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NORWEGIAN COMPUTING CENTER

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Ring grave detection in high resolution satellite images of agricultural land

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Collaborators:

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The Norwegian Space Centre (Norsk Romsenter)

Vestfold County Administration (Vestfold Fylkeskommune)

Museum of Cultural History - University of Oslo (Kulturhistorisk museum)

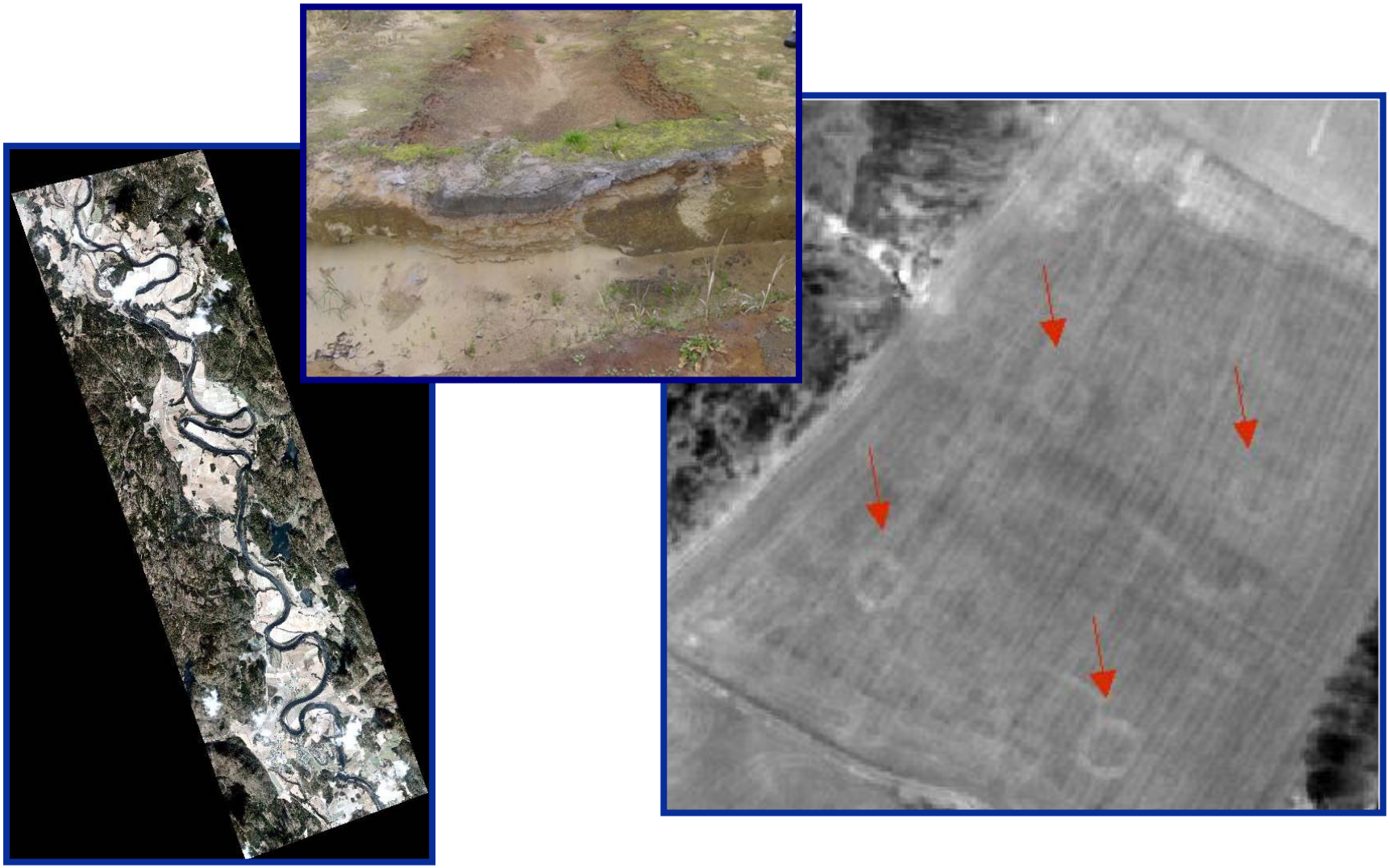
Outline

- Background
  - CultSearcher
  - Ring graves
- Algorithm
- Experimental results
- Discussion
- Conclusion

