# TUTORIAL

# Extraction of Geospatial Information from High Spatial Resolution Optical Satellite Sensors

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# Contents

# Land use and land cover mapping

David Holland

# Historical context

- Satellite imagery used in land cover mapping for decades
- AVHRR: 1978-present 1 km resolution
- LANDSAT: 1972-present MSS: 80 m, TM: 30 m resolution
- SPOT: 1986-present SPOT 1-4: 20m resolution, SPOT 5: 10m resolution
- All have different spectral responses.

# Historical context

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- “Traditionally” land-cover projects have been over large areas
- Each pixel in the image gives a generalised concept of land-cover class
- Applications include:
- Forestry
- Hydrology
- Ocean monitoring
- Agricultural monitoring
- Geology and geomorphology
- Topographic mapping…?

# High resolution satellite imagery

| | GSD (m) | Blue (nm) | Green (nm) | Red (nm) | IR (nm) |
|---|---|---|---|---|---|
| Ikonos | 4m | 450-520 | 520-600 | 630-700 | 760-850 |
| Quickbird | 2.8m | 450-520 | 520-600 | 630-690 | 760-900 |
| Orbview 3 | 4m | 450-520 | 520-600 | 625-695 | 760-900 |

- Corresponding almost exactly to bands 1-4 of Landsat
- Note that, unlike Landsat, there are no thermal or mid-infrared channels

## Spatial resolution

- When compared with the pixel size of Landsat:
- New hi-res satellite images show far more detail…
- …but also more “noise”

# Uses of high-resolution multispectral satellite data

- Multispectral in this case means 4-bands
- Can be used to derive the “traditional” indices such as NDVI (normalized difference vegetation index) using the red (R) and near infrared (IR) bands

