Wheat yield estimation based on analysis of UAV images at low altitude

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DNA sequencing technologies

1960s

1965 - Marshall Nirenberg

2018

Motivation and purpose

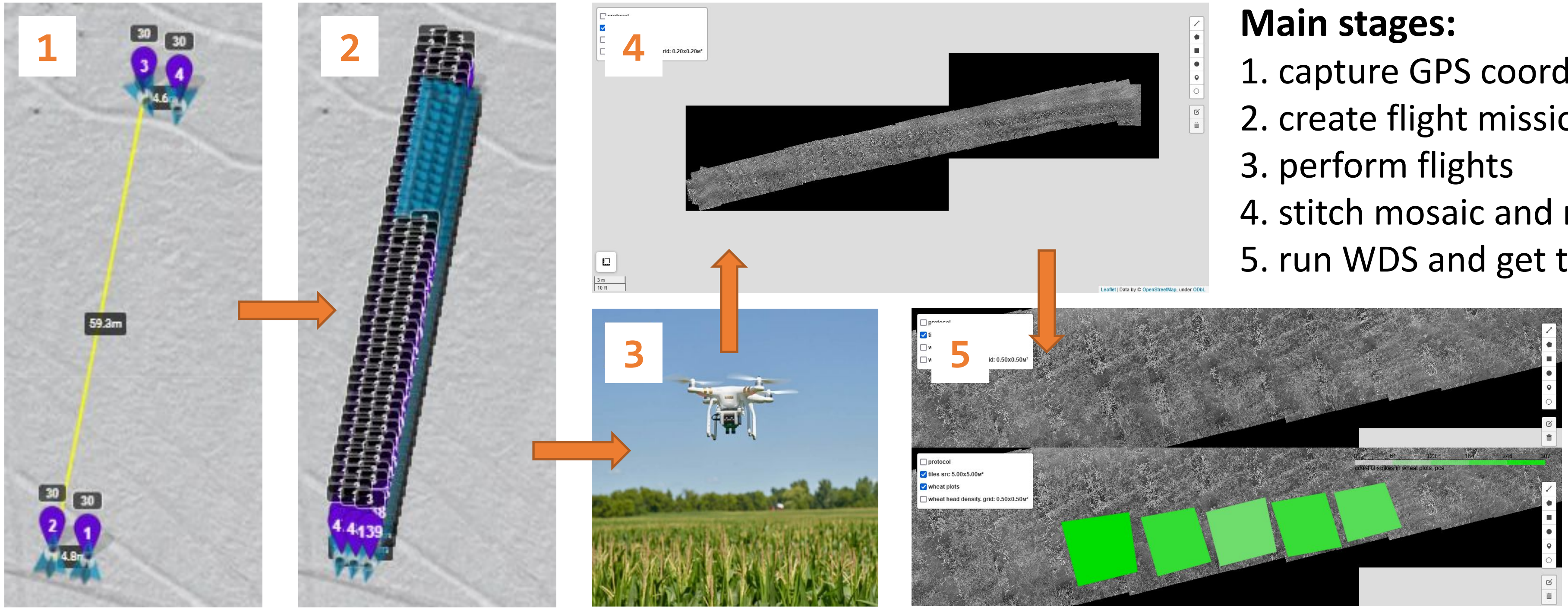
Protocols for manually counting the density of ears in crops have been the only way to estimate yields for a long time. However, this method is labour-intensive and time-consuming. An alternative is the development of automated systems operating in the field. Most of such systems allow to obtain 2D images of crops and use computer vision methods for their automatic processing, in particular, for counting ears in the image. Modern methods of image analysis based on neural network algorithms and deep learning allow ears identification on the image of crops and counting their number with high accuracy. The use of these technologies is justified due to the lower cost and acceptable accuracy compared to the labour costs of manual human observation.

