Crops as Time-Invariant Keypoints

Martijn Bos

Delft University of Technology

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Problem Description

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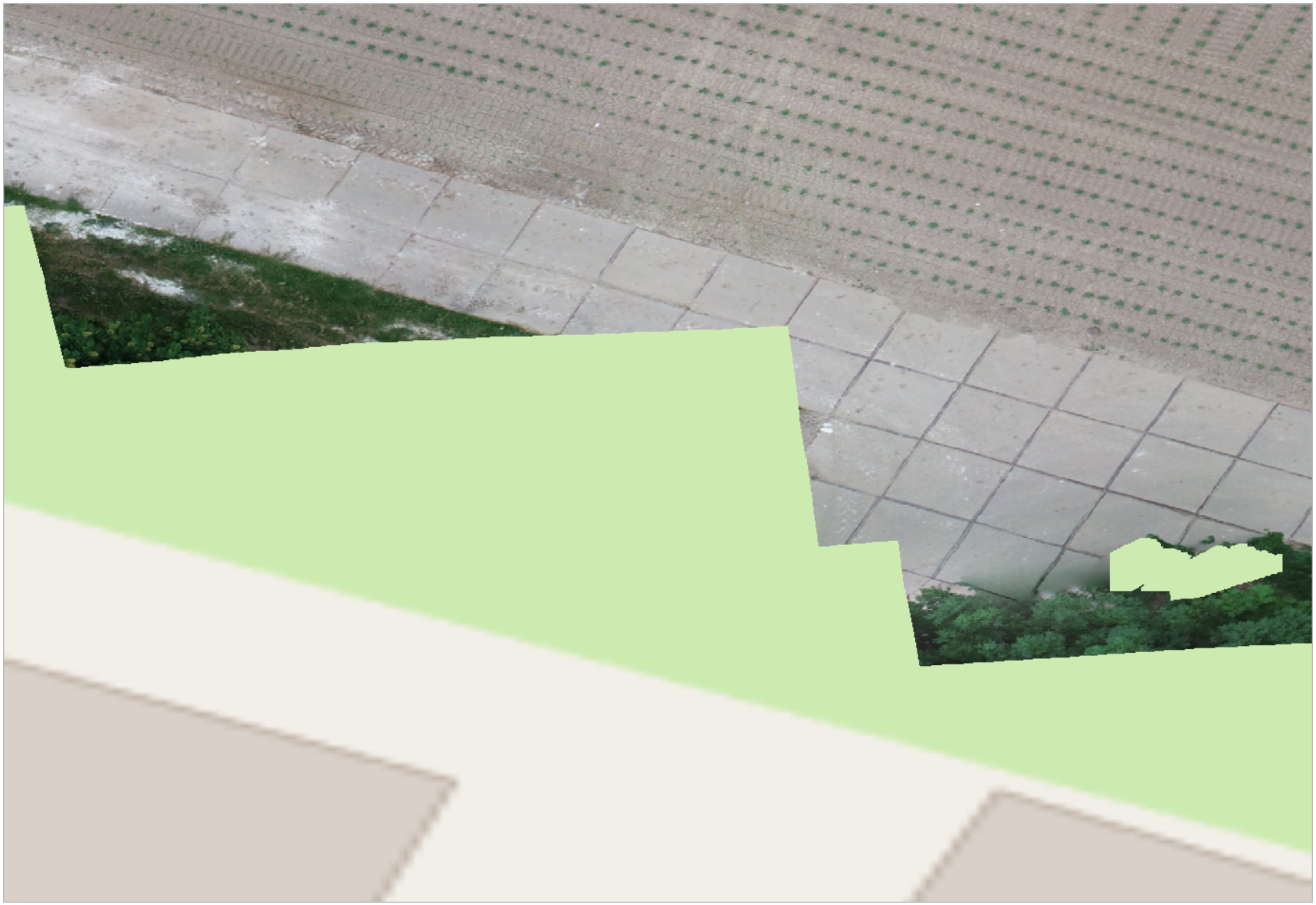

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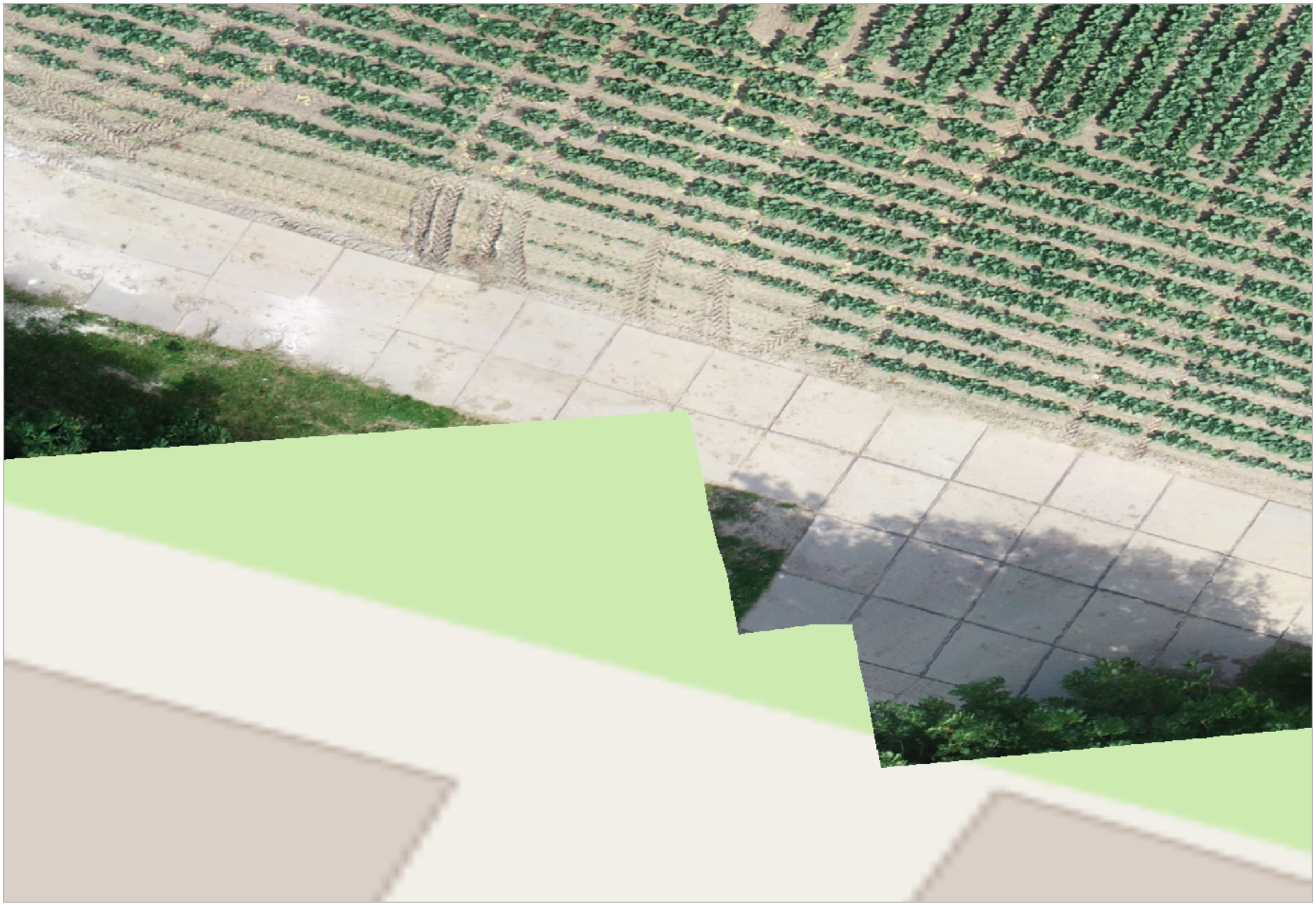