CultSearcher

- Software for computer assisted detection of potential cultural heritage sites
- Previously tailored to detection of amorphous patterns - remains of ditch, pit, buried walls etc. (Lars Aurdal at NOBIM 2006)
- Extended to include detection of circular patterns
- Soil marks:
  - the local soil profile is disturbed
  - refilled material with different characteristics (grain size, water storage capacity, composition, density)
- Crop marks
  - depends on soil, water content, drainage patterns, vegetation, climate, plant growth
  - vegetation relief (plants grow higher or grow on top of buried stones)

Ring graves visible from space



Why?

- Many grave localities are known, but far from all
- Other interesting sites are often poorly mapped
- Apart from the archaeological interest in inspection of heritage sites, there is also the aspect of localizing these sites before planning new construction projects (for buildings, roads, etc.)
- Surveys based on field inspection is very expensive
- Could satellites offer a cost effective alternative?
- The system will be a tool for **assisting** the archaeologists

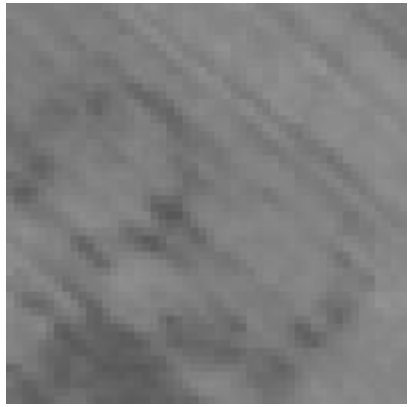
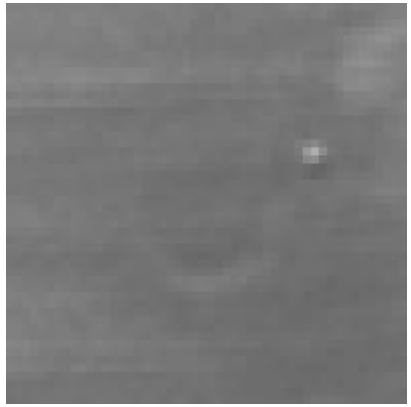
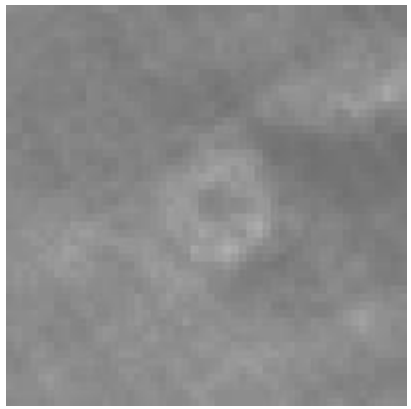
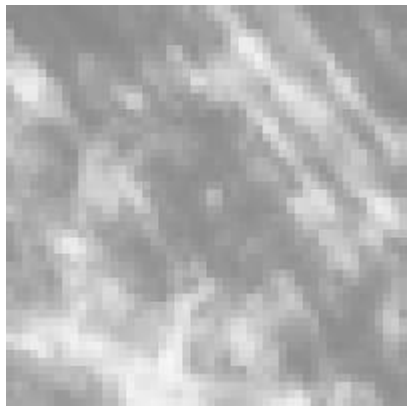
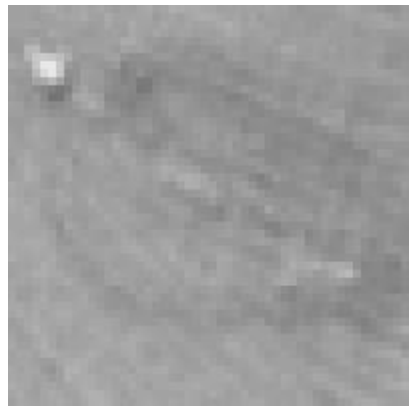
Where to look