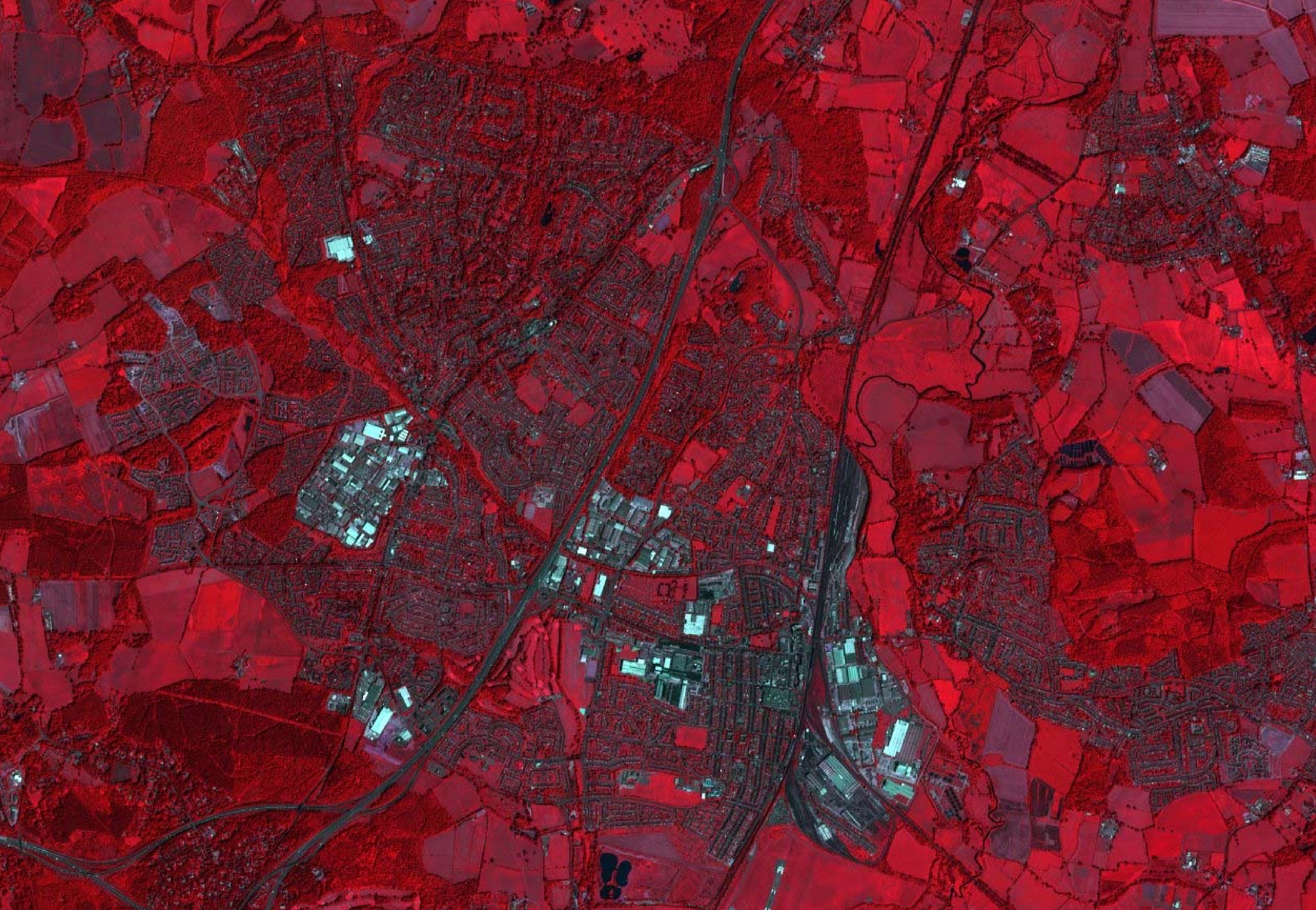
$$NDVI = \frac{IR - R}{IR + R}$$

# Characteristics of high resolution imagery

- Pixel resolution increases complexity of classification
- Most pixels show „mixed pixel“ characteristics
- Areas covered by one image are much smaller than remote sensing practioners are used to

# OEEPE (EuroSDR) Project

- To investigate the use of high-resolution satellite imagery for national mapping
- Started in 2001, involving mapping agencies and academic institutions from several European countries
- One aspect was to investigate land cover
- IKONOS 4m multispectral image of Chandler‘s Ford (Hampshire, UK)
- A mixture of urban, agricultural and wooded land cover



# Land cover from 4m Ikonos data – OEEPE results

- **Sweden**: Ikonos suitable for identification and capture of land cover types found in Swedish 1:10 000 scale mapping
- **UK**: Ikonos, when combined with national mapping vector data (OS MasterMap) suitable for identifying most of the CORINE land cover/land use classes
