CMSIN NSTP3-PF-031

Single Pixel Camera for Remote Sensing

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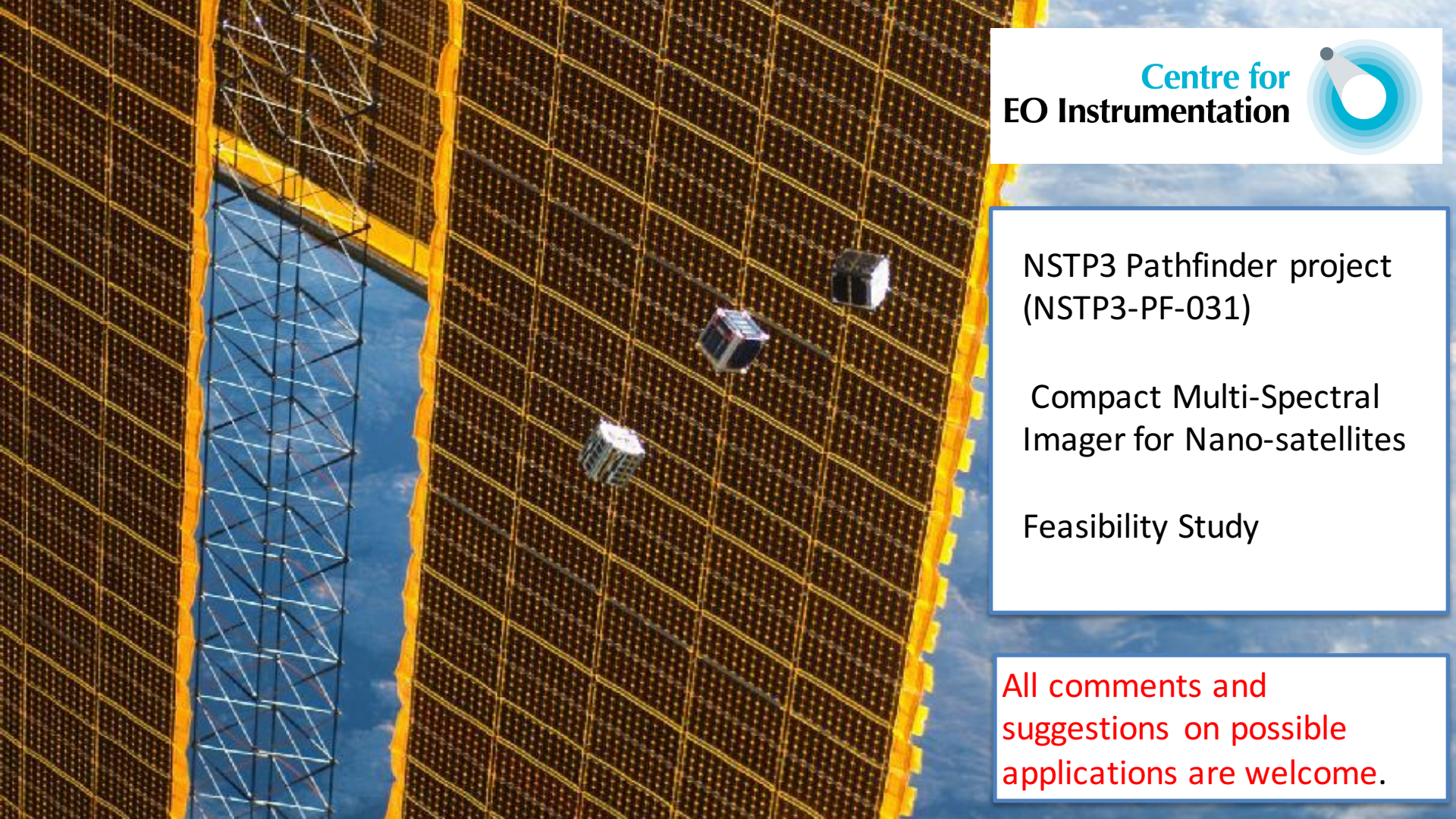