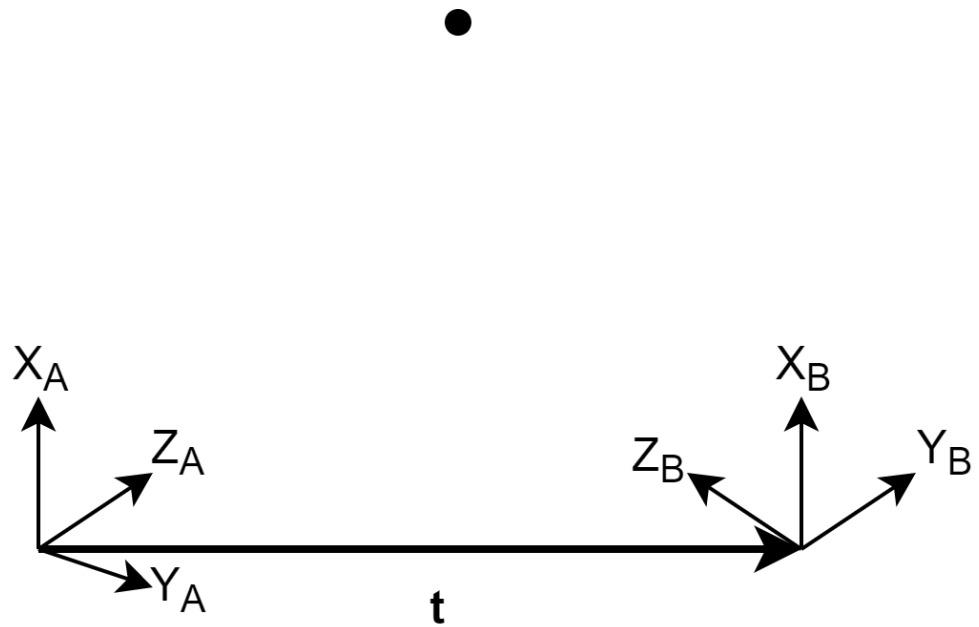
Overview

- 1. Aerial Images $\rightarrow$ Orthophoto (Framework, Literature)
- 2. Correcting Orthophotos (Suggested Method)
- 3. Preliminary Results & Future Work

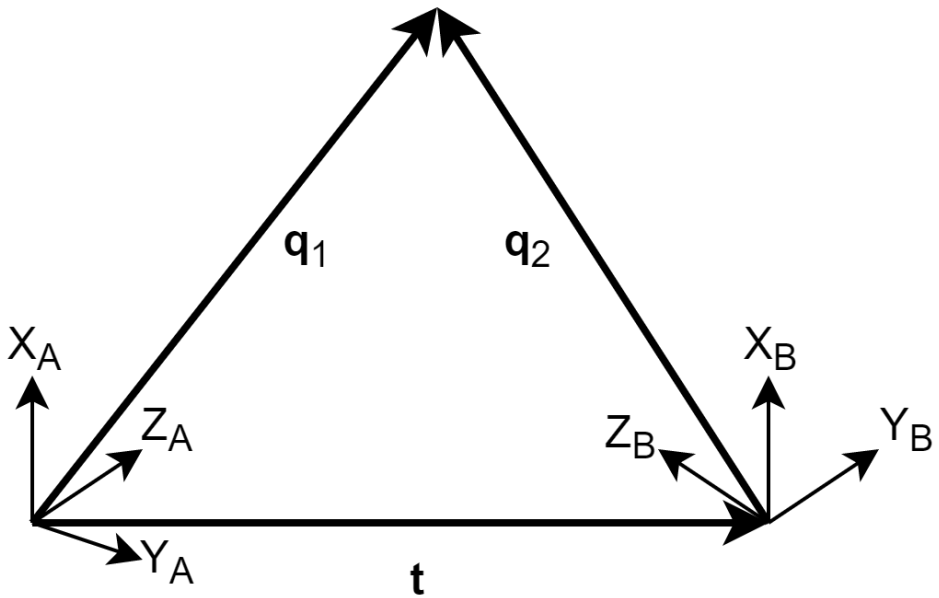
Framework

- When going from separate images to an orthophoto, a three-dimensional reconstruction is required.
- Crucial for doing so is the **Essential matrix**.

Framework - Essential Matrix



Framework - Essential Matrix



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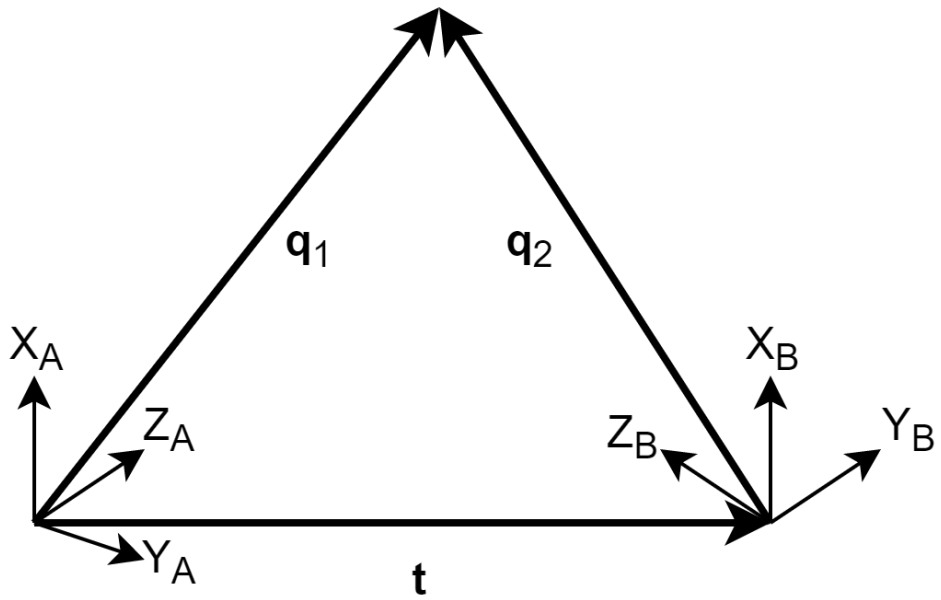

- $\boldsymbol{q}_1 \cdot \underbrace{\boldsymbol{t} \times R}_{E} \boldsymbol{q}_2 = 0$

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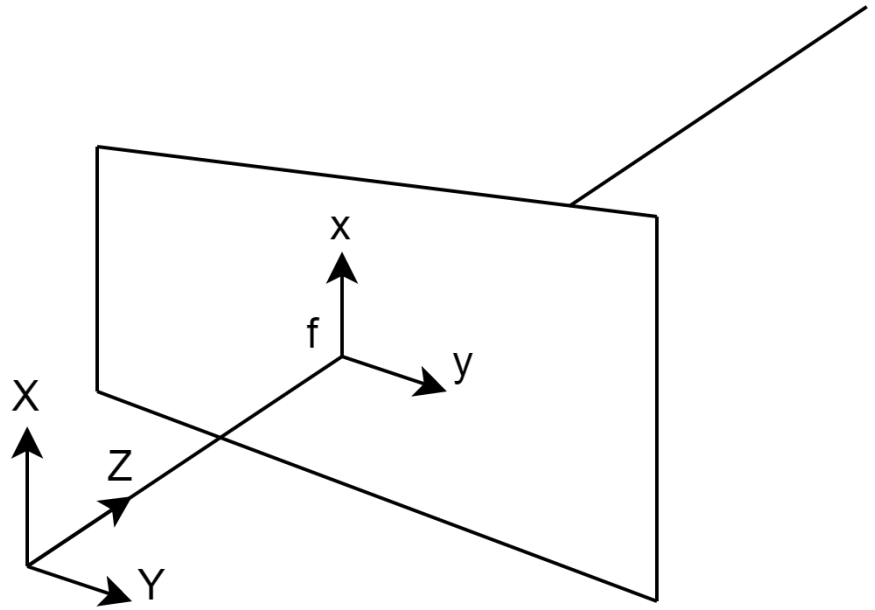