- **Germany**: Identified several problems when trying to classify the imagery on its own.

# OEEPE results - Some comments

- High-resolution imagery introduces shadows, which are generalised out of lower resoluton imagery. These shadows:
  - Could be used to identify shadow-casting objects
  - Or could be seen as a barrier to accurate classification

# OEEPE results - Some comments

- High-resolution imagery is very heterogeneous – a single residential property may have building, road, low vegetation, high vegetation, and water pixels within its boundary. These are usually averaged out in lower resolution imagery.
- This leads to **lower** accuracy when assessing pixel classification techniques
- ...sounds counter-intuitive.

# Successful applications of high-resolution imagery to land cover mapping

- Olive-tree identification (K. G. Karantzalos, D. P. Argialas, Greece)
- Crop monitoring (Josiane Masson, JRC, Italy)
- Forest mapping in the US and elsewhere
- Mapping urban sprawl in developing countries

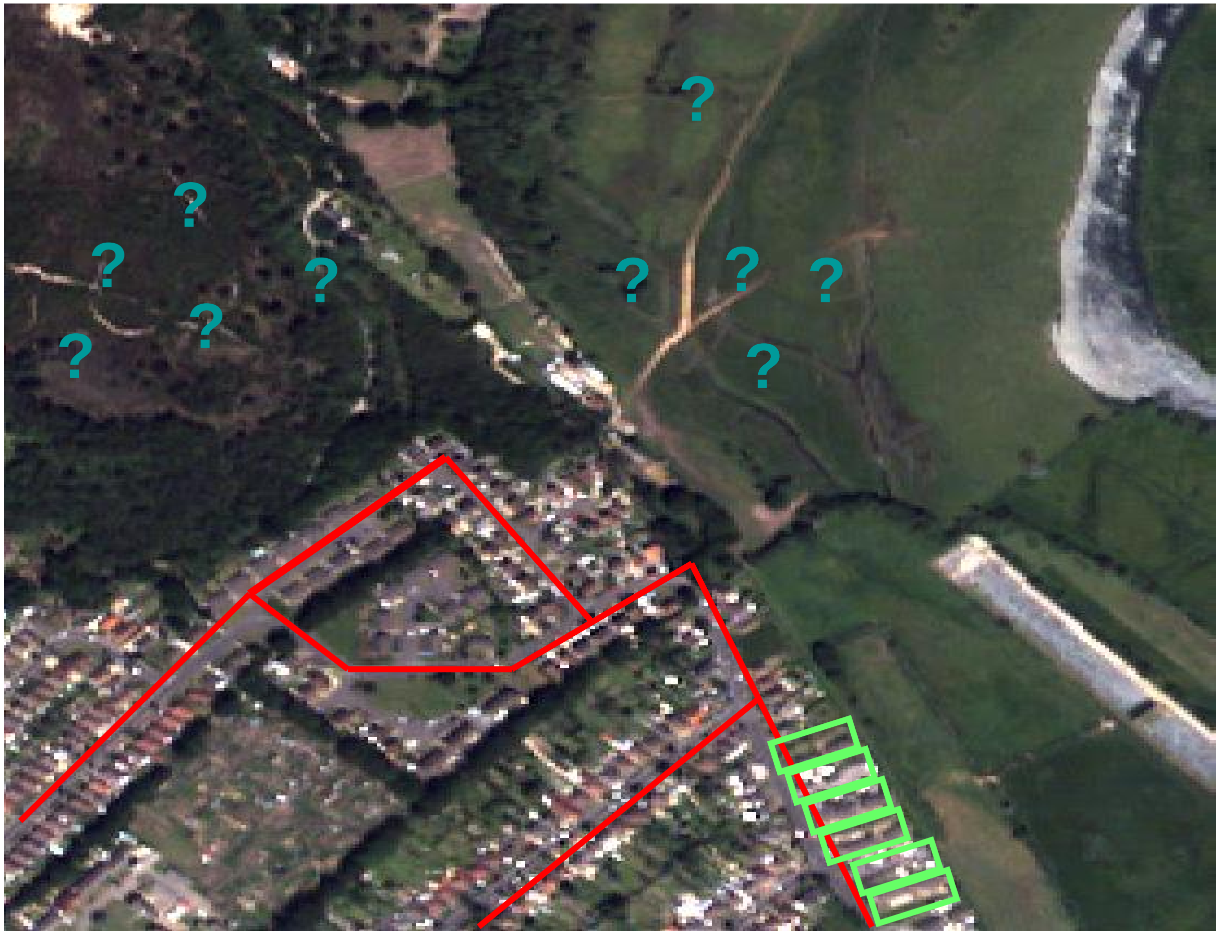
# Why not more application examples?

