BigVis 2019

FUTURECROPPING

Processing Satellite Imagery for Decision-Making in Precision Agriculture

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Motivation

- Precision agriculture
  - Advances in GPS and sensor-based technologies
- Anomaly or outlier detection in agriculture
  - Primarily to detect measurement errors
  - Less attention to poor decisions and choices
- Decision-making
  - Traditionally, based on experience
- Our goal
  - Enable data-intensive decision-making
  - Inter- and intra-field analysis tasks

Analysis tasks

- Inter-field analysis
  - Identify fields with unexpected behavior
    - Negative, low collected crop mass
    - Positive, unexpectedly high crop mass
  - Spatial (contextual) outlier detection
    - Define field neighborhood N_f
    - Weight neighbors importance w_i
    - Predict field's behavior based on its neighbors $f.\hat{\alpha}$

$$f.\widehat{\alpha} = \frac{\Sigma_{i=1}^{|N_f|}\{w_i \cdot n_i.\alpha\}}{\Sigma_{i=1}^{|N_f|} w_i}$$

Analysis tasks

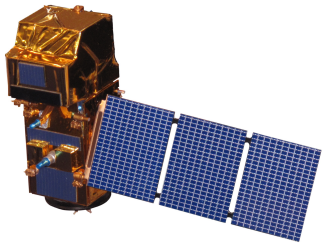
- Intra-field analysis
  - Triggered by inter-field analysis
  - Identify problematic areas inside a field
    - Action required
  - Detection
    - Partitioning of a field
    - Determine how behavior of an area or partition deviates from entire field's $|p_i.\alpha - f.\alpha|$

Case-study

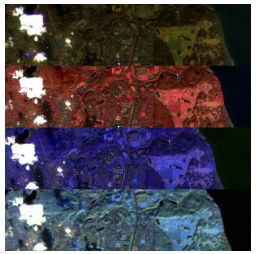
- Setup and data
  - Polygons and crop types
    - 590*k* fields in Denmark
  - Satellite imagery from ESA Sentinel-2
    - 6.3GB vegetation map
  - QGIS

Case-study

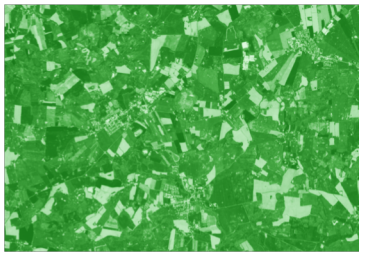
- Processing satellite imagery
  - Vegetation indices to monitor crop growth
  - Normalized Difference Vegetation Index (*NDVI*)
    - Attribute of interest α
    - Field value, $f.\alpha = \mu_f$



sentinel-2



$$NDVI = \frac{NIR-VIR}{NIR+VIR}$$



Case-study

- Inter-field analysis
  - Compute $f.\hat{\alpha}$ on each field f
  - Neighborhood
    - Fields of same crop type, at most 10 km away

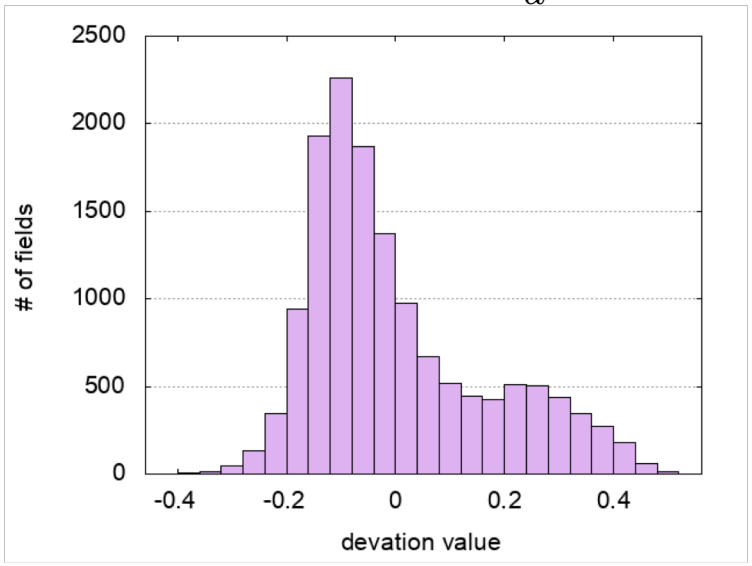
$$dist(f, n_i) = \begin{cases} ED(f, n_i) & \text{if fields } f, n_i \text{ have the same crop type} \\ MAX\_DIST & \text{otherwise} \end{cases}$$

  - Neighbor importance
    - Field distance, $dist$
    - *V*ariation of crop growth, σ_i

