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DETECTION OF BURIAL MOUNDS IN HIGH-RESOLUTION SATELLITE IMAGES OF AGRICULTURAL LAND

Øivind Due Trier (NR), Anke Loska (NDCH),
Siri Øyen Larsen (NR), and Rune Solberg (NR)

Collaborators:
The Norwegian Directorate for Cultural Heritage, NDCH (also funding)
The Norwegian Space Centre (also funding)
Vestfold County Administration
Museum of Cultural History - University of Oslo

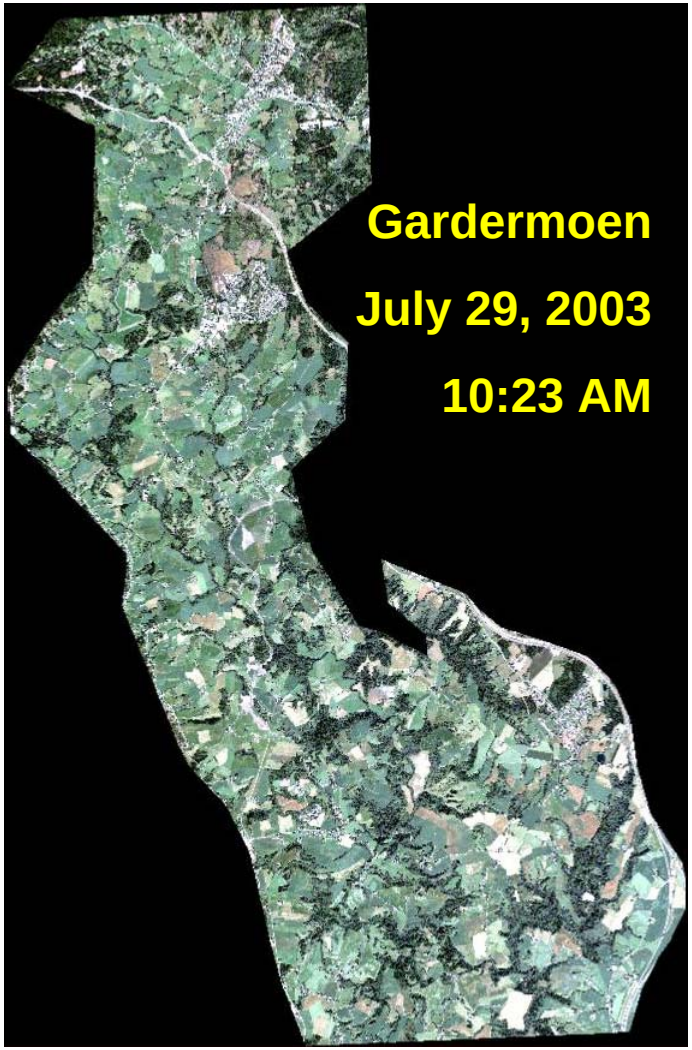
Outline

- Background
- Methods
  - contrast enhancement
  - template matching
  - classification experiments
- Results
- Conclusion

CultSearcher

- Software for computer assisted detection of potential cultural heritage sites
- Agricultural fields
- Soil marks
- Crop marks
- Circular patterns – could be remains of burial mounds