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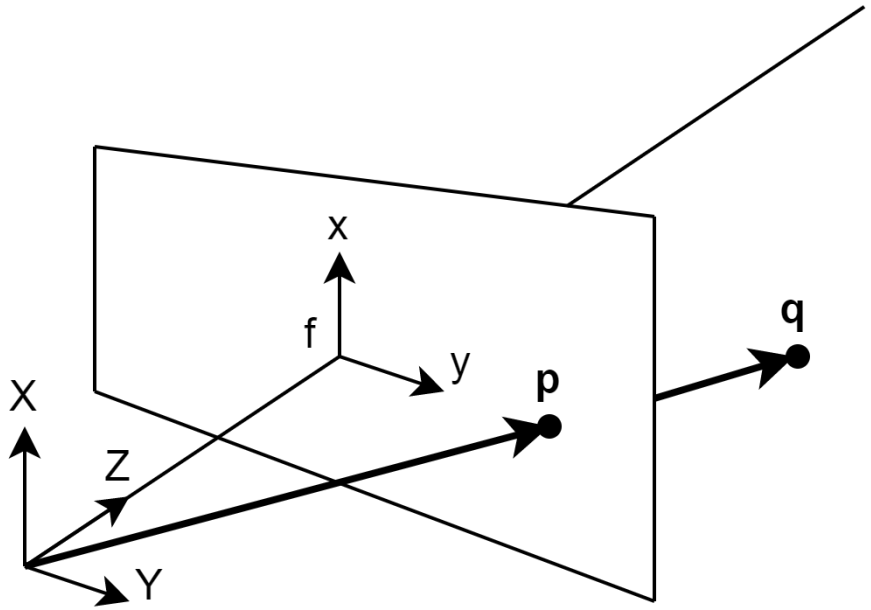

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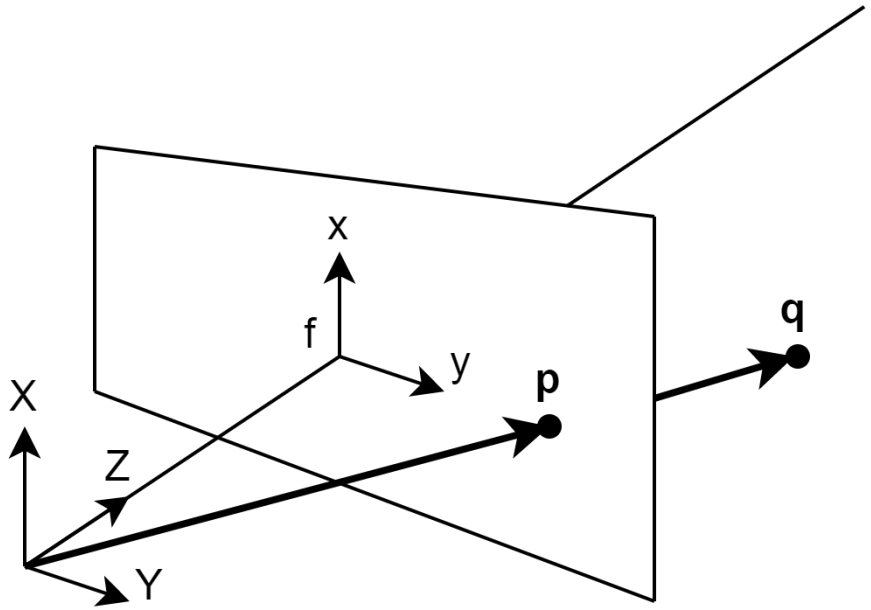

- $\boldsymbol{p} = \begin{bmatrix} p^x \\ p^y \\ 1 \end{bmatrix} = \frac{1}{q^Z} \begin{bmatrix} q^X \\ q^Y \\ q^Z \end{bmatrix} = \frac{1}{q^Z} \boldsymbol{q}$

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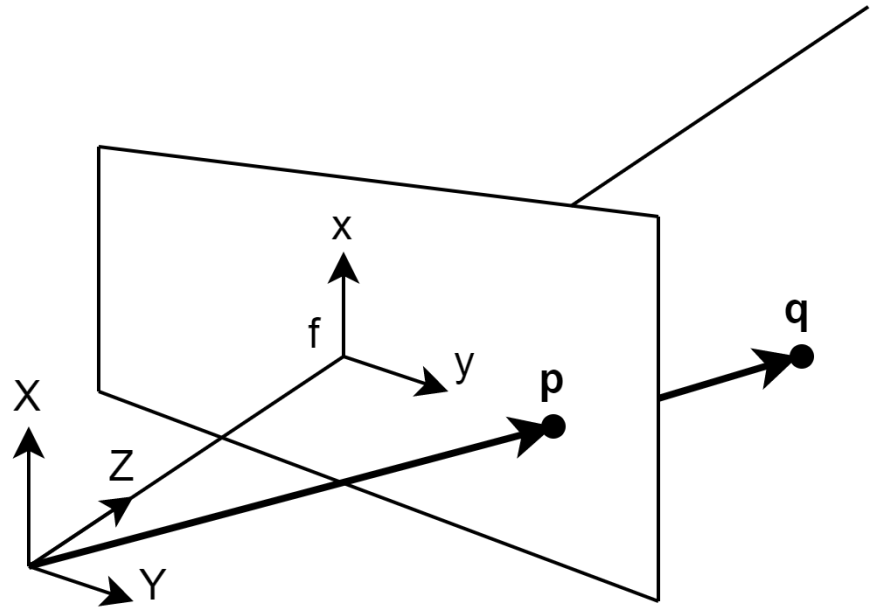

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- $\boldsymbol{q}_1^T E \boldsymbol{q}_2 = 0 \quad \Longrightarrow \quad \boldsymbol{p}_1^T E \boldsymbol{p}_2 = 0$

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- $\begin{bmatrix} p_1^x p_2^x & p_1^x p_2^y & \dots & p_2^y & 1 \end{bmatrix} \begin{bmatrix} E_{11} \\ \vdots \\ E_{33} \end{bmatrix} = 0$

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- $A\boldsymbol{x} = \mathbf{0}$
- "Eight-point problem"

Framework - Common Pipeline

I. **Keypoint Identification**
II. **Keypoint Matching**
III. **Filtering & Fitting E**
IV. Keypoint Triangulation
V. Dense Pointcloud
VI. Create Orthophoto

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- Extract keypoint locations $\boldsymbol{p}_i$.
- Describe each keypoint i in $\boldsymbol{f}_i$.

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- Candidate match for $i \in S^A$ is: $\iota = \arg\min_{\tau \in S^B} \|\boldsymbol{f}_i - \boldsymbol{f}_\tau\|$.
- Accept if: $\|\boldsymbol{f}_i - \boldsymbol{f}_\iota\| < C \min_{\kappa \in S^B \setminus \{\iota\}} \|\boldsymbol{f}_i - \boldsymbol{f}_\tau\|$, with $C \leq 1$.

Framework - Common Pipeline

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- Image pair with a set (> 8) matches ($\boldsymbol{p}_i \leftrightarrow \boldsymbol{p}_\iota$).
- Fit E using RANSAC (Random Sample Consensus):

1: **for** N iterations **do**
2: select eight random ($\boldsymbol{p}_i \leftrightarrow \boldsymbol{p}_\iota$) and determine $\tilde{E}$
3: count inliers that satisfy $(\boldsymbol{p}_i)^T \tilde{E} \boldsymbol{p}_\iota < \varepsilon$
4: **if** count $>$ best **then**
5: $E \leftarrow \tilde{E}$, best $\leftarrow$ count
6: **end if**
7: **end for**

