Remote Sensing Technology
TUM Department of Civil, Geo and Environmental Engineering
Technical University of Munich

Early Classification for Agricultural Monitoring from Satellite Time Series

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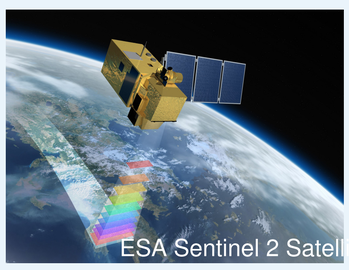
Objective

Satellite Data

$\boldsymbol{X} = (\boldsymbol{x}_0, \boldsymbol{x}_1, \ldots, \boldsymbol{x}_T)$



- collected at regular temporal intervals of 2-3 days
- measurements of 13 spectral bands
- data available globalls

Early Classification Model

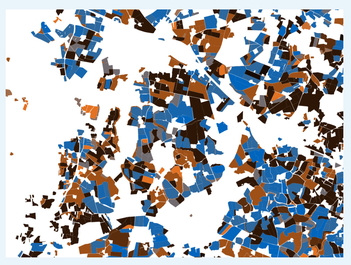
$\hat{\boldsymbol{y}}_t, p_t = f(\boldsymbol{X}_{\to t})$

$\boldsymbol{X}_{\to t}$ observation until t
$\hat{\boldsymbol{y}}_t$ class prediction scores
p_t probability of stopping.

Classifying a satellite time series **accurately** as **early** as possible

Crop Type Labels

$\boldsymbol{y} = (y_{\text{corn}}, y_{\text{barley}}, \ldots) \in \mathbb{R}^{13}$

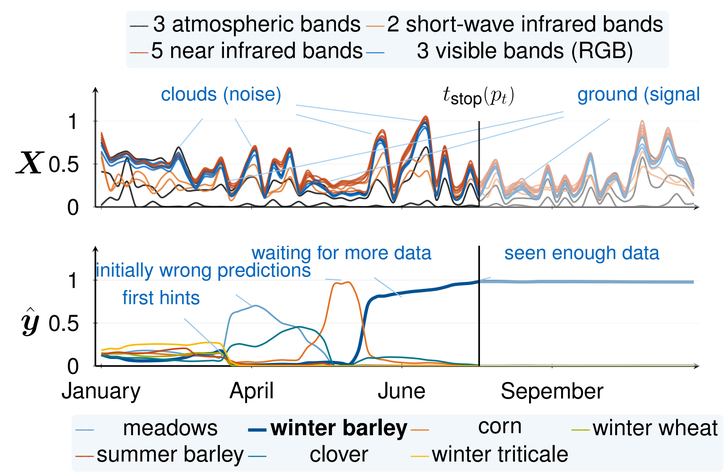


crop type labels

- European Common Agricultural Policy (CAP)
- collected yearly in entire Europe

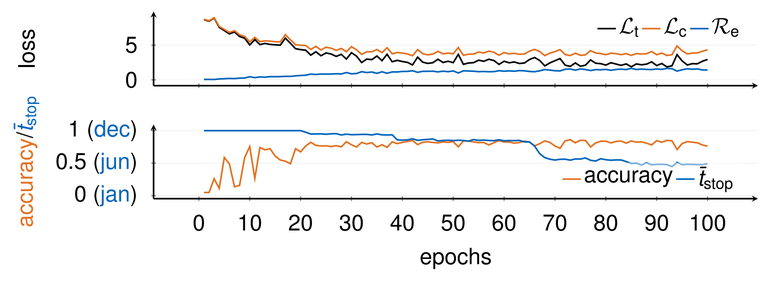
Results

Qualitative Example
Single example showing reflectance data $\boldsymbol{X}$ and predictions $\hat{\boldsymbol{y}}$ along with the stopping time $t_{\text{stop}} \sim \text{Ber}(p_t)$.



Losses during Training

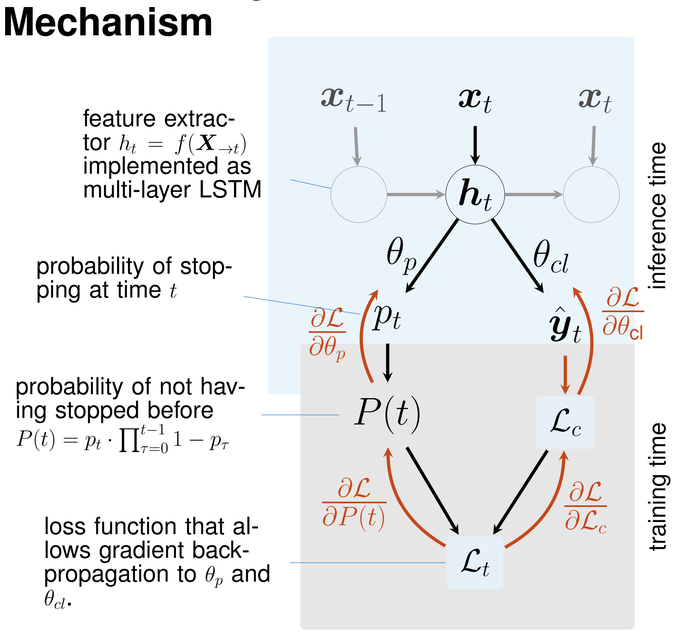
The combined loss L_t, as well as earliness L_e and accuracy L_e losses during training.



Method

Based on previous work (Rußwurm et al., 2019) applied to crop type mapping from remote sensing data.

