Reproducible Research, IPOL, and Satellite Stereo Images

UPF – DTIC SEMINAR
Barcelona, 9th Jan 2014

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CMLA, ENS Cachan, FR

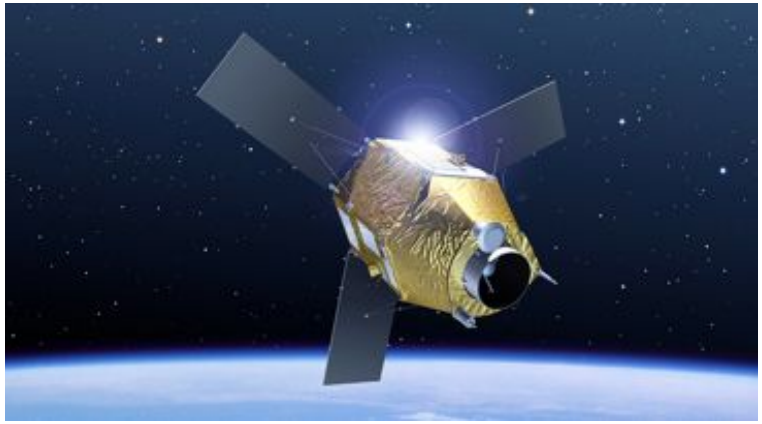
Plan

IPOL
IMAGE PROCESSING ON LINE

Some slides courtesy of N. Limare and E. Meinhardt

Plan

IPOL
IMAGE PROCESSING ON LINE



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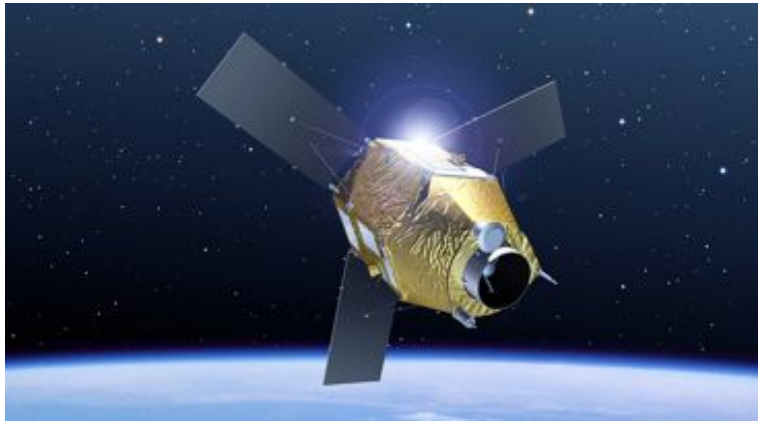

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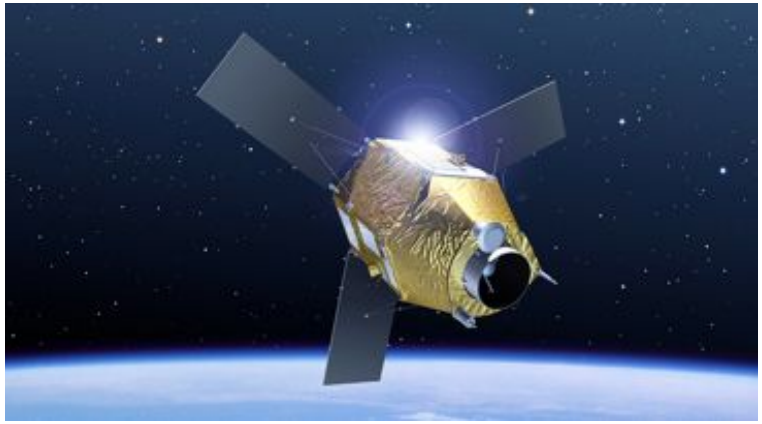

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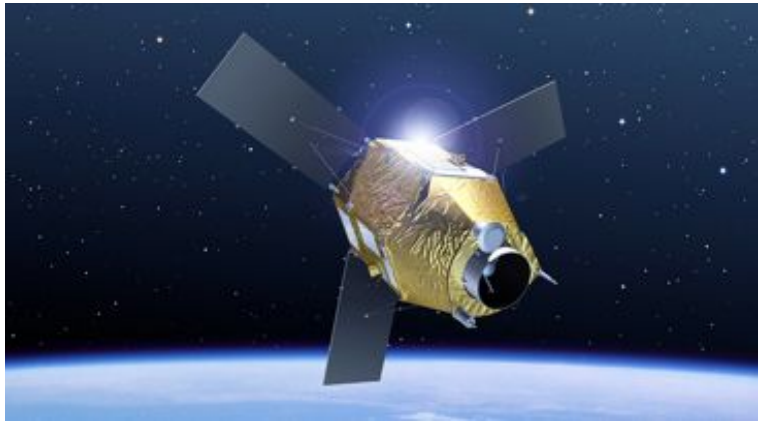
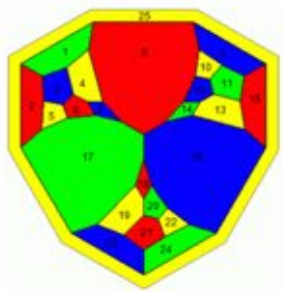
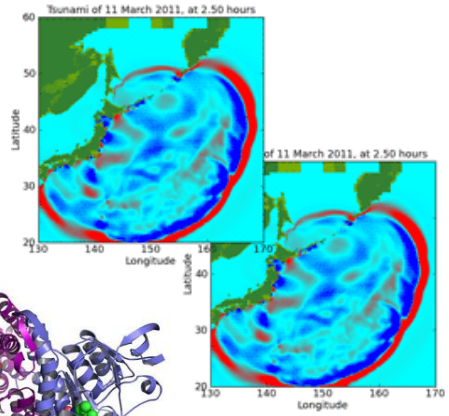
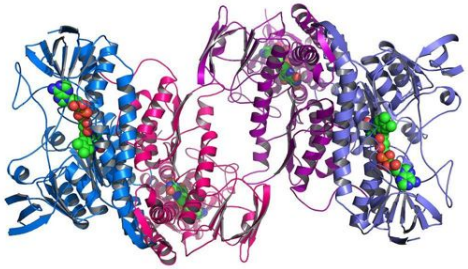


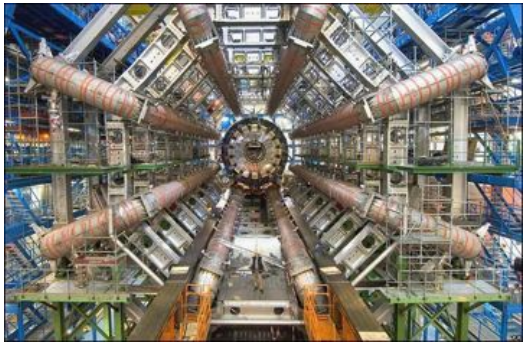
Software Everywhere

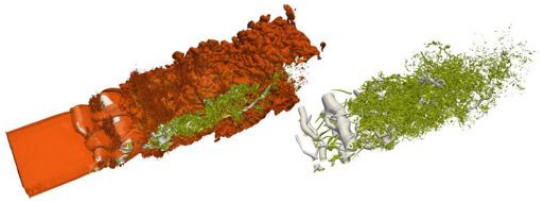
- physics
- econometrics
- signal processing
- chemistry
- archeology
- medicine
- climate & weather
- geophysics
- …

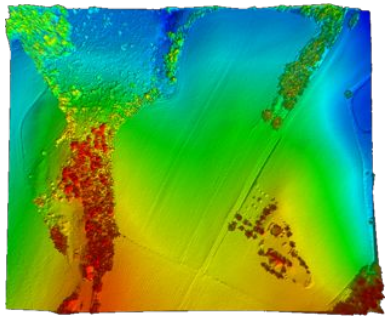








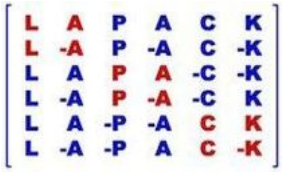




Software vs Science?

Research software is not like general-purpose equipment:
telescopes, supercomputers, compilers, libraries





Research software is made by scientists for scientists, specialized for an experimental process.

Most of the research software is:

- not released
- not published, not reviewed, not cited
- not completely specified
- … and often buggy

Reproducible Research

Research is reproducible if other researchers can independently obtain the same results from the published material.

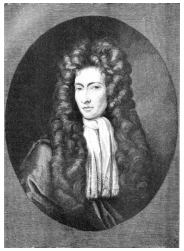
- Theoretical sciences have proofs
- Experimental sciences have procedures
- Computational sciences have ...
    - insufficient descriptions
    - missing parameters
    - missing pre/post processing steps
    - missing data

refs: Claerbout 1992, Donoho 1995, Stodden, Vandewalle

Research must be Reproducible

Scientific method (1200 - 1800)






Roger Bacon, Francis Bacon, Galileo Galilei, Robert Boyle, René Descartes, …

→ science **must be reproduced**

Reproducible research (1990 -)

Jon Claerbout, David Donoho, Serguei Fomel, Randy Leveque, Davis Bailey, Victoria Stodden,Juliana Freire, …

→ the science is in the **software**, **data** and **process**

The article is a mere teaser

David Donoho
Stanford

An article about computational science in a scientific publication is not the scholarship itself, it is merely **advertising** *of the scholarship. The actual scholarship is the complete software development environment and the complete set of instructions which generated the figures.*

Traditional Articles (in image processing)

Description of a method/algorithm with some results. The **code** used for the experiments is **rarely made public**


Fast Geodesic Active Contours

We can:

- **Read** the formulas
- **Believe** the results

We can't:

- Verify/**reproduce** the results
- View the images in **detail**
- Try with **new data**

Why not to distribute the research code?

- Maintain advantage w.r.t. other researchers
- Ashamed of the code
  (no time for cleanup & documentation)
- Prevent incorrect use
  (by choosing wrong parameters)
- ???

Revisit Objectives of Publishing Articles

Picture of a rare utopian community
in the act of sharing their research code

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Picture of a rare utopian community
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KEY to lure researchers into
sharing their code

Revisit Objectives of Publishing Articles

Traditional Research Articles

Source Code

Step 1: Make the code
a publication by itself

Revisit Objectives of Publishing Articles

Traditional Research Articles

Source Code

Step 2: Guide community
to cite implementations

IPOL : Image Processing On Line

http://ipol.im/

"*IPOL is a **research journal of image processing and image analysis**. Each article contains a text describing an **algorithm** and **source code**, with an **online demonstration** facility and an **archive** of online experiments. The text and source code are peer-reviewed and the demonstration is controlled. IPOL follows the **Open Access** and **Reproducible Research** models.*"

For every article, the **implementation** is:

- **Reviewed** and Published
- License GPL or BSD
- Following Software Guidelines for correctness, portability, documentation