- We only consider agricultural fields

Data

- Quickbird images:
  - Lågendalen, April 27th 2005
  - Gardermoen, July 29th 2003
- Alltogether 35 rings in the two images:
  - 15 strong rings (clear visibility)
  - 10 fairly strong rings (moderate visibility)
  - 10 weak rings (poor visibility)
- The rings vary in radius, thickness, grey tone intensity, degree of completeness, and contrast to the local background

Examples of rings identified by experts

Strong rings	Fairly strong rings	Weak rings
		
		

Local contrast enhancement

- The pixel value $p_{CE}(x, y)$ in the contrast enhanced image is computed as

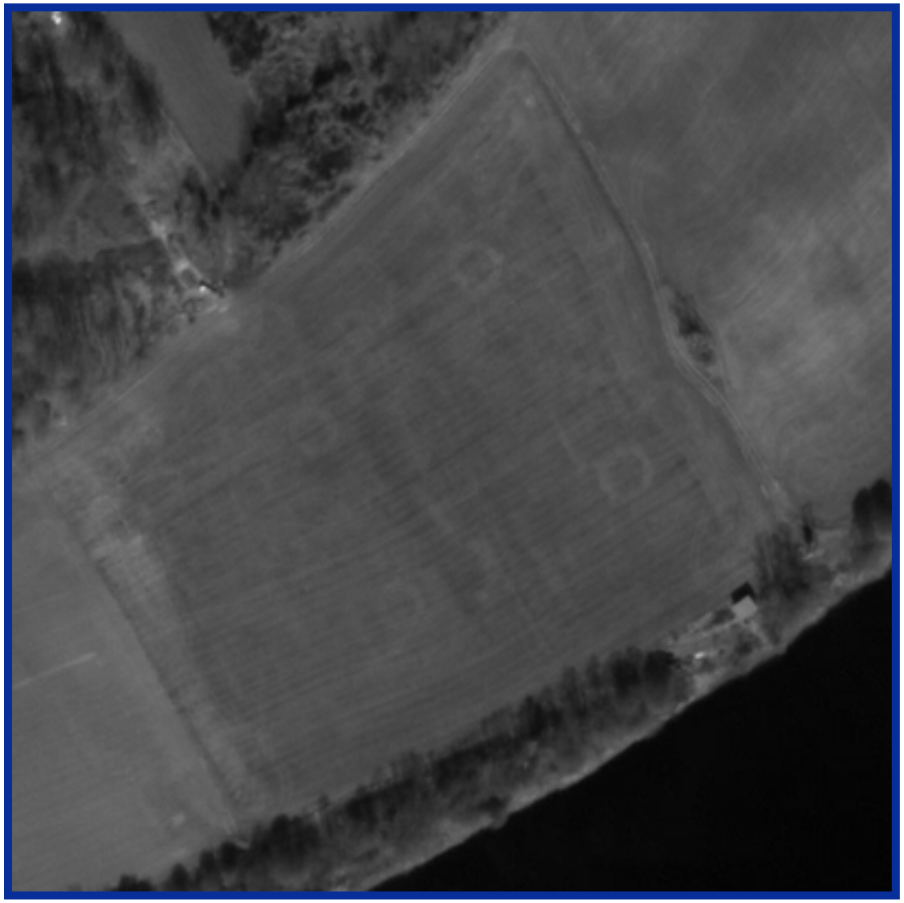
$$p_{CE}(x, y) = \frac{p(x, y) - \mu(x, y, N)}{\sigma(x, y, N)}$$

in a $N \times N$ neighbourhood centered on (x, y).

