Viewpoints in Astronomy, Astrophysics, Space and Planetary Sciences
October 28-29, 2021

UNIVERSITATEA TEHNICĂ
DIN CLUJ-NAPOCA
CERCETARE

# Compact Solution for Low Earth Orbit Surveillance

Radu Danescu, Razvan Itu, Mircea Muresan
Computer Science Department, TU Cluj-Napoca

Vlad Turcu
Astronomical Observatory Cluj-Napoca
Octavian Cristea
BITNET CCSS

# Research project

- Compact Image Acquisition and Position Measurement System for Targets in the LEO range
- Acronym: CAMELEON
- Project code: PN-III-P2-2.1-PED-2019-4819
- Project type: Experimental Demonstrator (PED)
- Funded by the Ministry of Research and Innovation, CNCS – UEFISCDI
- Duration: August 2020 – July 2022
- Partners: UTCN, Bitnet CCSS

# Objectives

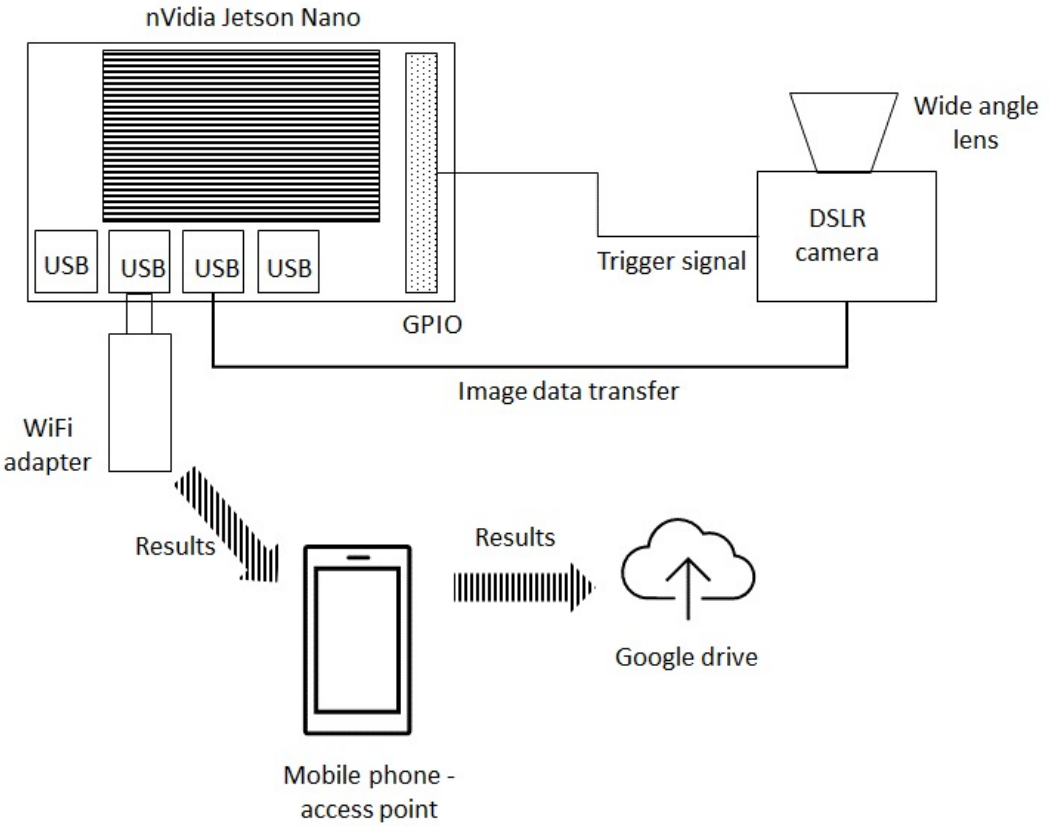
- Development of a real time image processing software package for the automatic detection of space objects in wide FOV images.
- Development of an integrated software and hardware system for real time image processing.
- Integration of the image processing tool into the ‘processing pipeline’ of an existing wide FOV SST sensor.

