Universidad de La Laguna

USING A PLENOPTIC CAMERA FOR VISION BASED NAVIGATION IN AN ACTIVE DEBRIS REMOVAL SCENARIO.

Ángela Hernández Delgado (ULL)
Noelia Martínez Rey (ULL)
Jonas Philipp Lüke (ULL)
José Gil Marichal Hernández (ULL)
José Manuel Rodríguez Ramos (ULL)
Manuel Sánchez Gestido (ESTEC-ESA)
Matthew Bullock (ESTEC-ESA)

Outline

- Introduction
  - Plenoptic technology: The light field
  - Why is plenoptic technology interesting? Applications
- Plenoptic navigator design
  - Decoding and rectification
  - Light field processing
- Experimental setup
- Results
- Conclusions and future work

Plenoptic technology is an acquisition technique that is useful in vision based navigation.

- We did a proof of concept of the technology for space.
- We tested it in an ADR scenario: ENVISAT uncooperative rendezvous.
- We will show some of the results.
- We want to show you that this technology exists.

Universidad de La Laguna

Plenoptic technology is related to all the technological developments around of the plenoptic camera

IT IS ABOUT CAPTURING LIGHT RAYS INSTEAD OF IMAGES

Plenoptic function

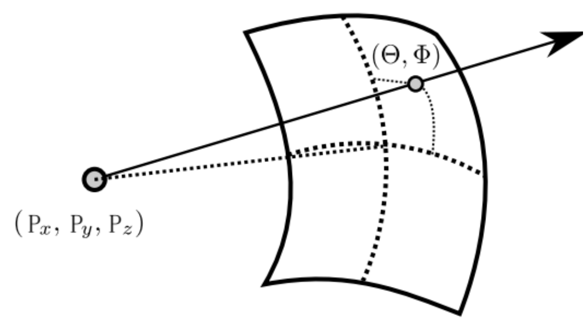
Light field

Plenoptic function

A 7D function that models the directional light distribution at all possible positions in 3D space.

[Adelson and Berger 1991]

$$P(\theta, \Phi, \lambda, t, P_x, P_y, P_z)$$



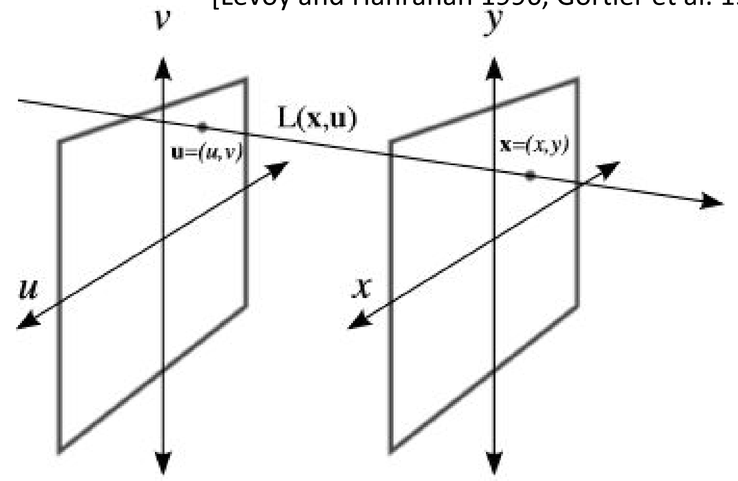
[Figures taken from Lüke 2014]

Light field

4D function that describes the light rays in free space.

2PP: Parameterized by L(x,y,u,v) where (u,v) is the cut point with the front plane and (x,y) is the cut point with the back plane.

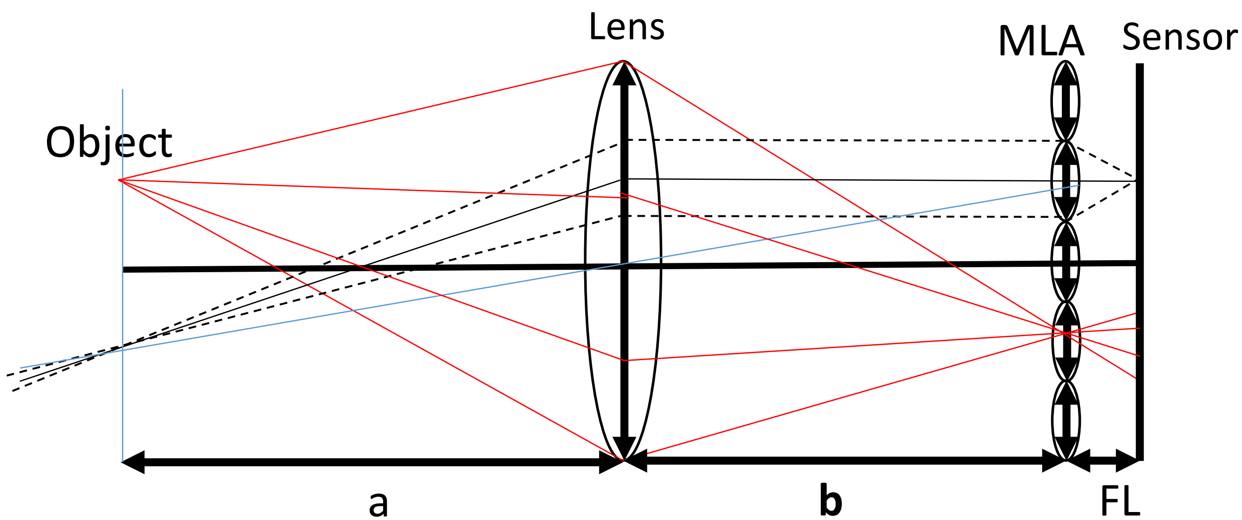
[Levoy and Hanrahan 1996, Gortler et al. 1996]



Front plane Back plane

Assuming that intensity does not change along a ray

Plenoptic camera



Commercial plenoptic cameras

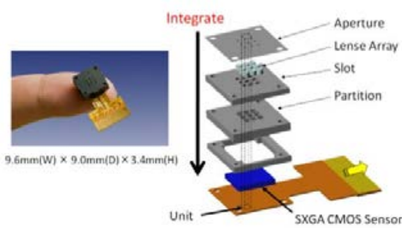
Lytro, Inc.

