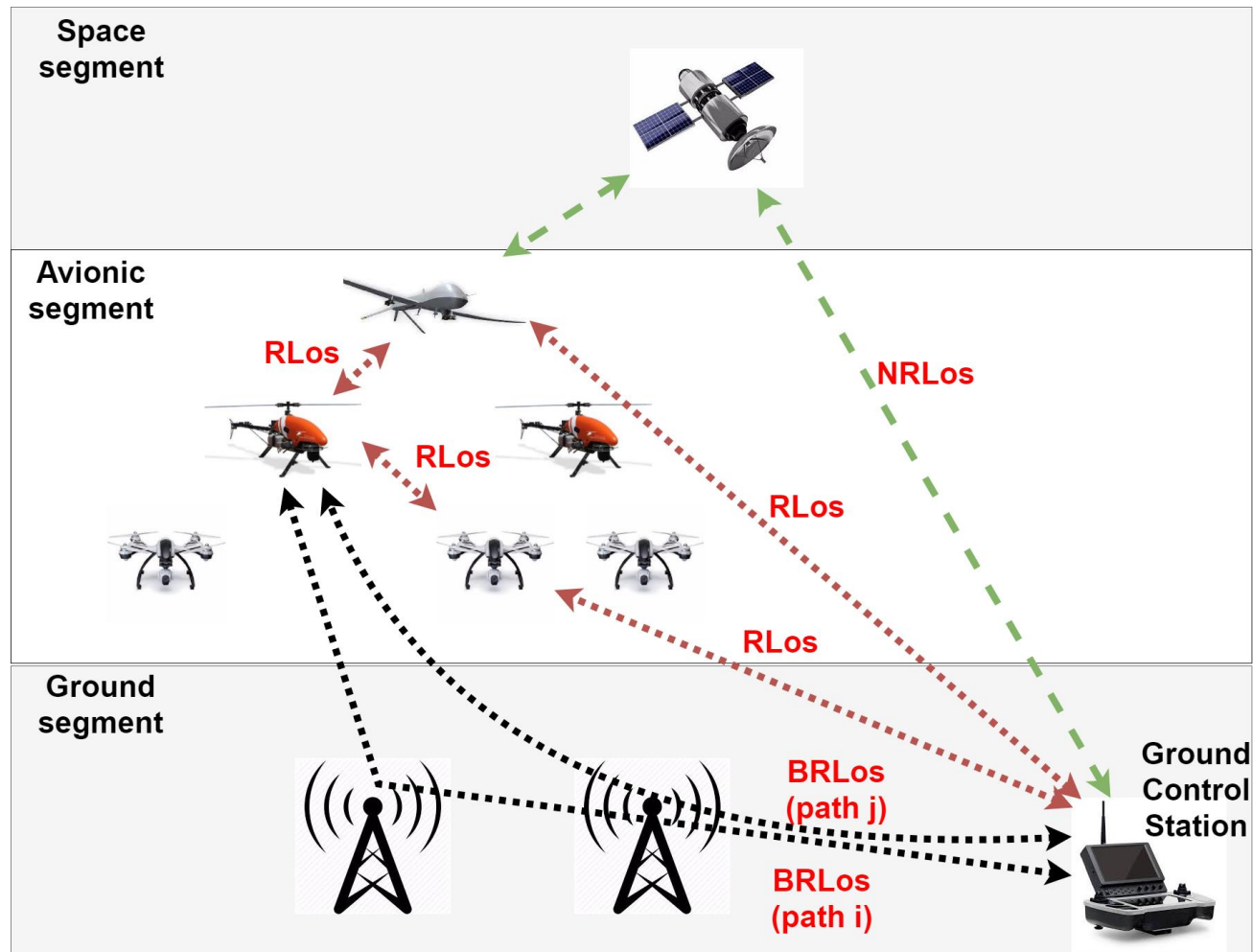
hierarchical architecture with different classes of UAVs

