Visual approach to Unmanned Aerial Vehicle (UAV)

Petar Ivanov

Graphics & Media Lab, CMC

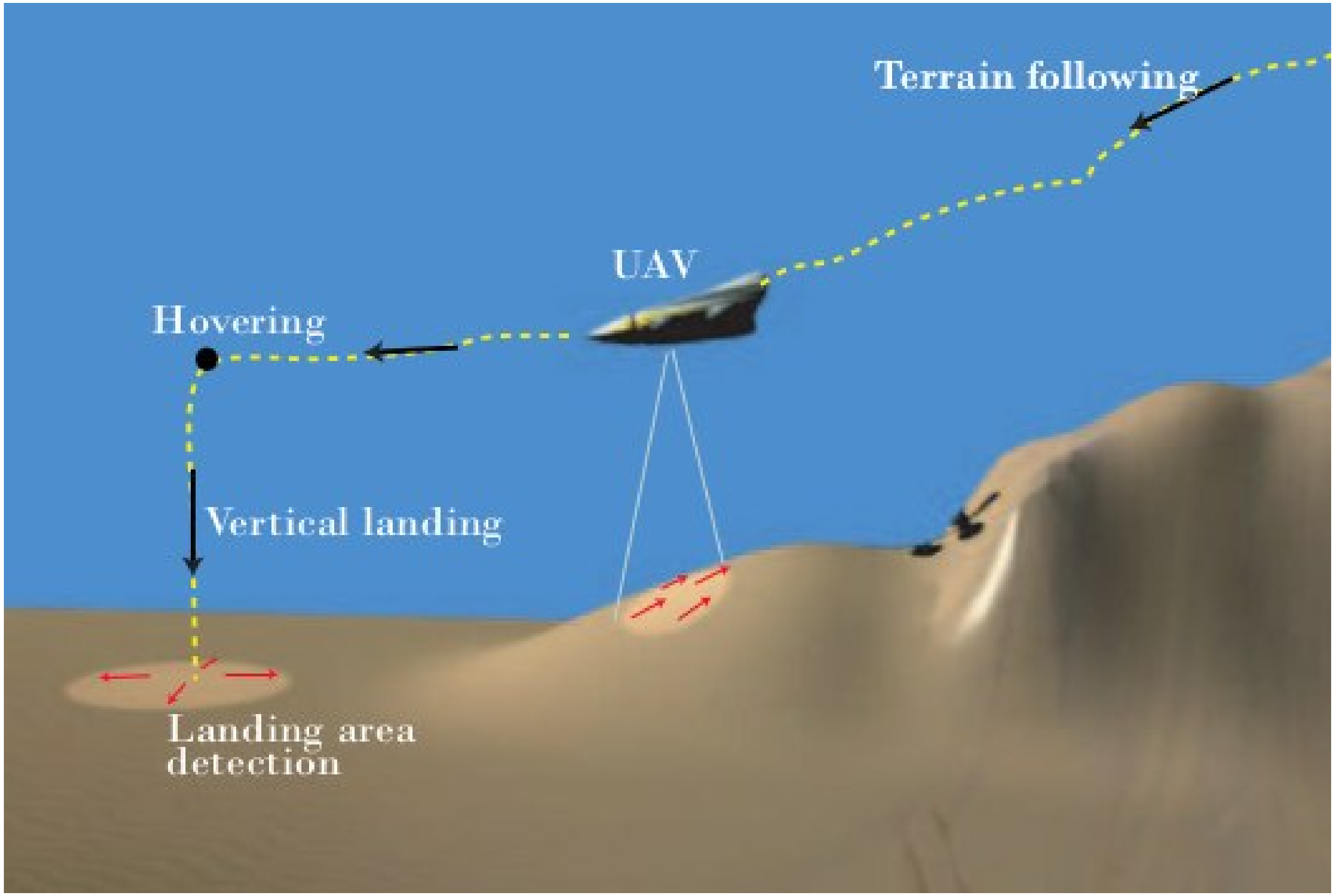
Lomonosov Moscow State Unviersity

May 6, 2013

Sensors

- Laser-based (accurate, but point-to-point)
- Sonar-based (cheap, but inacurate)
- Inertial-based (fast, but local errors grow with time)
- Global sensing, e.g. GPS/ГЛОНАСС (cool, but without local features)
- ***Vision-based (our method!)***
  - *passive, long-range, high-resolution*
  - *but maximal information gain by greedy*
  - *there should be features and they should be distinct!*

Visual odometry



Estimating position over time by consequtive imaging
(Mars rovers use it too!)