- Cost of the imagery?
- Limited extent of available data?
- Difficulty in obtaining suitable data (e.g. Too much cloud cover in Northern Europe)?
- No guarantee of continuity (no constellations of satellites)?
- Many remote sensing practitioners used to working with lower resolution imagery, and reluctant to abandon previous research?
- Many photogrammetrists used to working with higher resolution imagery, and reluctant to abandon previous research?
- A combination of the above?

# Super-resolution

- Narrow linear features are difficult to identify in HRS imagery
- Can we use „super-resolution“ techniques to make the task easier?
- Project undertaken by Southampton University (Matt Thornton, Pete Atkinson)
- Use:
  - soft classification techniques
  - pixel swapping
  - linear

# Super-resolution



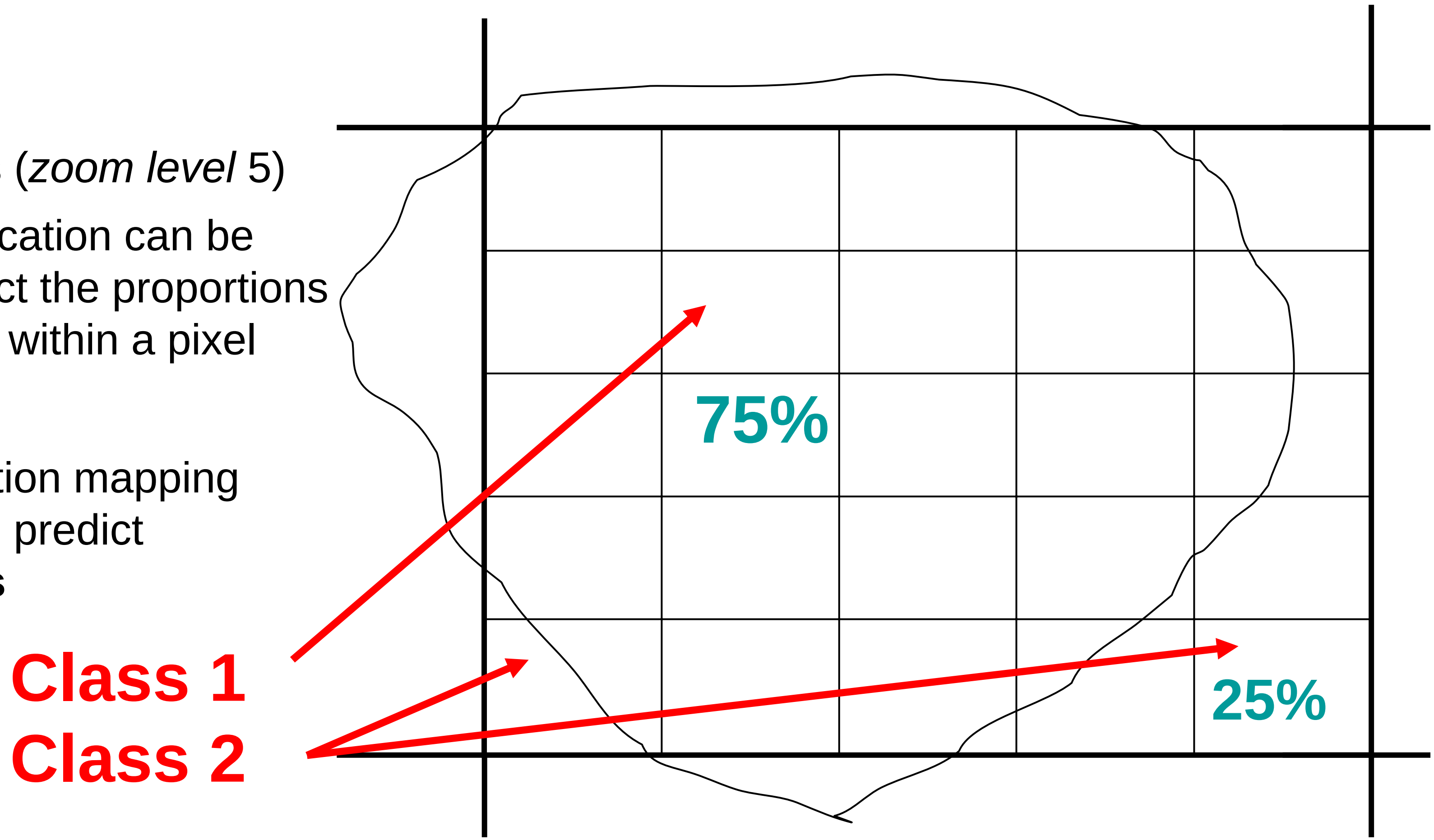
# Super-resolution

1 pixel

25 sub-pixels (*zoom level* 5)

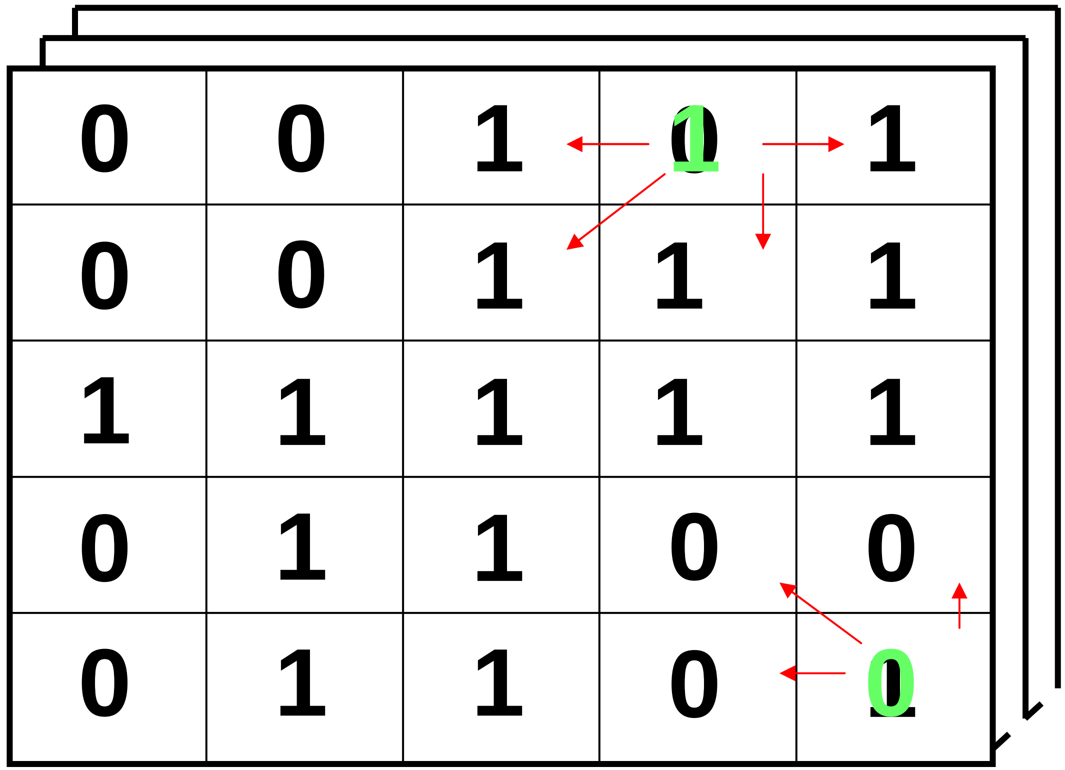
A soft classification can be used to predict the proportions of each class within a pixel