Raytrix, GmbH

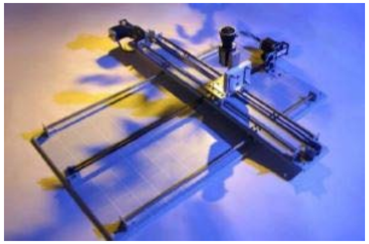
Other ligtht field capturing devices

Wilburn et. al. 2005

Geogiev & Intwala, 2006



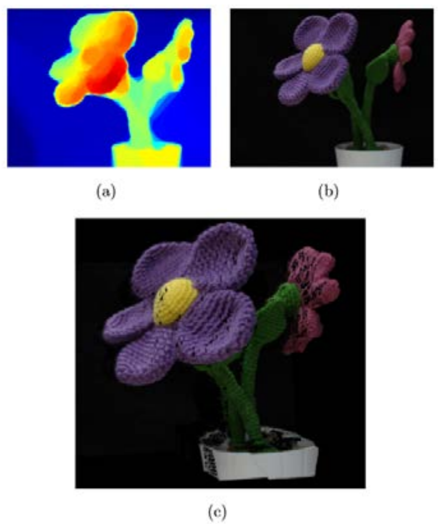
Tanida, 2007



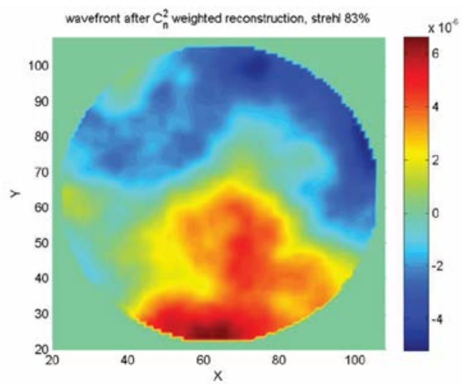
Unger et al., 2003

Why is plenoptic technology interesting? Applications

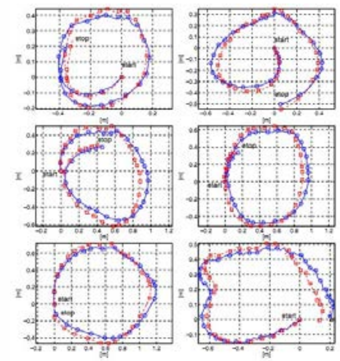
Digital refocusing after the shot (Ren Ng, 2006).



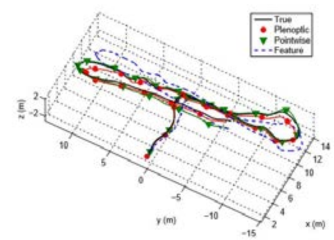
Depth estimation (Lüke, 2014).



Wavefront phase reconstruction (Montilla et al., 2010).



Dong et al. 2013



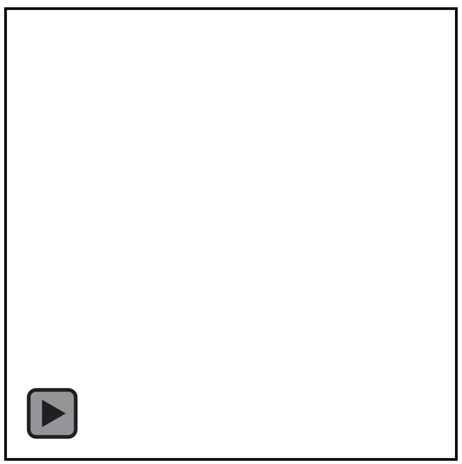
Dansereau et al. 2011

Robotic navigation.

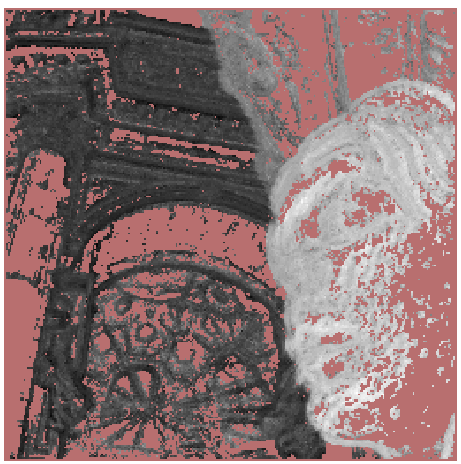
Why is plenoptic technology interesting? Applications