- Measures how much a pixel deviates from the average in its neighbourhood

Local contrast enhancement

Panchromatic image

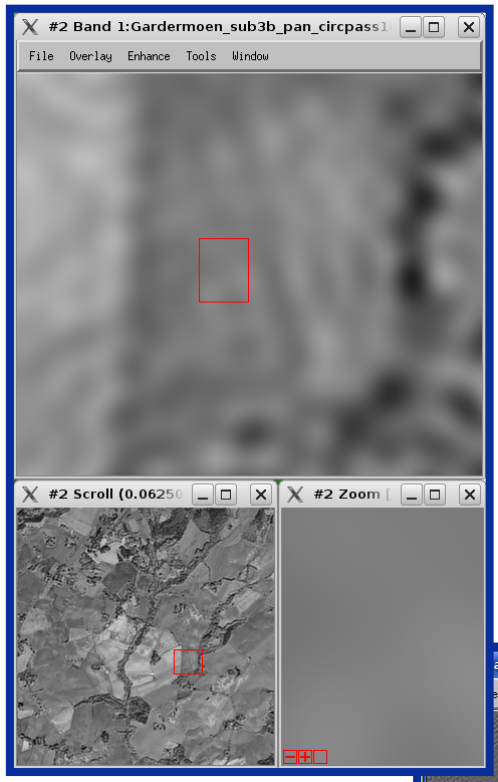


Contrast enhanced image

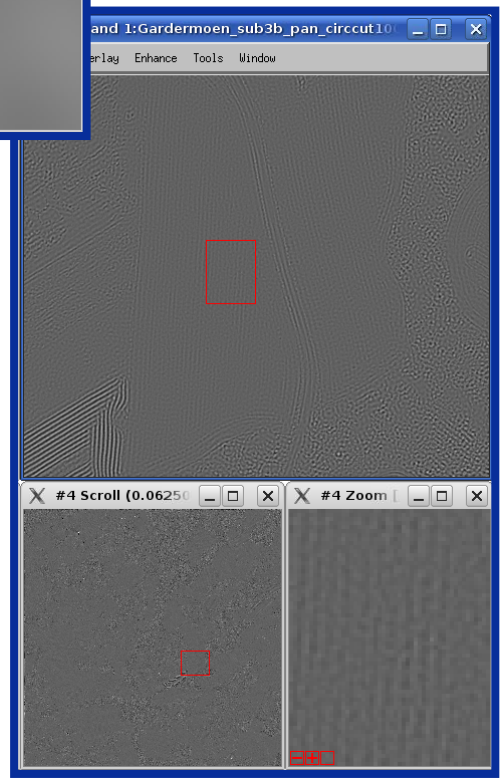
Filtering in the frequency domain

- Using the Fast Fourier Transform (FFT) on sub images of size 4096×4096 pixels
- We have tested various band pass and high pass versions
- Band pass filter with cut of radii 100 and 800 gave best results