Visual odometry

- Image correction: lens distortion, noise
- Frames comparison
  - Correspondence of two images without a long term feature tracking
  - Feature extraction and correlation
  - Optical flow field
- Outliers removal
- Estimation of the camera motion from the optical flow
  - Choice 1: Kalman filter for state estimate distribution
  - Choice 2: Geometric transformation optimization
- Repopulation of trackpoints

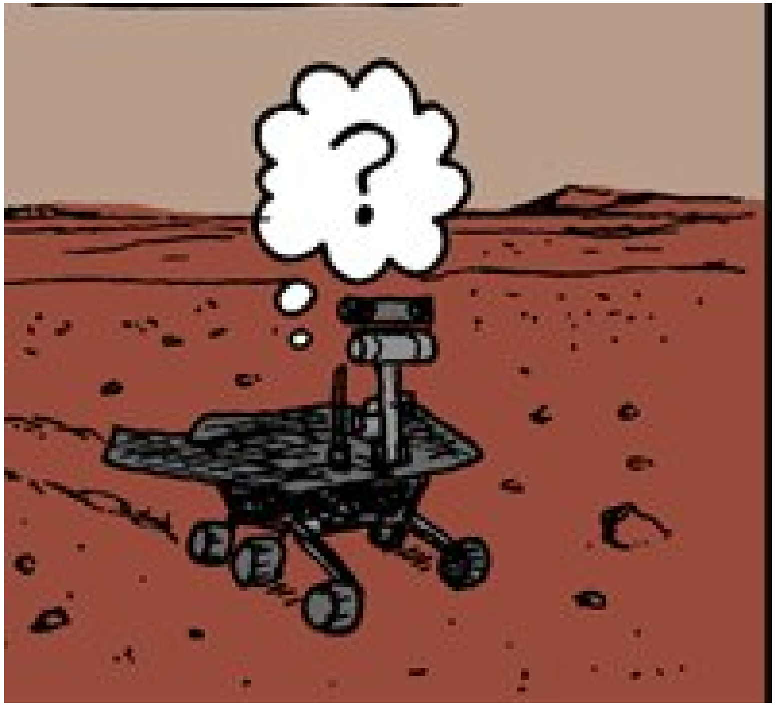
Visual odometry

Visual odometry can be incomporated with other odometry in a probabilistic scheme:

- IMU
- laser scanners
- wheel speed
- etc.

Robotics problem
Simultaneous localization and mapping

- Where am I?
  - Where I was?
  - What happened since than?
  - What do I see now?
    - … (chicken)
- What do I see now?
  - What have I seen before?
  - Where am I?
    - … (egg)



SLAM history

- 30 years ago: metric and topological approaches
- 20 years ago: probabilistic approach → measuring the noise → noise map

SLAM

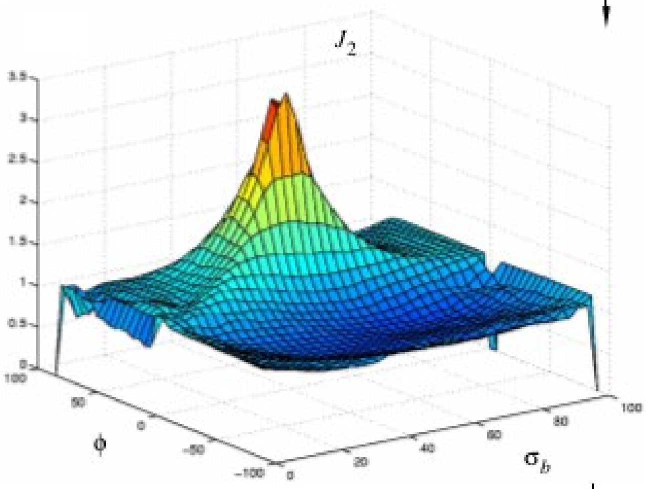
- SLAM problem can be decomposed into two aspects:
  - handling of map features
  - handling of uncertainty
- Many map-building algorithms not specifying the sensor type
- Feature recognition & tracking, 3D reconstruction → Feature map
- Vision Simultaneous localization and map-building (SLAM) approaches:
  - Kalman filter (KF)-based
  - Particle filter (PF)-based
  - Expectation-maximization (EM)-based
  - Set membership-based