# Related work

- E. Stoveken, 2005: classification of the techniques for satellites detection. Most solutions either track the sky (sidereal tracking) or the object (target tracking)
- R. Sara, 2017; M. Levesque, 2007: satellite detection as streak using matched filters
- F. Diprima, 2018: streak detection using the Hough transform
- P. Hickson, 2018: streak detection using the Radon transform
- H. N. Do, 2019: image registration for compensating the apparent movement of the stars (no sidereal tracking)
- R. Danescu, 2012: image difference followed by identification of elongated shapes, with sidereal tracking – **the starting point of this work**.

# Acquisition and processing

- The image acquisition and processing system



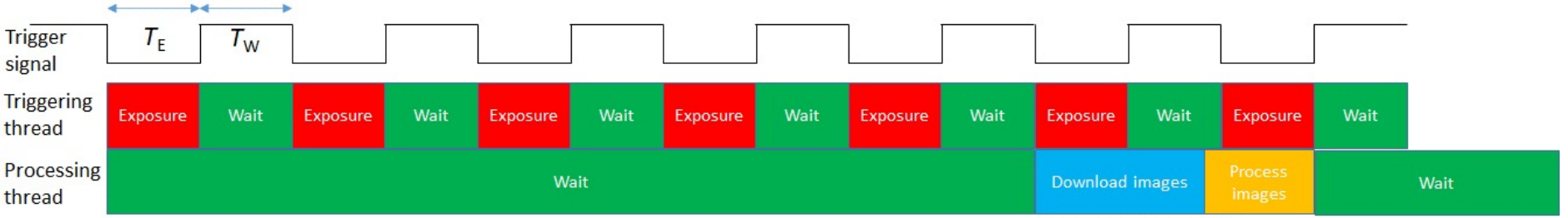
# Acquisition and processing

- Camera: Canon EOS 800D
  - 24 Megapixel CMOS sensor
  - Image size used: 2400x1600
  - ISO setting: 800
  - Bulb mode exposure, 3 seconds
- Lens: Sigma EX 20
  - Focal distance: 20 mm
  - Aperture: f/1.8