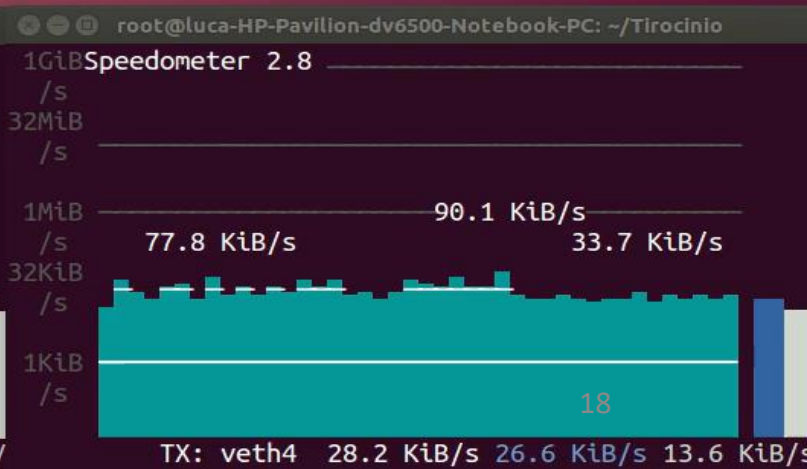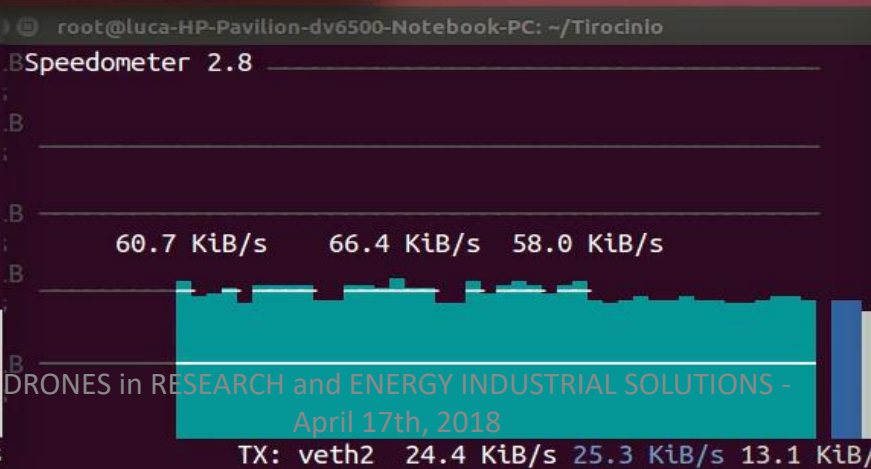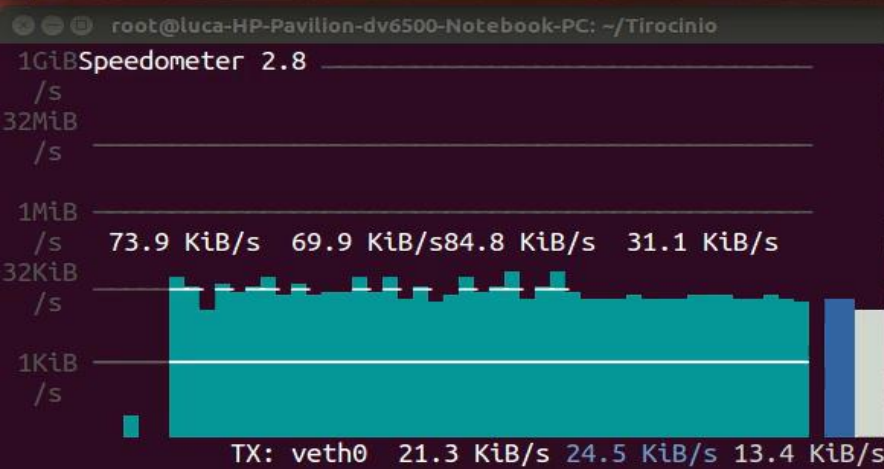# Experimental Platform