SLAM difficulties

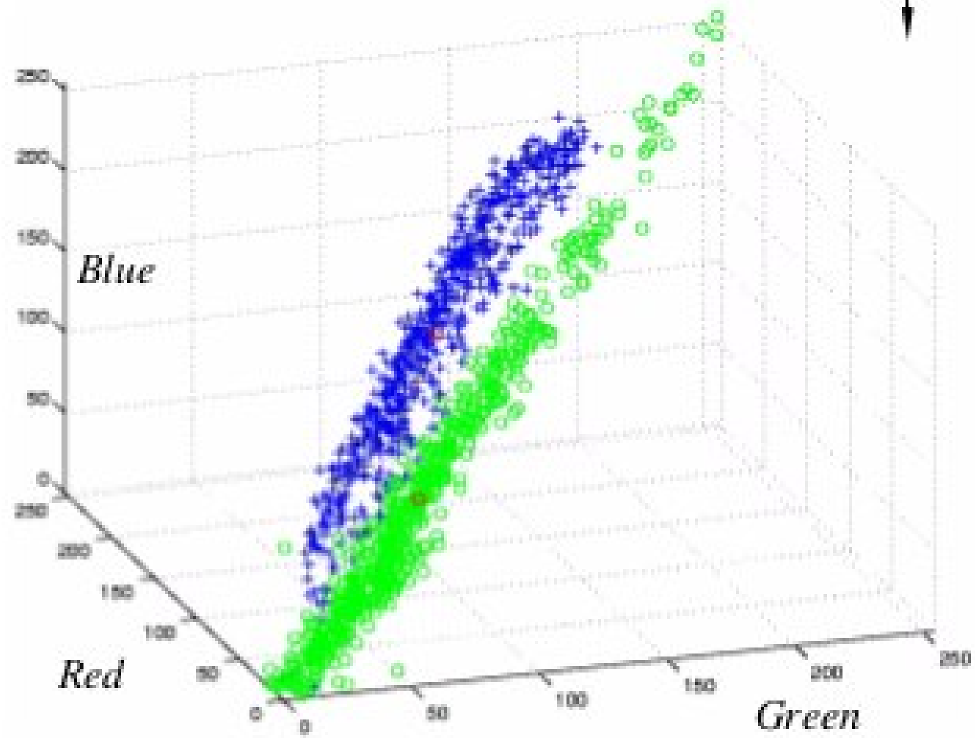
- Data association problem
  (Is this the same tree?!)
- Loop-closing problem (for consistent maps)
- Bearing-only SLAM (no initial map)

Ettinger, Nechyba, Ifju, Waszak – "Towards Flight Autonomy: Vision-Based Horizon Detection for Micro Air Vehicles", 2002

(a)