Quickbird images



Cross section of ditch that has surrounded bronze age burial mound

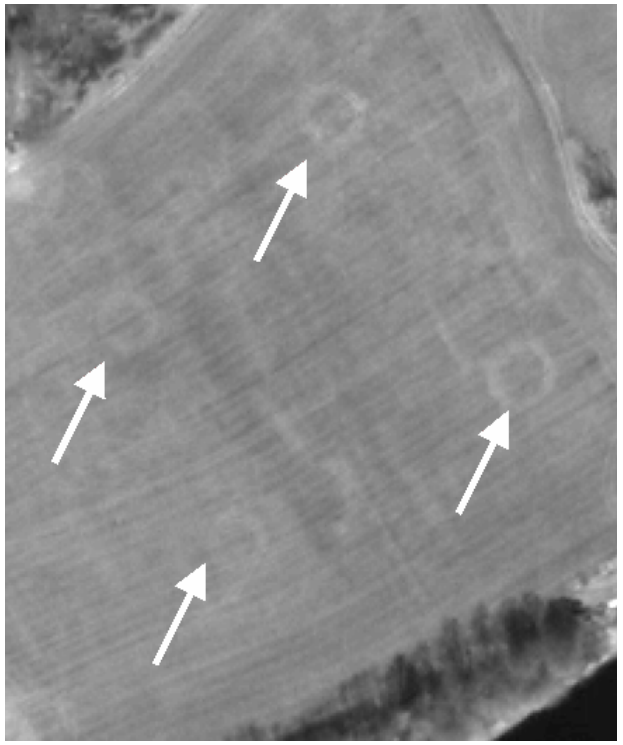
Detail of Lågendalen image

RGB

2.4 m

Near infrared

2.4 m



Panchromatic

0.6 m

Where to look

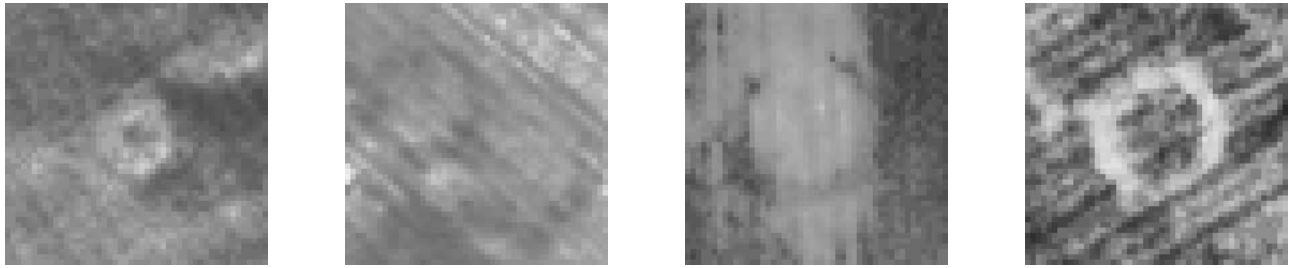
- We only consider agricultural fields

Test data

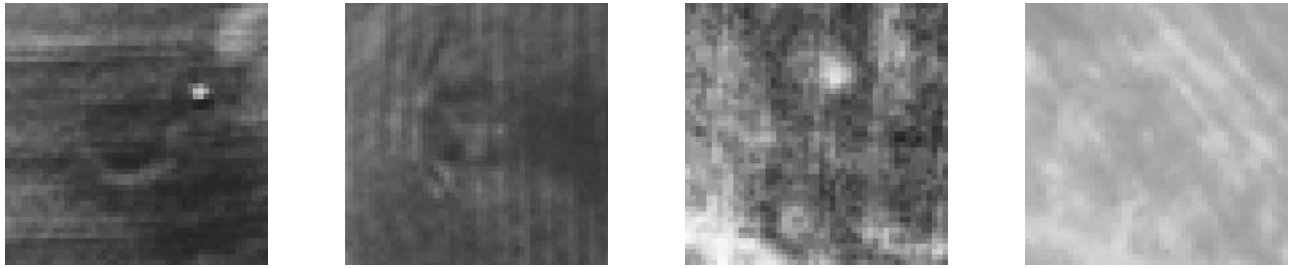
- Altogether 35 rings in the two images:
  - 15 strong rings (clear visibility)
  - 10 fairly strong rings (moderate visibility)
  - 10 weak rings (poor visibility)
- The appearance of different rings varies greatly:
  - radius,
  - thickness,
  - gray tone intensity,
  - degree of completeness,
  - contrast to the local background

Example ring marks

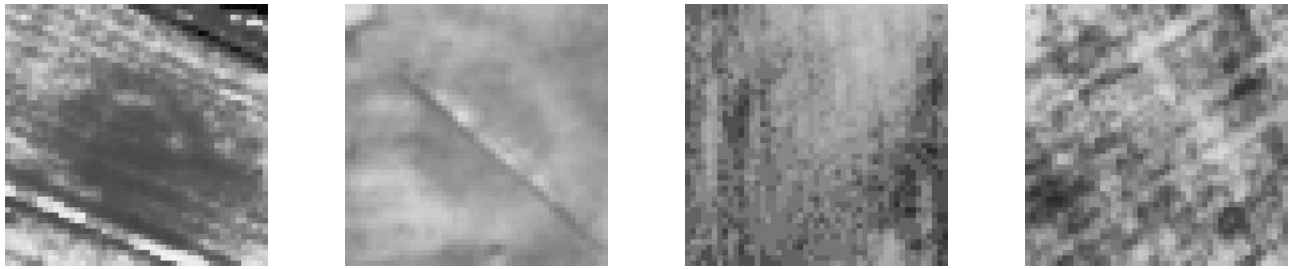
Strong rings:



Fair rings:



Weak rings:



The contrast has been adjusted to highlight the rings

Local contrast enhancement

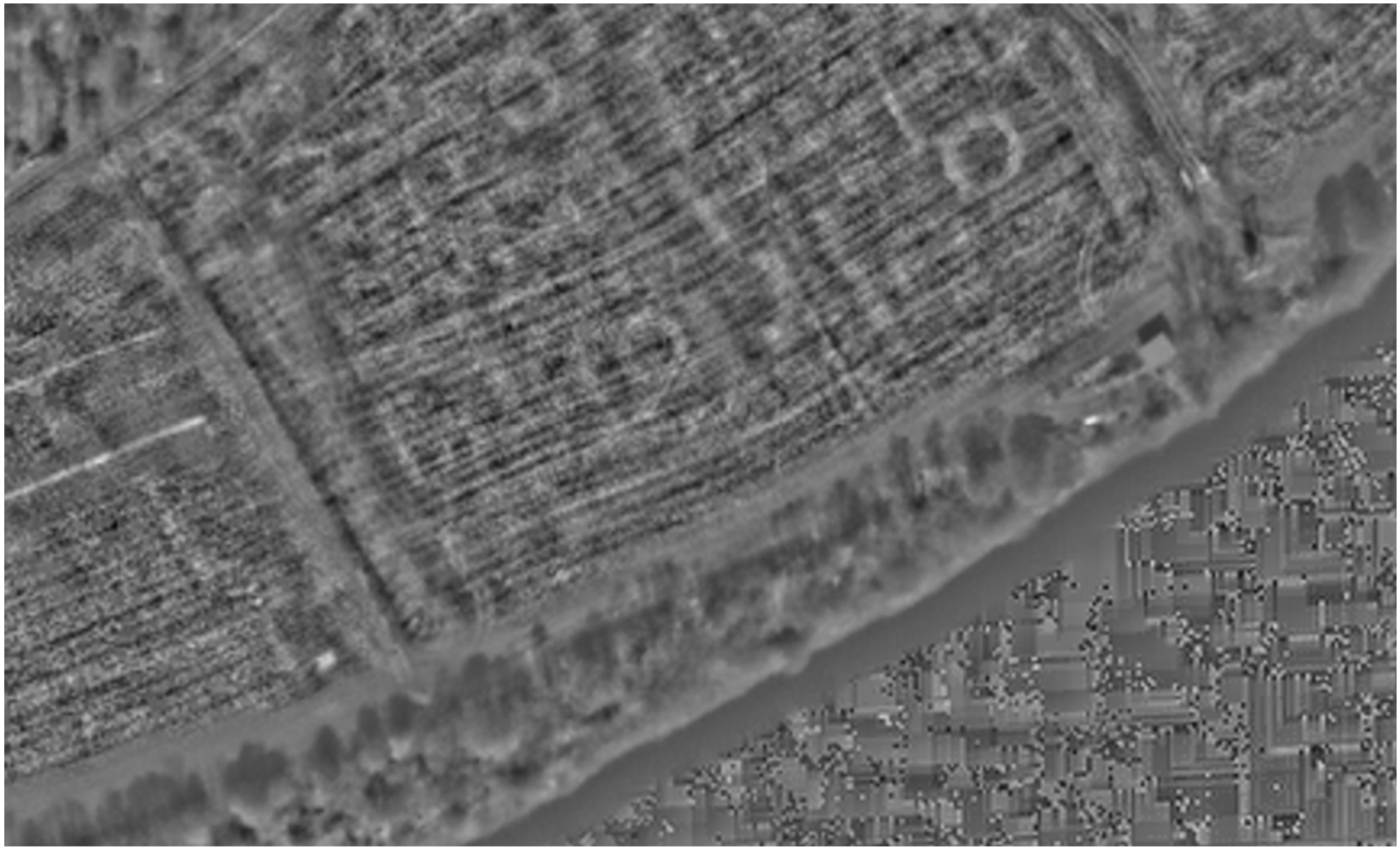
- The pixel value $p_{CE}(x,y)$ in the contrast enhanced image is computed as

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

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

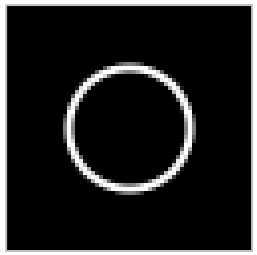
- Achieves more or less constant local contrast over the entire image.