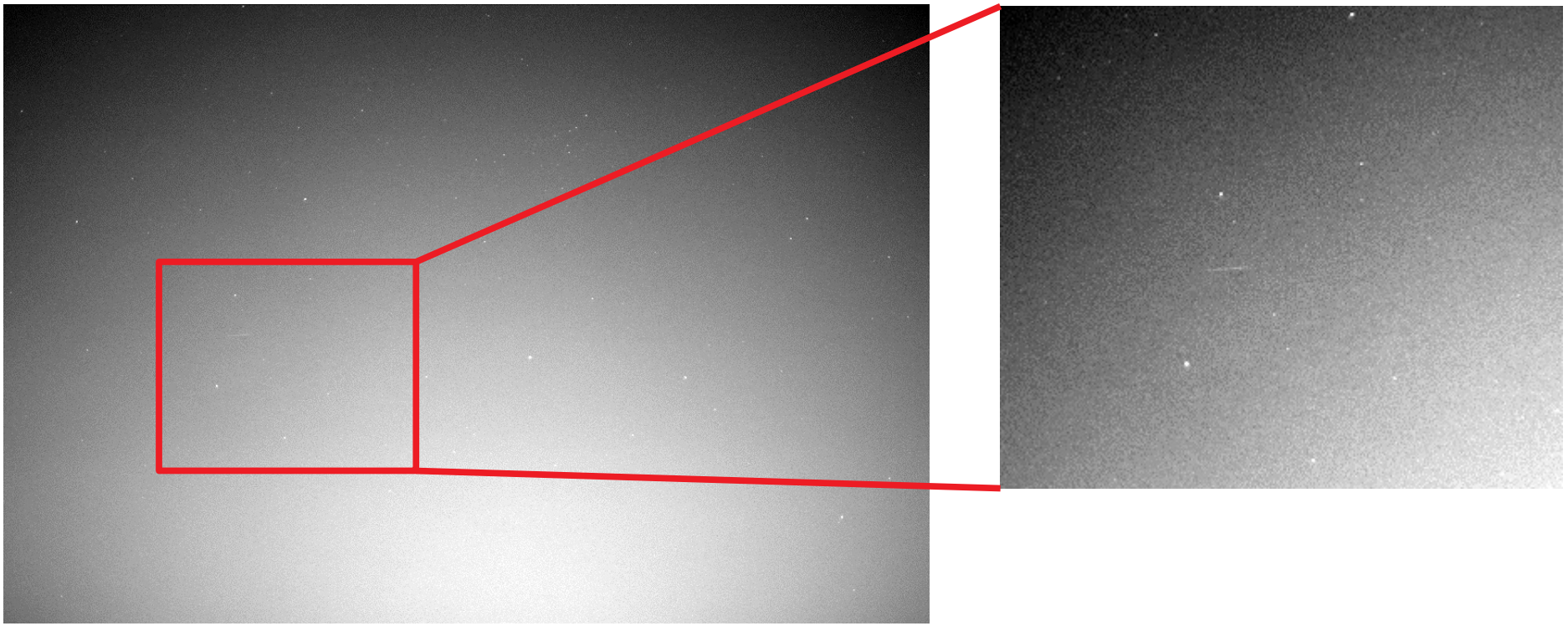
# Acquisition and processing

- The image acquisition and processing system

- Acquisition and processing pipeline

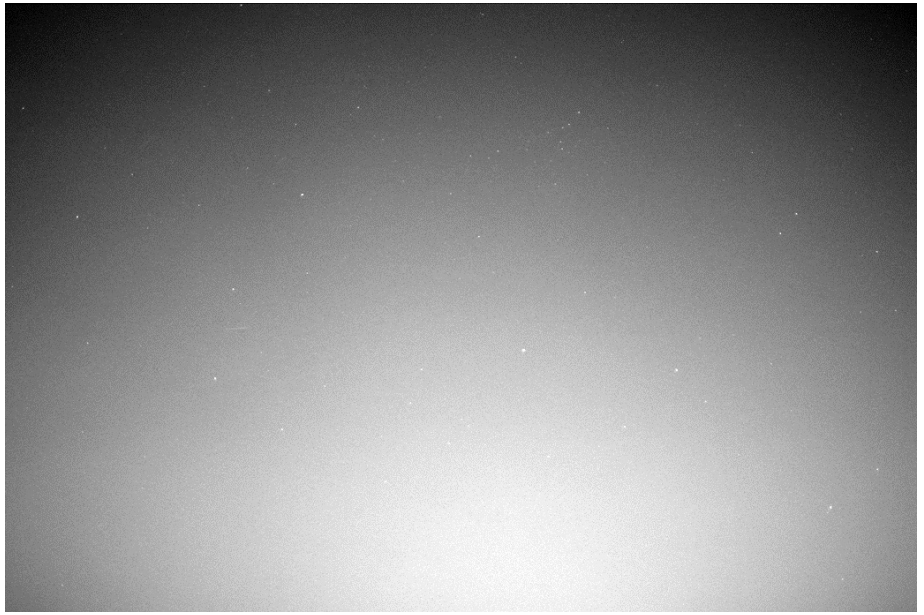


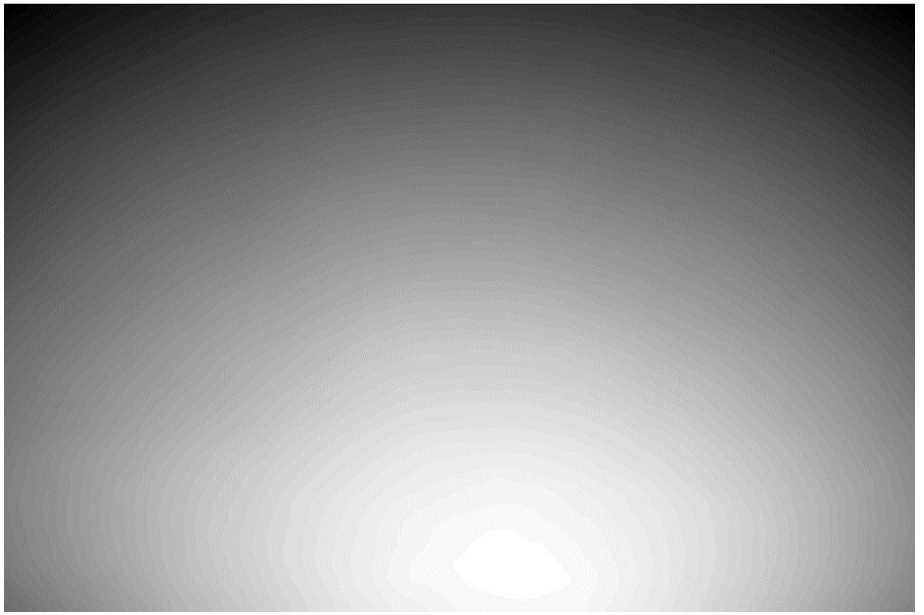
# Streak detection



- The LEO satellite moves fast during the image exposure time (3 s)
- Even without sidereal tracking, its trajectory is much more elongated than the trajectories of the background stars