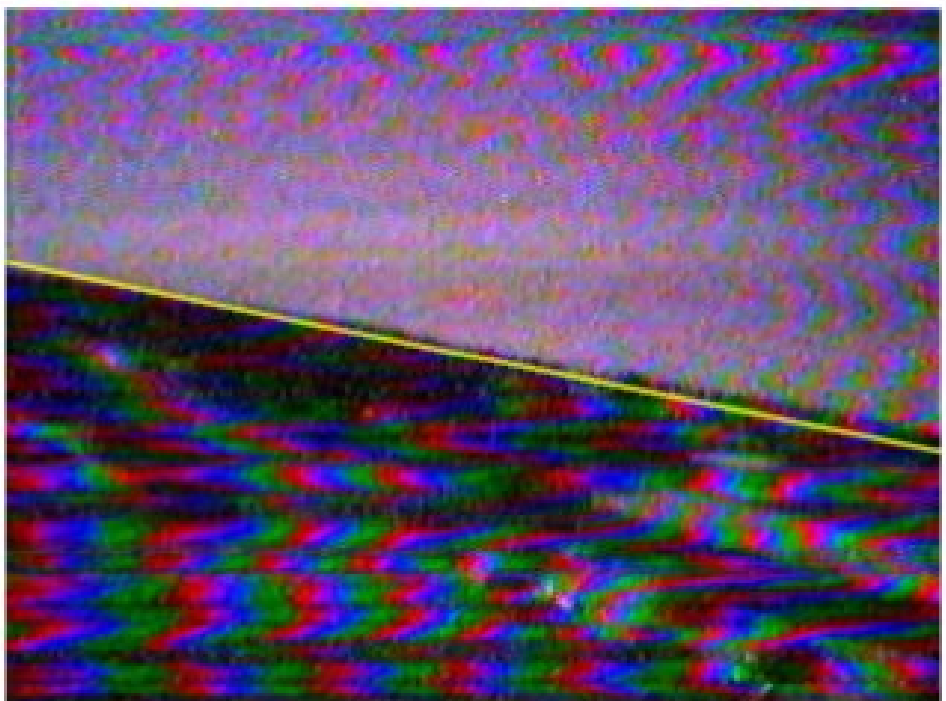


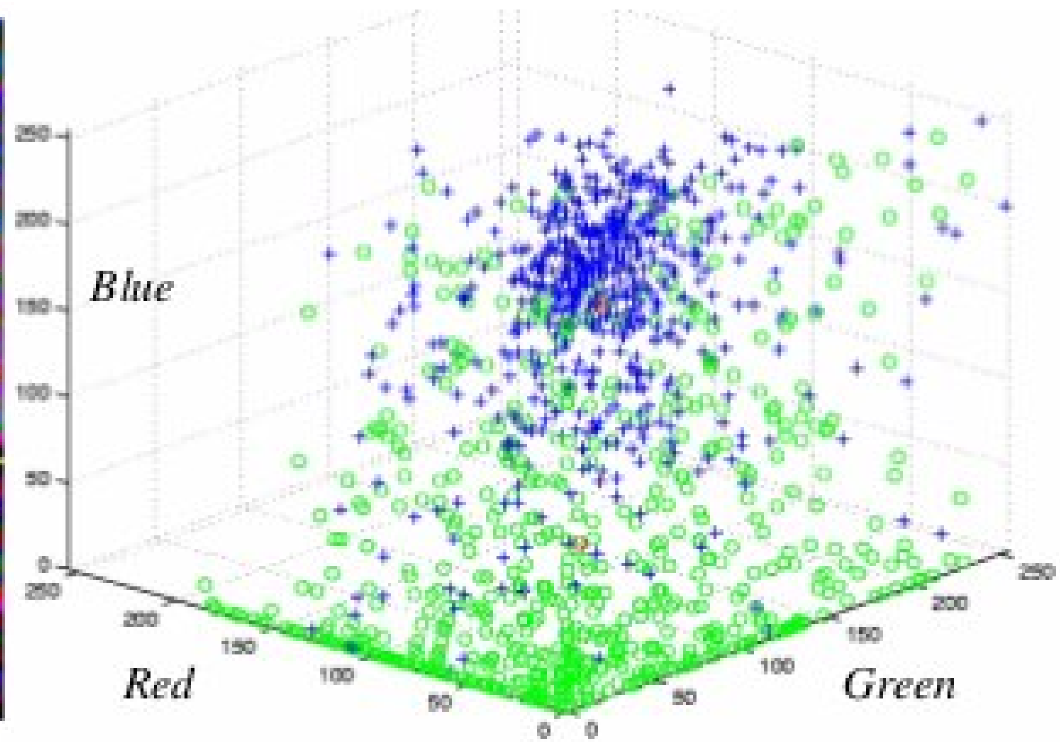
(b)



(c)

Ettinger, Nechyba, Ifju, Waszak – "Towards Flight Autonomy: Vision-Based Horizon Detection for Micro Air Vehicles", 2002





Complex scene

Ettinger, Nechyba, Ifju, Waszak – "Towards Flight Autonomy: Vision-Based Horizon Detection for Micro Air Vehicles", 2002

line horizon parametrization ***(m,b)***
→ ***(m,b)*** grid calculation of
|sky_cov_matrix| + |ground_cov_matrix|
→ binary search optimization near the maximum

where |cov_matrix({Pixels})| increases with {Pixels} colors being more scattered

Ettinger, Nechyba, Ifju, Waszak – “Towards Flight Autonomy: Vision-Based Horizon Detection for Micro Air Vehicles”, 2002

“[…] we first motivate the use of computer vision for the horizon detection task by examining the flight of birds (biological MAVs) […]”

Which is further explained as simply “birds have excellent eyes”.

McGee, Sengupta, Hedrick – “Obstacle Detection for Small Autonomous Aircraft Using Sky Segmentation”, 2012

Another horizon approach:

- SVM sky/non-sky segmentation
- Edges obtained by smoothing the binary image and obtaining 0.5 values
- Hough transform line detection
- Choose the most dangerous horizon line