Plant Phenotyping Technologies

1960s ICG SB RAS

2018

Pipeline

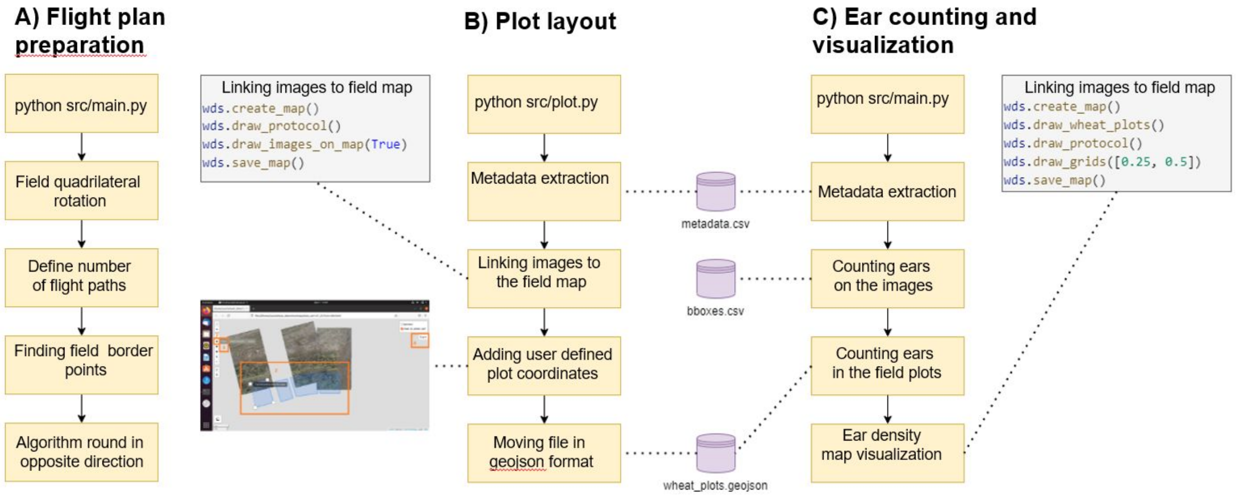


Main stages:

1. capture GPS coordinates for group of wheat plots
2. create flight mission with our script
3. perform flights
4. stitch mosaic and mark wheat plots manually
5. run WDS and get the results

Due to small size of wheat spike our protocol requires to fly at low elevation (3-4 meters). This makes impossible to use conventional pipeline (Pix4D capture and mapper):

- Pix4d Capture have programm limitation of minimal altitude 10 meters;
- Pix4d Mapper can't stitch orthomosaic because plants cover area between rows and constantly move because of wind and uav air flow.



Materials and methods

At the first stage of development we used 2 trained models from contest Global Wheat Head Detection 2020: Faster RCNN with ResNet-50 backbone and EfficientDet-D5.

Model testing was performed on the 27 sets of images added to GWHD in 2021. Each set is provided by one of 10 institutions. The variability of performance metrics and shooting conditions varies greatly. The best accuracy (73.54 on the mAP metric) is provided by the efficient-det model. The arithmetic mean mAP for these samples is **41.40 for faster rcnn and 37.51 for efficient-det.**

Then we trained first model on GWHD 2021 dataset to get better results.

To test accuracy of our wheat detection system we collected images in a field of SibNIIRS on July 29, 2021 at stage of ear formation phase. Flight mission was conducted around 13:00. Manual counting of ears was performed after harvesting from the area of 0.25 m^2. The number of productive stems was counted in four replications.

GWHD 2021 samples split:

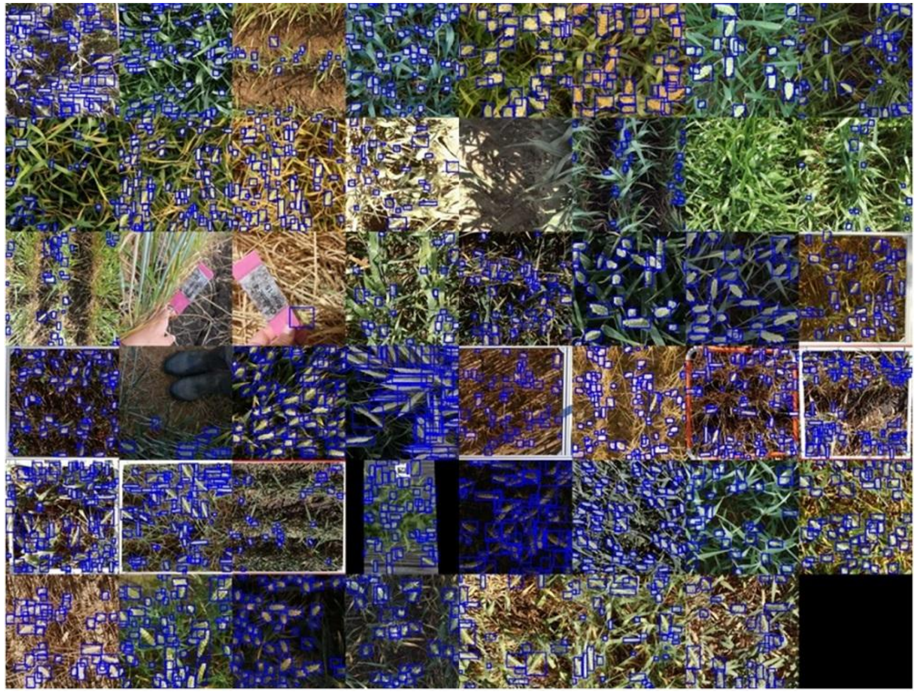
sample	№ images
train	3657
val	1476
test	1287

Optimizer:

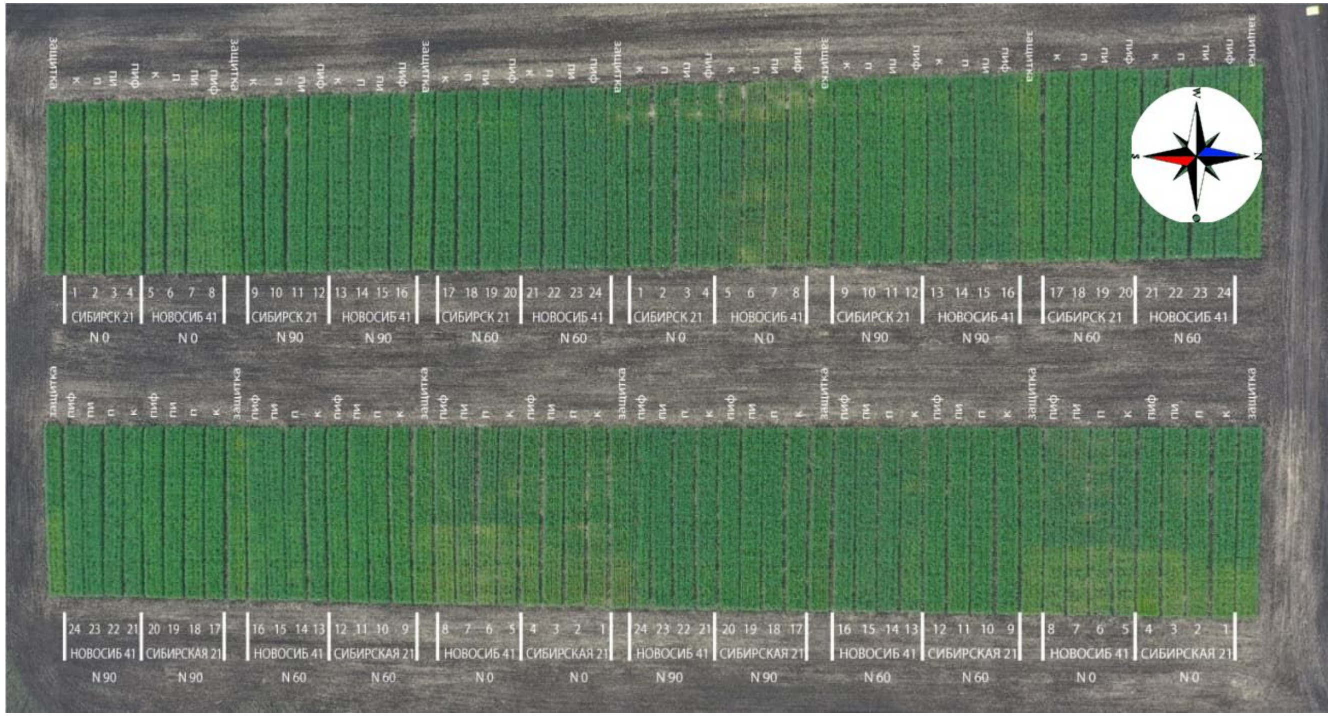
SGD with
- lr=0.005;
- momentum=0.9;
- weight_decay=0.0005;
- ReduceLROnPlateau.