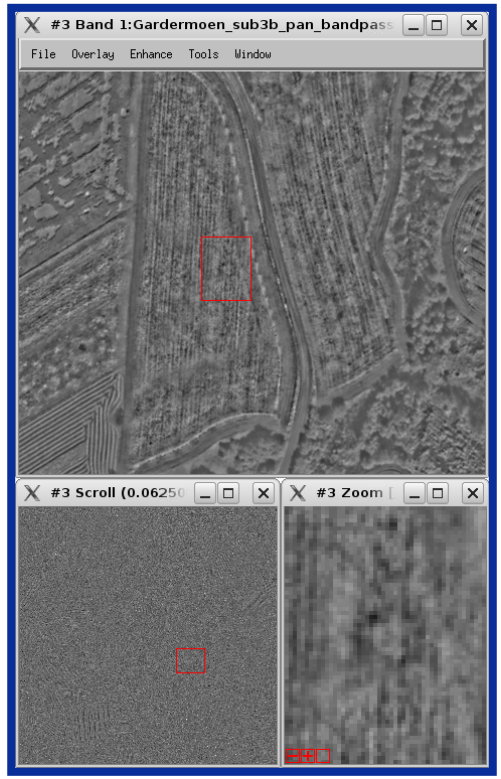
Original image



Removed information:
low frequencies



Kept information:
middle frequencies



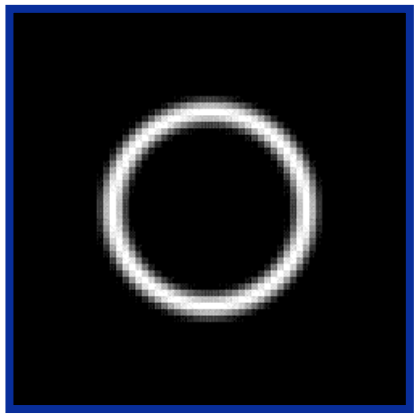
Removed information:
high frequencies

Template matching

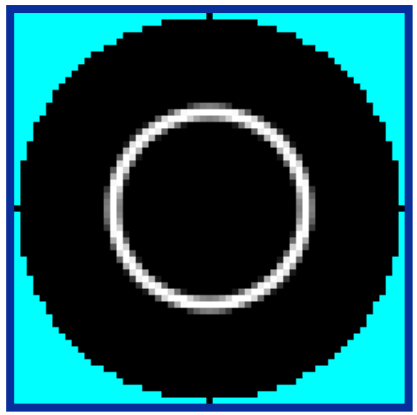
- Ring filter = predefined ”ideal” image of a ring
- Slide across the image to search for rings
- Locations with high correlation are regarded as ring candidates
- Predefined threshold τ:
  - correlation image > τ ⇨ bright ring
  - correlation image < -τ ⇨ dark ring

Ring template shapes

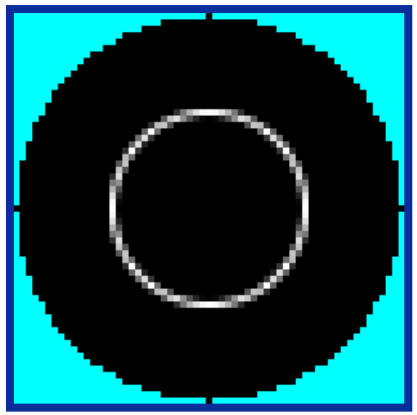
Quadratic boundary



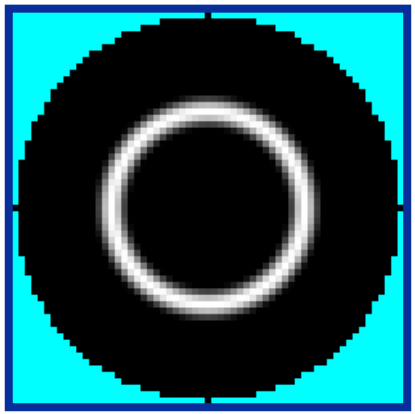
Two pixels thick



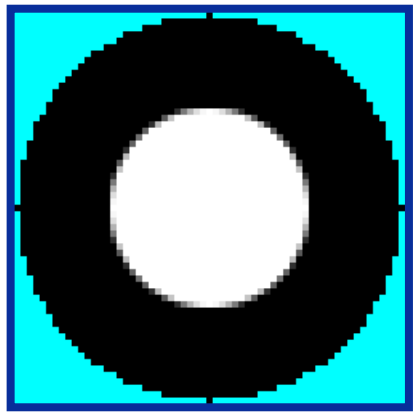
One pixel thick



ENVI's band pass filter



Disc



Description of the template that gave best results

- Template image size is $4 \times round(ring\ radius)+1$
- Template boundary radius $2 \times round(ring\ radius)$
- Values between 0 and 1
- Subtract mean filter value to get zero mean
  - positive values on the ring
  - negative values off the ring

Feature extraction and classification

- Decision tree classifier
- Features were extracted from *4r ×4r* sub image + binary sub image
  - ring cover
  - mean values (x and y) of binary image
  - Hu moment invariants (grey level and binary)
  - real weighted Fourier moments (grey level and binary)
- Limited test data set prevent us from using a statistical classifier

Combining the methods: Overall description of the best approach

1. Band pass filtering (optional)
   a. FFT
   b. Band pass filter
   c. Inverse FFT
2. Local contrast enhancement
3. Ring search
   a. Construct ring templates of various sizes
      (radii from 4.5 to 9.0 meters, 2 pixels thick)
   b. Convolve image with a ring template
   c. Threshold convolution result to find bright rings
   d. Threshold convolution results to find dark rings
   e. Repeat b-d for all ring template sizes

NOTE: No feature extraction and classification

Results

- The threshold value τ is the single most sensitive parameter that the user may adjust (low τ ⇨ many false positives)
- The CultSearcher software includes an edit module:
  - allows time efficient editing of the result
  - the user (archeologist) is guided through the list of possible detections in the image and asked to accept or reject each ring