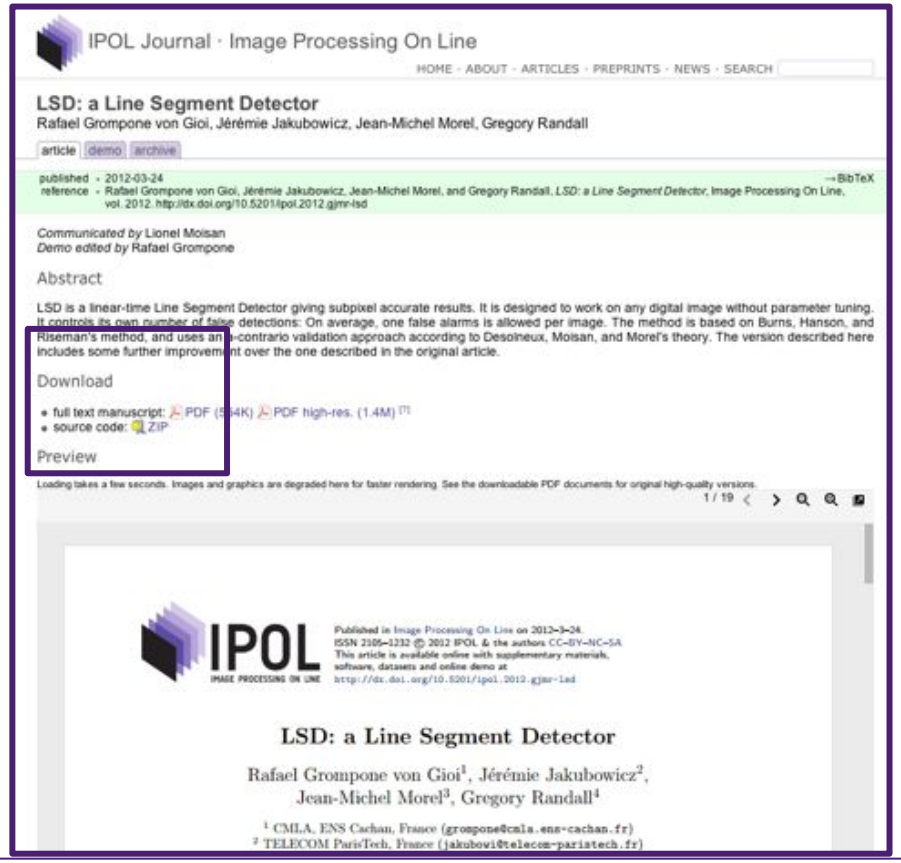
IPOL : Image Processing On Line

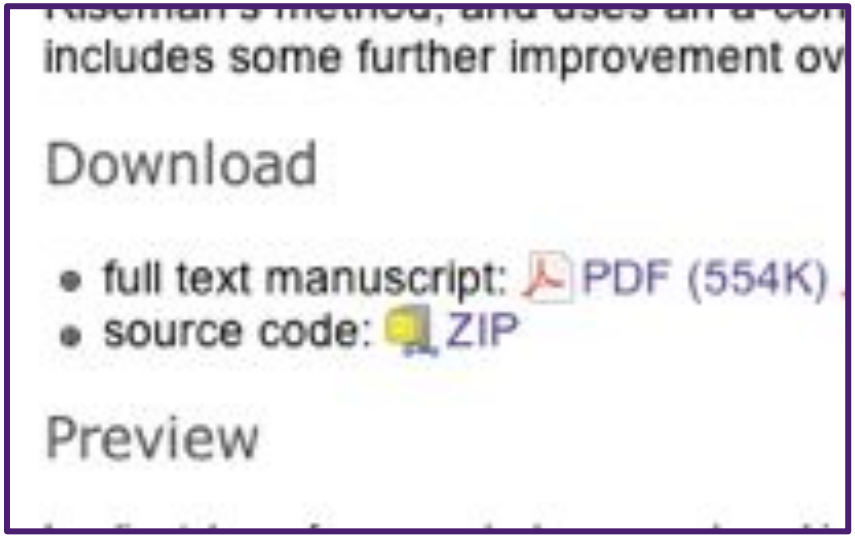
GOAL:
provide a reference implementations
of image processing algorithms

- IPOL is a journal (running since 2011):
  ISSN; DOI; Int'l editorial committee; ...
- Partnership with a SIAM
- IPOL exists because no other journal did it
- <u>IPOL publishes algorithms, not software.</u> Implementations are here to provide the full details and to run the algorithm

IPOL Article Components

1. Algorithm **description (PDF)**
2. Implementation source **code**
3. **Web demo** interface
4. Public **archive** with original test data





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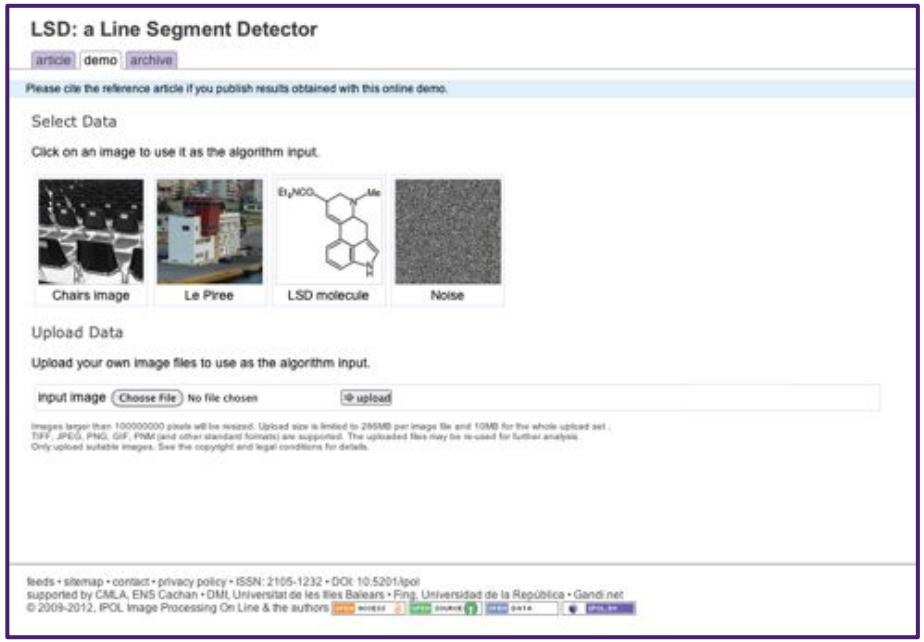

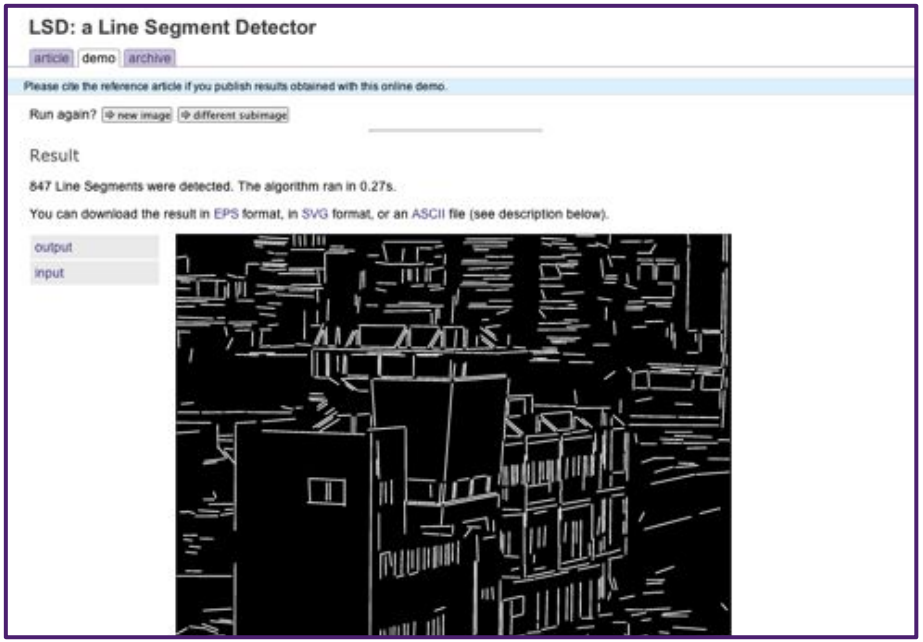

Test with new data and explore parameters without compiling

IPOL Article Components

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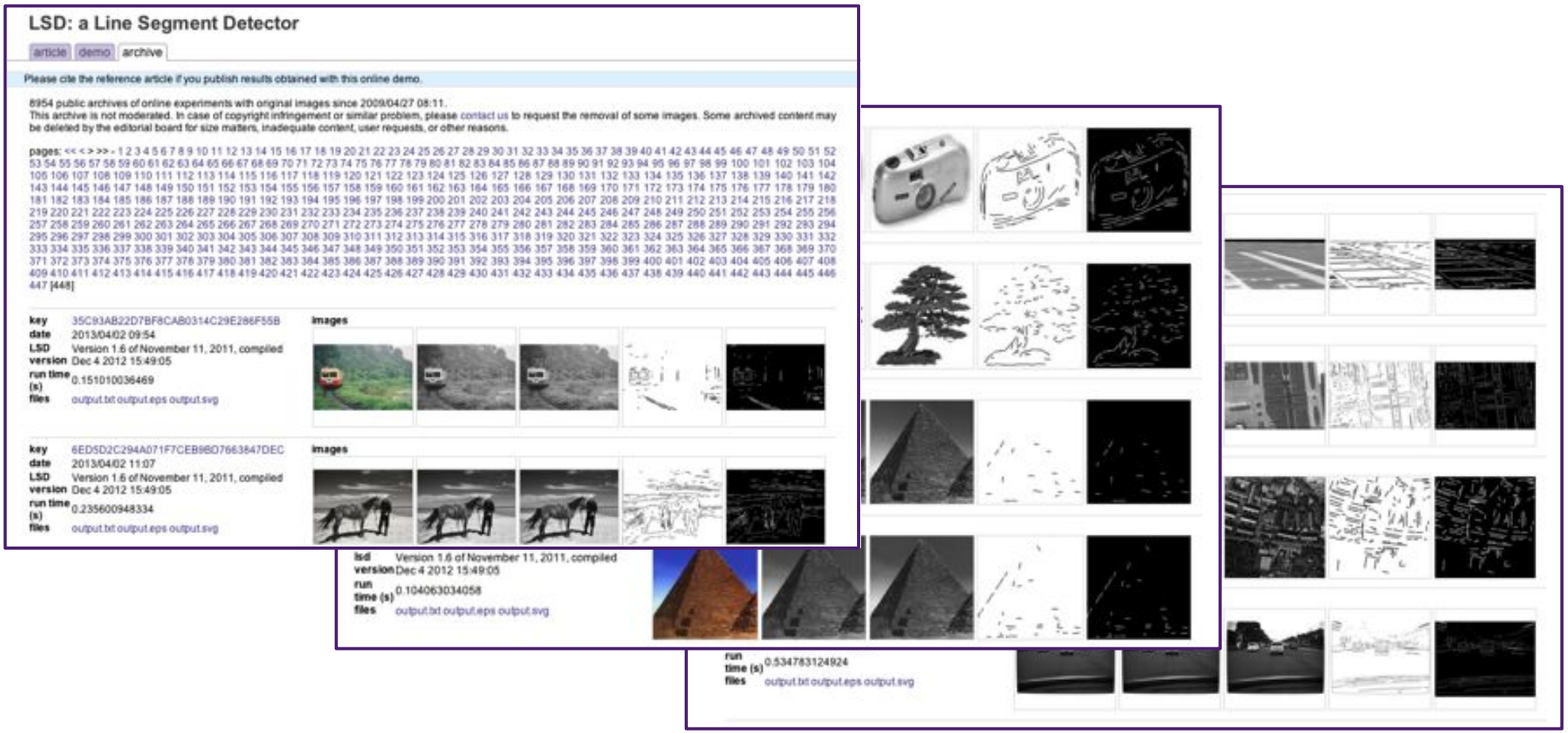

Importance of the online demo

CODE

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CODE

CODE + DEMO

- on-line demo facilitates experimentation
- and leads to a stricter verification of the claims

Importance of the online demo

CODE

CODE+DEMO+ARCHIVE

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IPOL Usage Stats

- 45 articles published with code and demo since 2011
- 20 articles in preparation
- 109 citations (cf. Google Scholar)
- 2012: 125k visits, 13k code/data downloads
- 2012: 50k demo runs, 30k archived runs on original data

Challenges

- Effort to prepare the code for publication isn't negligible
- Community must learn to cite the implementations

Follow-up to...