Method

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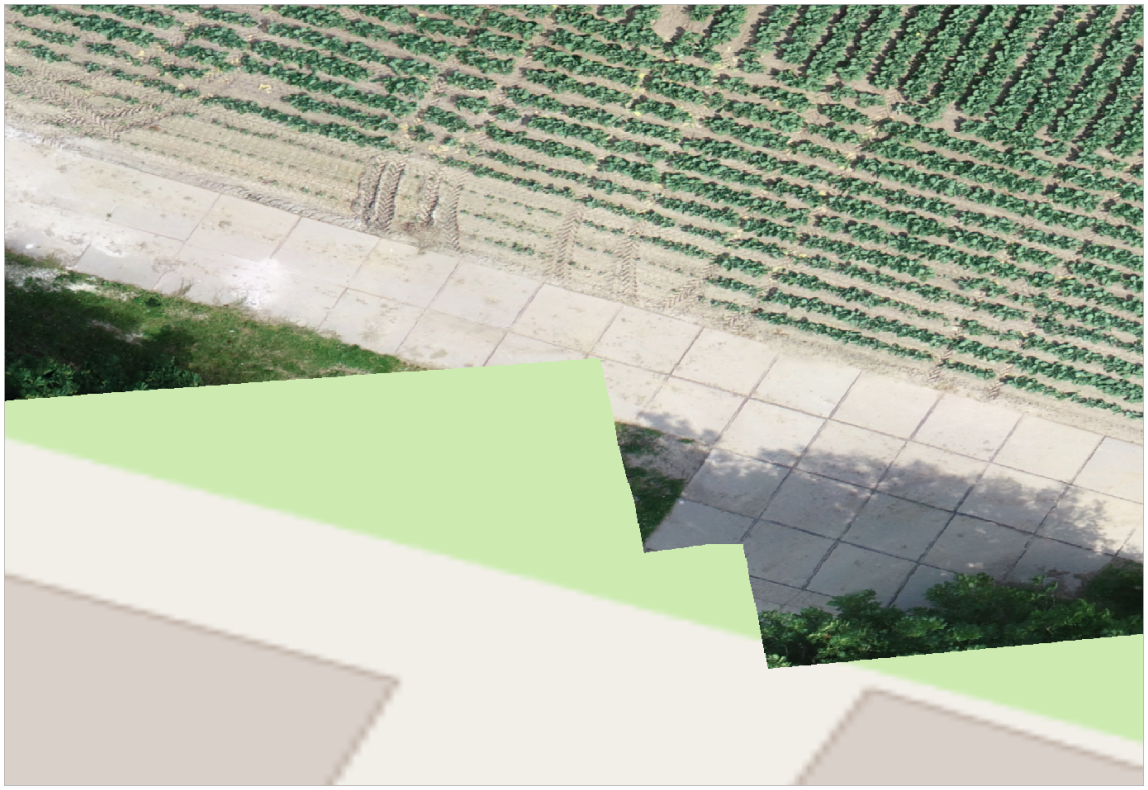

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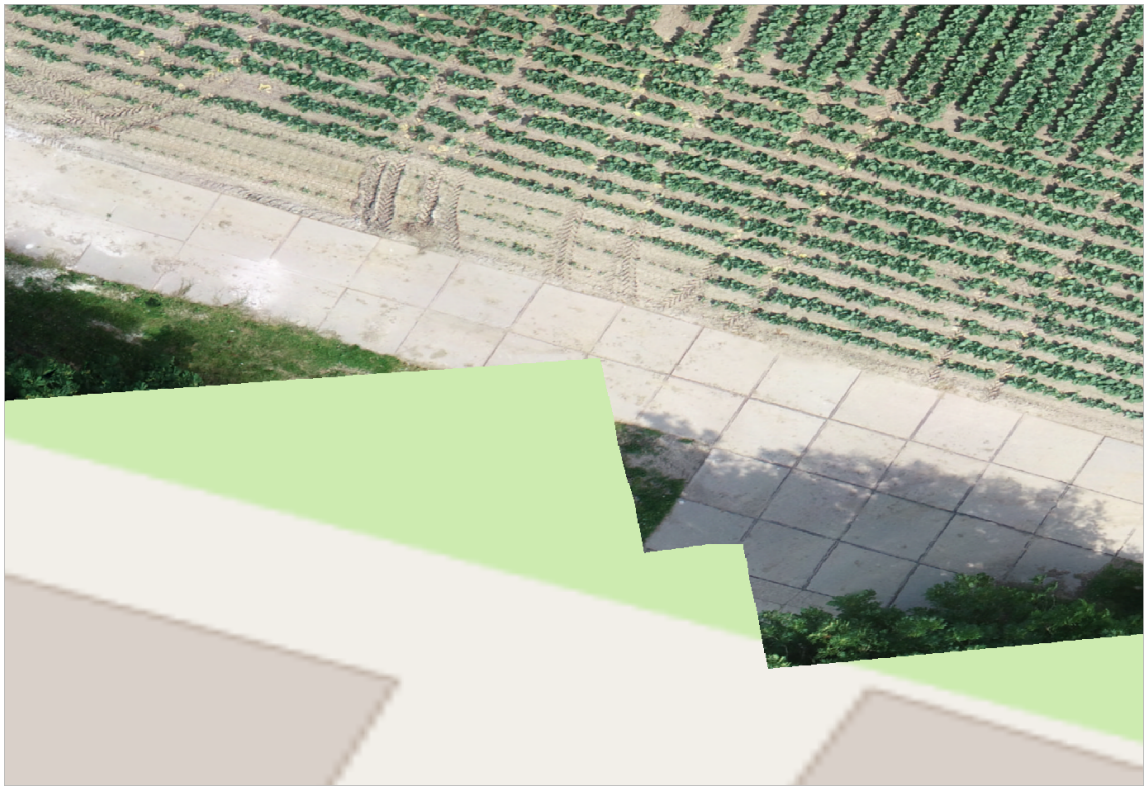

1. **Keypoint Identification** ← New way of extracting $\boldsymbol{p}_i$ and $\boldsymbol{f}_i$
2. **Keypoint Matching** ← Use in exact same way
3. **Filtering & Fitting E** ← Use in more or less same way

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- Crop parametrization:
  $\boldsymbol{r}(\xi, t) = r(\xi, t)\boldsymbol{n}(\xi) + \boldsymbol{c}, \qquad \boldsymbol{n} = \langle \cos\xi, \sin\xi \rangle$

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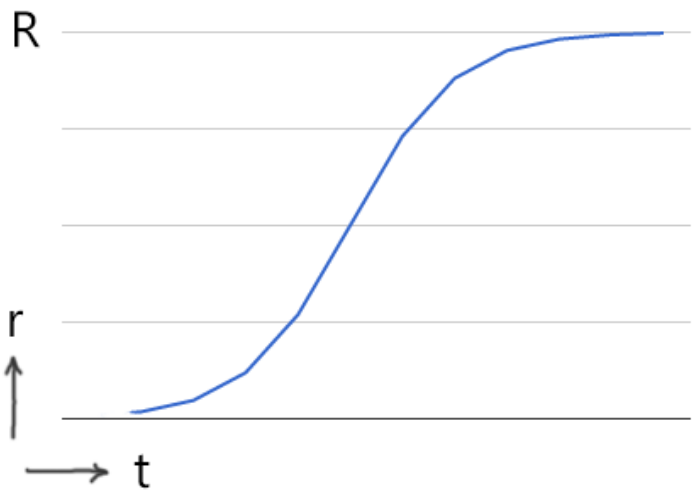
$$\frac{\partial r}{\partial t} = \alpha r \left(1 - \frac{r}{R}\right)$$



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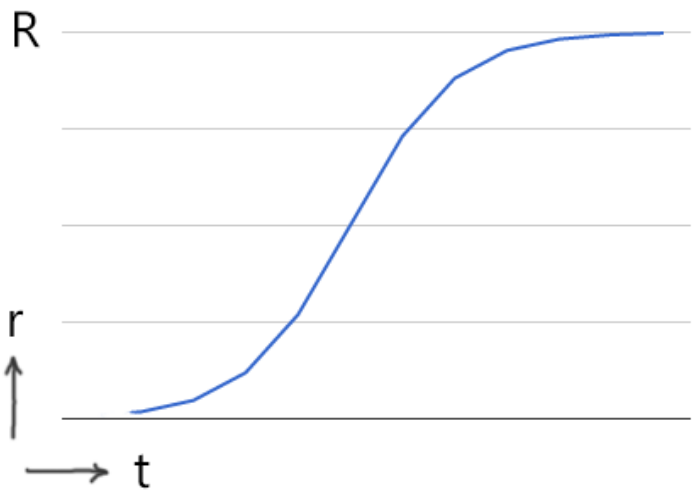

- Observe order preservation:
  $r_a(\xi_a, t_0) > r_b(\xi_b, t_0) \quad \Longrightarrow \quad r_a(\xi_a, t) > r_b(\xi_b, t) \quad$ for $t > t_0$

