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

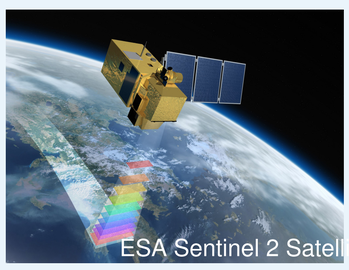
Early Classification for Agricultural Monitoring from Satellite Time Series

Marc Rußwurm[1], Romain Tavenard[2], Sébastien Lefèvre[2], Marco Körner[1]

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

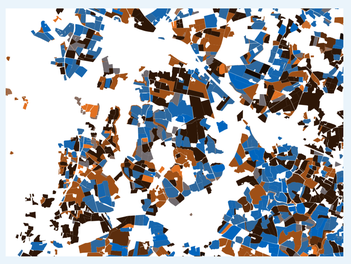
Early Classification Model

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

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

Crop Type Labels

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

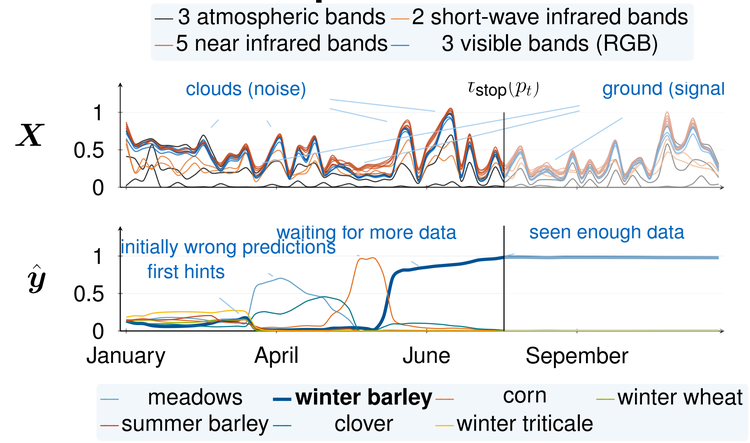


crop type labels

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

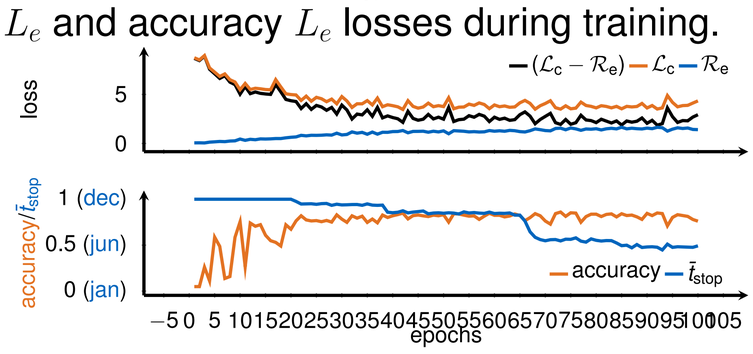
Results

Qualitative Example



Losses during Training

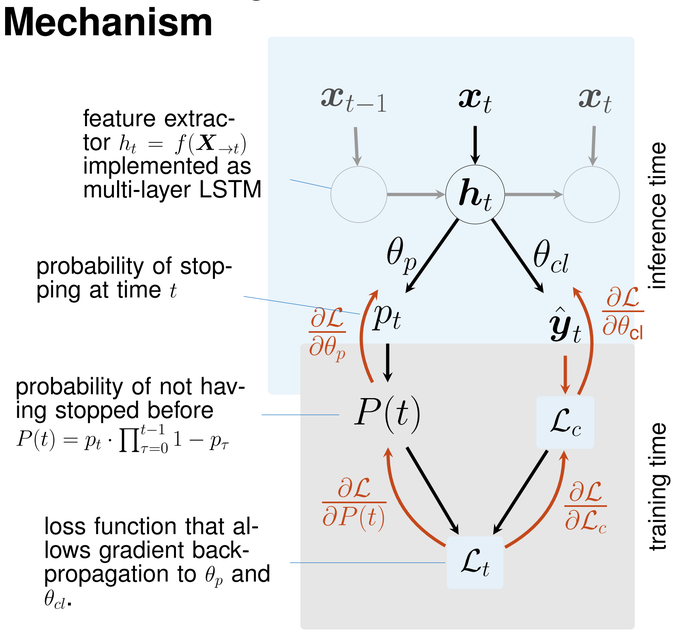
The combined loss L_t, as well as earliness L_e and accuracy L_e losses during training.