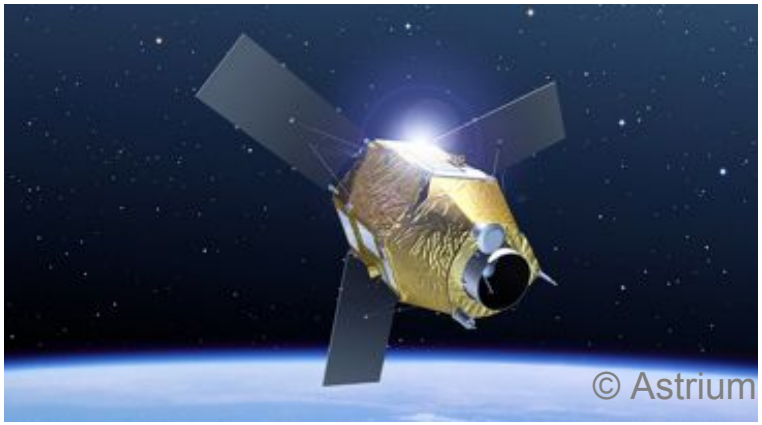
IPOL wouldn't be possible without the support and trust of the authors, reviewers and editors who contributed to it. Lots of help from Paris, Palma, Barcelona, Montevideo, Durham, …

IPOL
IMAGE PROCESSING ON LINE

http://ipol.im/
edit@ipol.im
discuss@list.ipol.im
@ipol_journal

ENS CACHAN
cnrs
erc
UIB Universitat de les Illes Balears
UPF
UNIVERSIDAD DE LA REPÚBLICA URUGUAY
TELECOM ParisTech
siam SIAM JOURNAL ON IMAGING SCIENCES

Satellite stereo images



S2P: satellite stereo pipeline

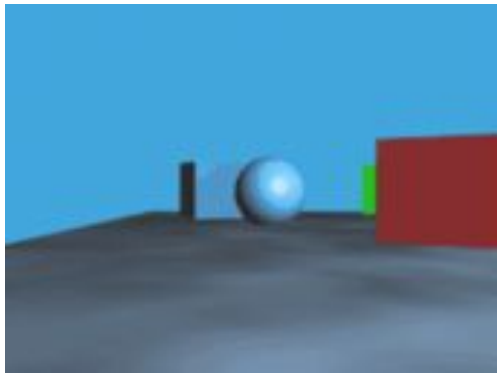
C. De Franchis, E. Meinhardt, J-M Morel, J. Michel, GF

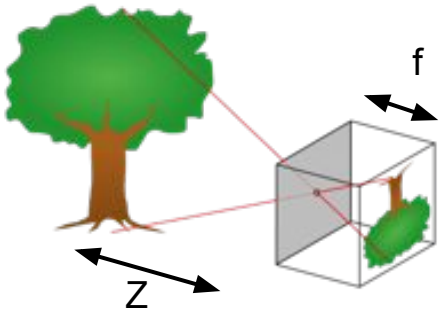
Some slides courtesy of C. De Franchis

Stereoscopy in one slide

Depth Z is inversely proportional to the parallax movement d

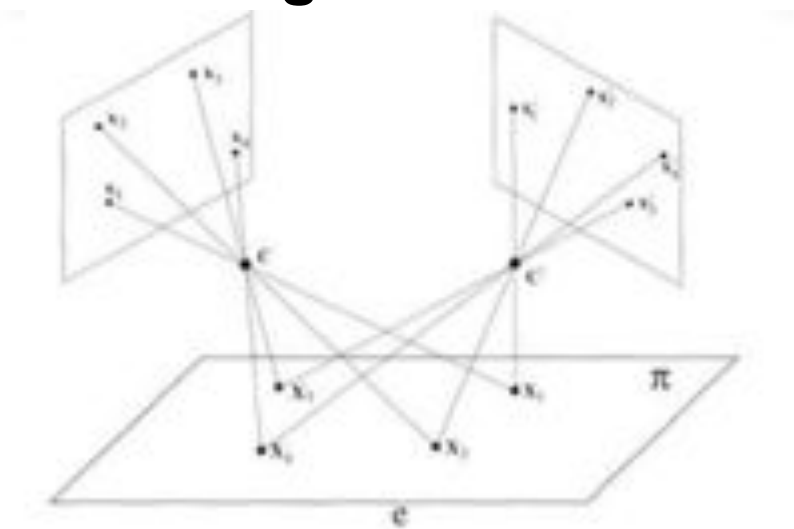
$$Z = B \cdot f / d$$

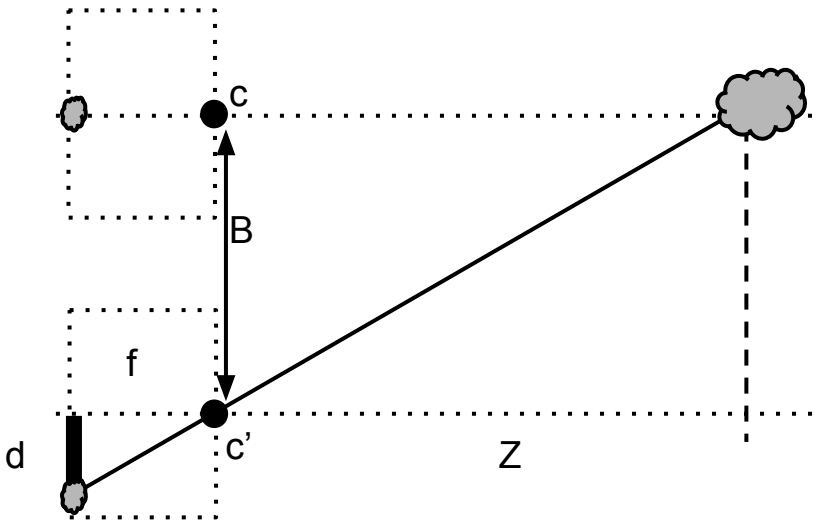




Projective camera

Two images





Book: Multiple View Geometry, Hartley Zisserman

Stereoscopy ~~in one slide~~

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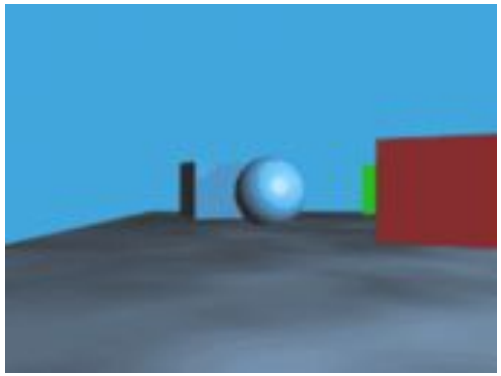

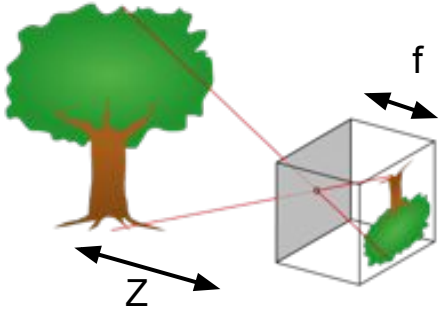

Projective camera

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Stereoscopy ~~in one slide~~

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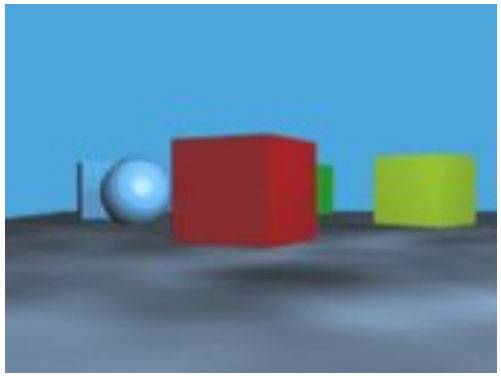
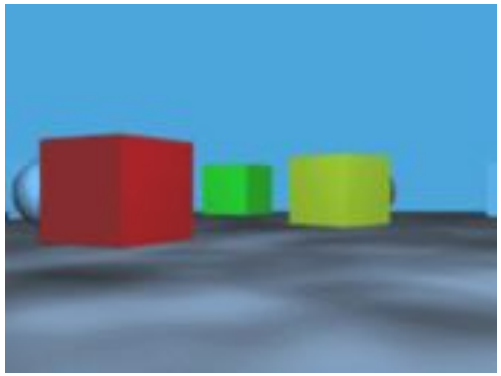


Close Mid Far

Estimated disparity (parallax movement)

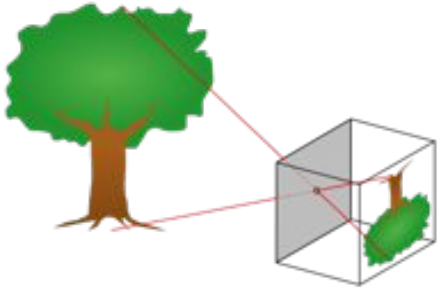
Stereoscopy ~~in one slide~~

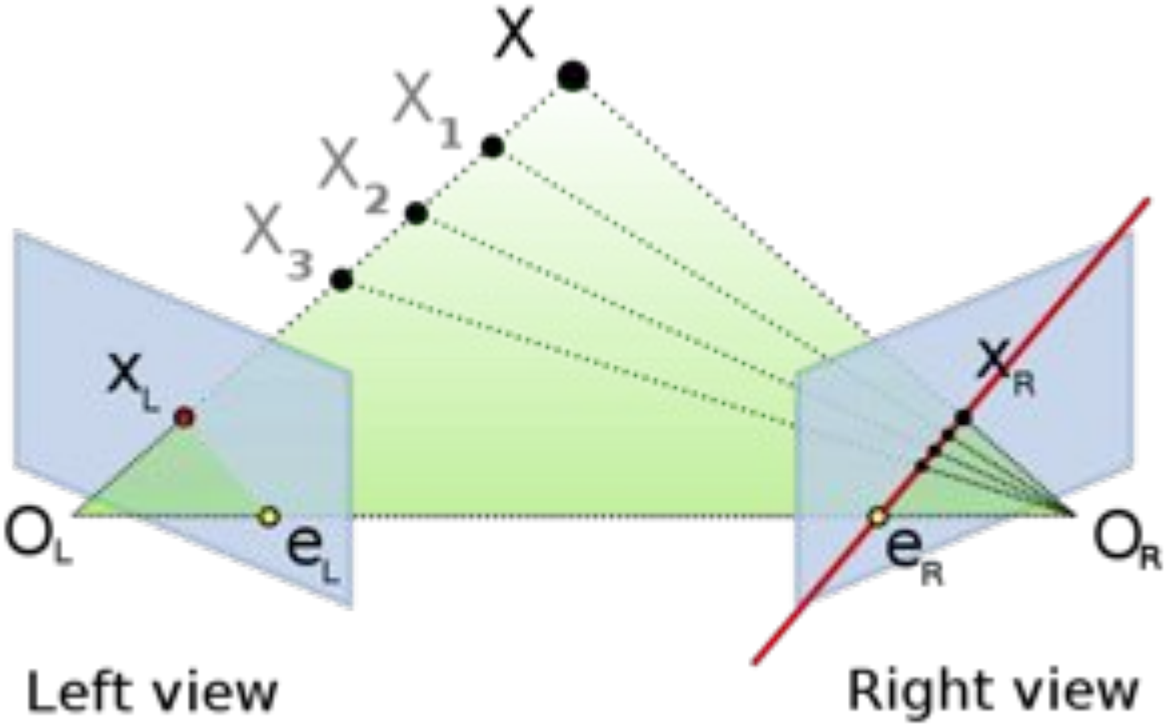
Depth Z is inversely proportional to the parallax movement d