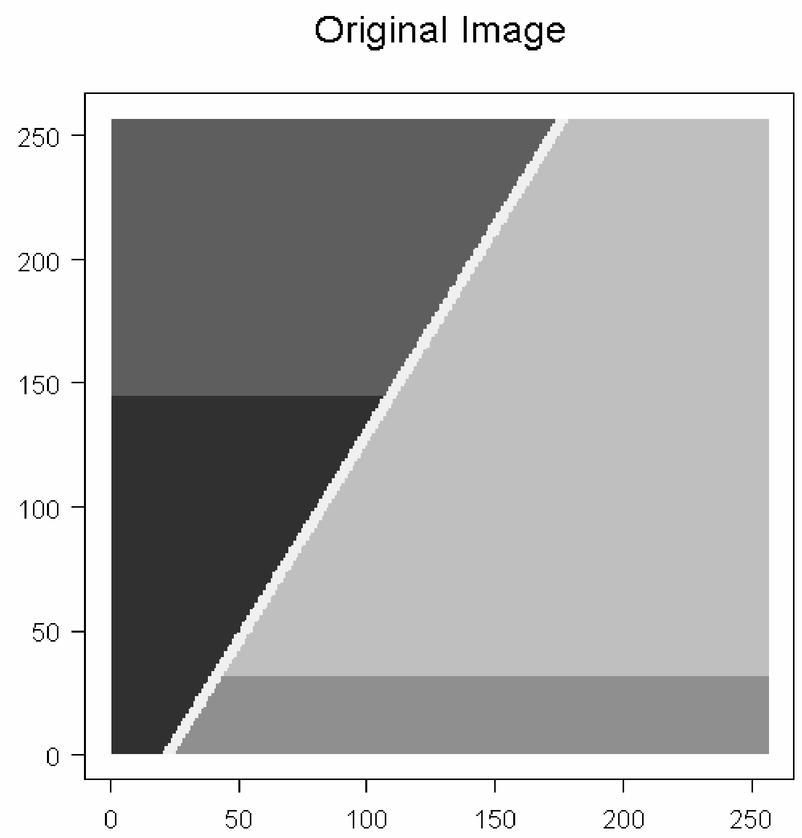
Super-resolution mapping enables us to predict the **locations**