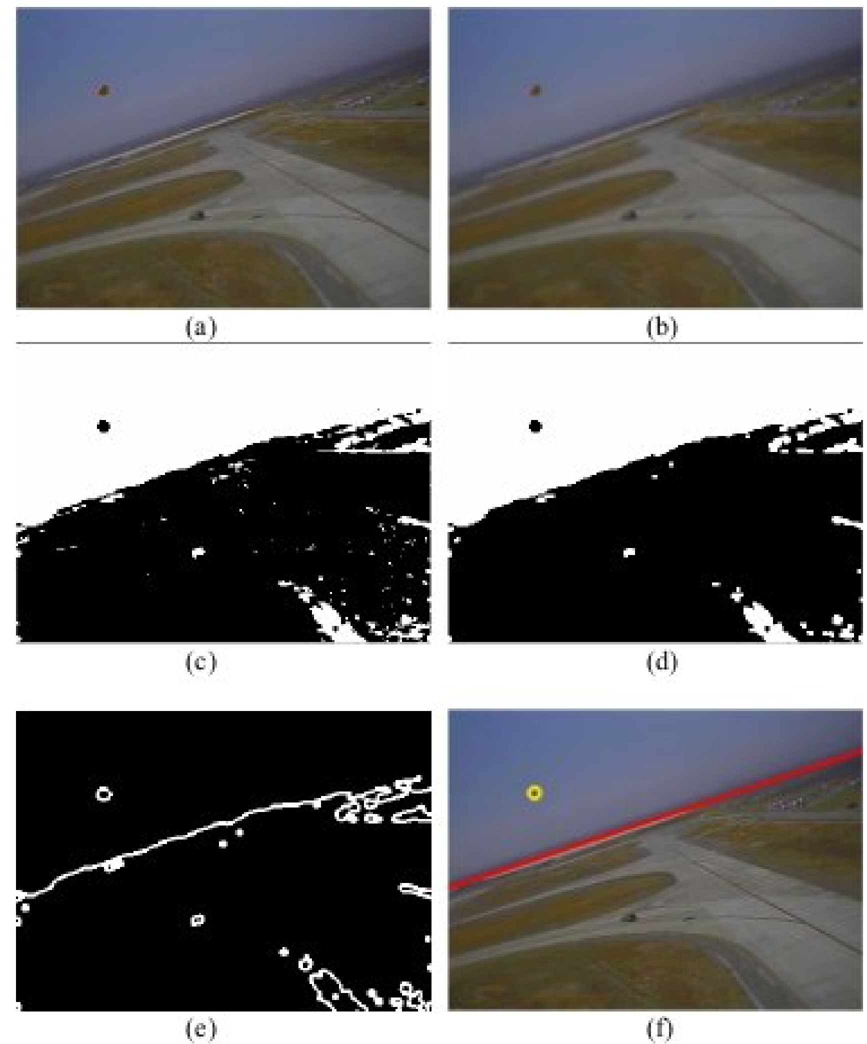


Fig. 4 Vision algorithm:
a)original image. b) smoothed image
c) binary segmented image d)erosion and dilation
e)sky/non-sky border f)horizon and obstacle found

Xu, Zhang, Ji, Cheng, Tian – “Research on computer vision-based for UAV autonomous landing on a ship”, 2009

Infrared radiation images →

Otsu tresholding →

Sobel edge detection →

Affine moment invariants →

Calculating yaw

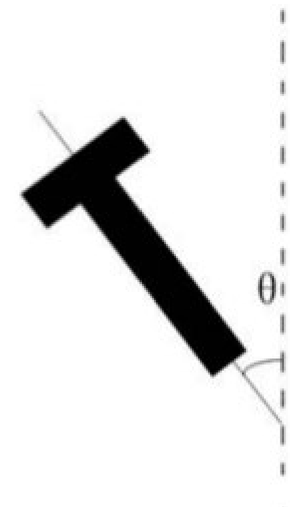
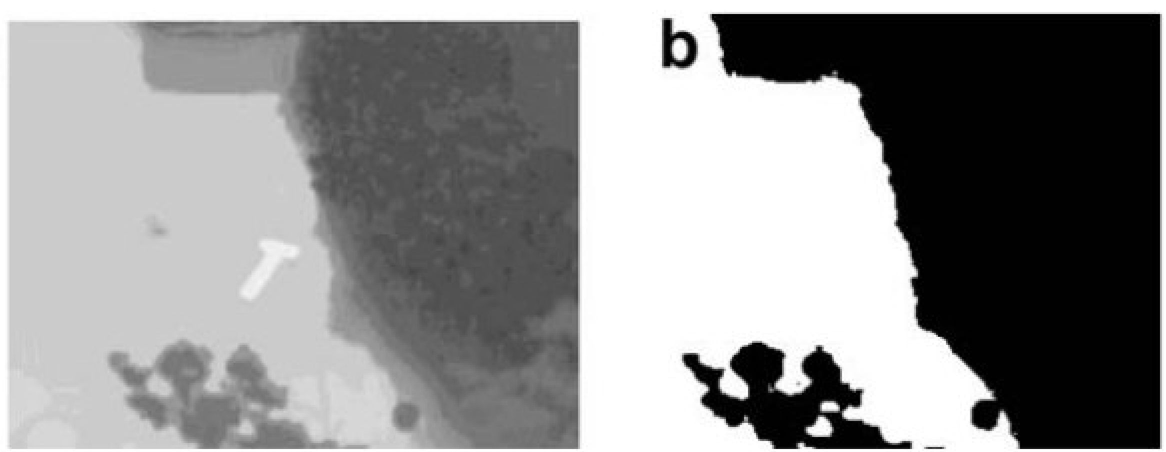