The movement is always “horizontal” for rectified images

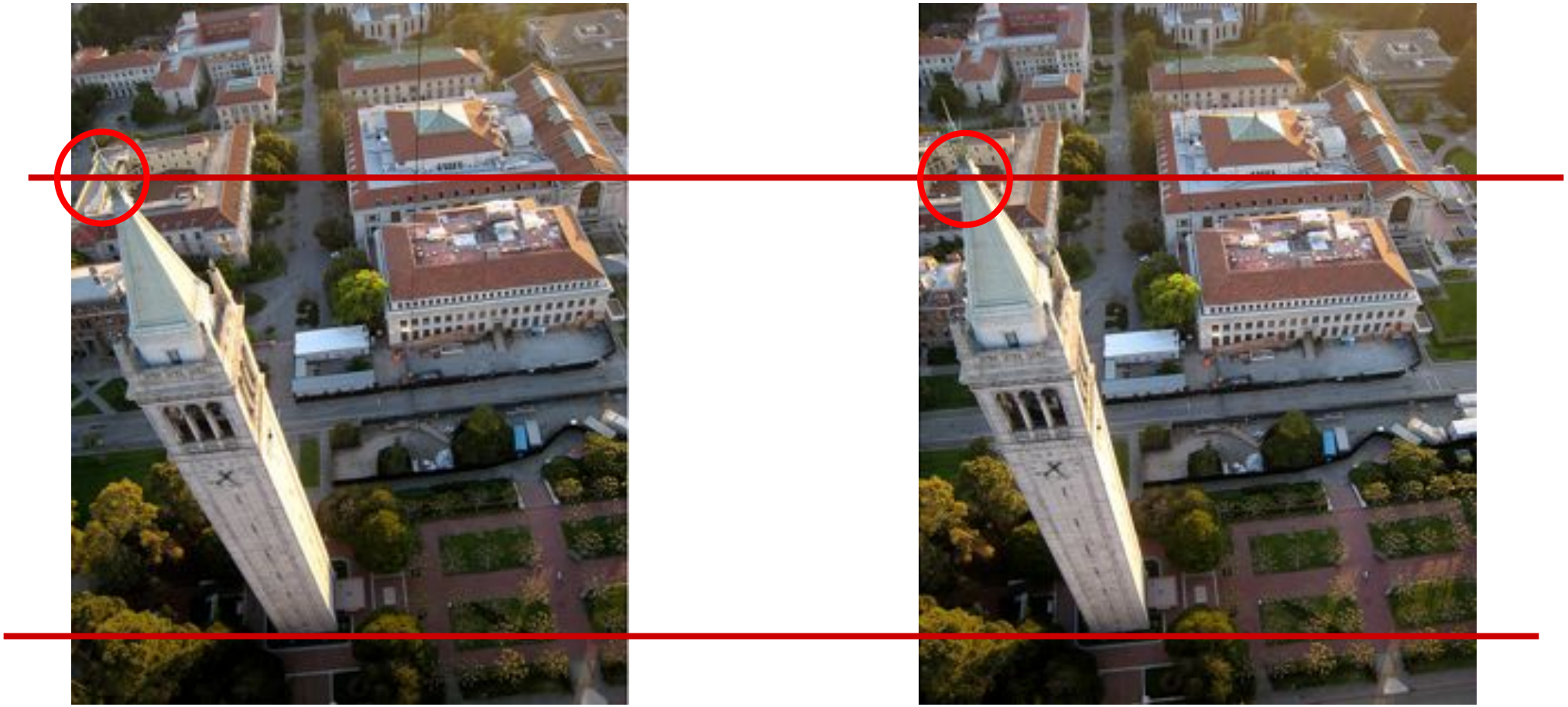
Epipolar lines





The correspondent in the right view of a point X_L lies on the line that passes through e_R

Rectification (projective cameras)



These images can be rectified

Book: Multiple View Geometry, Hartley Zisserman

Epipolar lines

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Book: Multiple View Geometry, Hartley Zisserman

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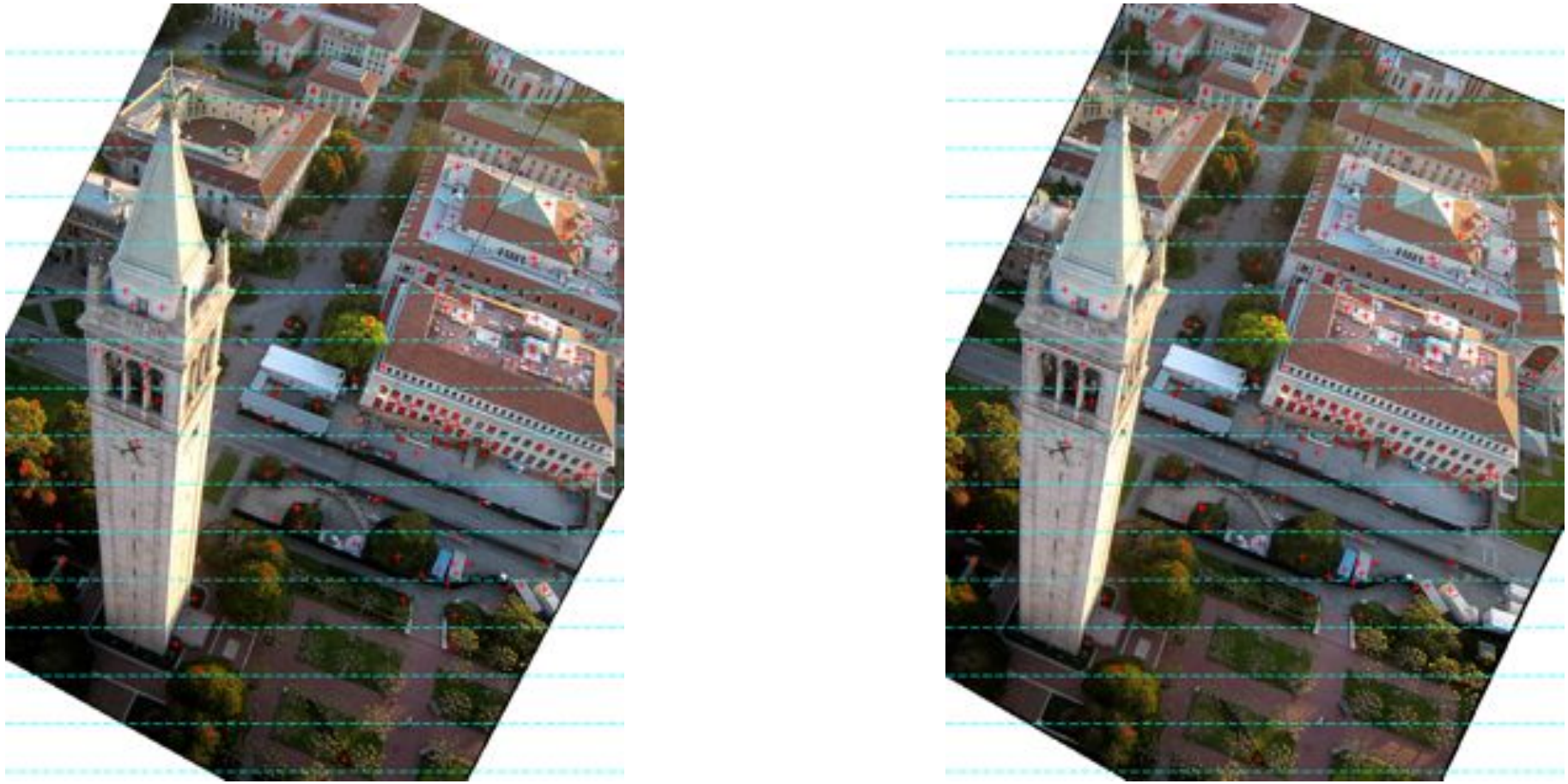