Same data can provide several outputs

Focal stack

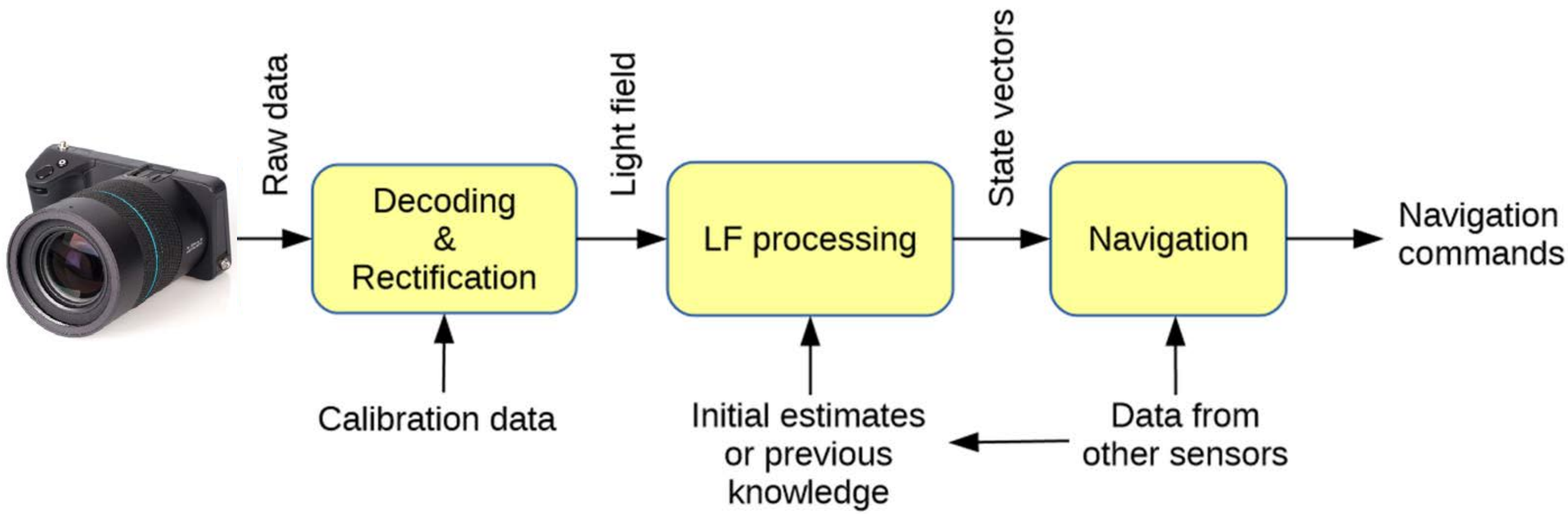


Sparse depth estimation

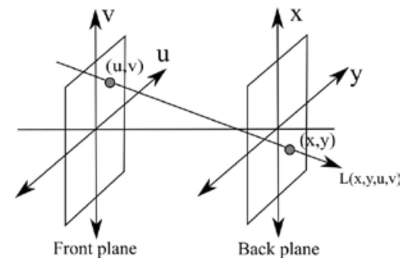


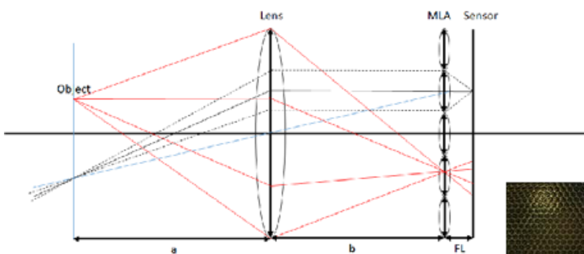
All-in-focus image

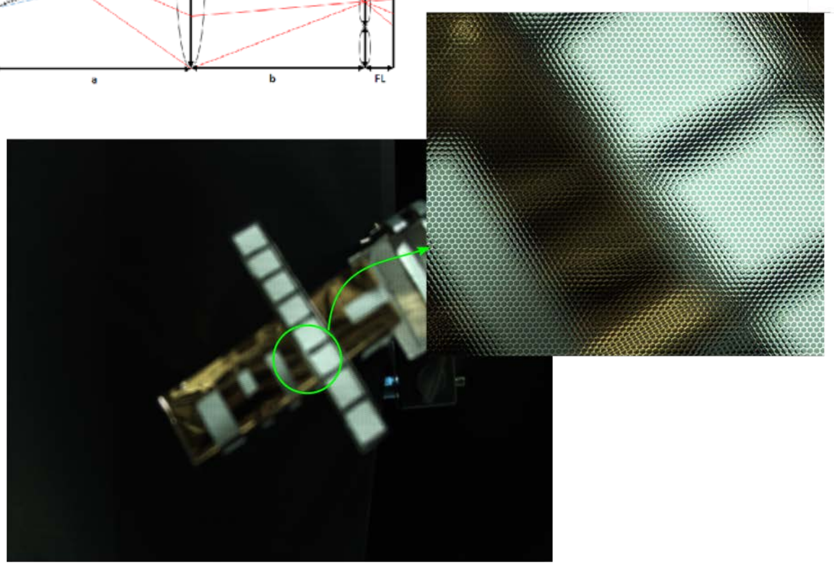
Plenoptic navigator design: Proof of concept