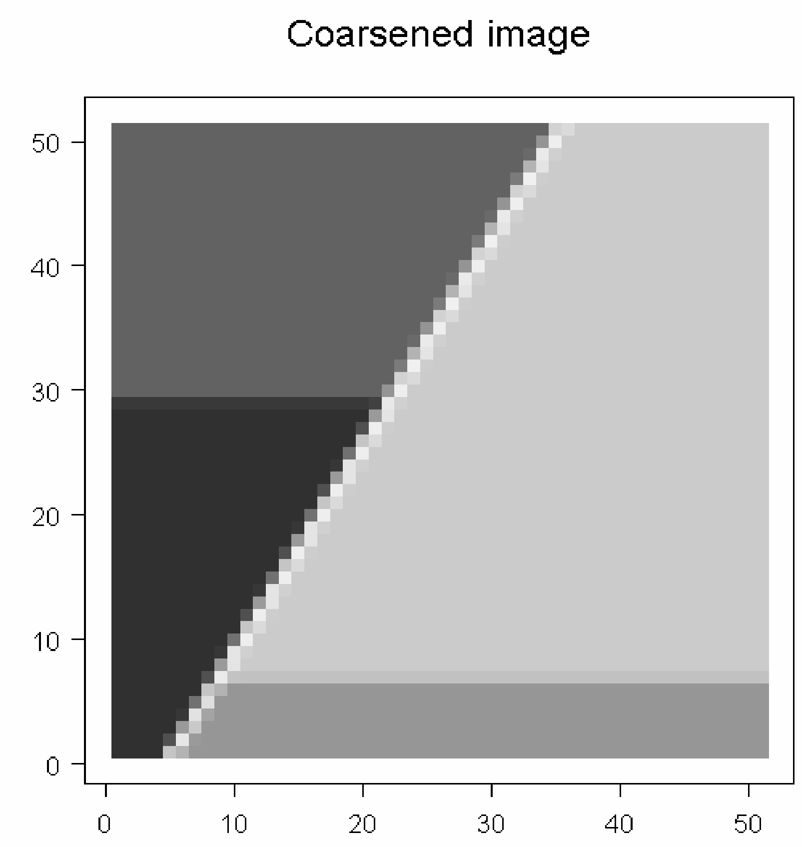


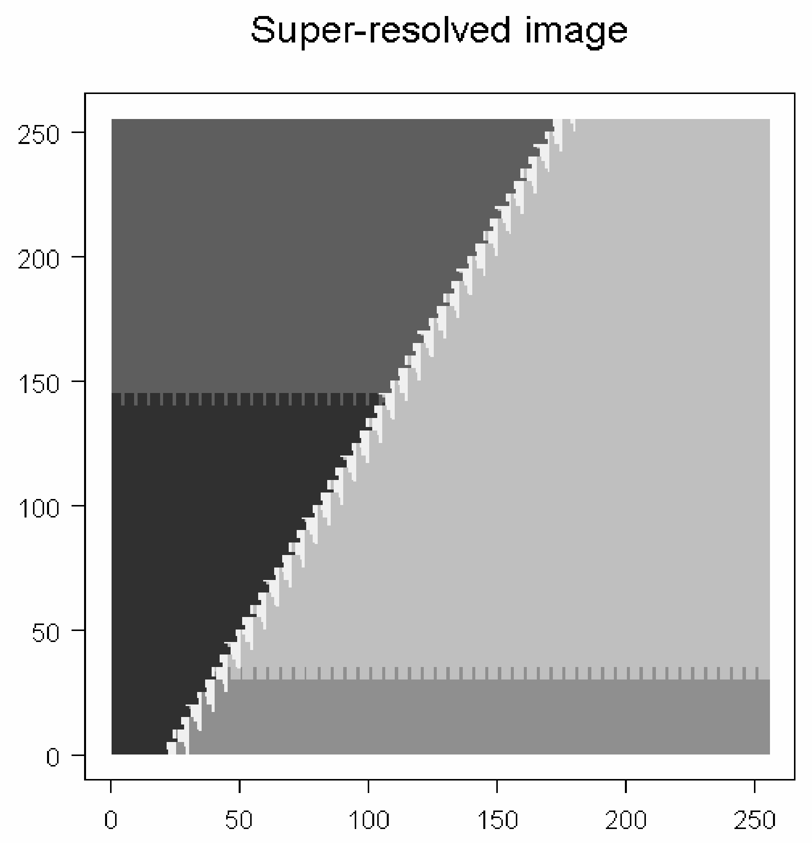
# Pixel swapping

- Super-resolution "pixel-swapping" (Atkinson, 2005)
- Objective of pixel-swapping is to maximise *spatial correlation* within and between sub-pixels based on the phenomenon of *spatial dependence*
- Simulated annealing framework
  - randomly select sub-pixels, one target, one background
  - Measure 'attractiveness' based on exponential distance-decay model




Original Image
250
200
150
100
50
0
0
50
100
150
200
250


Coarsened image
0
10
20
30
40
50
0
10
20
30
40
50


Super-resolved image
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200
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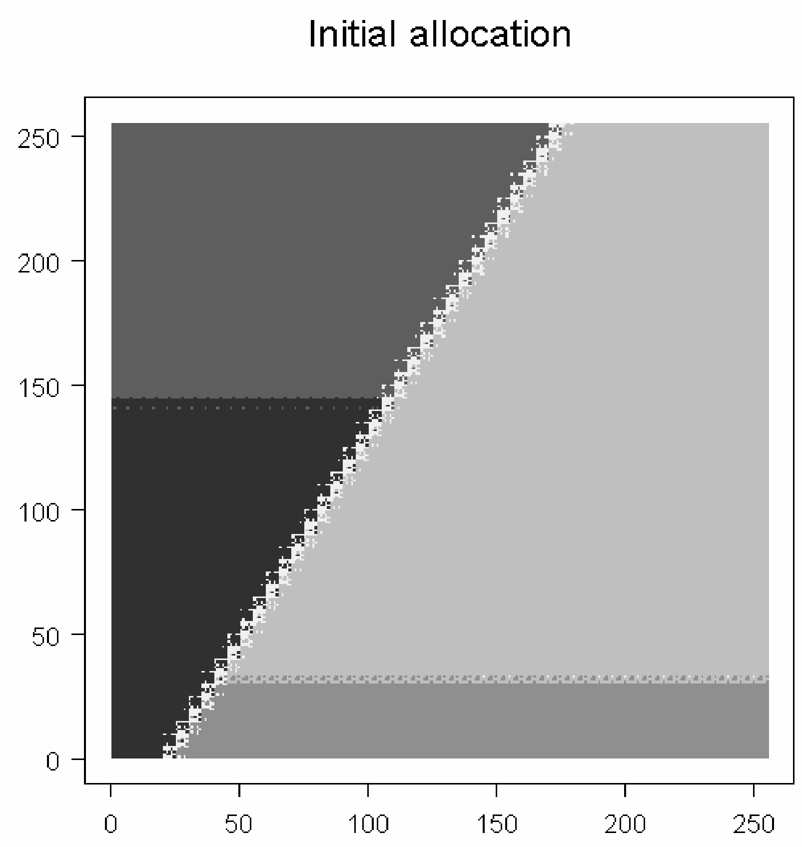
100
50
0
0
50
100
150
200
250