Method

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

Mechanism



feature extractor $h_t = f(\boldsymbol{X}_{\rightarrow t})$ implemented as multi-layer LSTM

probability of stopping at time t

probability of not having stopped before $P(t) = p_t \cdot \prod_{\tau=0}^{t-1} 1 - p_\tau$

loss function that allows gradient backpropagation to θ_p and θ_{cl}.

Loss function

composite loss function

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

A Loss function including accuracy and earliness

Classification Loss — Earliness Reward

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

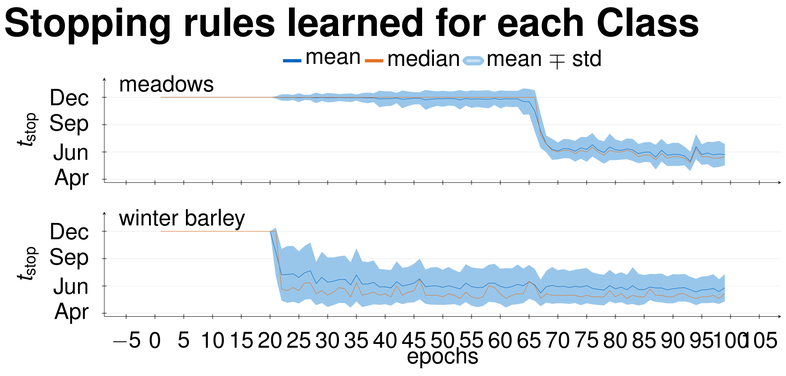
$$\mathcal{L}_c = -\log(\hat{y}_t^+)$$

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 with a high score

Stopping rules learned for each Class



Balancing Earliness and Accuracy

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

experiments varying the trade-off factor α and observing the achieved earliness and accuracy.

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.

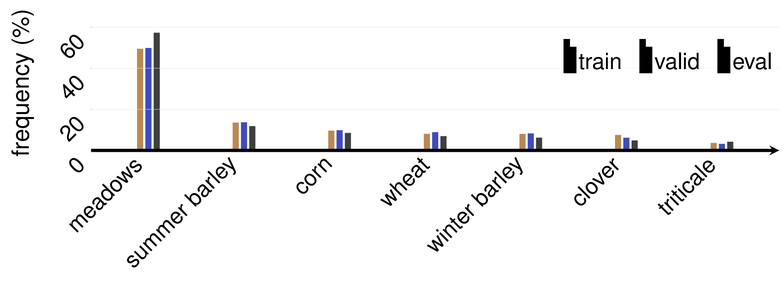
Application

Agriculture

- early assessment of cultivated crops
- completely end-to-end trainable
- can be applied globally without region-specific expert knowledge
- basis for early crop yield estimation
- method generalizes to other time series applications

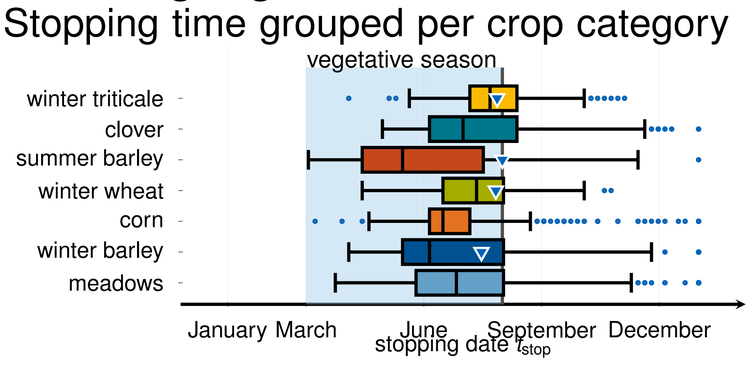
Dataset and Area of Interest

49 000 field parcels of 6 main crop types covering 40 by 30 kilometer in central Germany.



Extracting Vegetation Characteristics

Stopping time grouped per crop category



Technical University of Munich[1]
TUM Department of Civil, Geo and Env. Engineering
Remote Sensing Technology
Arcisstr. 21, 80333 Munich, Germany

IRISA-Obelix[2]
Université Bretagne Sud
IRISA, UMR 6074 CNRS
Campus de Tohannic, 56000 Vannes, France

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