min augmentation
- horizontal / vertical flip

max augmentation
- random crop (800x800 square from 1024x1024 image)
- random brightness contrast / hue saturation value
- to gray
- horizontal / vertical flip
- cutout of 8 squares 64x64



Results



	augmentation:			augmentation:	
val / test	**min**	**max**	**val / test**	**min**	**max**
4	21.69	22.39	**4**	**44.96**	44.74
8	25.32	22.56	**8**	40.95	44.63

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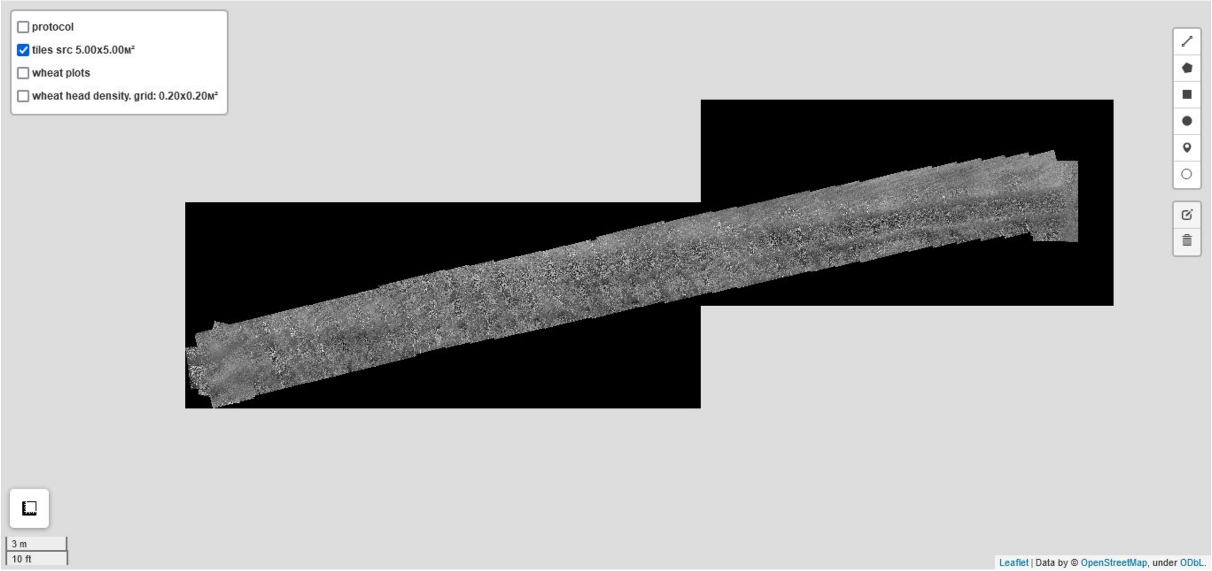
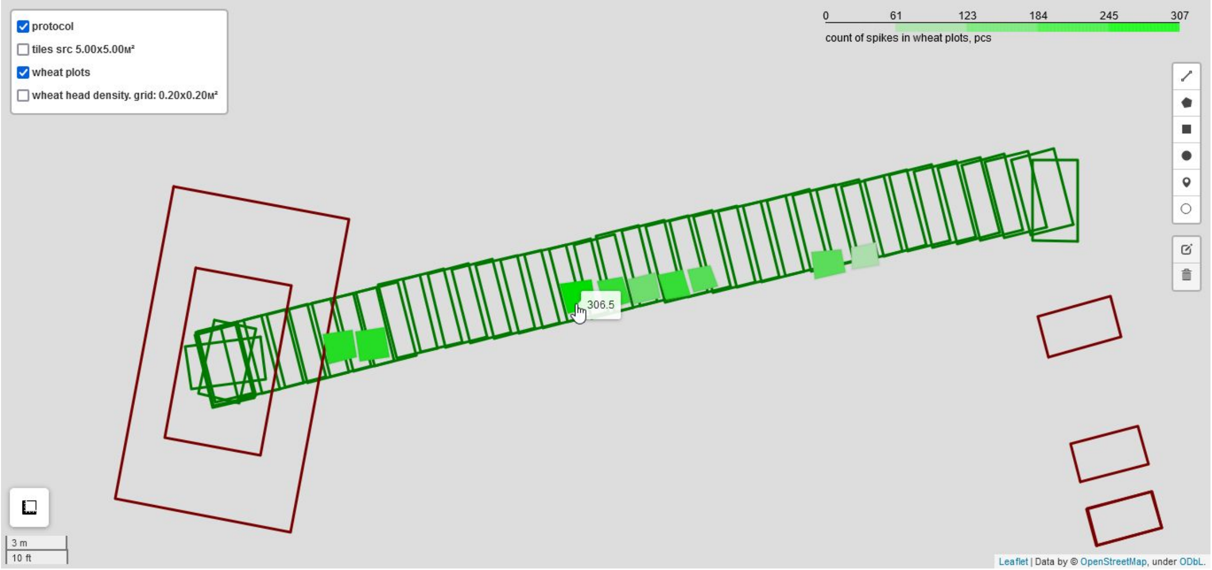
Faster RCNN model trained on more diverse data from 2021 contest allowed to improve mAP metric to **44.96**