$$w_i = \left[1 - \frac{dist(f, n_i)}{MAX\_DIST}\right] \cdot [1 - \sigma_i]$$

Case-study

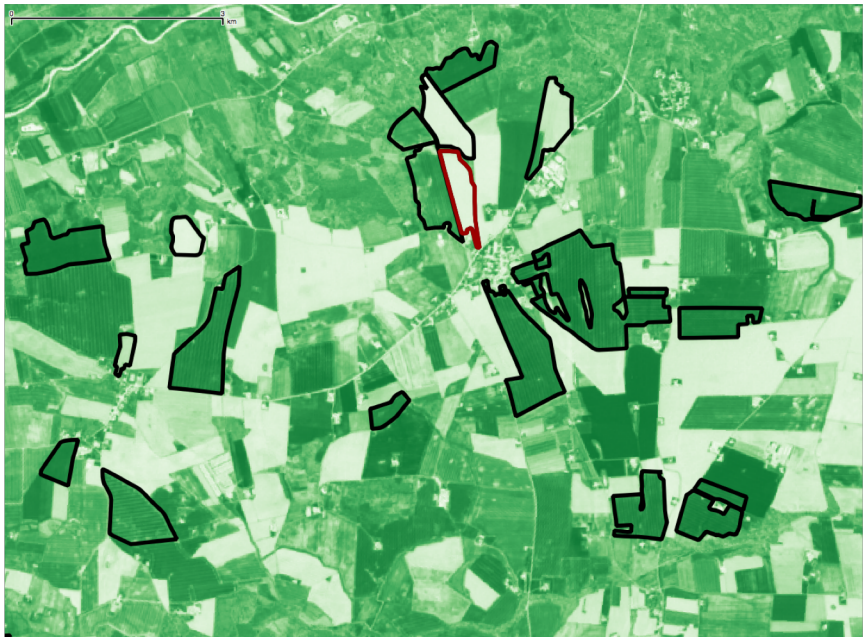
- Inter-field analysis
  - Statistical approach for extreme deviation $f.\widehat{\alpha} - f.\alpha$
    - 95% of fields have deviation inside $[\mu_d - 3 \cdot \sigma_d, \mu_d + 3 \cdot \sigma_d]$
    - Outlying fields have $\frac{|f.\widehat{\alpha} - f.\alpha - \mu_d|}{\sigma_d} \geq 3$



Case-study

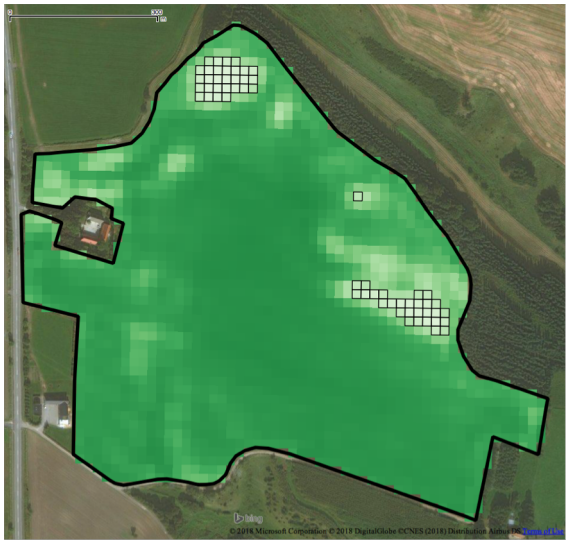
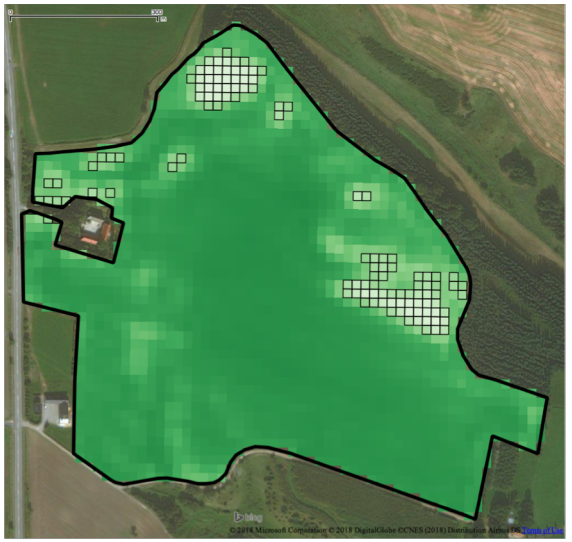
- Inter-field analysis

field	α $(NDVI)$	$dist(f, n_i)$ (in meters)	σ_i	w_i
f	0.176	–	–	–
n_1	0.183	14	0.071	0.928
n_2	0.764	264	0.054	0.921
n_3	0.762	311	0.056	0.914
n_4	0.777	452	0.056	0.901
n_5	0.724	435	0.059	0.900
n_6	0.604	75	0.098	0.895
n_7	0.629	5	0.110	0.889
n_8	0.753	1,277	0.067	0.814
n_9	0.787	1,644	0.028	0.813
n_{10}	0.347	408	0.169	0.797
n_{11}	0.762	1,754	0.036	0.795
n_{12}	0.719	1,216	0.138	0.757
n_{13}	0.175	1,967	0.078	0.741
n_{14}	0.791	2,522	0.033	0.723
n_{15}	0.742	2,173	0.082	0.719
n_{16}	0.787	2,321	0.073	0.712
n_{17}	0.808	2,717	0.033	0.704
n_{18}	0.783	2,537	0.057	0.704
n_{19}	0.335	2,695	0.057	0.689
n_{20}	0.689	3,219	0.063	0.635



Case-study

- Intra-field analysis
  - Partitioning based on image resolution 10*m* x 10*m*
    - Pixel or grid cell -> field partition p_i
  - Identify extreme values for $|p_i.\alpha - f.\alpha|$ deviation

Future work

- Incorporate other types of information
  - E.g., rain distribution, soil type and/or morphology
- Collect and evaluate feedback
  - Visualization tools for farmers
- Intra-field to recommend explicit actions
- Monitor outliers over time
- Predictive analytics
  - Machine learning techniques

Questions ?