Centre for
EO Instrumentation

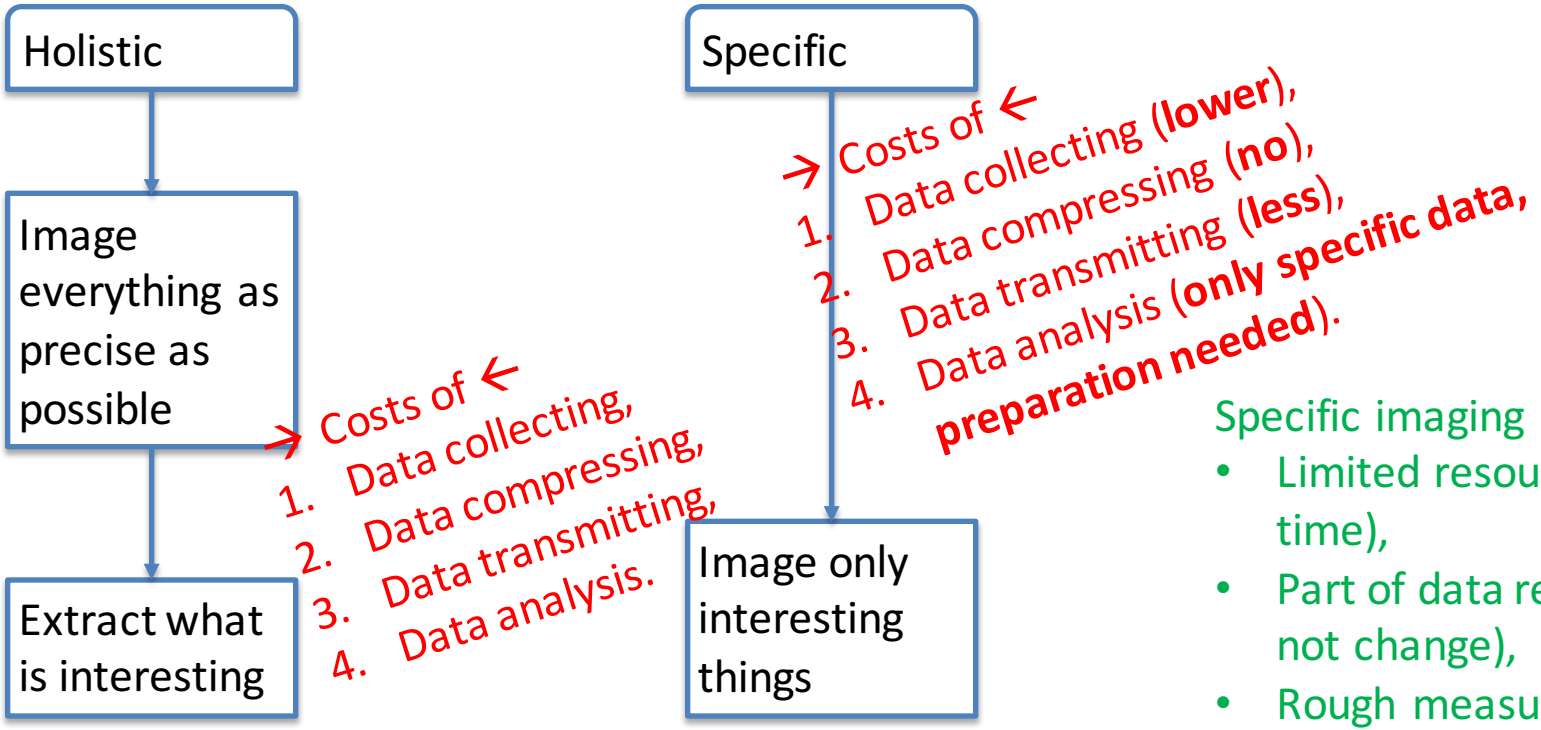
NSTP3 Pathfinder project (NSTP3-PF-031)

Compact Multi-Spectral Imager for Nano-satellites

Feasibility Study

All comments and suggestions on possible applications are welcome.