Results

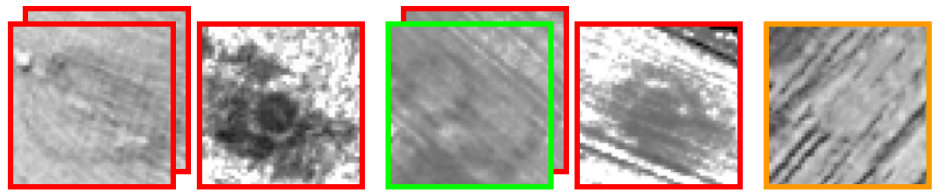
- Compromise:
  - 10 out of 15 strong rings are found
  - 2 out of 10 fairly strong rings are found

  } 48%
  - none of the weak rings are found
  - 2.5 times as many false positives as true positives
- Alternatively:
  - 64% of the strong and fairly strong rings are found
  - seven times as many false positives as true positives
- Never able to detect all the strong and fairly strong rings

Results

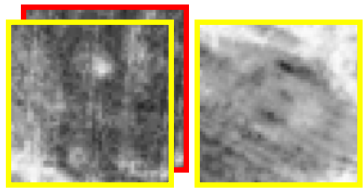
Gardermoen sub1:

Gardermoen sub2:

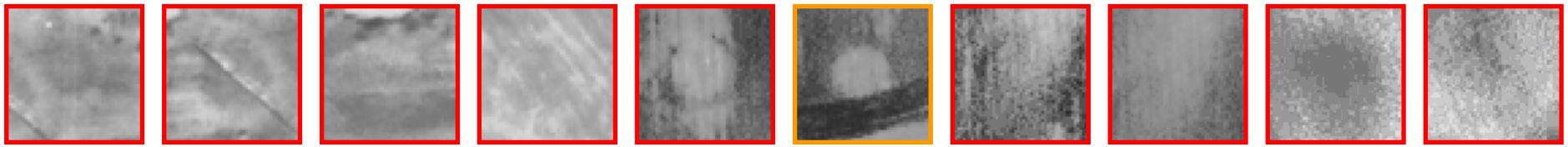


Gardermoen sub3:

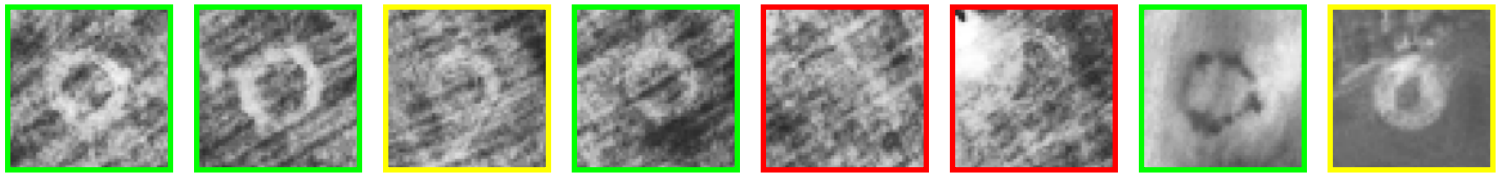
Gardermoen sub4:



Laagen sub1:



Laagen sub3:



8+4+4+19=35

Discussion

- Classification did not help to discriminate false rings from true rings
- The better the template matching, the less there is to gain on improving classification
- Feature information ”already used”?

Future work

- Include features extracted from multi-spectral imagery:
  - the four individual bands
  - NDVI
  - pan-sharpened image
- More data ⇨ large training set ⇨ statistical classification?
- Additional variations of the ring template

Conclusion

- The experiments demonstrate that the proposed algorithm is able to detect many circular patterns. Still, many are also missed by the algorithm. If the goal is to detect each and every circular pattern, then the algorithm needs to be improved to be really useful.
- Some circular patterns may only be visible from time to time. In order to find these, one may have to process images from, say, a ten year period, and, say, 5-10 images per year. In this perspective, our approach can be used to process large volumes of satellite images that would otherwise not be inspected, thus detecting many new sites.

Thank you for the attention!