- Key idea for detection: identify difference areas that have elongated shape

# Streak detection

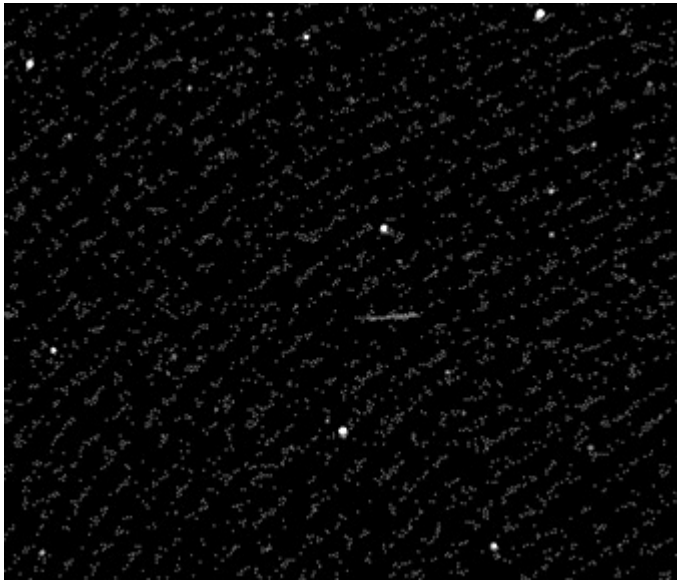




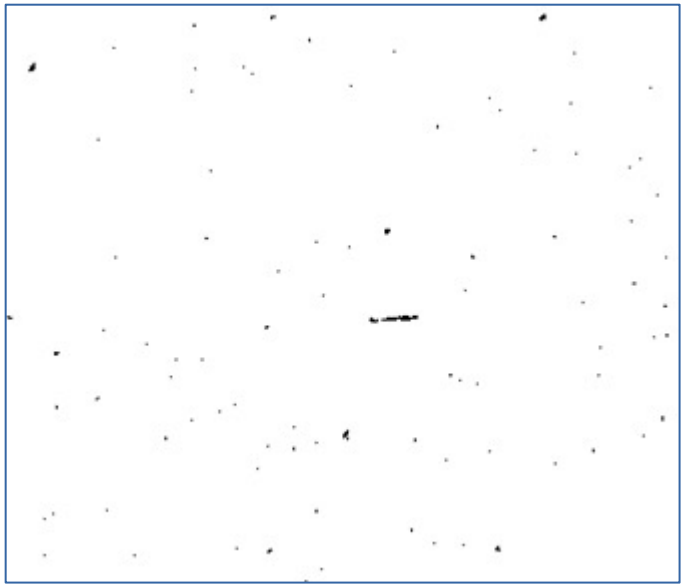
Background modeling by median filtering

- The LEO satellites are visible at dawn and at dusk. Unfortunately, this is also the time when the sky is unevenly lit
- The background illumination is extracted by using a median filter with a large radius (>50 pixels), which is larger than the stars and also than the streaks