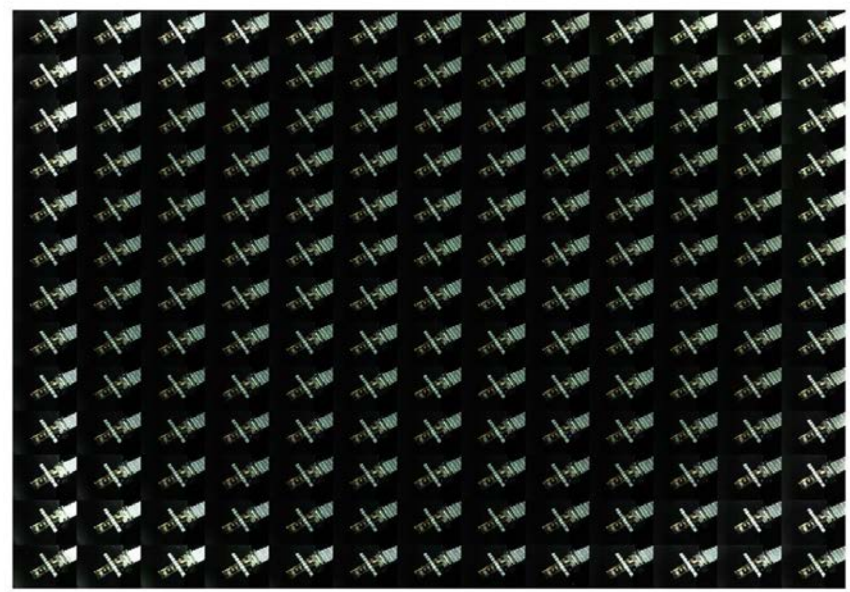


Decoding and rectification





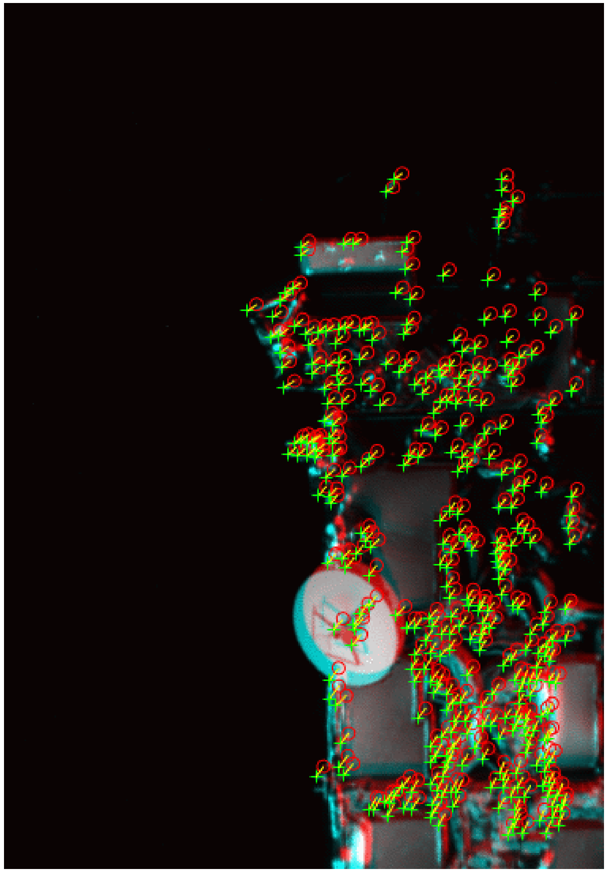




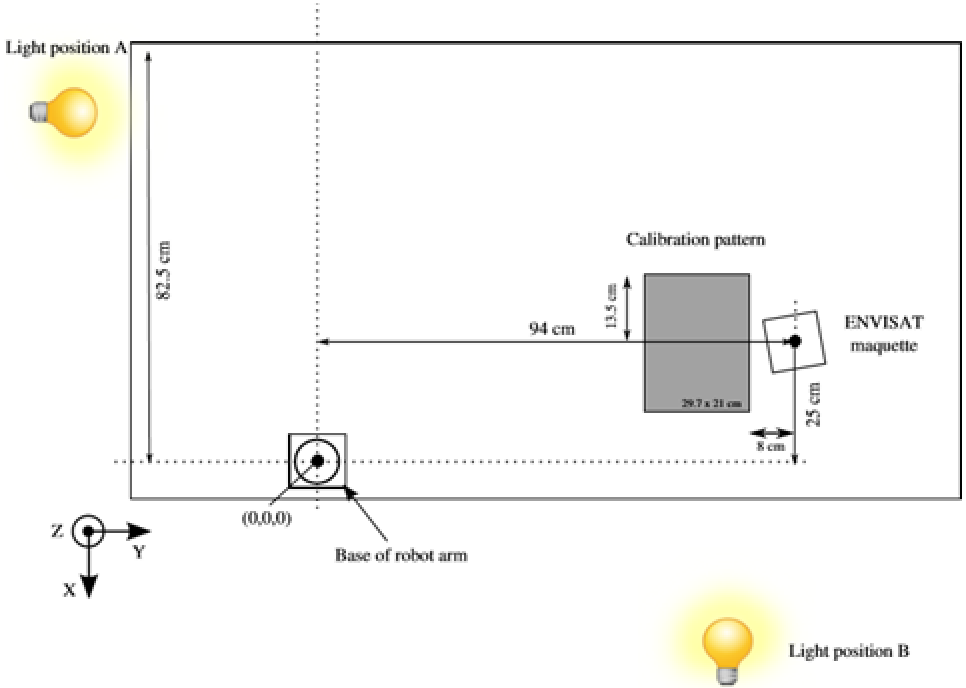
Universidad de La Laguna

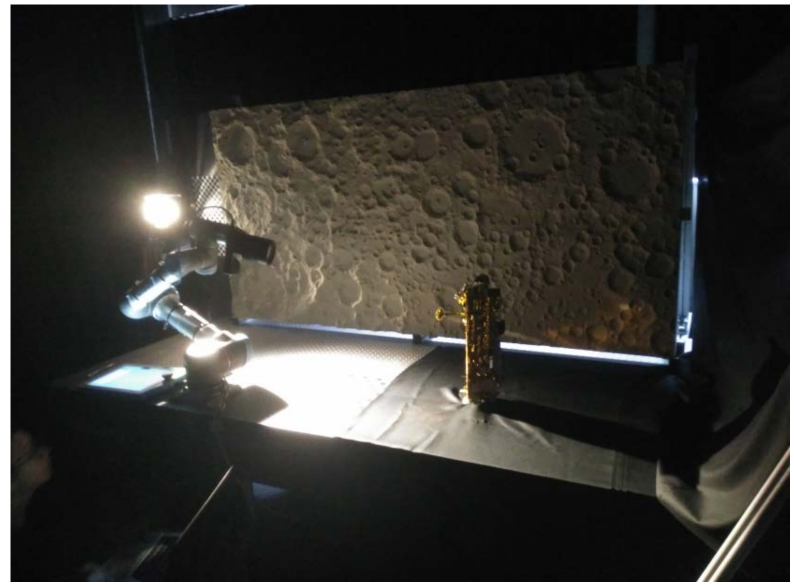
Feature tracking + Disparity Maps = Matched 3D point clouds