UAV's Multipath Transmitter

Channel Shaper

Multipath Receiver

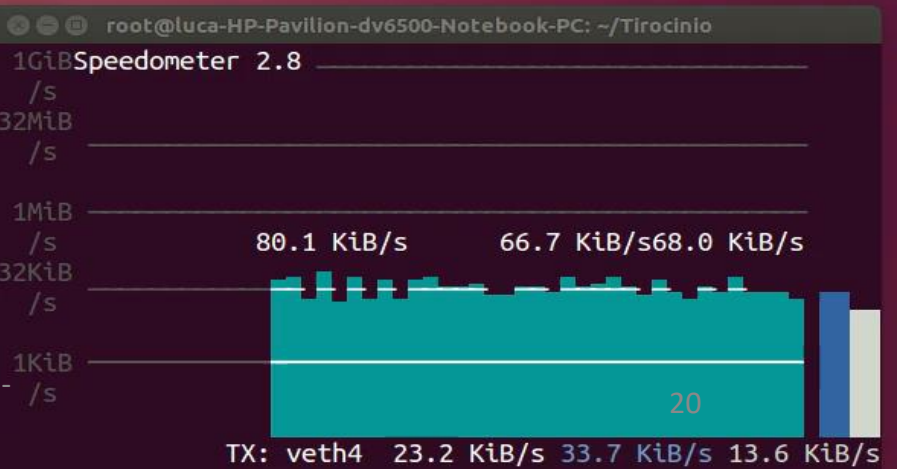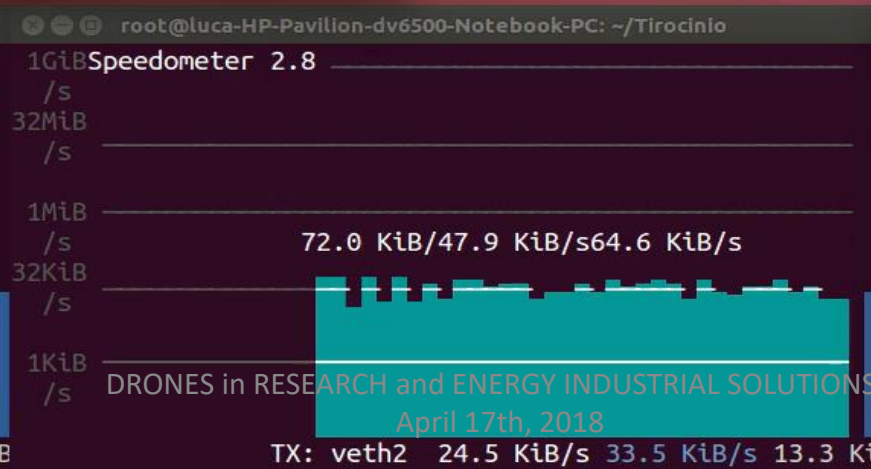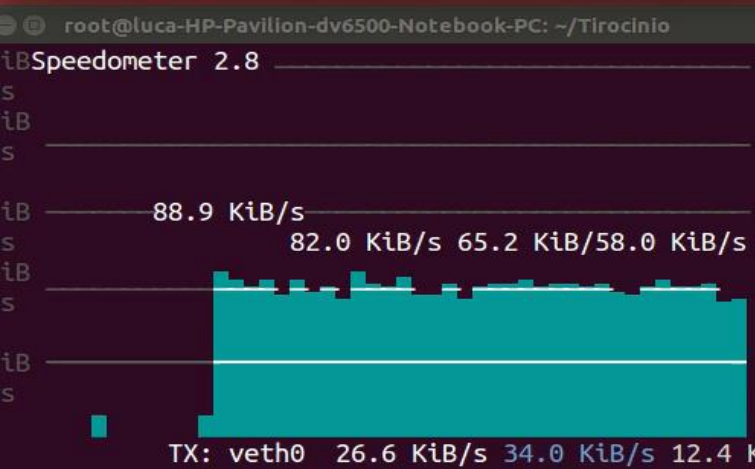# Multipath communications lacking a *smart* scheduler (video 1)

client

client

luca@luca-HP-Pavilion-dv6500-Notebook-PC: ~/Tirocinio

Percentuale di carico su canale 1: 33.333333

luca@luca-HP-Pavilion-dv6500-Notebook-PC: ~/Tirocinio

Percentuale di carico su canale 2: 33.333333

luca@luca-HP-Pavilion-dv6500-Notebook-PC: ~/Tirocinio

Percentuale di carico su canale 3: 33.333333
~
~
"actweight3.txt" 1L, 45C   1,1   Tut

luca@luca-HP-Pavilion-dv6500-Notebook-PC: ~/Tirocinio

canale 1 ---> RTT:100ms   PLR:0%
canale 2 ---> RTT:100ms   PLR:0%
canale 3 ---> RTT:100ms   PLR:0%
~
~
"stampa.txt" 3L, 96C   1,1   Tut

root@luca-HP-Pavilion-dv6500-Notebook-PC: ~/Tirocinio

1GiBSpeedometer 2.8
 /s
32MiB
 /s

1MiB
 /s   73.9 KiB/s   69.9 KiB/s84.8 KiB/s   31.1 KiB/s
32KiB
 /s

1KiB
 /s
        TX: veth0 21.3 KiB/s 24.5 KiB/s 13.4 KiB/s

root@luca-HP-Pavilion-dv6500-Notebook-PC: ~/Tirocinio

.BSpeedometer 2.8
.
.