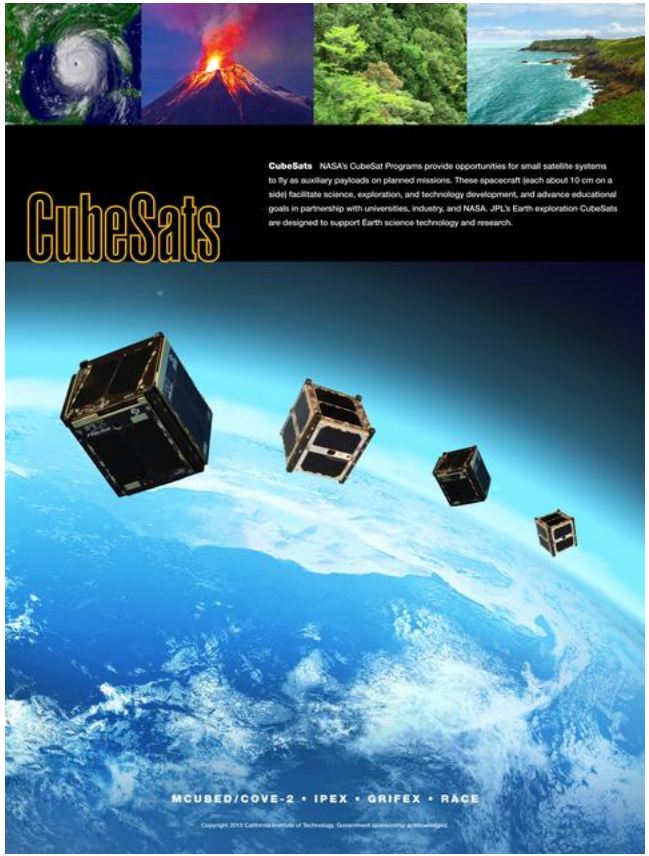
Main Imaging Paradigms



Specific imaging is useful when

- Limited resources (power or time),
- Part of data redundant (do not change),
- Rough measurement followed by more holistic.

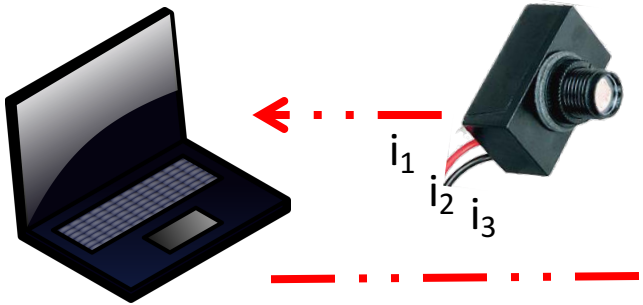
Cube Sats

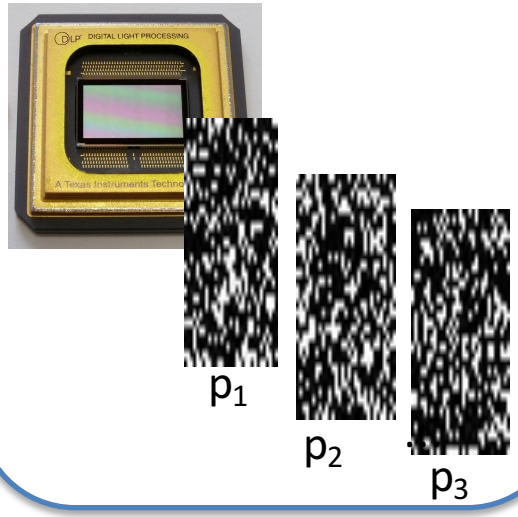


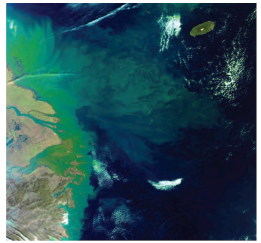
features of Cube Sats:

- Small,
- Cheap,
- Flexible,
- Short-life,
- Limited power,
- Off-the-shelf components.