Pose estimation

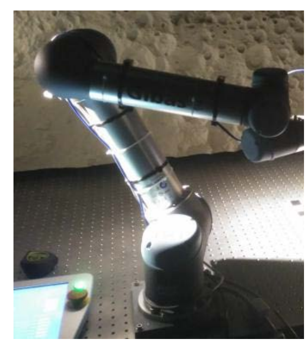


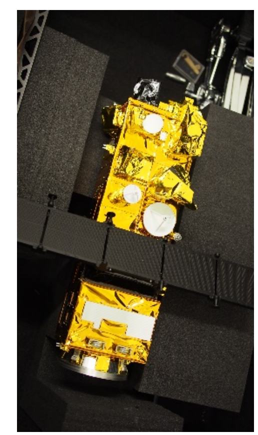
Test scenario





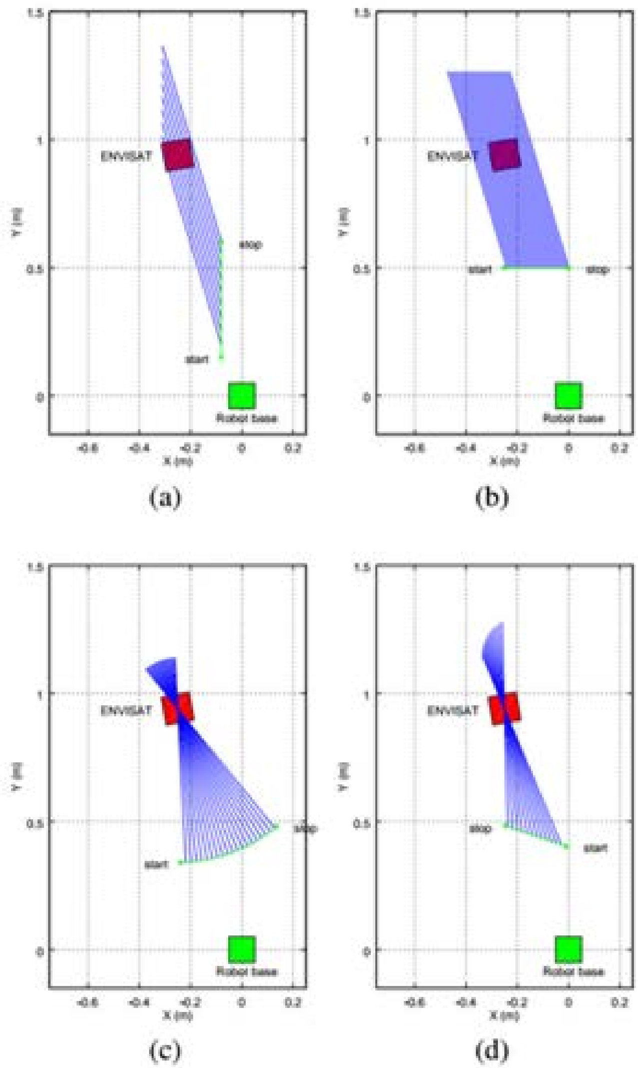
Maquette scale: 1:25





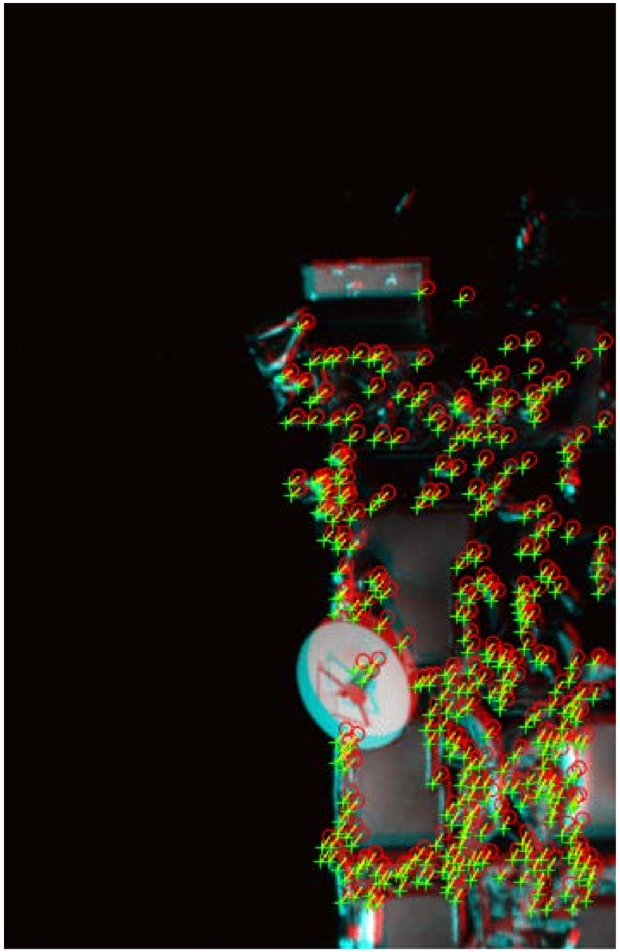
Test trajectories

(a) ENVISAT linear A
(b) ENVISAT linear B
(c) ENVISAT rotation A
(d) ENVISAT rotation B