Two projective images now rectified

Book: Multiple View Geometry, Hartley Zisserman

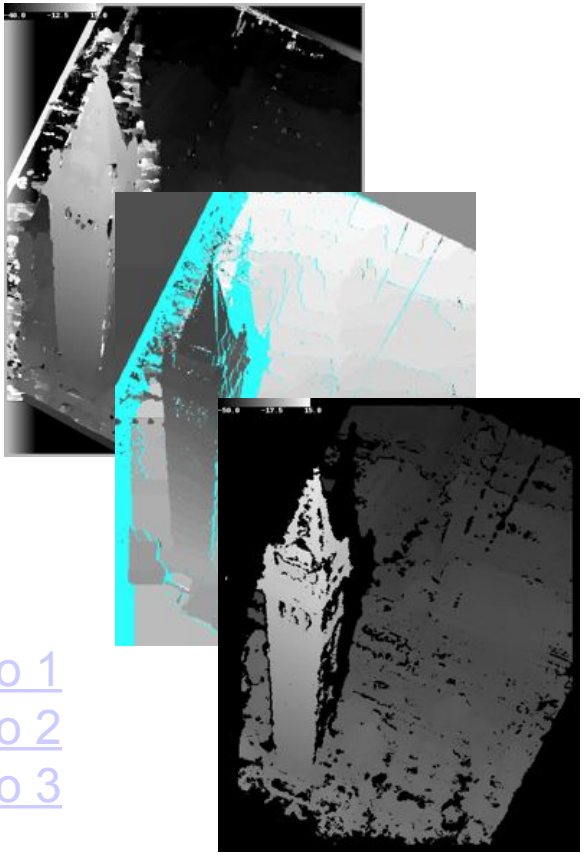
Stereoscopy summary

Rectification

IPOL demo

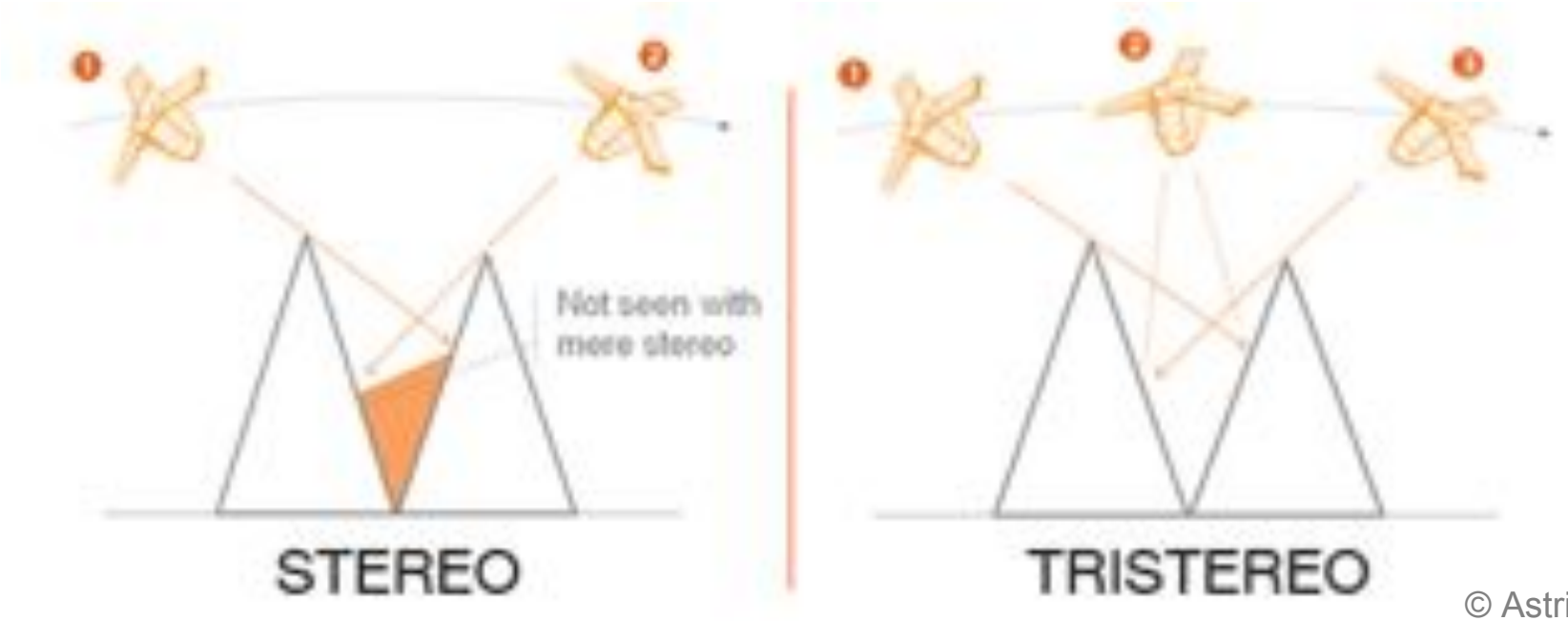
Match

IPOL demo 1
IPOL demo 2
IPOL demo 3



Pleiades satellite

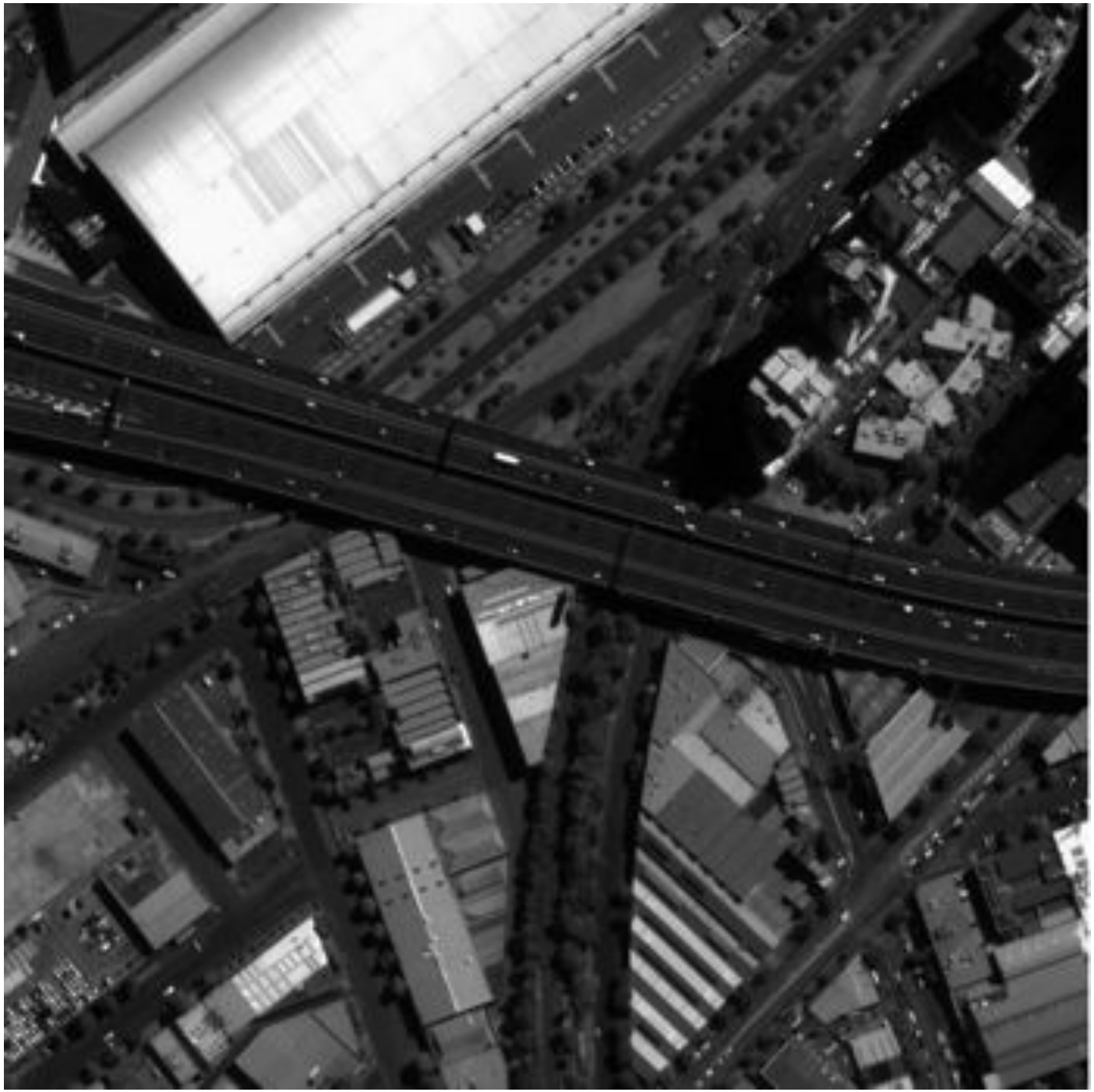
- Altitude: 700km
- Sensor: **pushbroom** 70cm GSD
- Images: panchromatic **40k x 40k**, RGBI 10k x 10k
- Complete **calibration data** (co-localization functions)
- **Agility**: stereo, tristereo and more



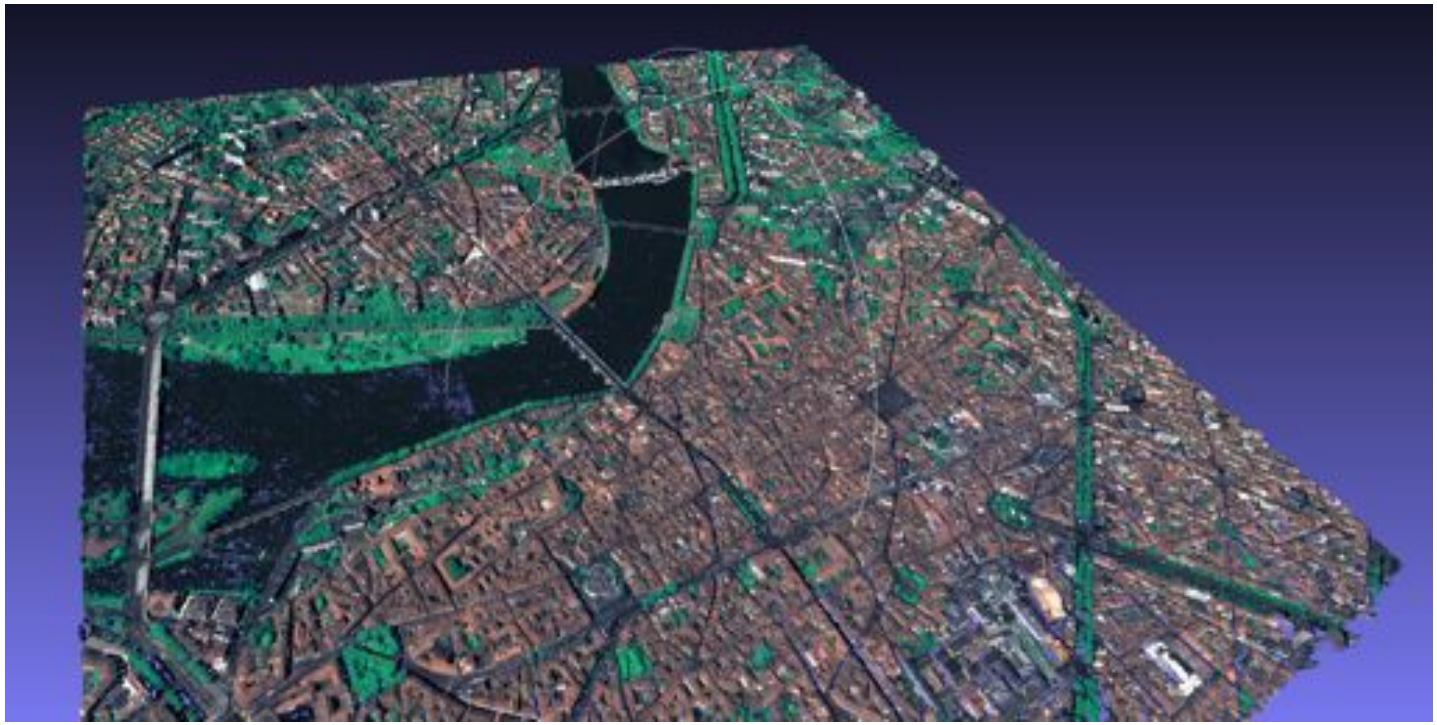
Agility:

Wait!
Intensity
isn’t constant!