Local contrast enhancement

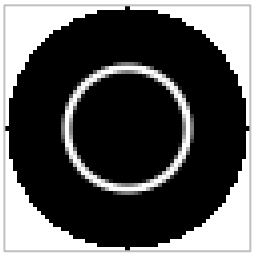


Template matching

- A ring filter is convolved with the image
- Correlation image; pixel value indicate how well the ring filter agrees with the image when centered on the respective location



Square boundary



Circular boundary

Locating potential ring sites

- Locations with high correlation

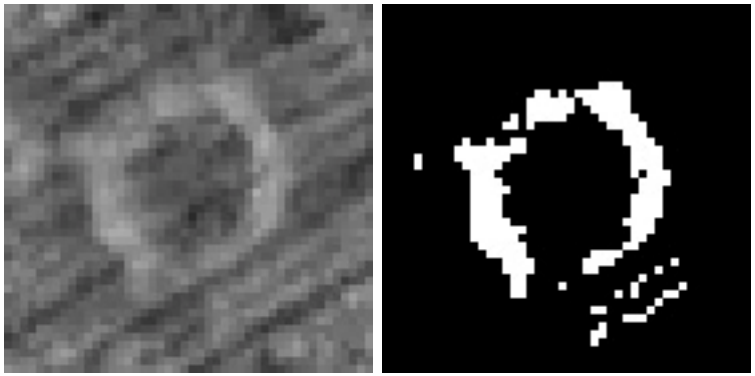
- Threshold τ:
  - correlation image > τ ⇨ bright ring
  - correlation image < -τ ⇨ dark ring

- The threshold τ may be adjusted by the user
  - influence true ring recognition rate vs. number of false detections

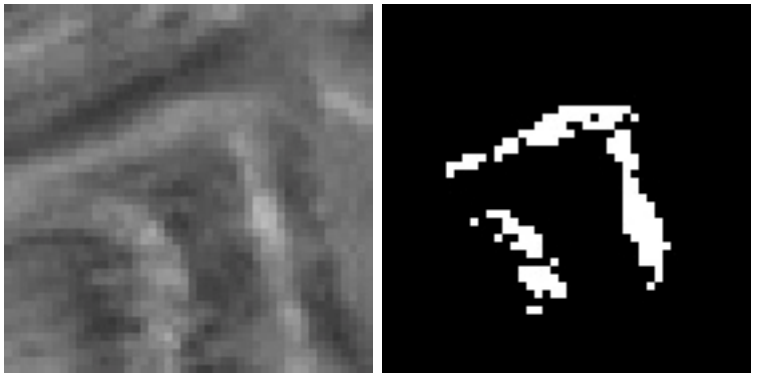
Classification experiments

- Are there features that can discriminate false positives from true rings?
- Features extracted from $4r \times 4r$ sub images (panchromatic + binary) containing ring candidates