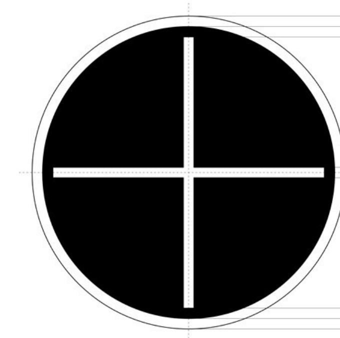
Fig. 5. Angle of yaw.

a

b

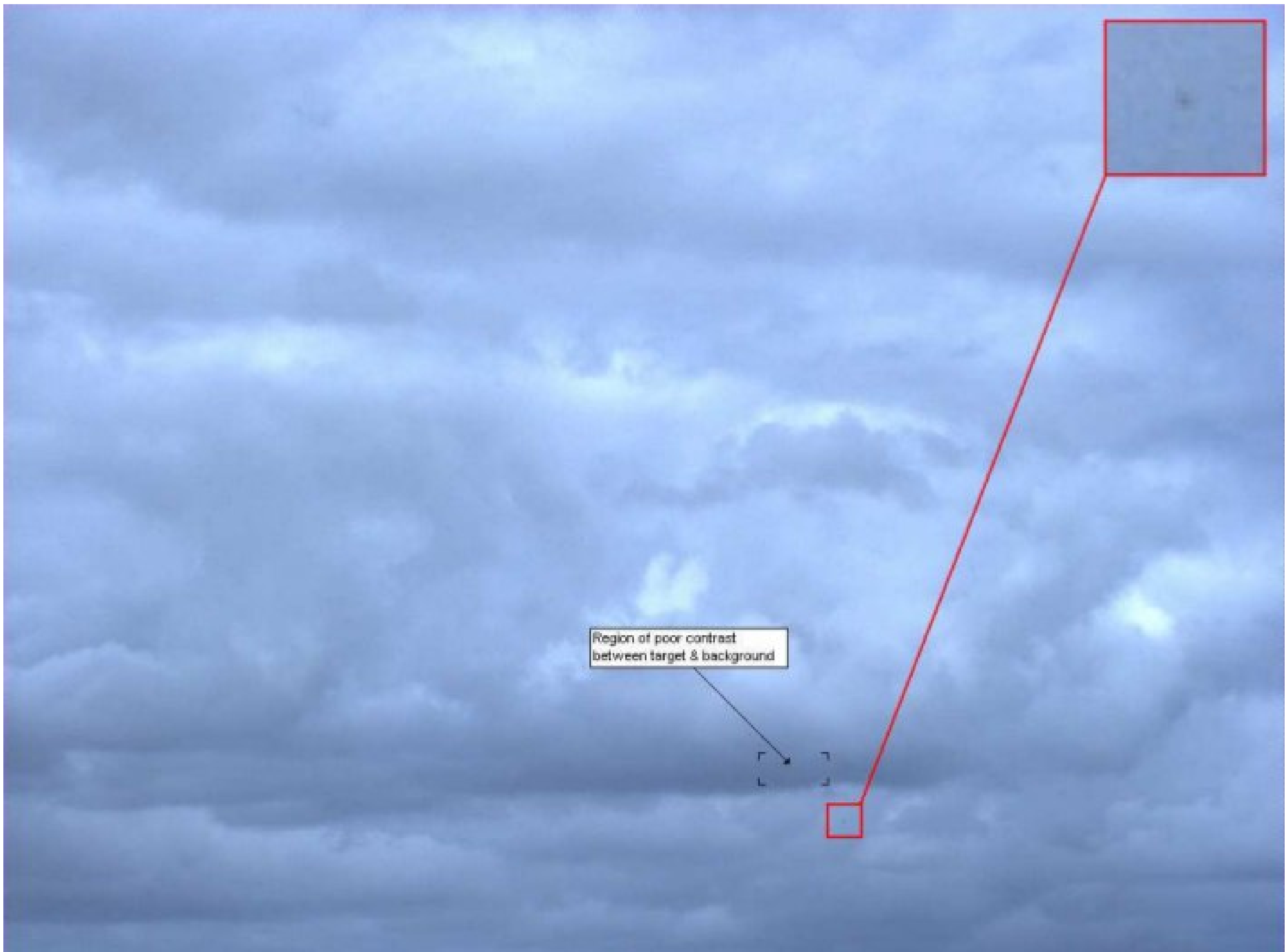


Наша точка посадки



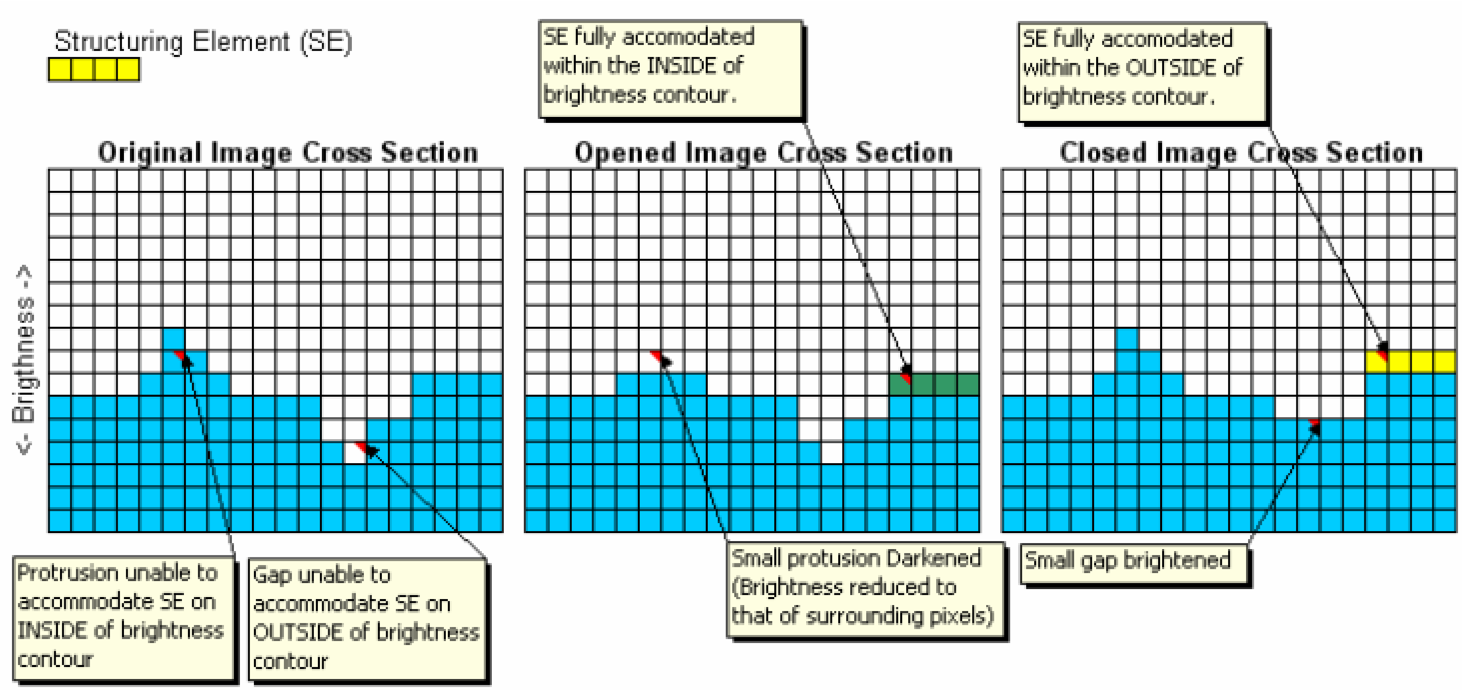
1. Mapping black and white regions
2. Binarisation
3. Hough transform for the lines
4. Hough transform for the ellipse

Carnie, Walker, Corke – "Computer-Vision Based Collision Avoidance for UAVs", 2005



Carnie, Walker, Corke – "Computer-Vision Based Collision Avoidance for UAVs", 2005