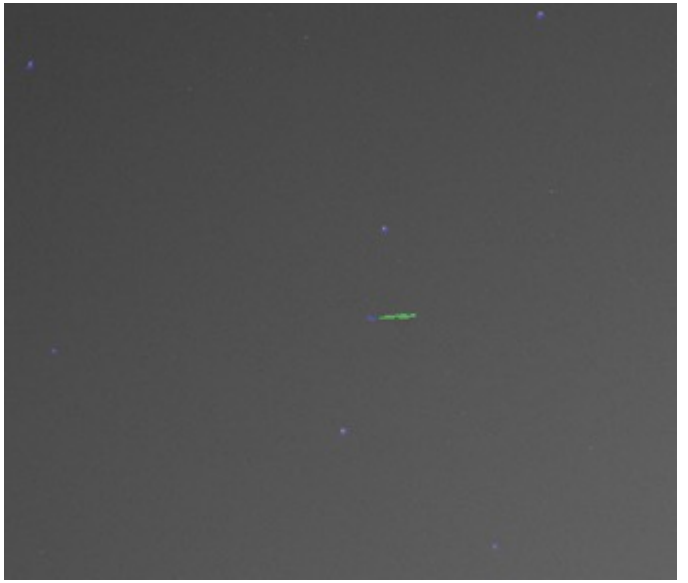
# Streak detection



Background subtraction



Difference thresholding



Elongated shapes selection

- The satellites are moving, therefore they will be seen as differences between frames
- The differences are thresholded with a very low threshold
- Connected components are analyzed for elongated shape

# Tracklet formation

- Consecutive streaks that share a similar orientation are grouped into ”tracklets”
- This allows the generation of a complete observation file for a satellite
- Tracklets also allow for elimination of false positives

# Typical sequence

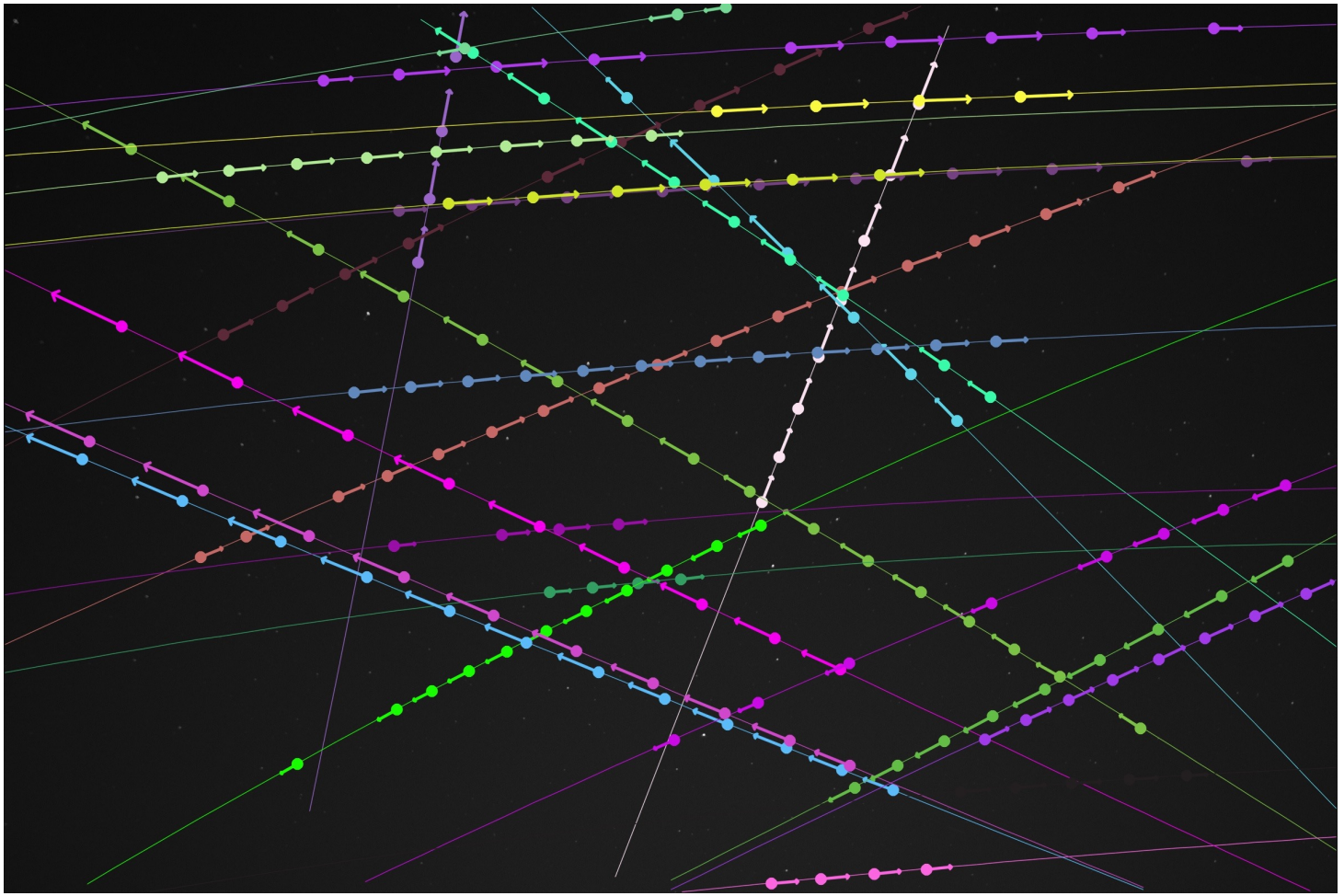
- The urban environment causes significant background light
- Most of the satellites cannot be seen by a human observer
- Lack of sidereal tracking causes the stars to move between consecutive frames