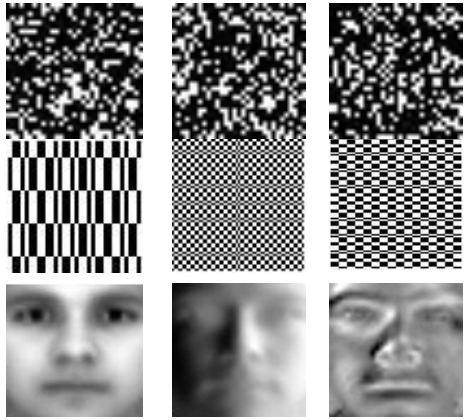
Single-pixel camera







- in non-typical wavelength ranges
- limited space
- Simple electronics
- resolution dependent on masks
- Adaptive measurements
- Computer vision
- **Compressive sensing**



Compressive sensing

Limited amount of measurements of unknown object

Many possible objects fit the data

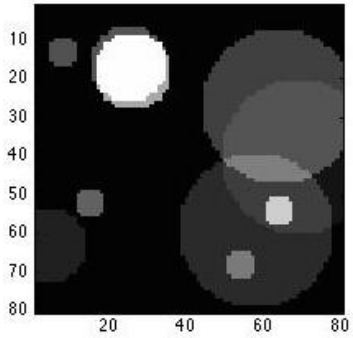
Ill defined problem

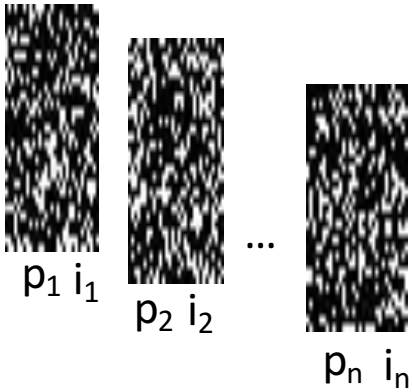
The correct solution is unique – the one with the most sparse description