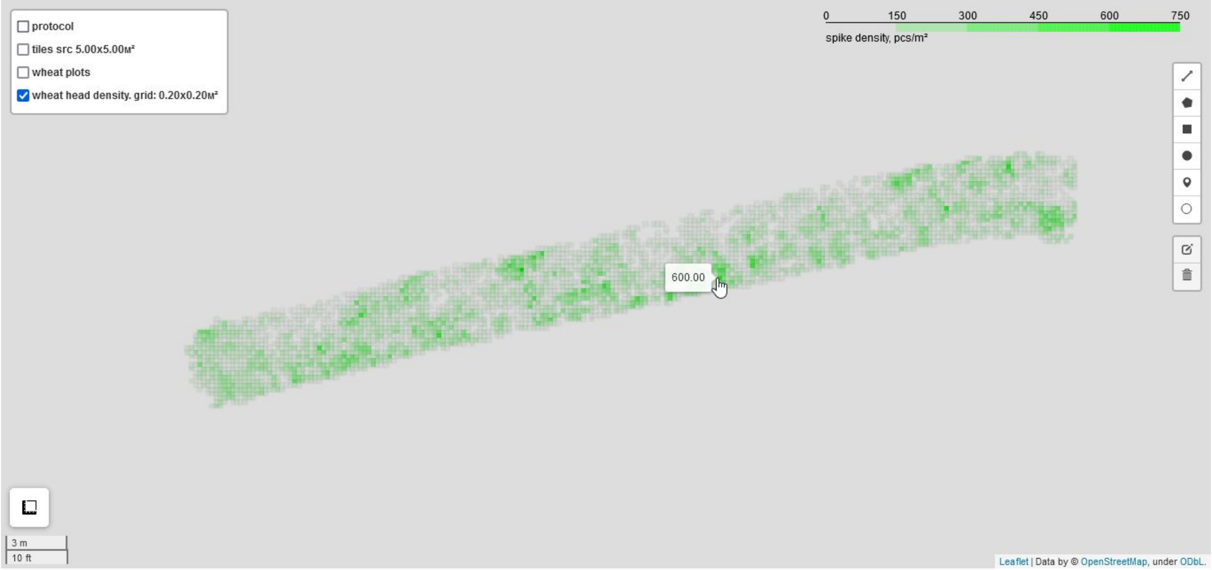
A comparison of the ear density estimates made using our approach and those made manually showed that the Spearman and Pearson coefficient values between them are **0.6176**, p-value=0.0013 and **0.5405**, p-value=0.0064, respectively.

Conclusion

We have developed a software package to estimate wheat yield based on counting the number of ears in UAV images of wheat crops, which does not require image stitching. The software package allows to form a flight plan for low altitude flying over the crops (~3 m), to count the number of ears on each image by a deep learning neural network, to link the obtained images to the crop map, and to visualize the density of ears for the studied crops.







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Thank you for attention!

source code available at:
https://github.com/Sl07h/wheat_detection
https://github.com/Sl07h/flight_mission_by_4_coordinates