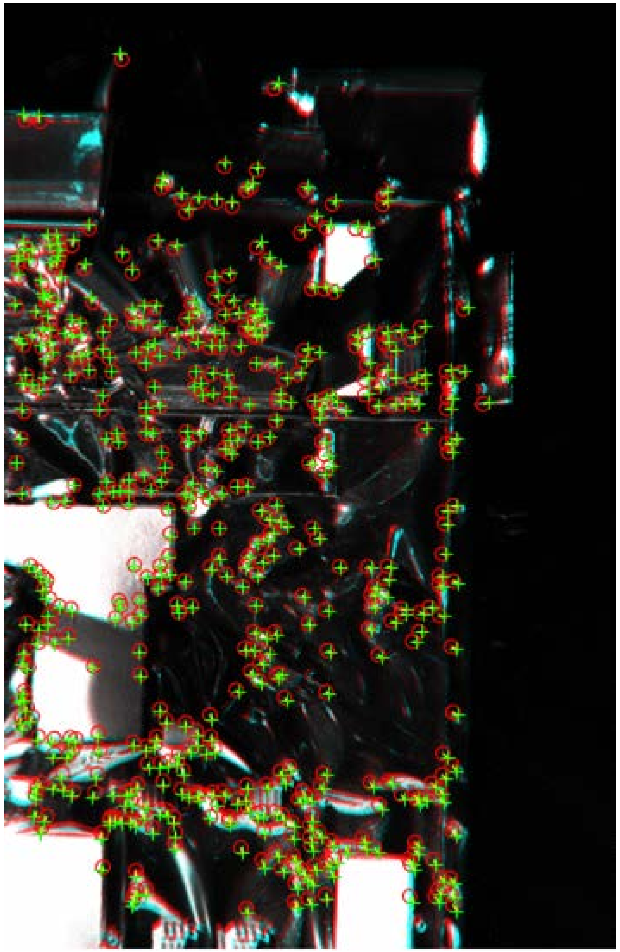


Tracking

ENVISAT linear A

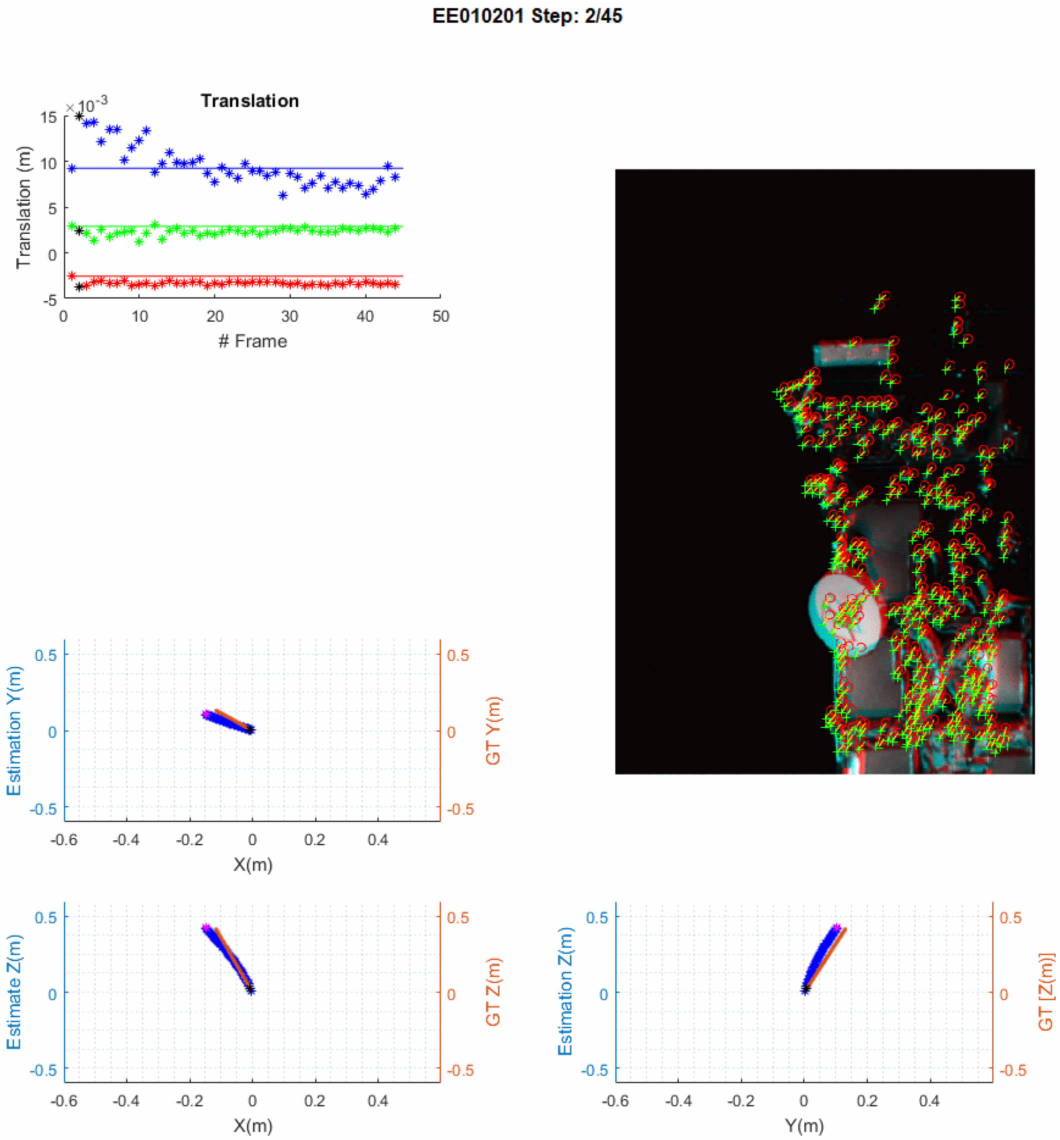


ENVISAT rotation B



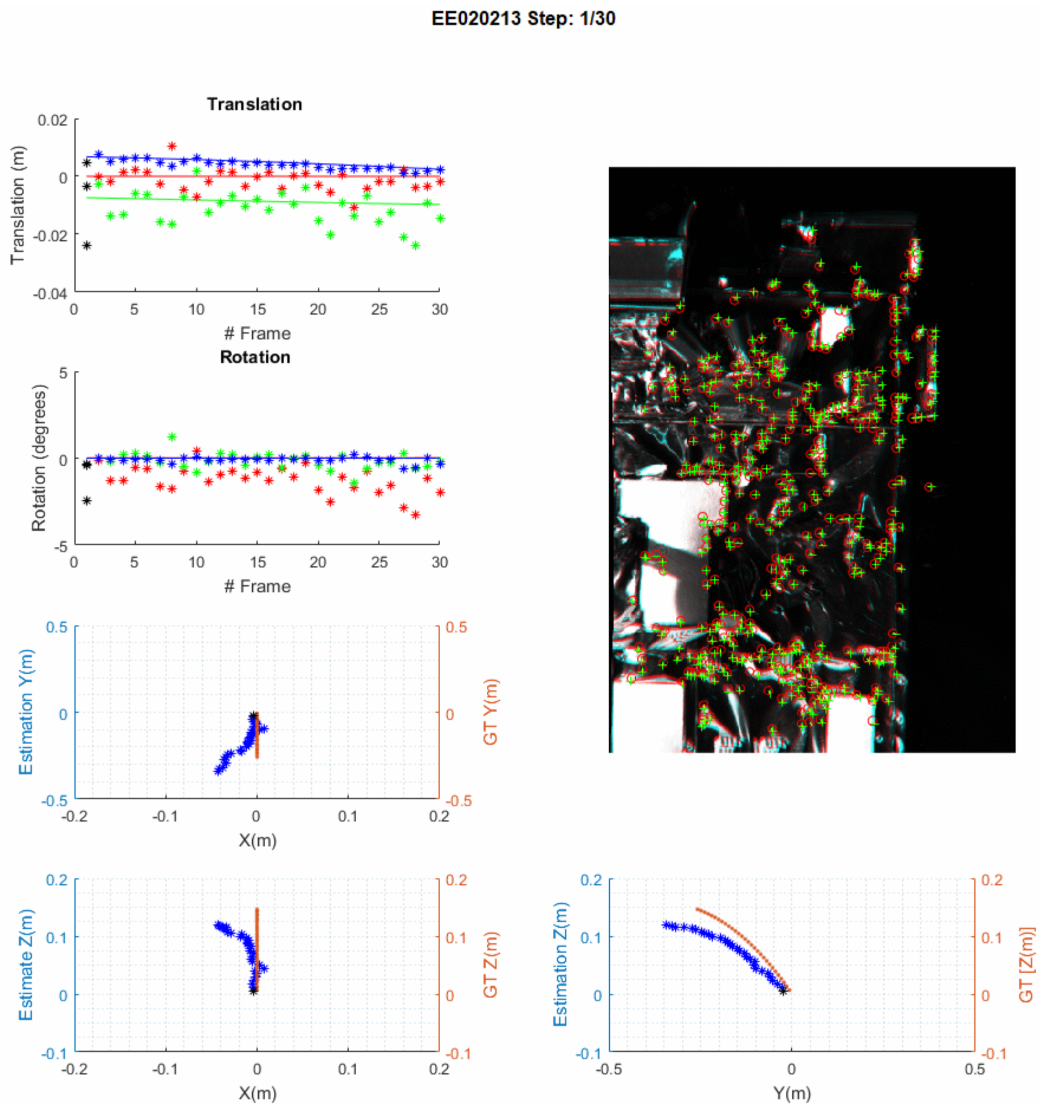
Results

Pure translation



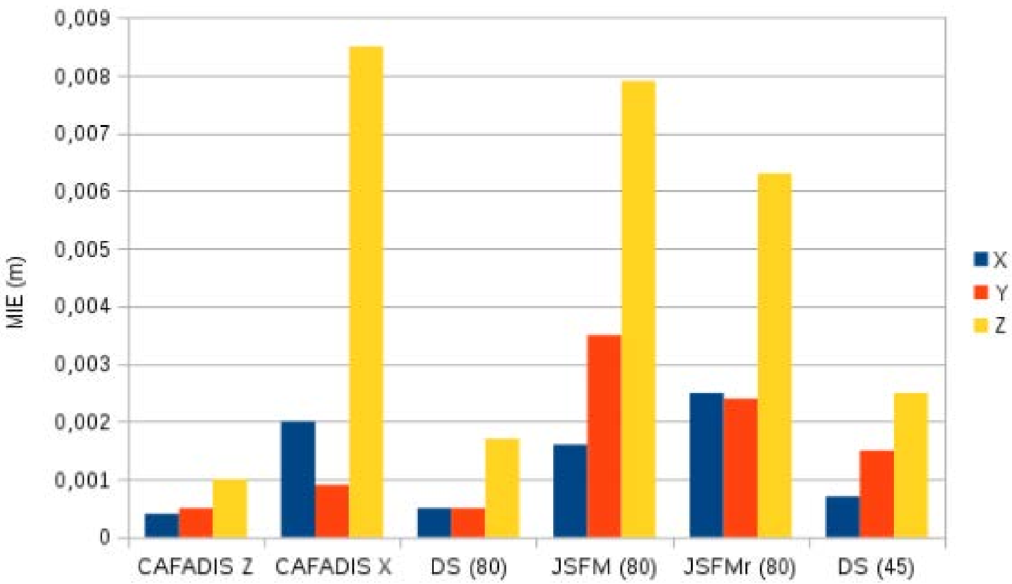
Results

Translation & rotation



Results

- Results show that incremental motion estimation is possible with the plenoptic.
- Important to choose the right algorithm.
- Optical configuration is also important.
- When rotation is estimated errors raise.