Reason enough
to avoid moving
too much

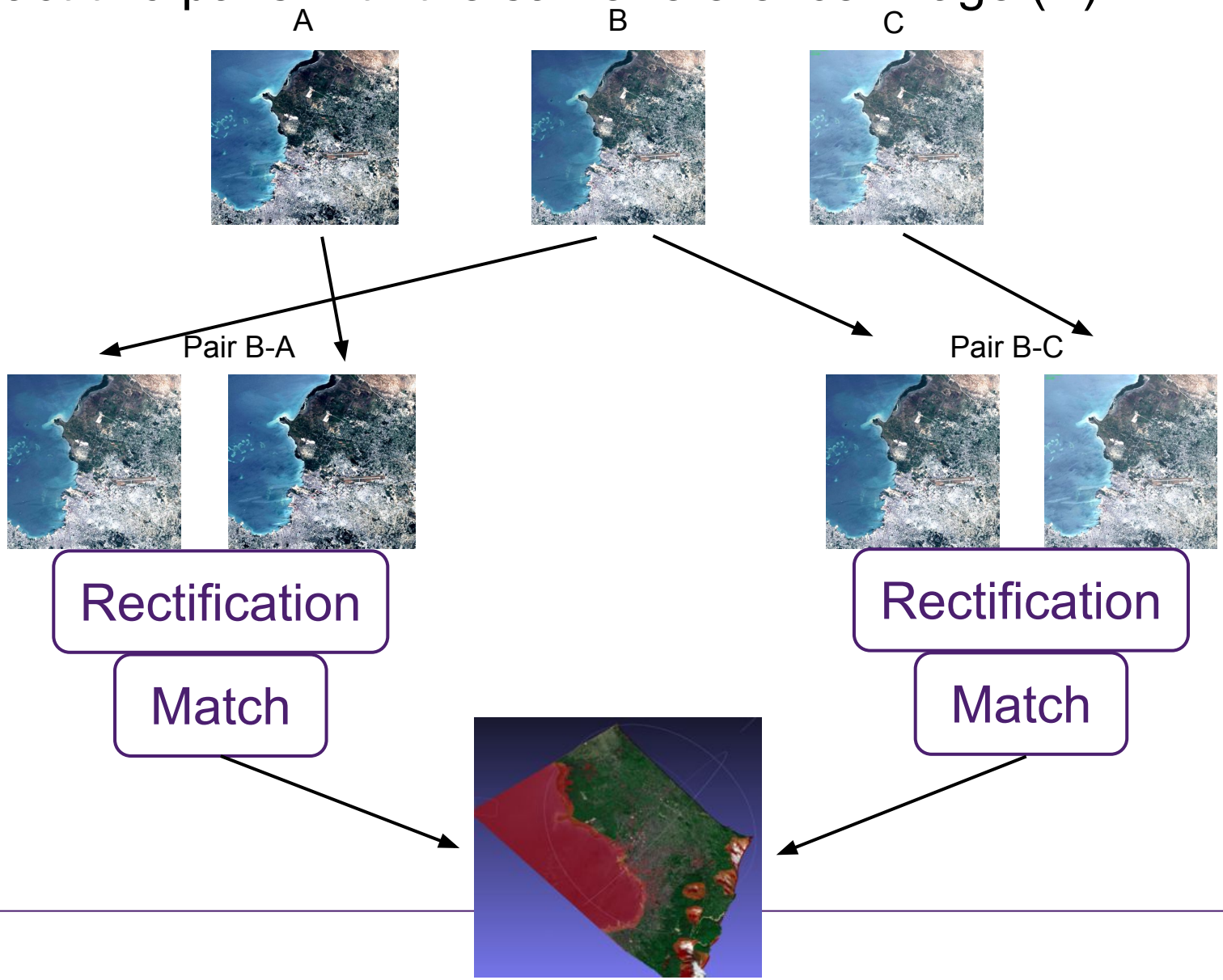


S2P: Tristereo chain

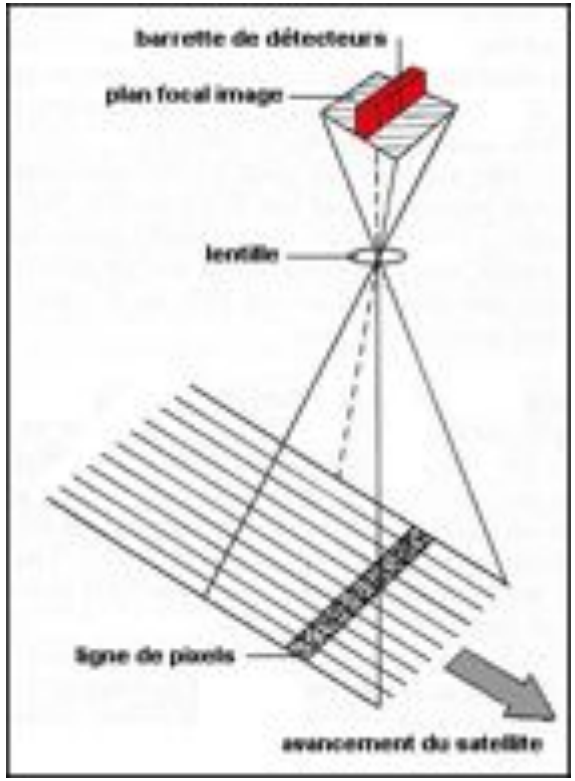


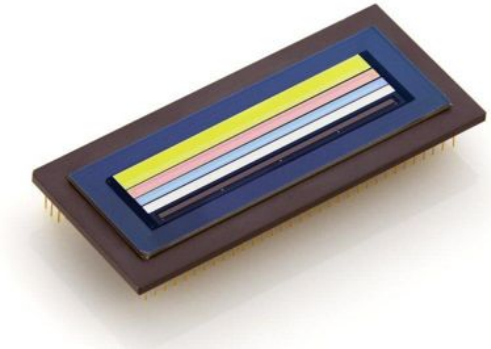
S2P: Tristereo chain overview

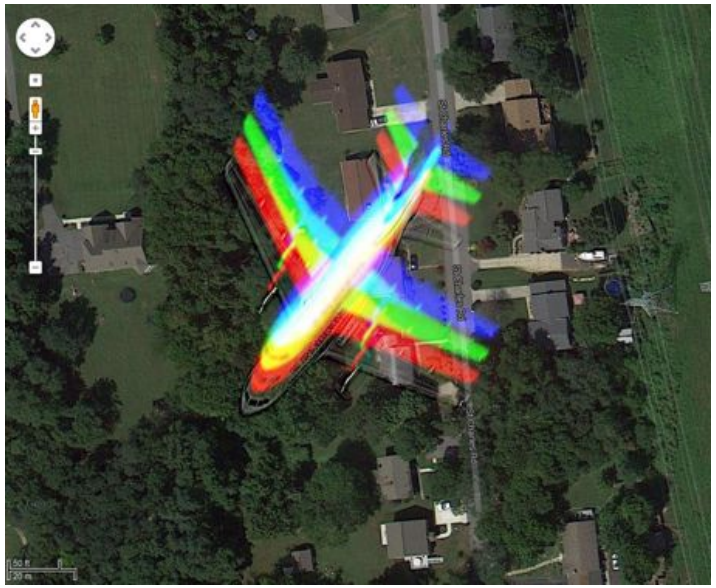
Extract two pairs with the same reference image (B)



Pushbroom isn't Pinhole







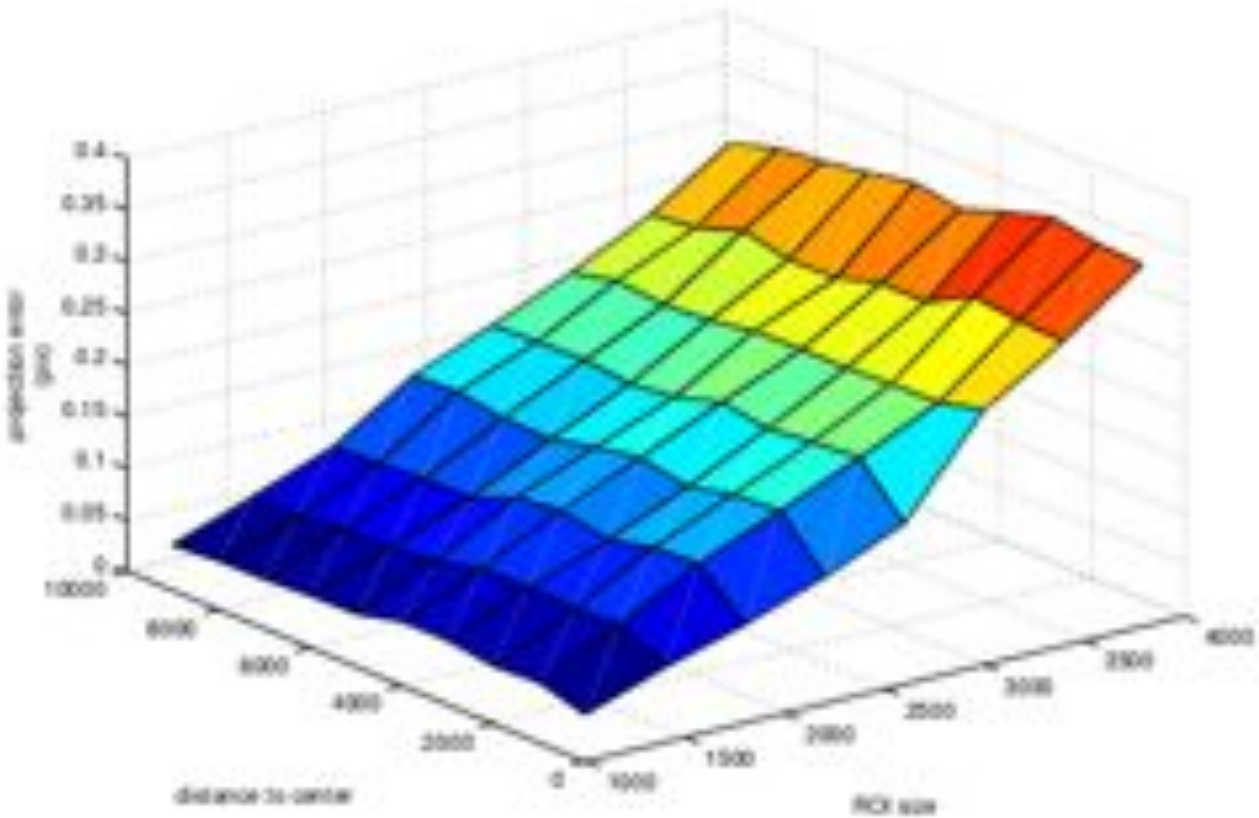
[The mystery of rainbow airplanes]

No epipolar rectification for pushbroom

"Linear Pushbroom Cameras", Hartley and Gupta '97

Pushbroom isn't Pinhole

However for small subimages the geometry is almost pinhole
We use tiles of ~ 1000x1000

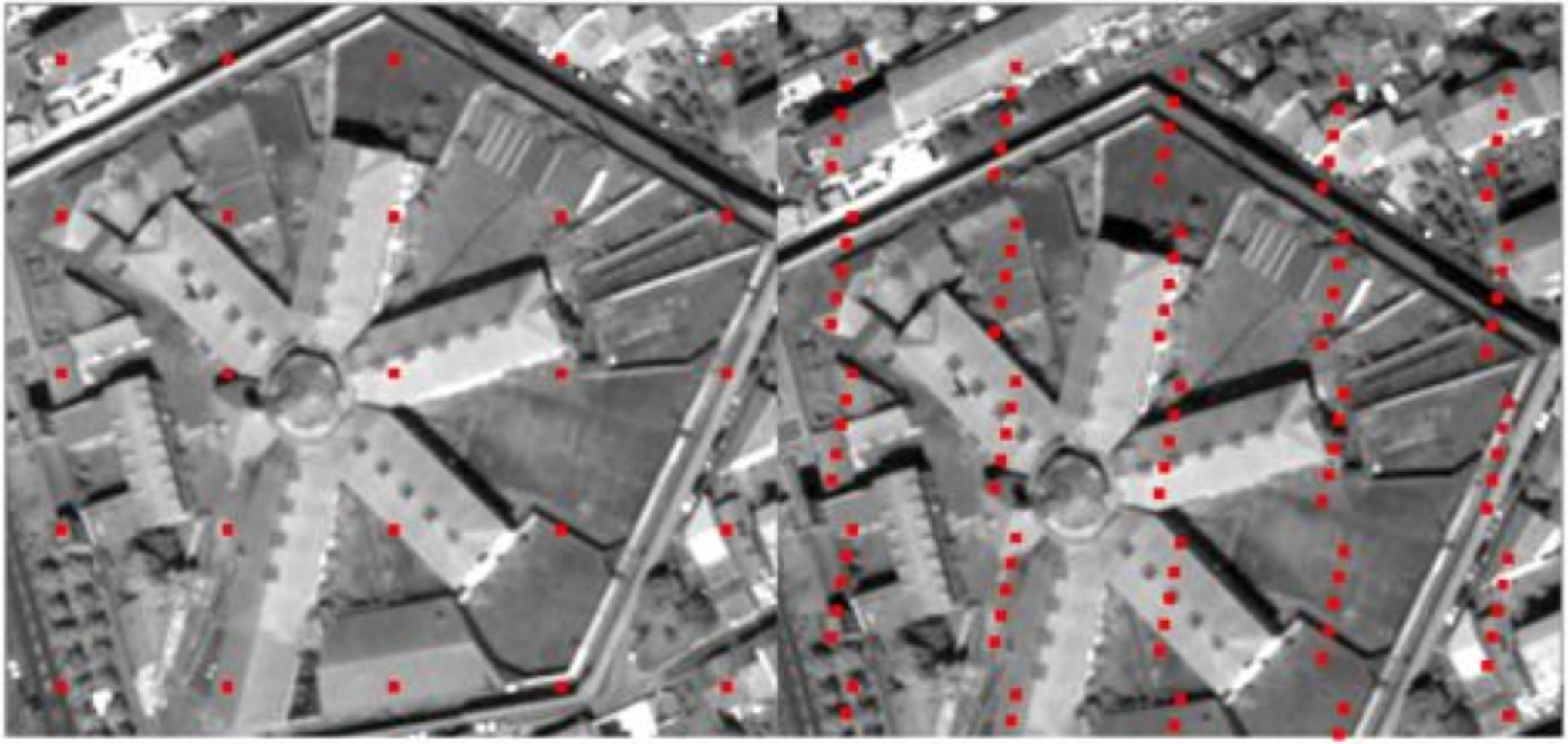


Degenerate rectification cases

Rectification using keypoint matches may fail because overall the scene is flat

Use calibration data to rectify

Rectification using virtual matches extracted from the provided calibration data (RPC co-localization functions)