There exists a sparse description

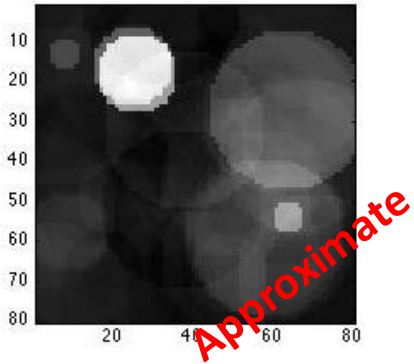
Measurements can be found

pixels = 6400

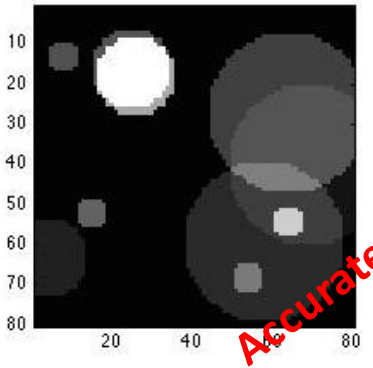




measurements n=130

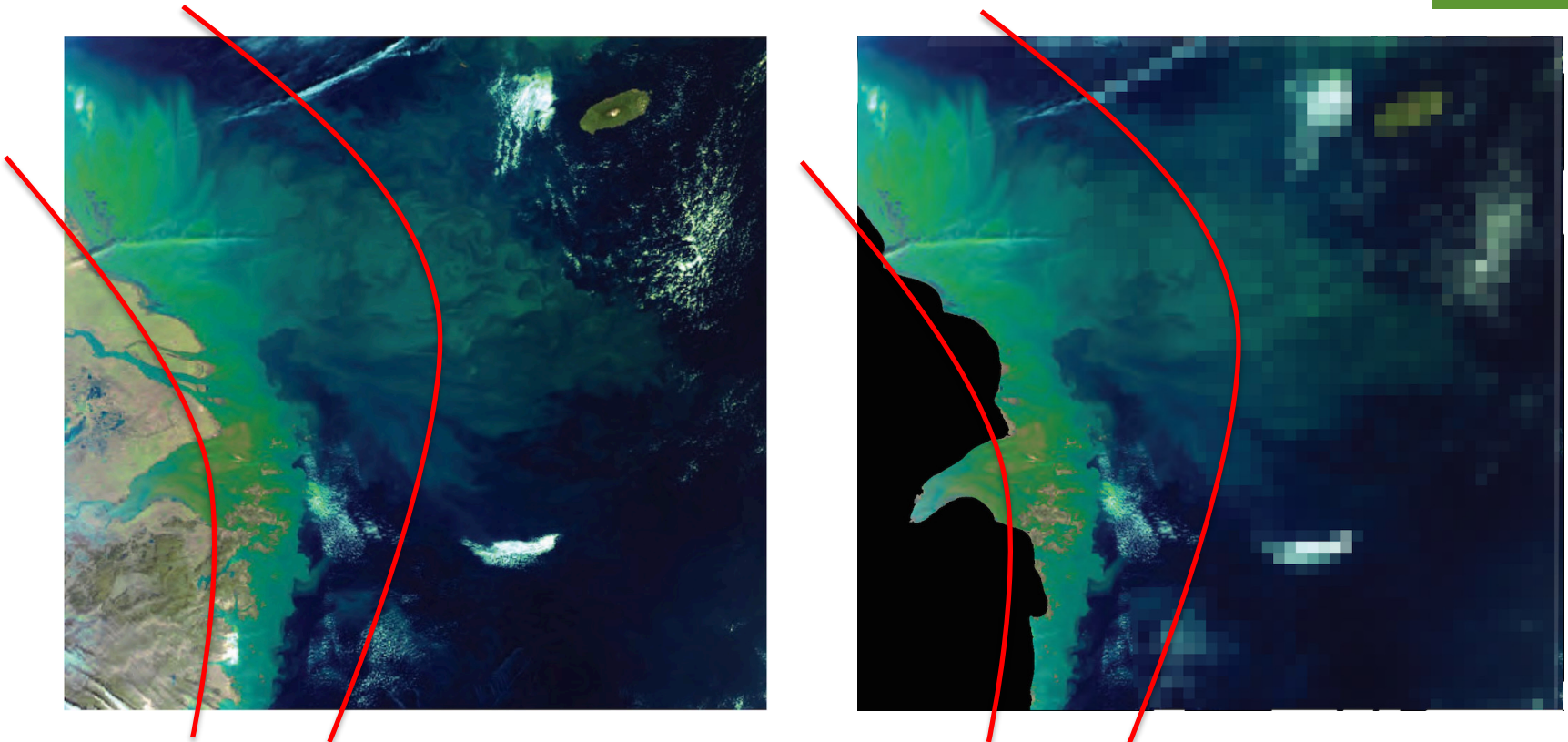


n=150



2.5% of # pixels

Variation of resolution, data reduction



Resolution improvement locally, if needed

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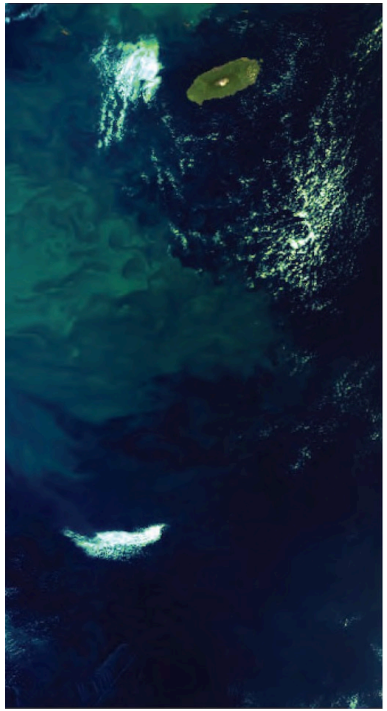
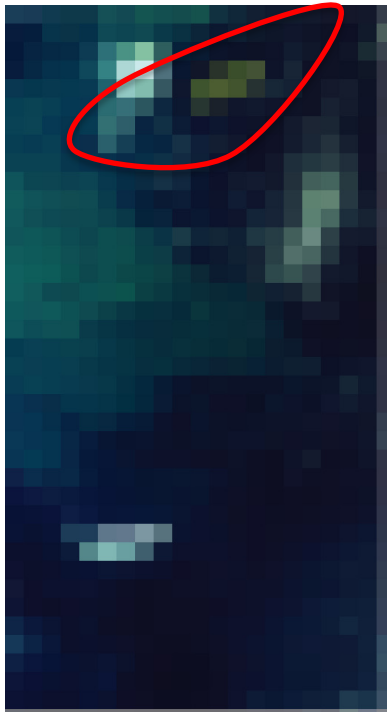
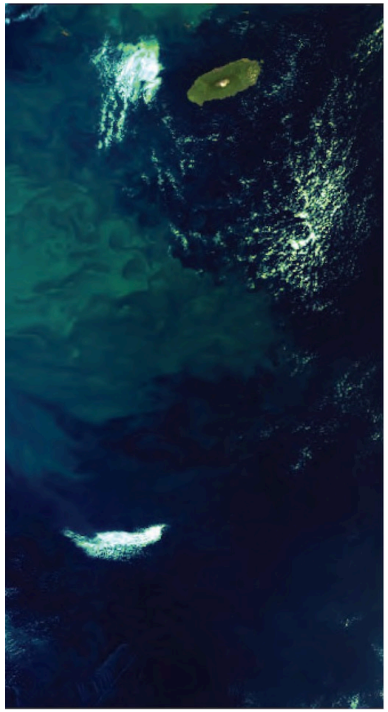
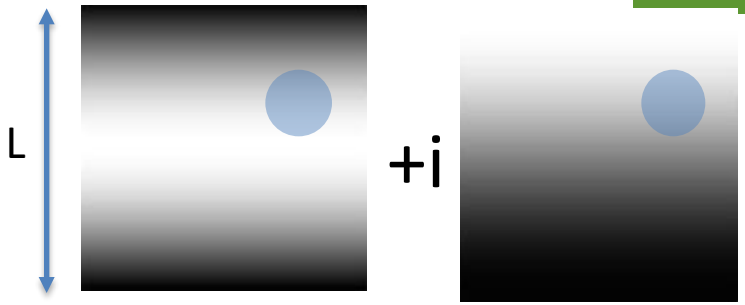