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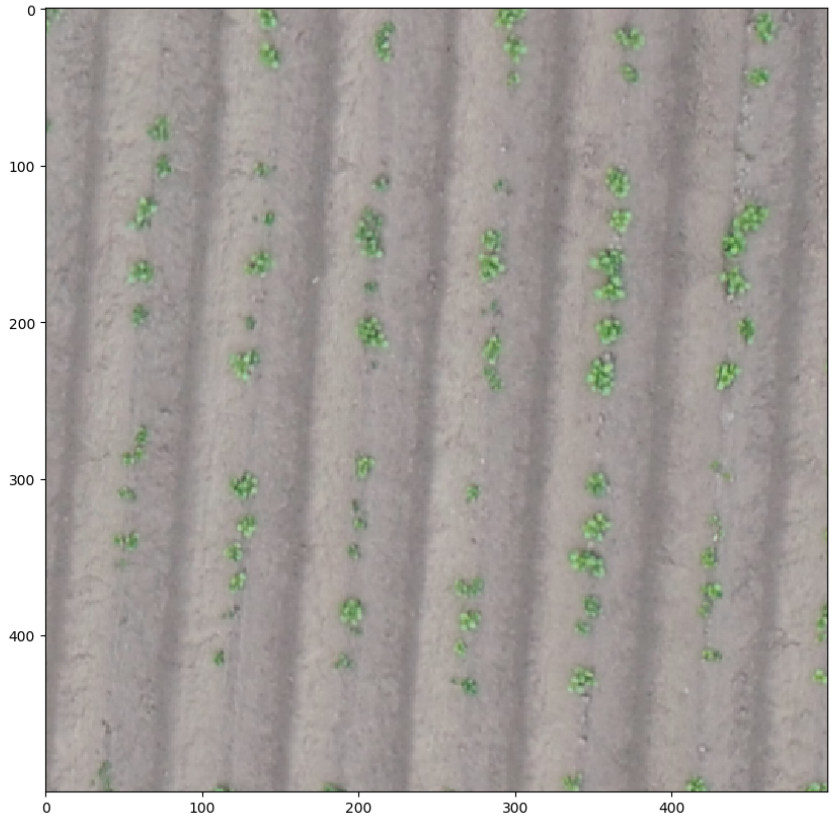
  - $f_{i,j} \leftarrow v \quad \text{if } l_v \leq f_{i,j} < l_v + 1$

Example



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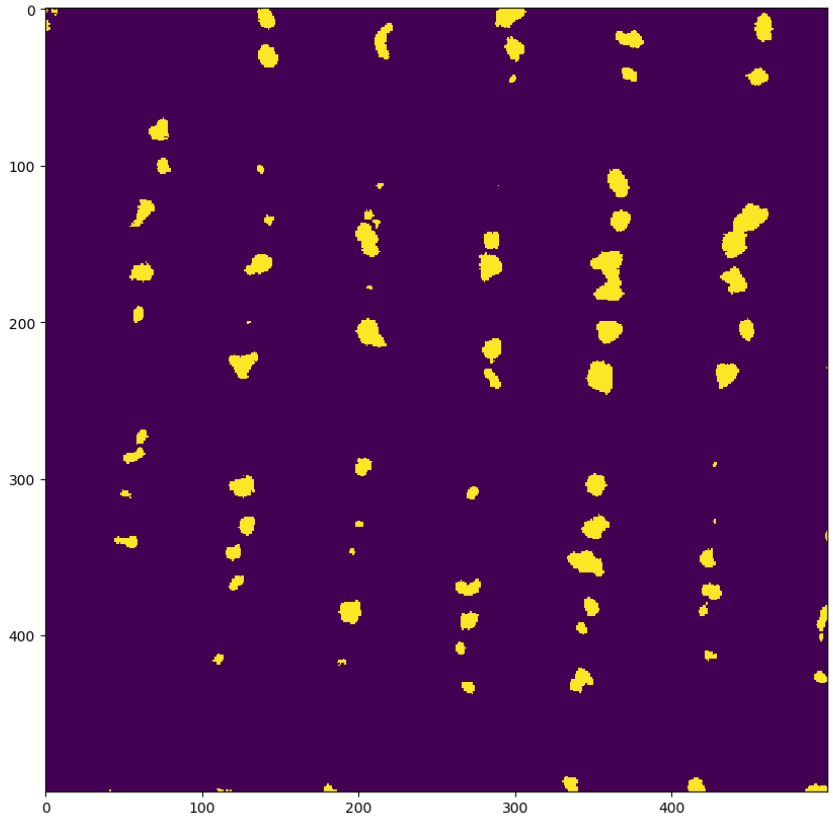

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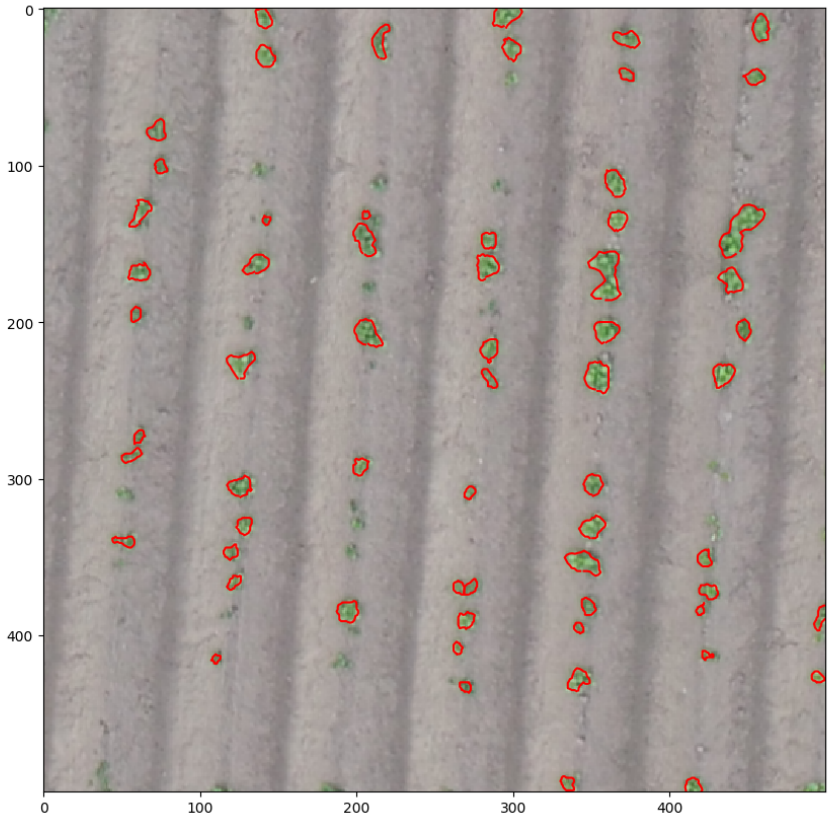

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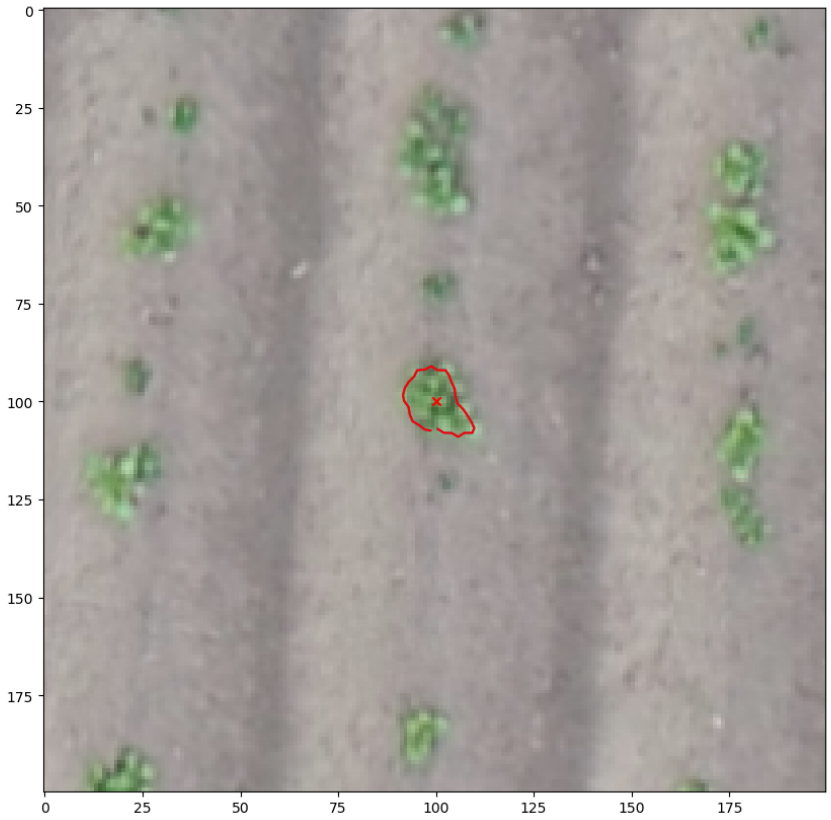