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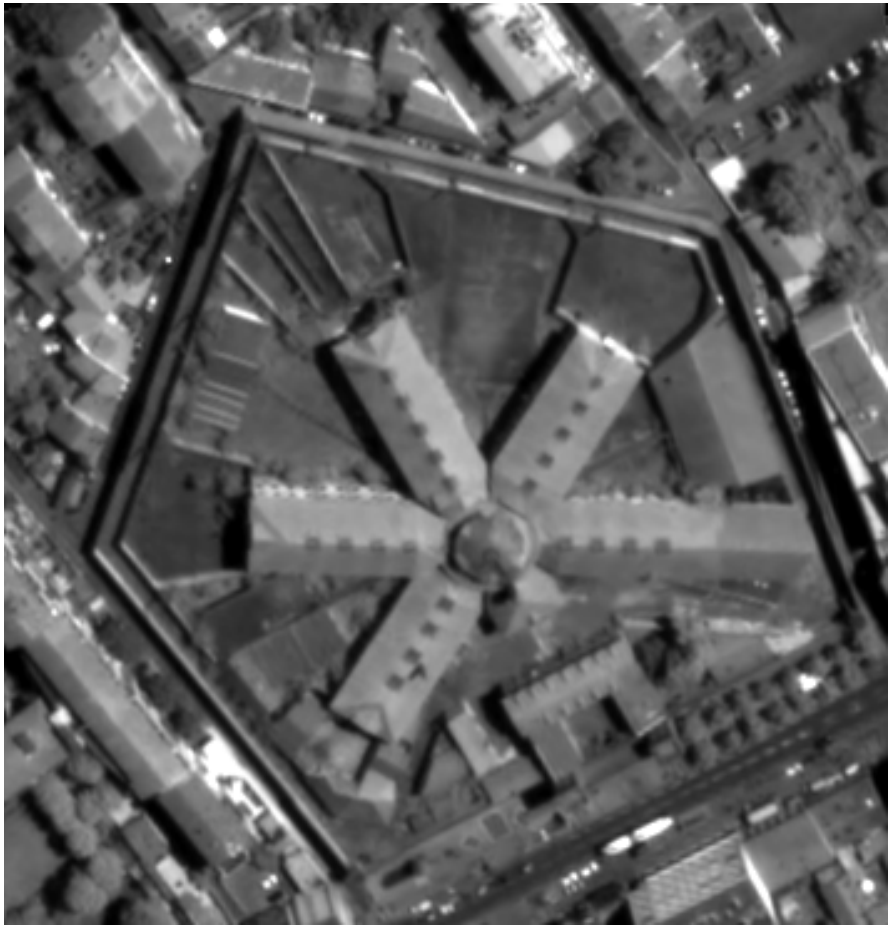
Rectify using virtual matches extracted from the **provided calibration data** (RPC colocalization functions)



…

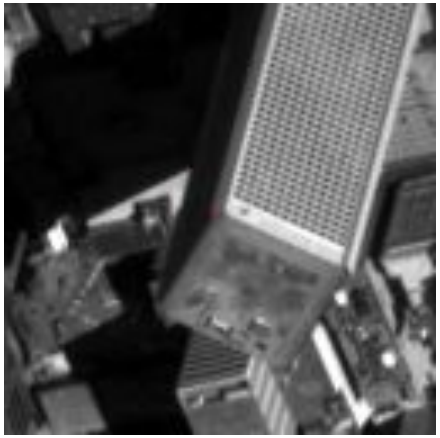
Use calibration data to rectify

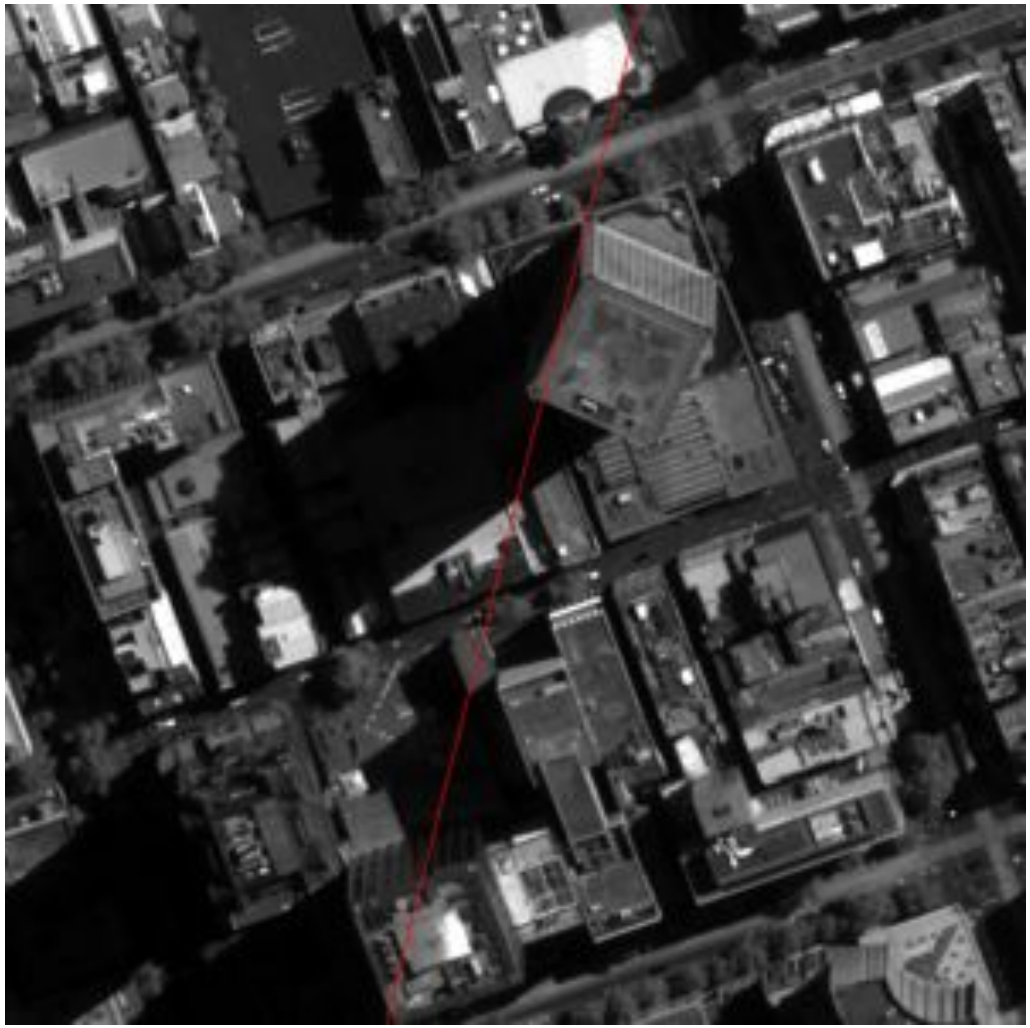
Rectify using virtual matches extracted from the **provided calibration data** (RPC colocalization functions)

…

It’s moving vertically, isn’t it?

Errors in the colocalization functions





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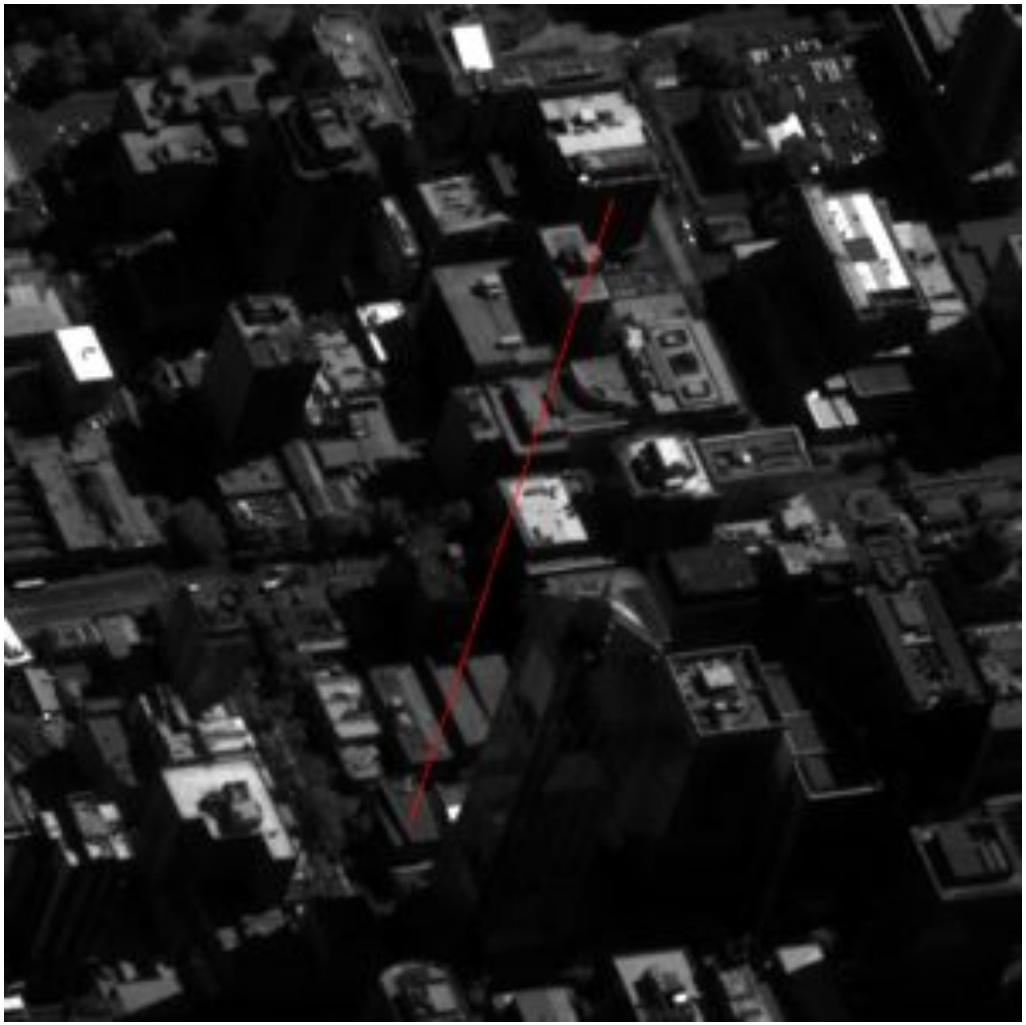
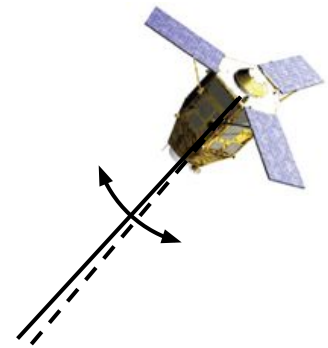
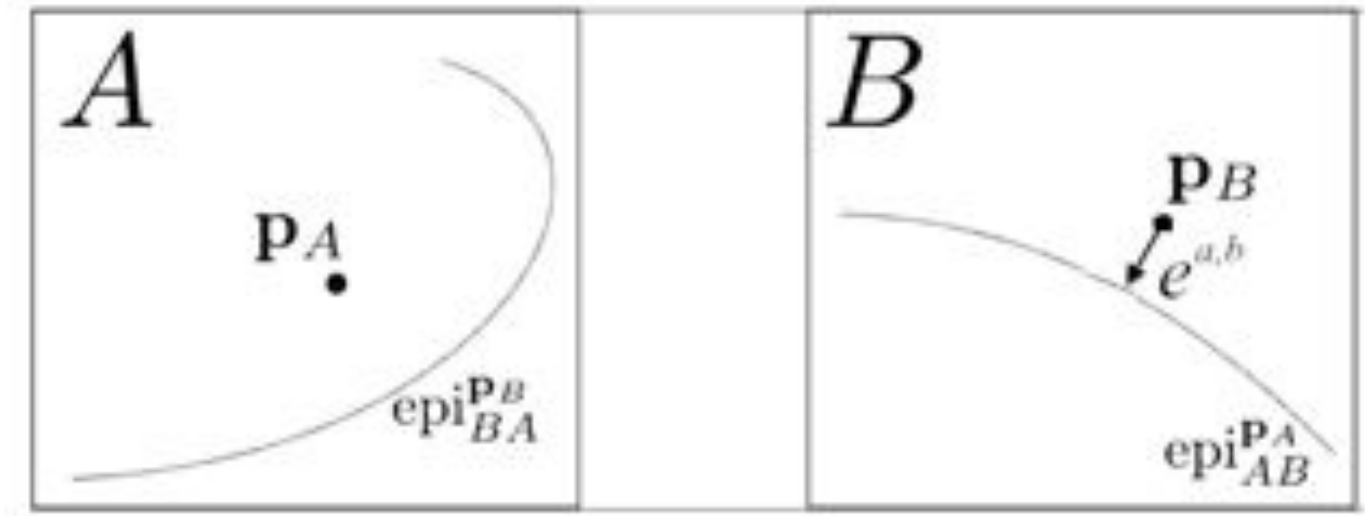