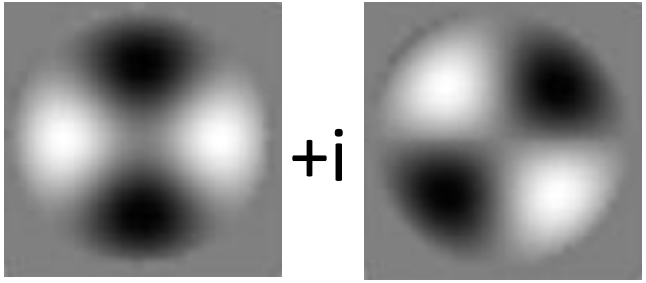


Fast localisation of position and orientation with measurement of 6 intensities





$$F_1[g(x-d)] = F_1[g(x)]e^{i\pi d/L}$$



$$F_2[g(r,\phi-\theta)] = F_2[g(r,\phi)]e^{2\pi i\theta}$$

Summary and challenges

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What we can offer?

Why the single-pixel camera for nano-sats?

- Cheap, simple, efficient (off-the-shelf components)
- Specific imaging
- Low transmission rate
- Programmable (machine vision techniques on board including compressive sensing)
- Works well in constellations
- Multispectral (vis, mid IR)

Challenges:

- Moving platforms, acquisition speed
- Case dependent software, real time signal processing
- SNR of current implementations

Possible solutions:

- See Fowler, compressive pushbroom and whiskbroom sensing for hyperspectral remote-sensing imaging, ICIP, 2014 IEEE.
- Machine learning, preprocessing, efficient algorithms being developed,
- Alternative architectures being investigated.

Single-pix. cam

- M. Duarte, M. Davenport, D. Takhar, J. Laska, T. Sun, K. Kelly, and R. Baraniuk, "Single-pixel imaging via compressive sampling," IEEE Signal Process. Mag., (2008).

Compressive sensing

- E. Candes and T. Tao, "Decoding by linear programming," IEEE Trans. Inf. Theory, (2005).
- D. Donoho, "Compressed sensing," IEEE Trans. Inf. Theory, (2006).
- M. Duarte, M. Davenport, D. Takhar, J. Laska, T. Sun, K. Kelly, and R. Baraniuk, "Single-pixel imaging via compressive sampling," IEEE Signal Process. Mag., (2008).

Single-Pixel Remote Sensing

- J. Ma, "Single-Pixel Remote Sensing" IEEE Geoscience and remote sensing Lett. (2009).
- J. E. Fowler, "Compressive pushbroom and whiskbroom sensing for hyperspectral remote-sensing imaging", ICIP IEEE (2014).