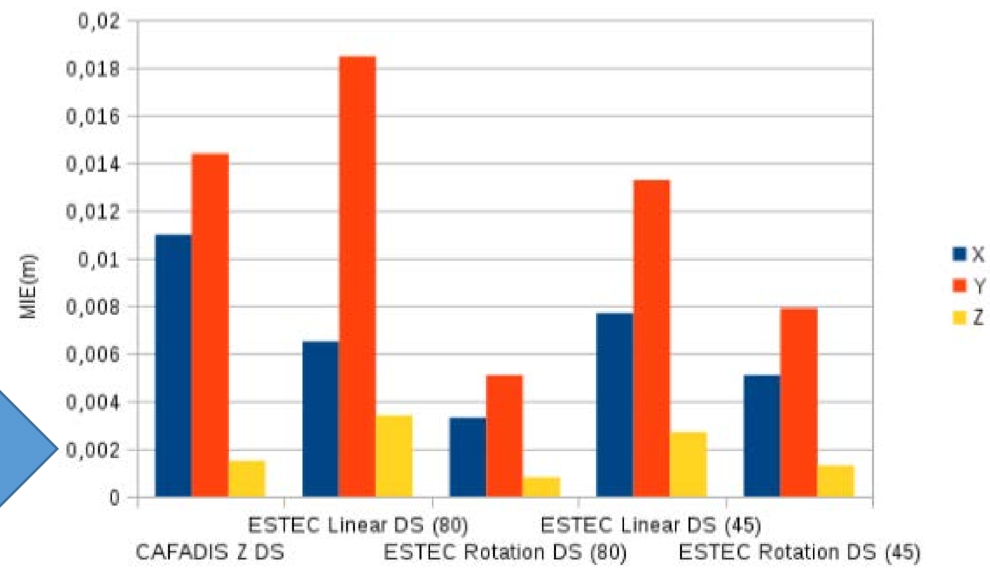


Pure motion

Step size: 1 cm

Errors raise

Translation + Rotation



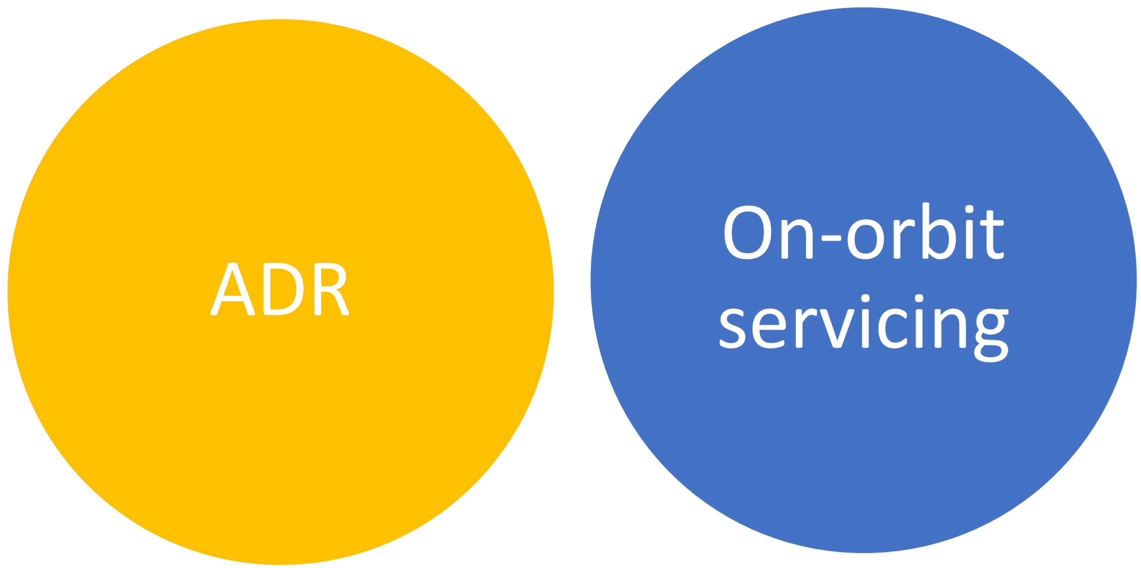
Conclusions

- Results show that incremental motion estimation is possible.
- The achieved RMSE of the trajectories is about 0.0264m (0.66 m in real scale), if no rotation is estimated.
- With rotation estimation error increases dramatically for the case of pure translations and for motions with a rotational component a RMSE of 0.05 m is reached (1.25 m at real scale).
- The operating distances are approximately between 2-15 m.

- Limitations of the experimental approach have been detected: Not scalable

The plenoptic camera might be useful as a complementary sensor.

Close range operations (< 15 m)



Future work

- Experiments at real scale: Overcome scaling problems.
- Computational aspects must be deeper explored:
  - Algorithm design and implementation.
  - Implementation on flight computers.
- Development of custom plenoptic cameras or other light field capture devices.

Universidad de La Laguna

Thank you for your attention

ACKNOWLEDGEMENTS

The research presented in this talk was carried out under a programme of and funded by the European Space Agency. ESA Contract No. 4000116083/15/NL/FE/as.

The authors would also thank to the staff of the ESTEC-ESA laboratory, specially to Tudor Mureşan, Irene Huertas and Olivier Dubois-Matra, for the help they gave us during the test campaign at ESTEC.