# Results

- Low thresholds allow for detection of faint streaks
- Tracklets allow for the rejection of most of the false positives due to clouds or other causes

# Results

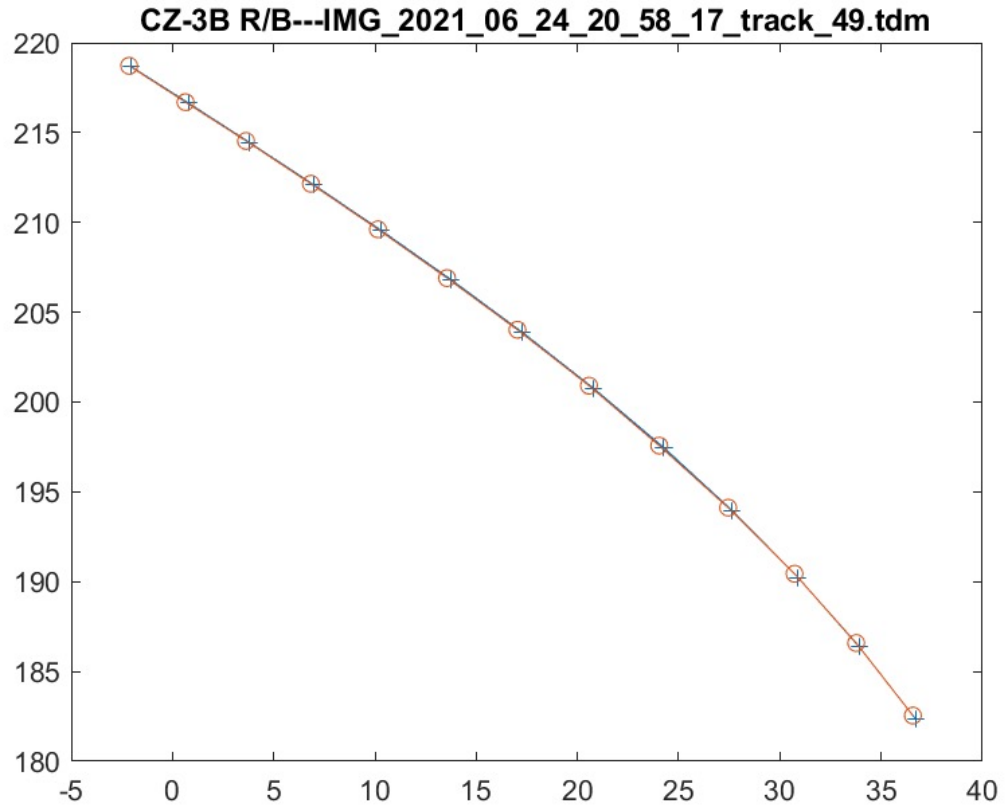
- Trajectories detected in 1h 30 m, urban location