Mechanism



Loss function

composite loss function

$$\mathcal{L}(\boldsymbol{x}, \boldsymbol{y}) = \sum_{t=0}^{T} P(t; \delta_{\to t}) \mathcal{L}_t(\boldsymbol{X}_{\to t}, \boldsymbol{y})$$

A Loss function including accuracy and earliness

Classification Loss — Earliness Reward

$$\mathcal{L}_t(\boldsymbol{X}_{\to t}, \boldsymbol{y}) = \alpha \mathcal{L}_c(\boldsymbol{X}_{\to t}, \boldsymbol{y}) - (1-\alpha)\mathcal{R}_e(t, \hat{y}_t^+)$$

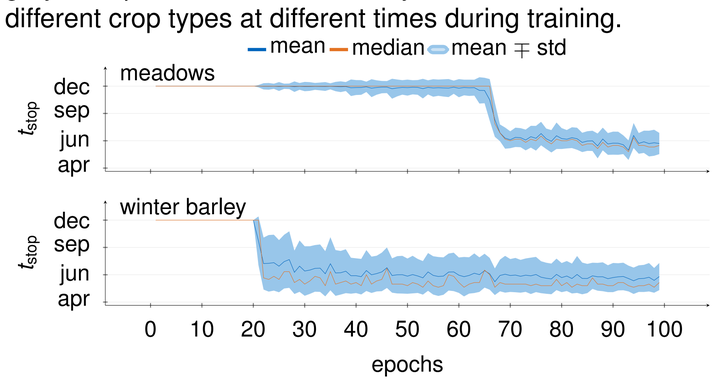
$\mathcal{L}_c = -\log(\hat{y}_t^+)$
cross entropy loss for accurate classifications

$\mathcal{R}_e(t, \hat{y}_t^+) = \hat{y}_t^+ \left(1 - \frac{t}{T}\right)$
reduces loss for earlier classifications $1 - \frac{t}{T}$ if the correct class $\hat{y}_t^+$ has been predicted

Rußwurm, M., Lefèvre, S., Courty, N., Emonet, R., Körner, M., and Tavenard, R. End-to-end learning for early classification of time series. arXiv preprint arXiv:1901.10681, 2019.

Stopping Condition Parameterization

Stopping times throughout the training grouped by crop category. The parameterization of early classification is learned for different crop types at different times during training.



Balancing Earliness and Accuracy

Evaluting the effect of the trade-off parameter α on the accuracy and earliness (t_{stop}). Runs repeated three times to evaluated the sability of the results.

α	accuracy	$\bar{t}_{\text{stop}}$	precision	recall	f_1	κ
.0	.25 ± .22	.10 ± .17	.19 ± .20	.25 ± .17	.16 ± .20	.12 ± .19
.2	.81 ± .03	.40 ± .02	.70 ± .01	.74 ± .01	.71 ± .01	.71 ± .04
.4	.80 ± .09	.47 ± .03	.71 ± .02	.74 ± .01	.71 ± .02	.71 ± .10
.6	.85 ± .02	.88 ± .07	.73 ± .04	.74 ± .03	.73 ± .03	.77 ± .03
.8	.84 ± .01	.93 ± .05	.72 ± .02	.75 ± .01	.73 ± .02	.76 ± .02
1.0	.83 ± .03	1.00 ± .00	.72 ± .03	.75 ± .01	.72 ± .03	.75 ± .04

Application

Agriculture

Early Crop Detection
- early assessment of cultivated crops
- basis for early crop yield estimation

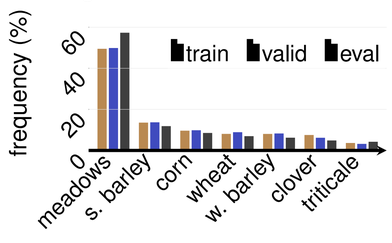
Extraction of Crop Phenology
- extraction of vegetation specific events
- monitoring time of classification
- regional or temporal variations

Generalization
- end-to-end trainable
- applicable globally
- no region-specific expert knowledge

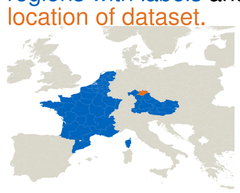
Dataset and Area of Interest

Hollfeld region Bavaria
- 49k field parcels
- 6 main crop types
- covering 40km by 30 km
- central Germany

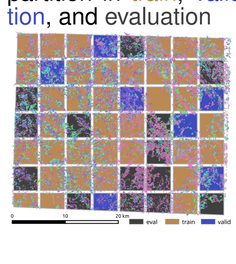
Challenge: Class imbalance



regions with labels and location of dataset.

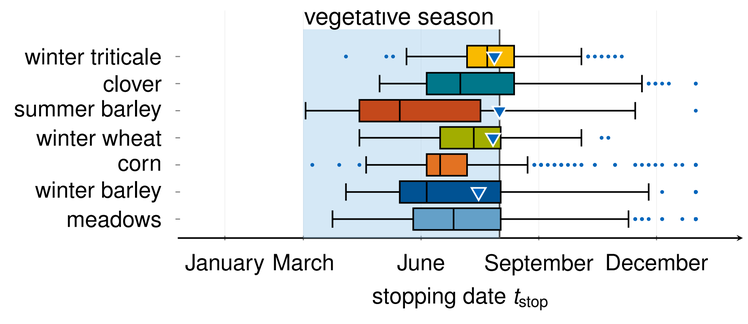


partition in train, validation, and evaluation



Extracting Vegetation Characteristics

Stopping time per crop category reveals characteristic variations in type of vegetation confirmed by date of harvest (▼) from local authorities.



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Data & Code
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https://twitter.com/MarcCoru
www.lmf.bgu.tum.de/vision