Close-Minus-Open

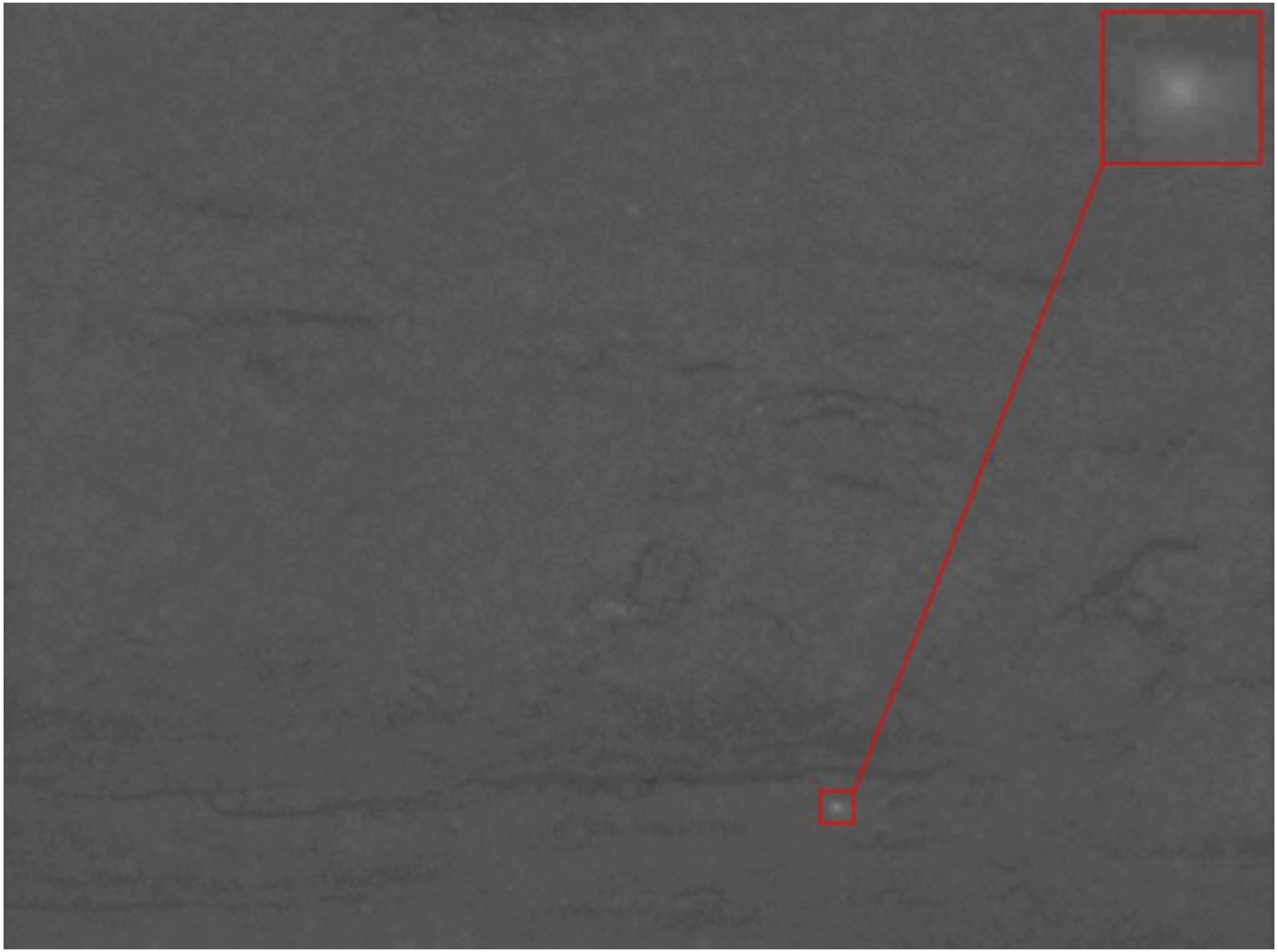


For all (u, v):

Track-before-detect temporal Filtering Dynamic Programming

$$F_{uv}(i,j,k) = [(1-\alpha) f(i,j,k)] + [\alpha \times \max_{(i',j') \in Q(i,j,u,v)} F_{uv}(i',j',(k-1))]$$

Carnie, Walker, Corke – “Computer-Vision Based Collision Avoidance for UAVs”, 2005



Dynamic Programming Output

Conclusion

Computer vision can help your flying robot:

- Measure distance (Stereo or Distance from Motion)
- Measure self-motion (Odometry)
- Find the horizon
- Find a place to land
- Detect a missile or a bird