# Astrometry

- Every 20 frames one frame is used for astrometric reduction
- Blind astrometry using the tool from astrometry.net
- Conversion from pixel coordinates to astronomic coordinates RA (right ascension) and DEC (declination)
- Compensation for the movement of the Earth – the RA results are compensated with the elapsed time between the detection time and the calibration frame (1h = 15 degrees of RA)
- Tracklets are converted to .tdm files

# Matching with known LEOs




```
CZ-3B R/B

1 47232U 20092B   21175.73504320  .00002477  00000-0  60799-4 0  9996
2 47232  97.3560 253.6718 0092738  43.4329 317.4173 15.37314528 30790


Cross Track Error: 0.038582 degrees
Along Track Error: 0.215358 degrees
```

CREATION_DATE = 2021-06-25T05:19:42.000000
ORIGINATOR = UTCN
META_START
COMMENT LONGITUDE 23.604004 EAST
COMMENT LATITUDE 46.760134 NORTH
COMMENT ALTITUDE 376.000000 M
TIME_SYSTEM = UTC
ANGLE_TYPE = RADEC
REFERENCE_FRAME = EME2000
META_STOP
DATA_START
ANGLE_1=2021-06-24T20:56:59.000000 218.720825
ANGLE_2=2021-06-24T20:56:59.000000 -2.139564
ANGLE_1=2021-06-24T20:57:5.000000 216.695496
ANGLE_2=2021-06-24T20:57:5.000000 0.645652
ANGLE_1=2021-06-24T20:57:11.000000 214.536118
ANGLE_2=2021-06-24T20:57:11.000000 3.633773
ANGLE_1=2021-06-24T20:57:17.000000 212.154160
ANGLE_2=2021-06-24T20:57:17.000000 6.836154
ANGLE_1=2021-06-24T20:57:23.000000 209.615738
ANGLE_2=2021-06-24T20:57:23.000000 10.145784
ANGLE_1=2021-06-24T20:57:29.000000 206.900635
ANGLE_2=2021-06-24T20:57:29.000000 13.560871
ANGLE_1=2021-06-24T20:57:35.000000 204.022842
ANGLE_2=2021-06-24T20:57:35.000000 17.035784
ANGLE_1=2021-06-24T20:57:41.000000 200.913162
ANGLE_2=2021-06-24T20:57:41.000000 20.569042
ANGLE_1=2021-06-24T20:57:47.000000 197.574432
ANGLE_2=2021-06-24T20:57:47.000000 24.038864
ANGLE_1=2021-06-24T20:57:53.000000 194.119431
ANGLE_2=2021-06-24T20:57:53.000000 27.442705
ANGLE_1=2021-06-24T20:57:59.000000 190.442932
ANGLE_2=2021-06-24T20:57:59.000000 30.719671
ANGLE_1=2021-06-24T20:58:5.000000 186.584808
ANGLE_2=2021-06-24T20:58:5.000000 33.764694
ANGLE_1=2021-06-24T20:58:11.000000 182.546356
ANGLE_2=2021-06-24T20:58:11.000000 36.564613
DATA_STOP

# Conclusions

- Real time acquisition and processing for a wide field sensor (40x60 degrees)
- No sky tracking, no ideal lighting conditions (urban site)
- Suppression of false positives (clouds, etc)
- Future improvements:
  - Better timing accuracy
  - Integration of the detection/astrometry pipeline

# Contact


- E-mail: radu.danescu@cs.utcluj.ro
- Project web site: http://cv.utcluj.ro/cameleon


Thank you!