True ring



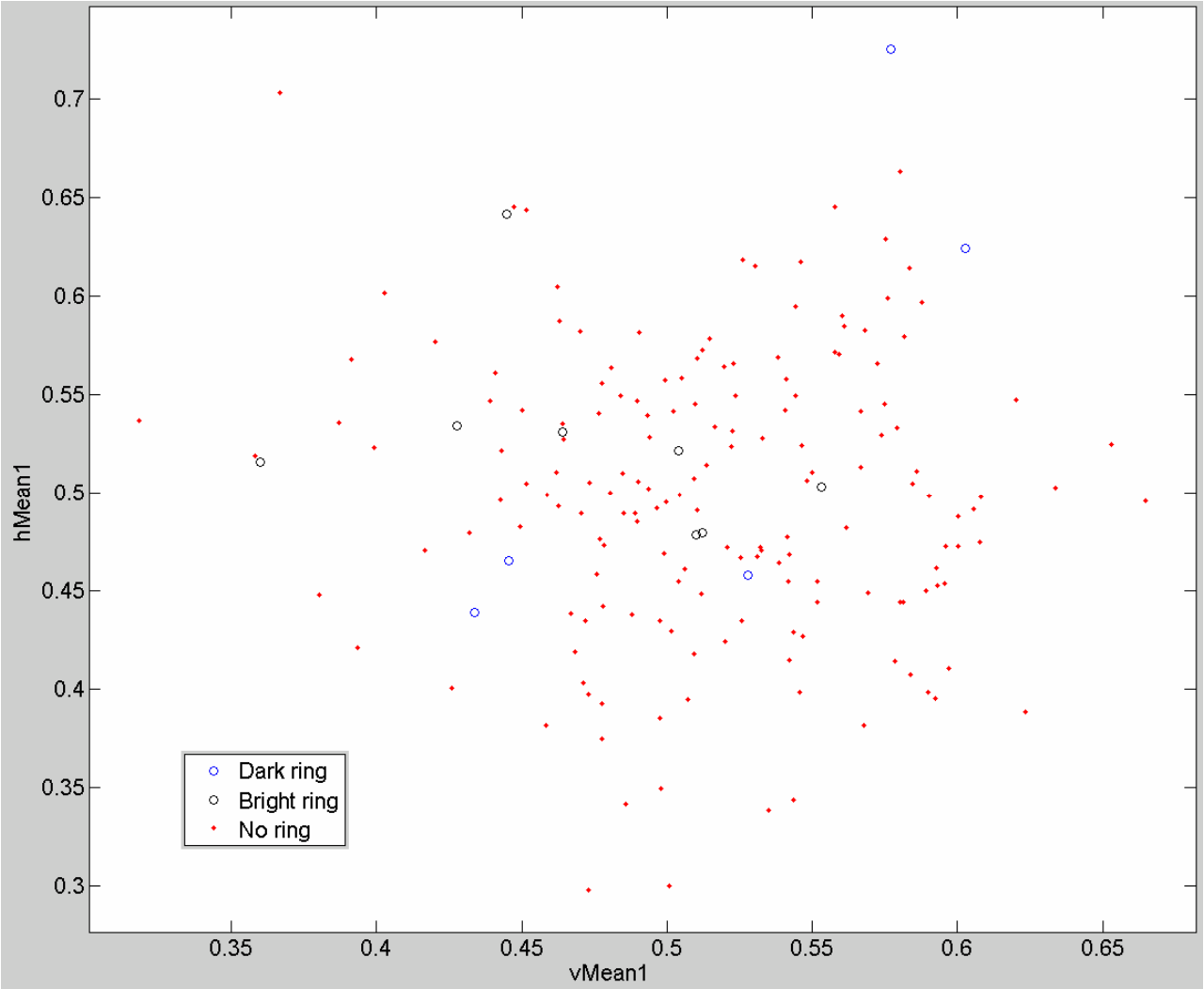
False ring



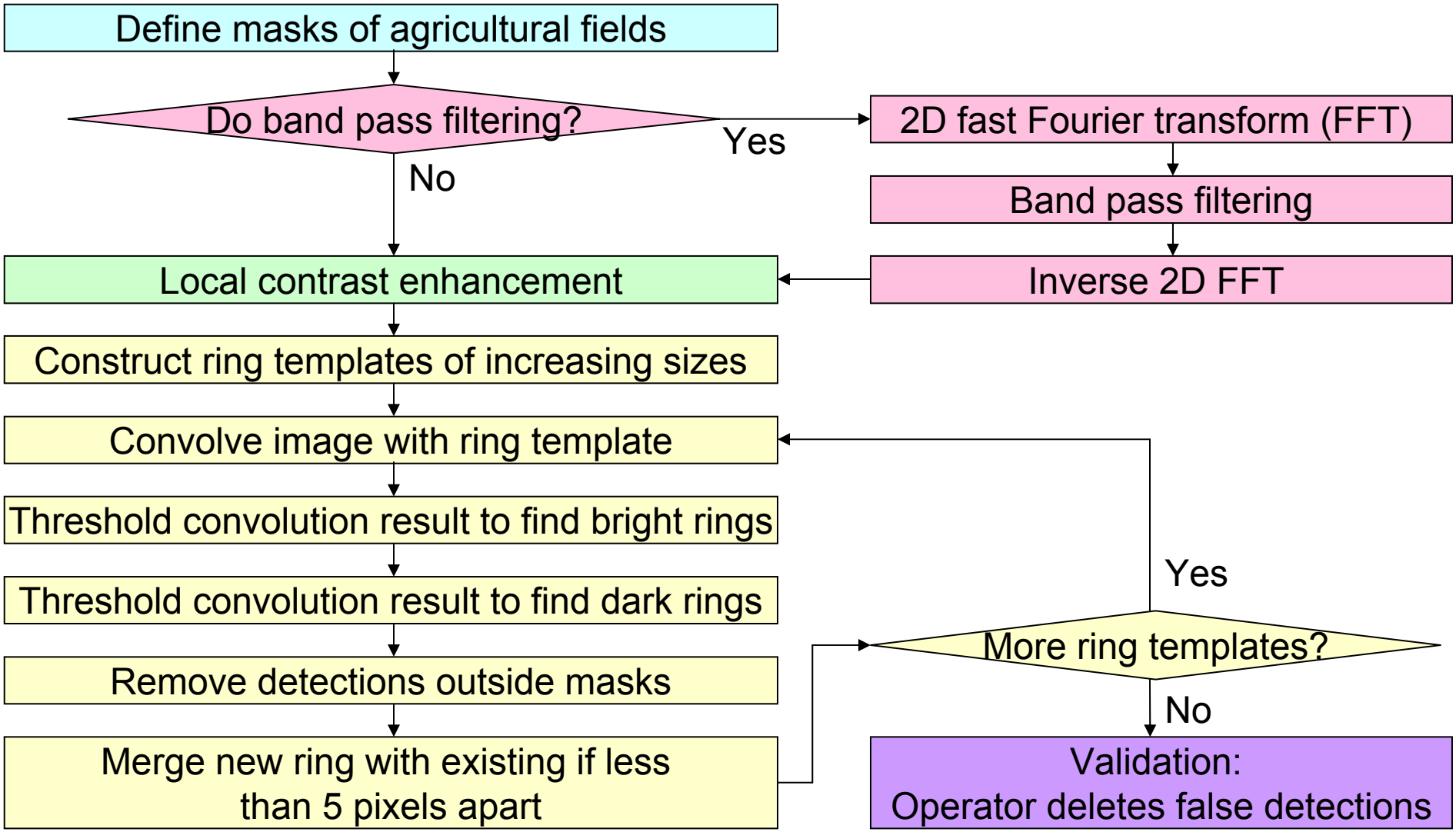
Classification experiments

- Features include:
  - ring cover; overlap between binarized sub image and binary version of the ring filter
  - mean x- and y-coordinates of binarized image
  - Hu moment invariants
  - Real weighted Fourier moments
- Desicion tree classifier
- Results discourage the use of classification

Scatter plots



Flowchart of algorithm

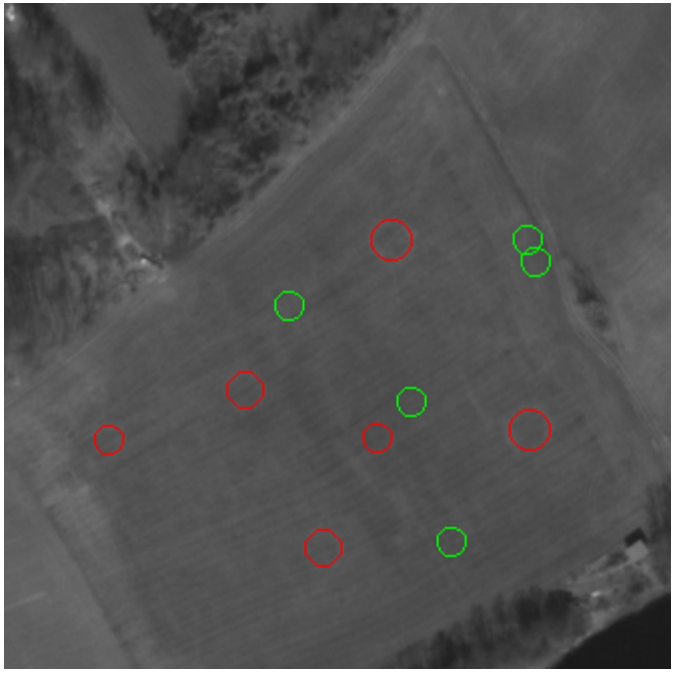


Results

band pass	corr. thresh.	strong rings	fair rings	weak rings	true rings	false rings
no	0.30	11	5	0	16	450
no	0.33	11	5	0	16	109
no	0.35	10	2	0	12	39
no	0.40	8	0	0	8	3
yes	0.35	12	3	0	15	174
yes	0.38	11	2	0	13	48
yes	0.39	10	2	0	12	31
yes	0.40	9	1	0	10	12
ground truth		15	10	10	35	

Verification

Detected rings



Verified rings

Bright rings

Dark rings

Conclusion

- Detection of rings is a challenging task.

- Local contrast enhancement
- Template matching

- Archaeologists state that the software tool is helpful.
  - Avoid manual inspection of entire images.
  - Easy to remove false detections.

Thank you for your attention