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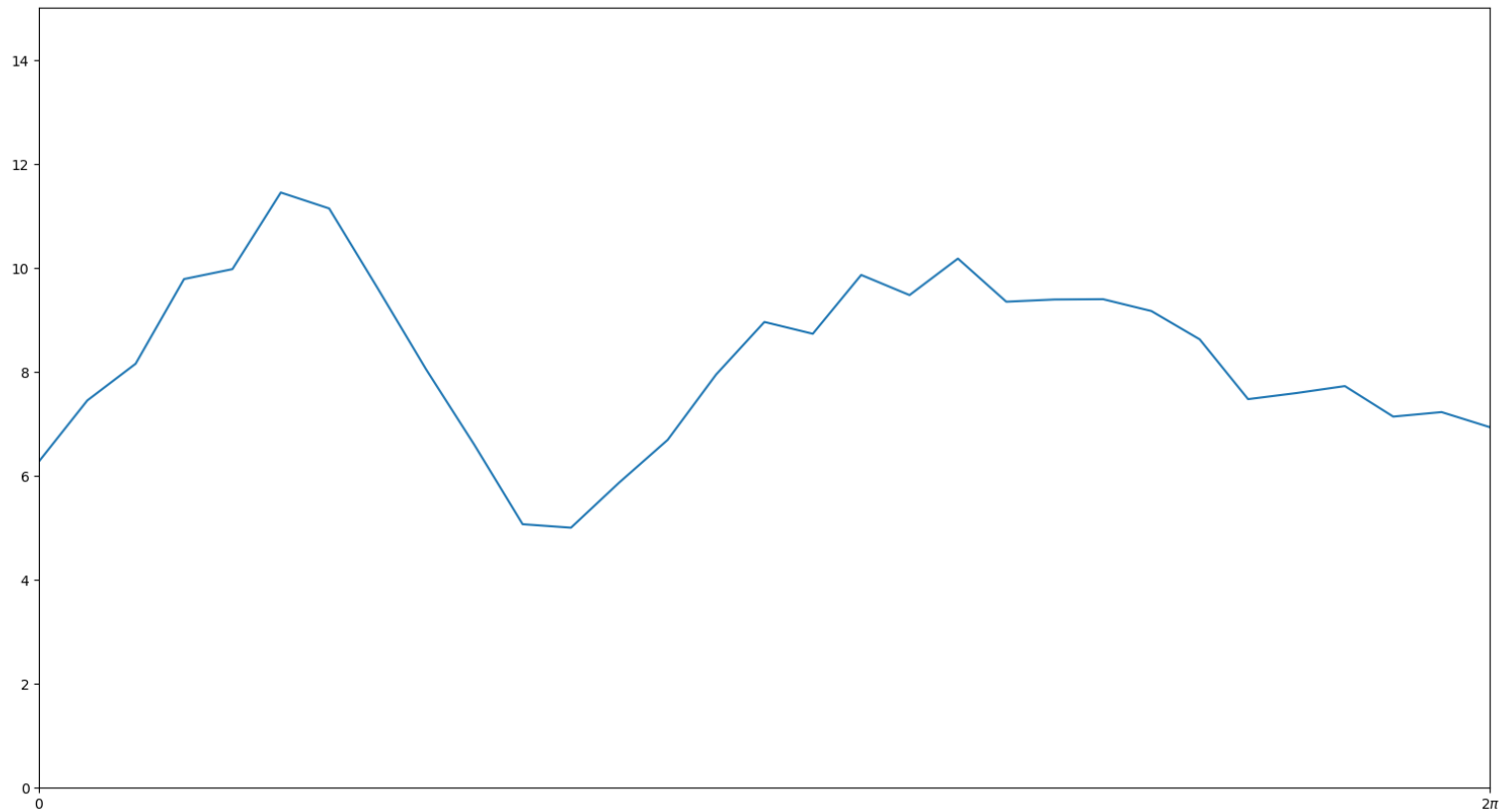

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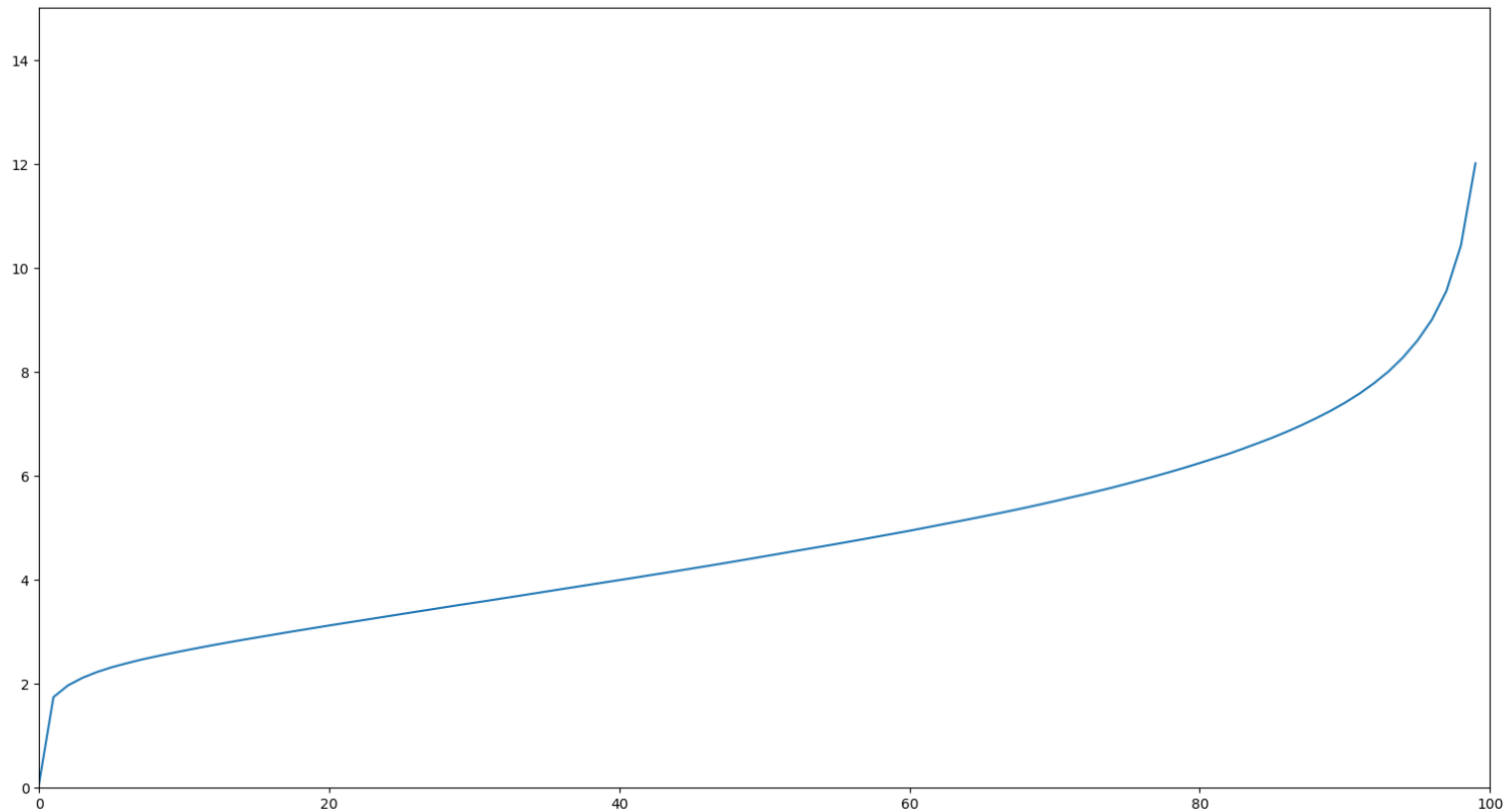