Pointing error

Imprecise orientation of the satellite
Note that 1×10^{-6} rad = 1 pixel





Quantify:

- Use keypoints pairs p_A, p_B extracted from the images
- Compute the epipolars using the calibration function
- The error *e* is the distance to the predicted epipolars

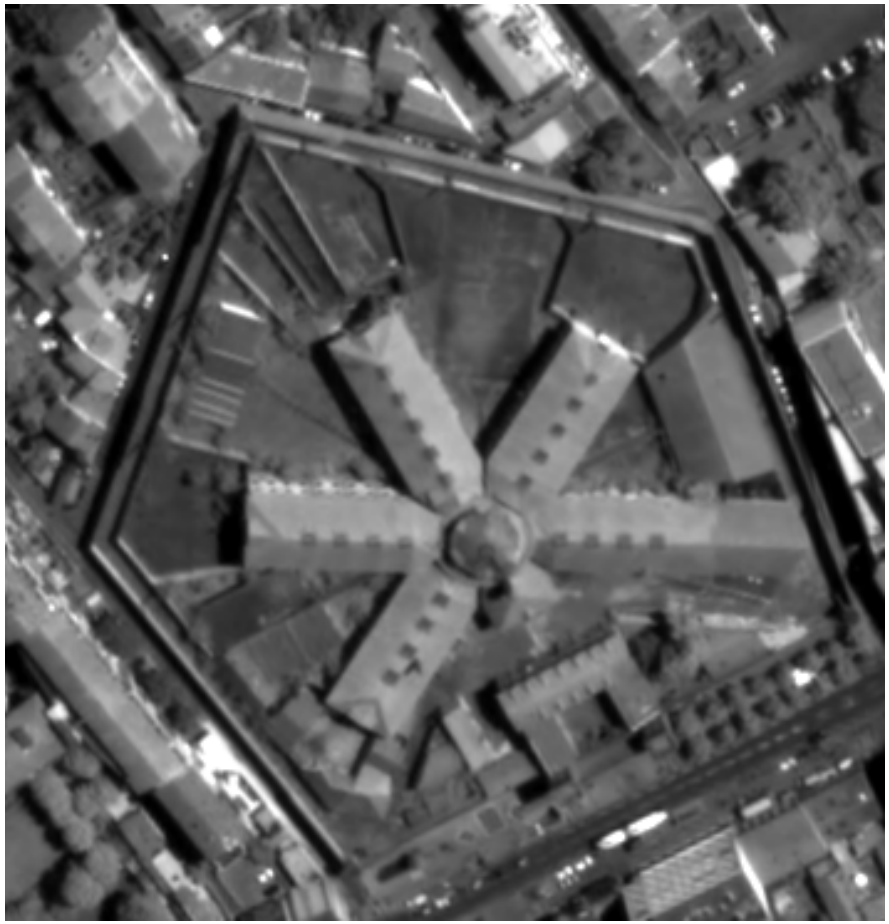
Pointing error correction

- Correct one of the images by an affinity A_b
- Optimize A_b to minimize

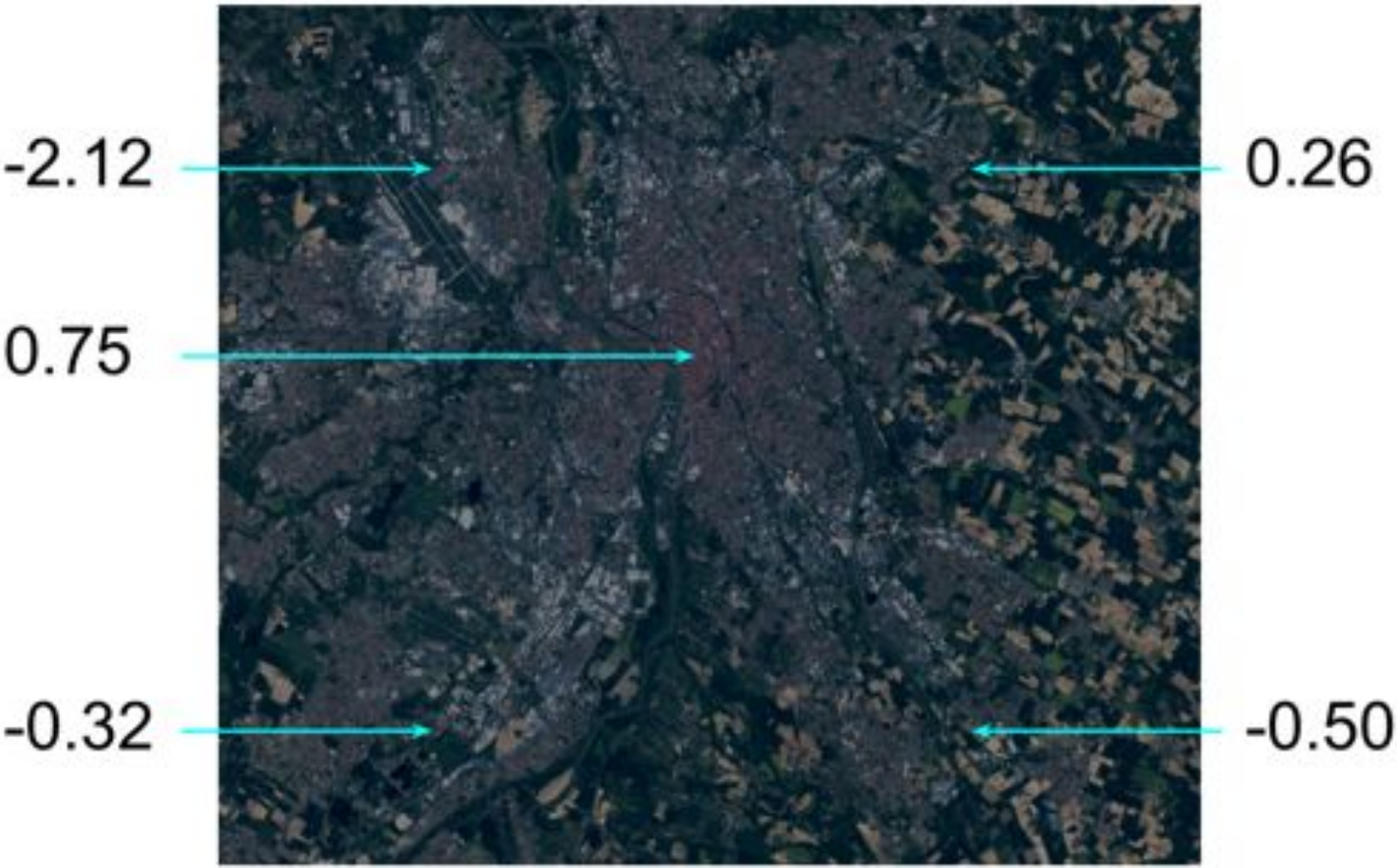
$$f(A_b) = \sum_{k=1}^{m} e_k^{a,b} + 0.01 |h_k^{a,b} - h_k^{a,b_0}|^2$$

Rectification after pointing correction

Rectification after pointing correction

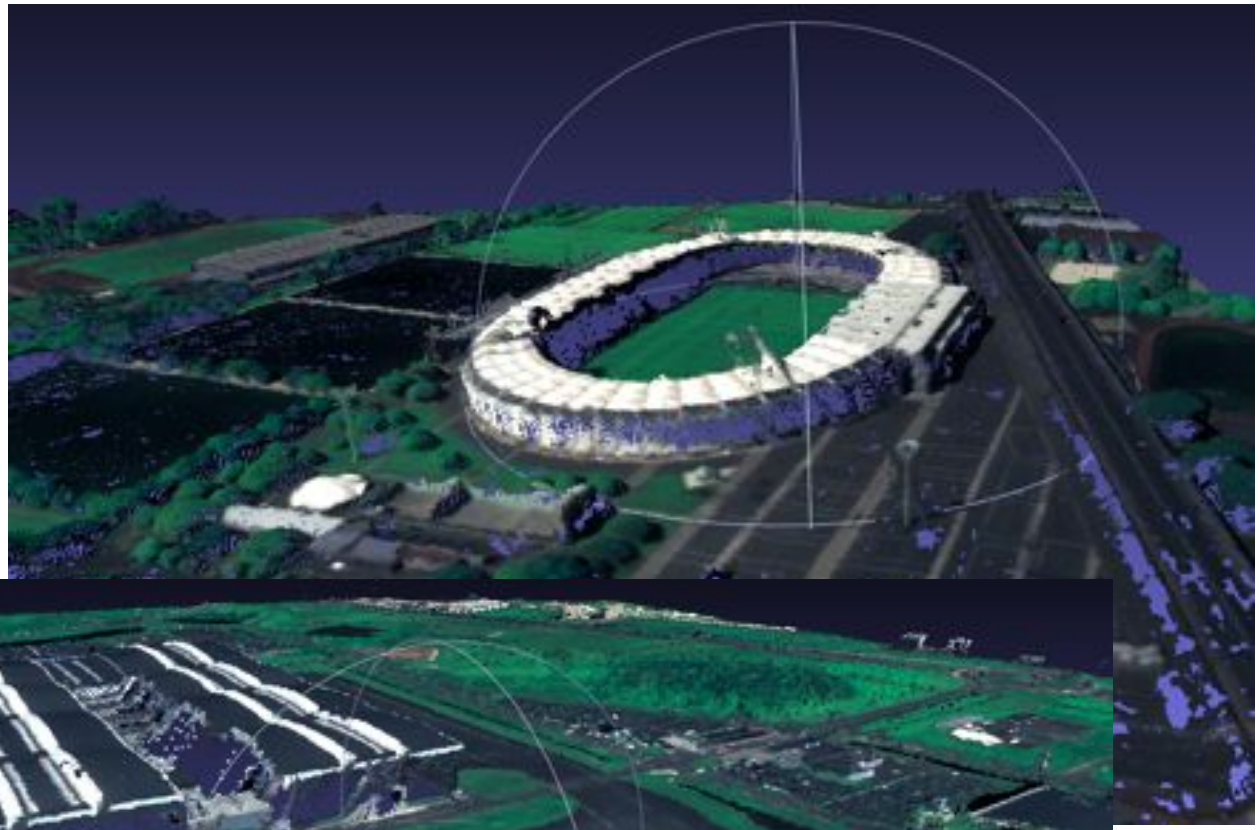


Pointing error across the image



Online demo

IPOL Demo



Results:

- Cliffs
- Houses
- Airbus
- Stadium