Initial allocation
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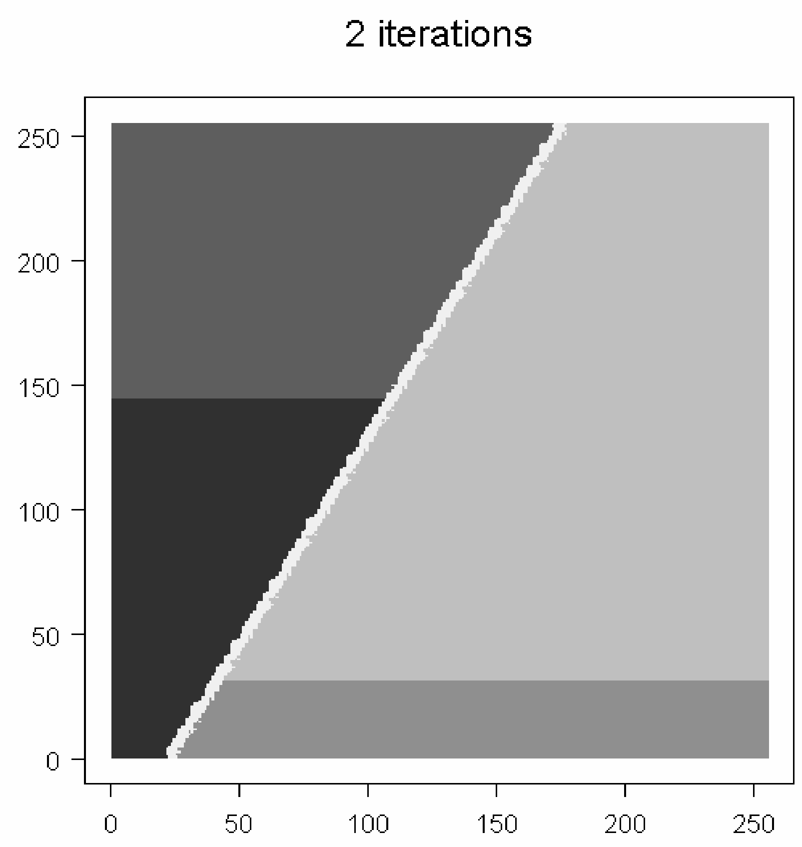
200
150
100
50
0
0
50
100
150
200
250


2 iterations
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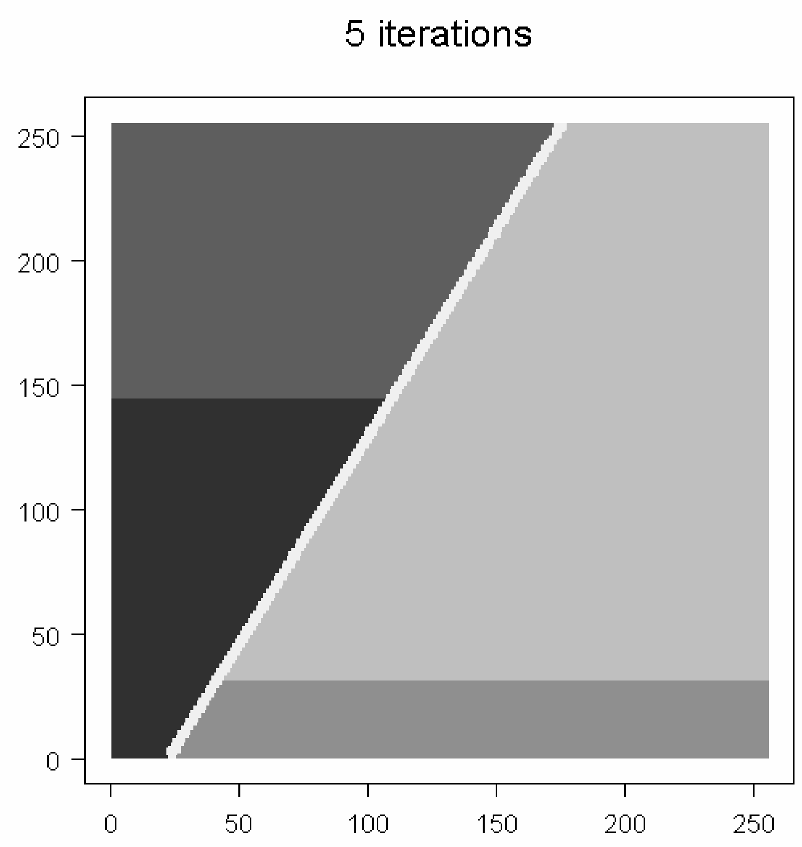
200
150
100
50
0
0
50
100
150
200
250