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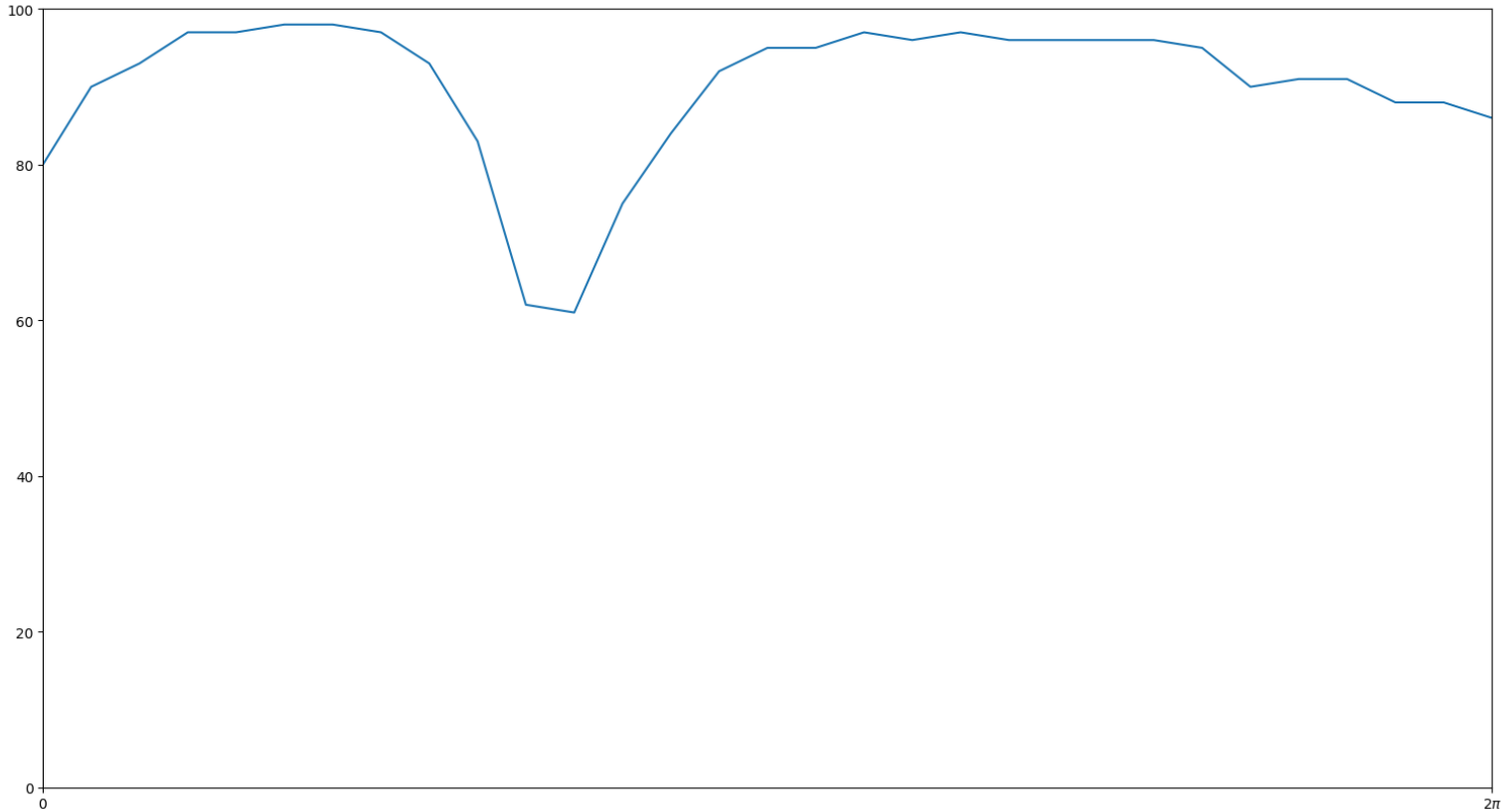
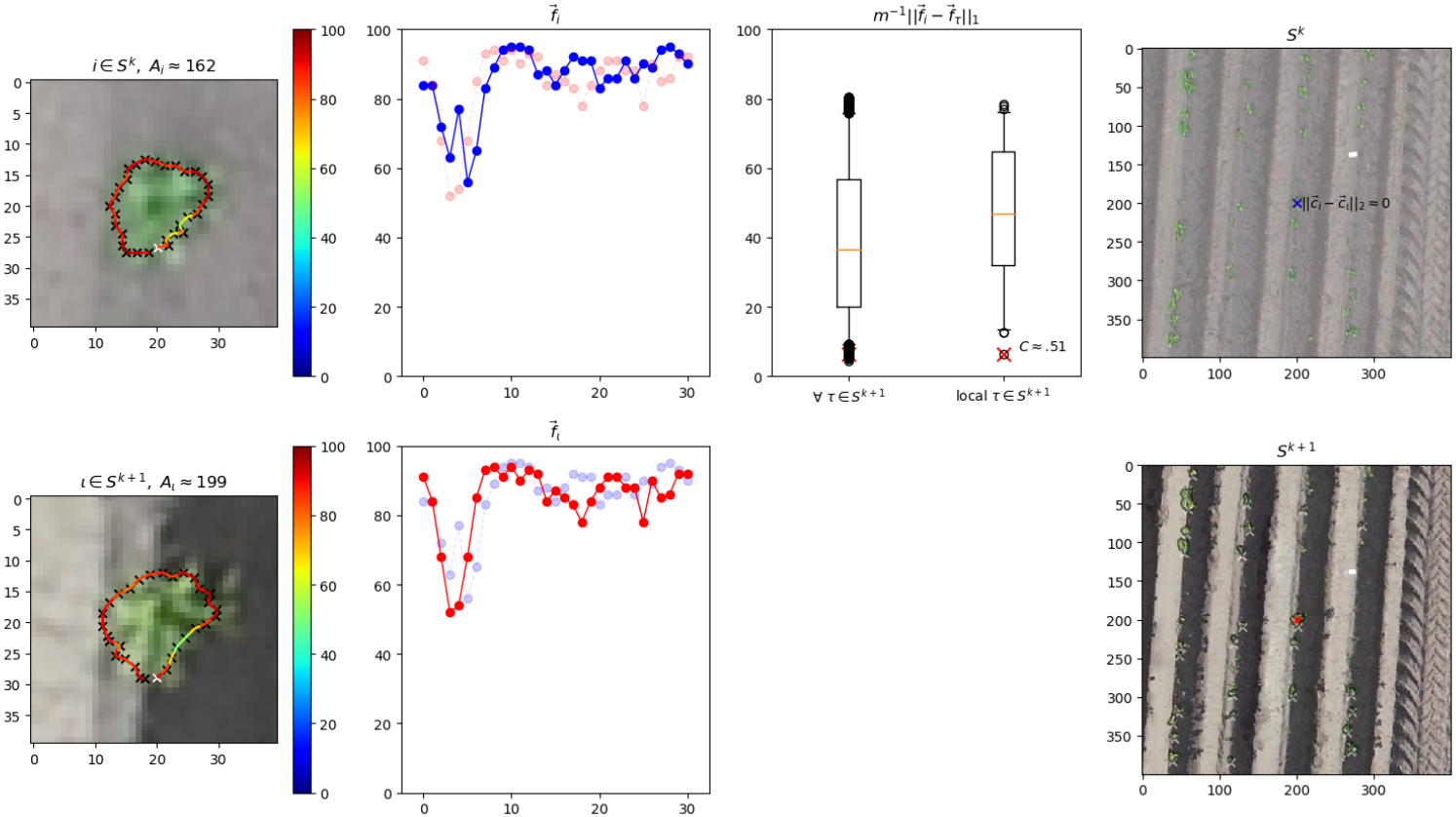


