Multiple Plant Tracking for Precision Agriculture Applications

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Introduction

Motivation:

- The steadily increasing global population.
- The decreasing availability of agricultural workers.
- **Fertigation** and **yield prediction** are critical tasks in agriculture.
- Plants and fruits should be **sprayed or counted exactly once**.

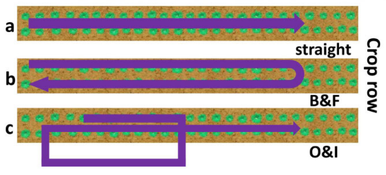
Context:

- The use of agricultural robots is still under-explored.
- Great part of the perception systems rely on computer vision.
- Modern computer vision makes use of deep learning models.
- Tracking in agricultural scenarios imposes additional challenges such as homogeneity of objects.

Case Study Dataset

LettuceMOT [1]

- Sequences: 8
- Navigation types: 3
- Instances: 707
- Frames: 5466
- Annotations: 42735



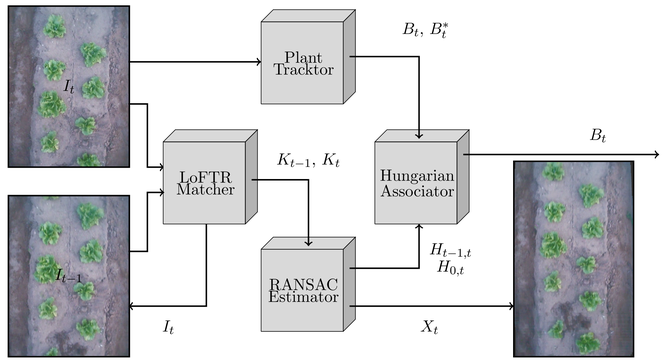
Baseline & Experiments

LettuceMOT [1]: Training with **straight1** and **straight3**. Testing on the remaining sequences.

LettuceTrack [2]: Training with **straight3** and **straight4**. Testing on the remaining sequences.

Approach

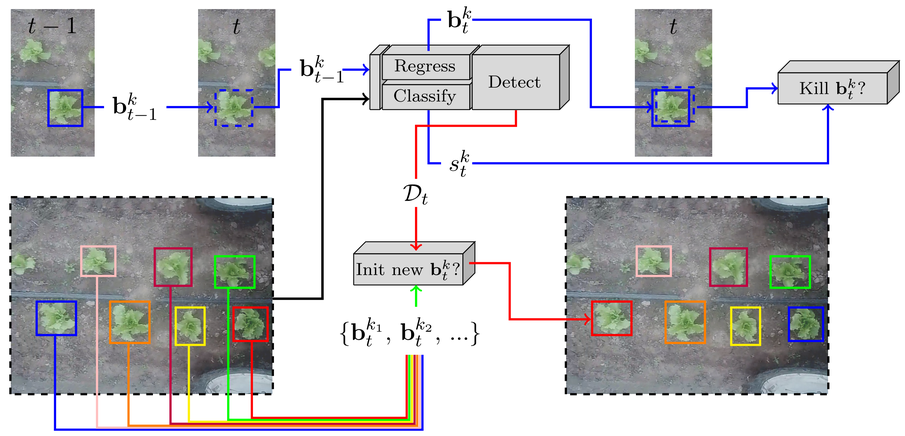
Global framework: Improved Tracktor [3] + spatial association module.



Definitions:

Name	Description
I_t	frame at time t
K_t	keypoints found for frame at time t
B_t	bounding boxes for active tracks at time t
B_t^*	bounding boxes for potential new tracks at time t
X_t	global camera position at time t
$H_{u,v}$	transformation between camera positions at u and v
$\mathbf{b}_t^k$	bounding box for track k at time t
s_t^k	confidence scores for track k at time t
$\mathcal{D}_t$	set of detections at time t

Plant Tracktor: Tracking by detection inspired in [3] adapted for plant tracking.



Quantitative Results

Dataset	Method	HOTA	IDF1	Dataset	Method	HOTA	IDF1
B&F1	LettuceTrack [2]	76.81	85.3	B&F2	LettuceTrack [2]	70.32	81.9
	Ours	**98.1**	**98.6**		Ours	**98.1**	**98.4**
O&I1	Best in LettuceMOT [1]	65.6	58.7	O&I2	Best in LettuceMOT [1]	52.9	46.2
	Ours	**74.11**	**61.3**		Ours	**72.6**	**58.1**
straight1	Best in LettuceMOT [1]	80.0	94.0	straight3	-	-	-
	Ours	**98.5**	**98.7**		Ours	**98.2**	**98.6**
straight2	Best in LettuceMOT [1]	87.2	94.7	straight4	Best in LettuceMOT [1]	84.4	92.7
	Ours	**98.2**	**98.5**		Ours	**97.1**	**95.5**

Qualitative Illustration

Leveraging spatial relationship amongst plants:

Conclusions

- The tracking-by-detection paradigm is well-suited for related agricultural tracking problems.
- The novel method for spatial association improves tracking performance as long as at least one object remains visible to the camera.
- The tracking paradigm offers a framework to convert detection datasets into tracking datasets.

References

[1] N. Hu, S. Wang, X. Wang, Y. Cai, D. Su, P. Nyamsuren, Y. Qiao, Y. Jiang, B. Hai, and H. Wei, "LettuceMOT: A dataset of lettuce detection and tracking with re-identification of re-occurred plants for agricultural robots," *Frontiers in Plant Science*, vol. 13, 2022.

[2] N. Hu, D. Su, S. Wang, P. Nyamsuren, Y. Qiao, Y. Jiang, and Y. Cai, "LettuceTrack: Detection and tracking of lettuce for robotic precision spray in agriculture," *Frontiers in Plant Science*, vol. 13, 2022.

[3] P. Bergmann, T. Meinhardt, and L. Leal-Taixe, "Tracking without bells and whistles," in *IEEE/CVF International Conference on Computer Vision*, pp. 941–951, 2019.