5 iterations
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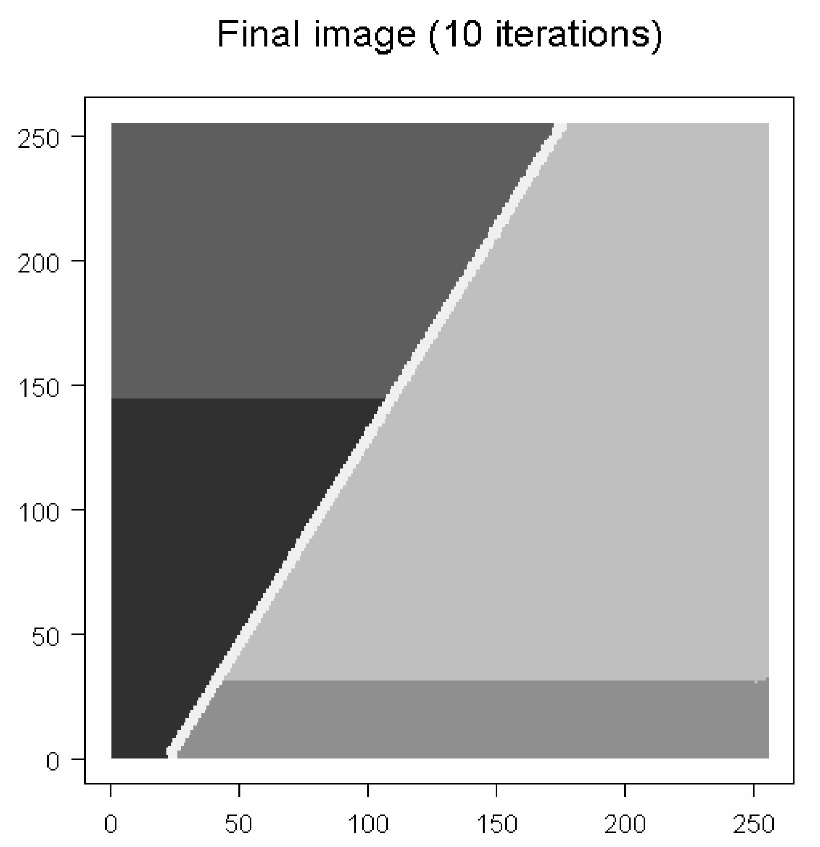
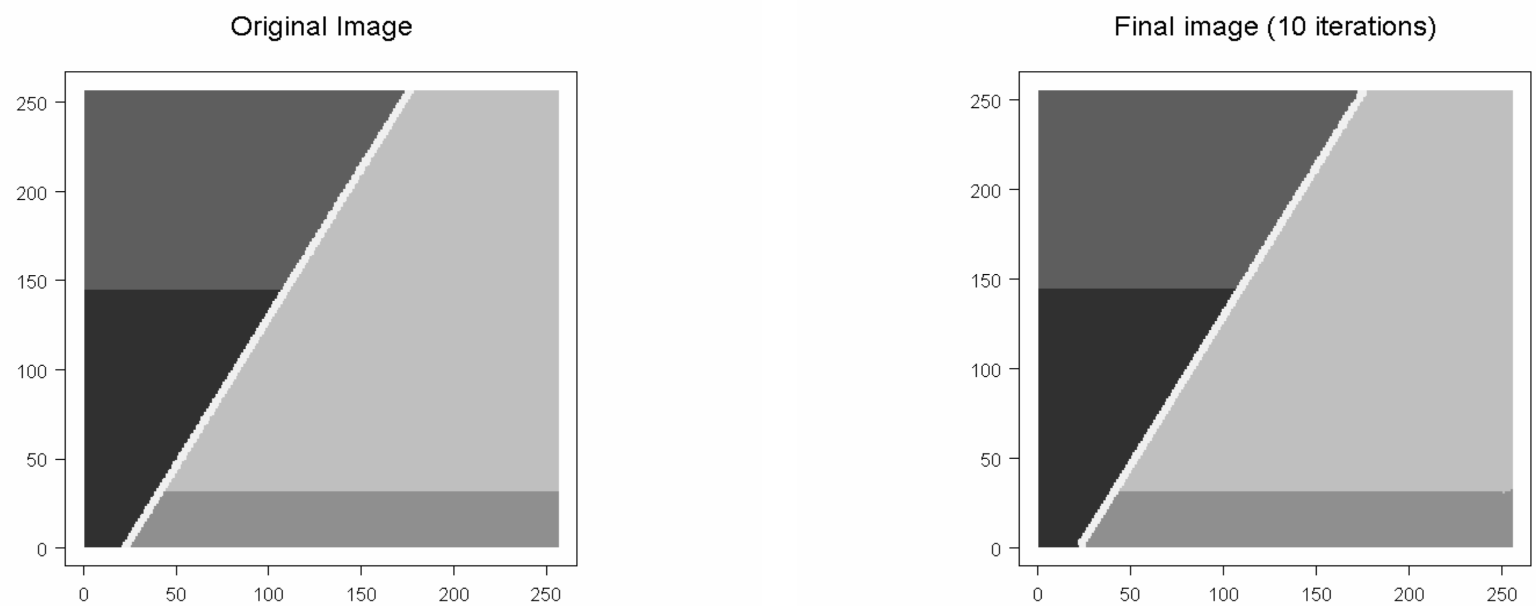
200
150
100
50
0
0
50
100
150
200
250


Final image (10 iterations)
250
200
150
100
50
0
0
50
100
150
200
250


Original Image
250
200
150
100
50
0
0
50
100
150
200
250
Final image (10 iterations)
250
200
150
100
50
0
0
50
100
150
200
250

# Super-resolution results

- Works well on simulated imagery
- Less successful on real QuickBird imagery
- Further work shows some promise of identification of sub-pixel linear features, when combined with linear pattern-matching techniques

# Land cover - conclusions

- HRS imagery can be used for land cover identification for some applications
- Has characteristics not found in low resolution imagery:
  - Shadows are present
  - Image is very heterogeneous
  - Only 4 bands – impose some limitations
- Has been used in real applications (beyond research labs)
- Liekly to be of greater significance when more satellites are in orbit