Preliminary Results



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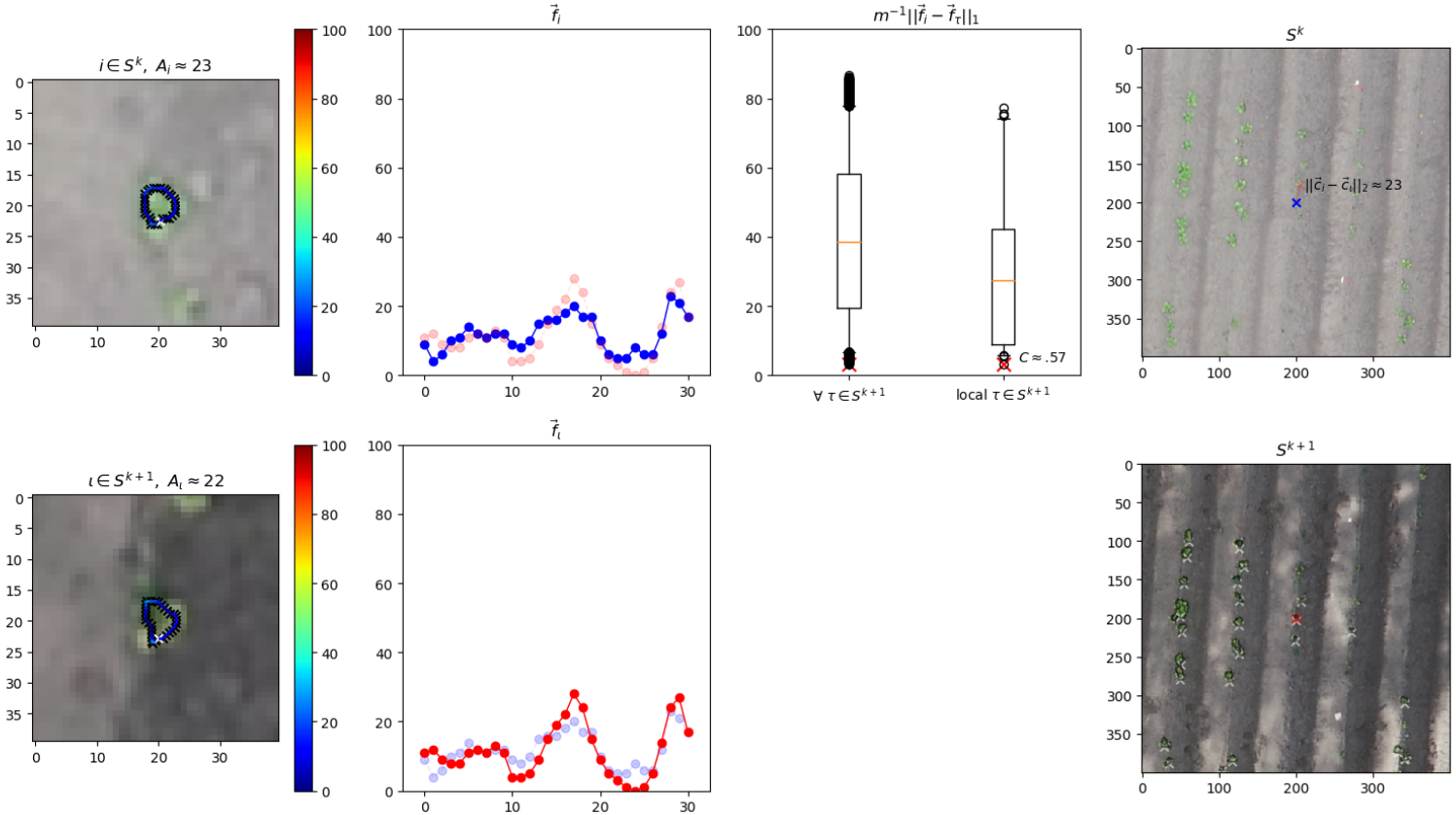

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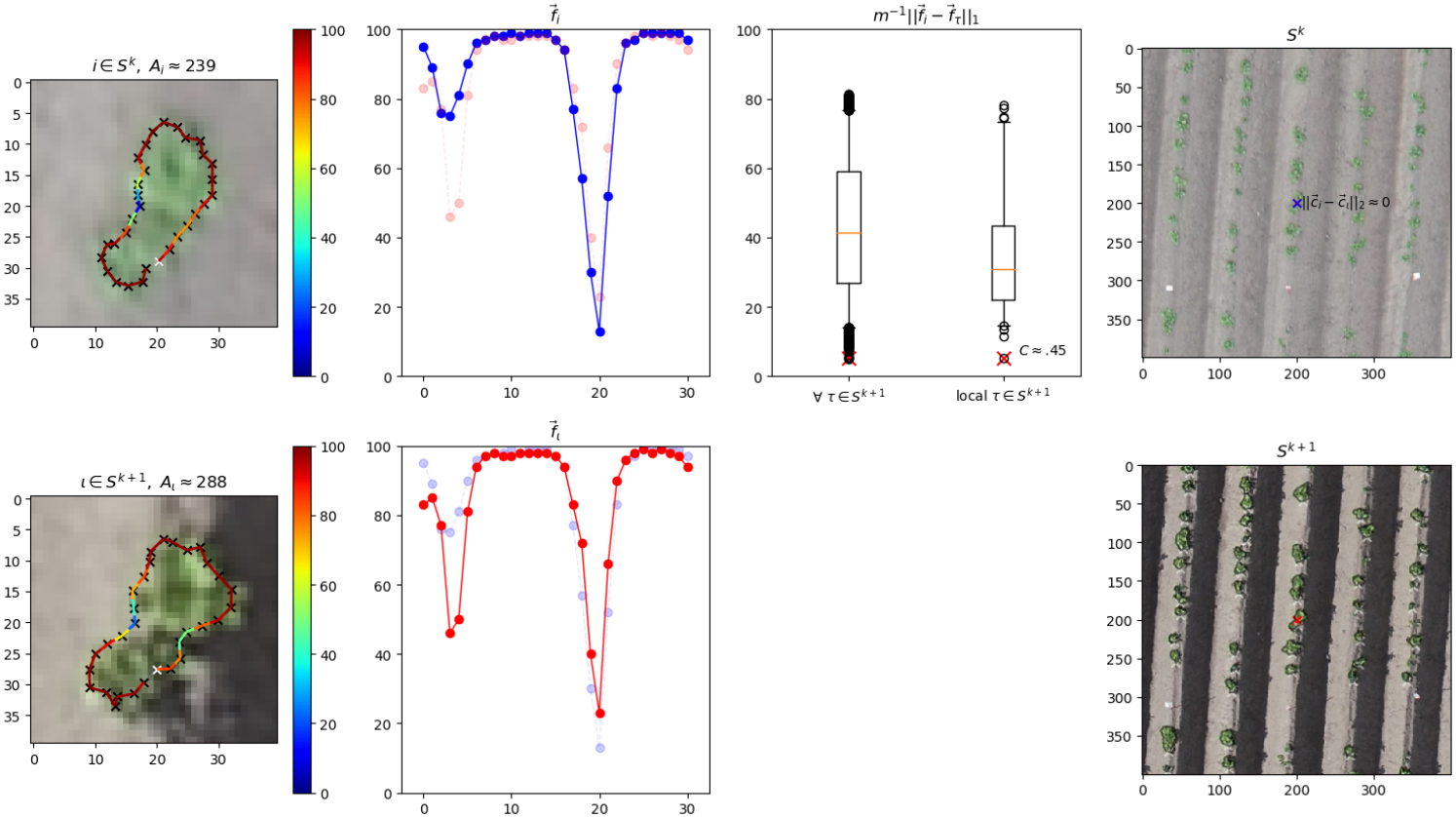

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- Testing effectiveness of method under various conditions and parameter settings.
- Extension of method for merging canopies, which would require extra preprocessing.