.B   60.7 KiB/s   66.4 KiB/s   58.0 KiB/s
.

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April 17th, 2018
        TX: veth2 24.4 KiB/s 25.3 KiB/s 13.1 KiB/

root@luca-HP-Pavilion-dv6500-Notebook-PC: ~/Tirocinio

1GiBSpeedometer 2.8
 /s
32MiB
 /s

1MiB   90.1 KiB/s
 /s   77.8 KiB/s   33.7 KiB/s
32KiB
 /s

1KiB
 /s   18
        TX: veth4 28.2 KiB/s 26.6 KiB/s 13.6 KiB/

Multipath communications using a *smart* scheduler (video 2)

client

Percentuale di carico su canale 1: 33.717347

Percentuale di carico su canale 2: 35.172169

Percentuale di carico su canale 3: 31.110484
~
~
"actweight3.txt" 1L, 45C   1,1   Tut

canale 1 ---> RTT:100ms   PLR:0%
canale 2 ---> RTT:100ms   PLR:0%
canale 3 ---> RTT:100ms   PLR:0%
~
~
~
~
"stampa.txt" 3L, 96C   1,1   Tut

Speedometer 2.8

88.9 KiB/s
        82.0 KiB/s 65.2 KiB/58.0 KiB/s

TX: veth0   26.6 KiB/s   34.0 KiB/s 12.4 KiB

Speedometer 2.8

        72.0 KiB/47.9 KiB/s64.6 KiB/s

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TX: veth2   24.5 KiB/s 33.5 KiB/s 13.3 Ki

Speedometer 2.8

        80.1 KiB/s   66.7 KiB/s68.0 KiB/s

20

TX: veth4   23.2 KiB/s   33.7 KiB/s 13.6 KiB/s

Multipath communications using a *smart* scheduler and FEC techniques
(video 3)
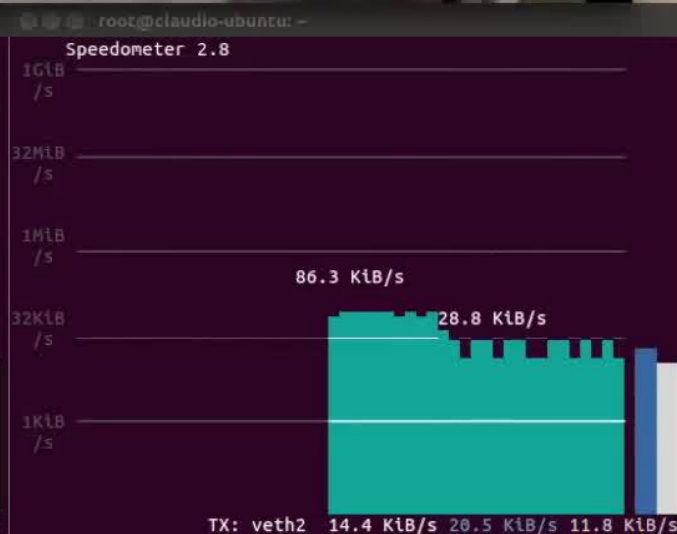
Conclusions and future work

- Dealing with UAV swarms is challenging, but at the same time an extremely wide set of open issues are still to be investigated
  - SCIADRO is a 2-year regional project that is facing a subset of this pool of issues
  - SCIADRO has been also investigating on swarm control, cybersecurity, collision avoidance and sensing applications
- At the time being, we have
  - developed 2D/3D processing software (already tested in lab)
  - collected training set (still limited)
- We aim to:
  - Extend datasets
    - Data acquisition campaigns
  - Extend classification
    - Train classifiers with more classes
    - Detectors for other powerlines component
  - Integration of 2D/3D processing

Thank you!

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CNR – Pisa

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