

High throughput crop phenotyping systems

M.I. Anchekov, K.Ch. Bzhikhatlov, A.M. Leshkenov

Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences
360010, Russia, Nalchik, 2 Balkarov street

Annotation. In this paper, the analysis of systems of high-performance phenotyping of agricultural crops is carried out. Systems based on mobile robots, unmanned aerial vehicles and software and hardware systems were considered. It is shown that despite the fact that there are ready-made solutions on the market, they do not cover the entire range of tasks.

Key words: phenotyping, selection, robotics

REFERENCES

1. URL: <https://www.un.org/ru/global-issues/population> (дата обращения 31.10.2022 г.)
2. Mueller-Sim T. The Robotanist: A ground-based agricultural robot for high-throughput crop phenotyping. *IEEE International Conference on Robotics and Automation (ICRA)*. 2017. DOI: 10.1109/ICRA.2017.7989418.
3. Fischler M.A., Bolles R.C. Random sample consensus. *Commun. ACM*. 1981. Vol. 24. No. 6. Pp. 381–395.
4. Coulter R. Implementation of the pure pursuit path tracking algorithm. Carnegie Mellon University – Robotics Institute, *Tech. Rep.*, January 1992.
5. Baret F., de Solan B., Thomas S. [et al]. Phenomobile: A fully automatic robot for high-throughput field phenotyping of a large range of crops with active measurements. April 2022, https://www.robopec.com/wp-content/uploads/2020/08/IAMPS_Phenomobile.pdf
6. Madec S., Baret F., de Solan B. [et al]. High-throughput phenotyping of plant height: comparing unmanned aerial vehicles and ground lidar estimates. *Frontiers in Plant Science*. 2017. No. 8. DOI: 10.3389/fpls.2017.02002.
7. Volpato L. [et al]. High Throughput Field Phenotyping for Plant Height Using UAV-Based RGB Imagery in Wheat Breeding Lines: Feasibility and Validation. *Front. Plant Sci.* 2021. Vol. 12. <https://doi.org/10.3389/fpls.2021.591587>
8. Chivasa W., Mutanga O., Burgueño J. UAV-based high-throughput phenotyping to increase prediction and selection accuracy in maize varieties under artificial MSV inoculation.

Computers and Electronics in Agriculture. 2021. Vol. 184. DOI: 10.1016/j.compag.2021.106128.

9. *Su W. [et al]. Phenotyping of Corn Plants Using Unmanned Aerial Vehicle (UAV) Images. Remote Sensing.* 2019. Vol. 11. No. 17. <https://doi.org/10.3390/rs11172021>
10. *Buchaillet Ma.L. [et al]. Evaluating Maize Genotype Performance under Low Nitrogen Conditions Using RGB UAV Phenotyping Techniques. Sensors.* 2019. Vol. 19. No. 8. DOI: 10.3390/s19081815.
11. *Arunachalam A., Andreasson H. Real-time plant phenomics under robotic farming setup: A vision-based platform for complex plant phenotyping tasks. Computers & Electrical Engineering.* 2021. Vol. 92. DOI: 10.1016/j.compeleceng.2021.107098.
12. *Gehan M. A. [et al]. PlantCV v2: Image analysis software for high-throughput plant phenotyping. PeerJ.* 2017. Vol. 5. DOI: 10.7717/peerj.4088.
13. *Rueden C. T. [et al]. ImageJ2: ImageJ for the next generation of scientific image data. BMC Bioinformatics.* 2017. Vol. 18. No. 1. <https://doi.org/10.1186/s12859-017-1934-z>
14. *Klukas C., Chen D., Pape J.-M. Integrated Analysis Platform: An Open-Source Information System for High-Throughput Plant Phenotyping. Plant Physiology.* 2014. Vol. 165. No. 2. Pp. 506–518. <https://doi.org/10.1104/pp.113.233932>
15. *De Vylder J. [et al]. Rosette Tracker: An Open Source Image Analysis Tool for Automatic Quantification of Genotype Effects. Plant Physiology.* 2012. Vol. 160. No. 3. Pp. 1149–1159. <https://www.jstor.org/stable/41693984>
16. *Ubbens J. R., Stavness I. Deep Plant Phenomics: A Deep Learning Platform for Complex Plant Phenotyping Tasks. Front. Plant Sci.* 2017. Vol. 8. <https://doi.org/10.3389/fpls.2017.01190>
17. *Apelt F. [et al]. Phytotyping 4D: a light-field imaging system for non-invasive and accurate monitoring of spatio-temporal plant growth. Plant J.* 2015. Vol. 82. No. 4. Pp. 693–706. DOI: 10.1111/tpj.12833
18. *Zhang C. [et al]. 3D Robotic System Development for High-throughput Crop Phenotyping. IFAC-PapersOnLine.* 2016. Vol. 49. No. 16. Pp. 242–247. <https://doi.org/10.1016/j.ifacol.2016.10.045>
19. *Mazis A. [et al]. Application of high-throughput plant phenotyping for assessing biophysical traits and drought response in two oak species under controlled environment. Forest Ecology and Management.* 2020. Vol. 465. P. 118101. <https://doi.org/10.1016/j.foreco.2020.118101>
20. URL: <https://phenospex.com/> (дата обращения 31.10.2022 г.)
21. *Rakutko E.N. Determination of the crown structure of plants during their automated phenotyping. Tekhnologii i tekhnicheskiye sredstva mekhanizirovannogo proizvodstva produktsii rasteniyevodstva i zhivotnovodstva [Technologies and technical means of mechanized production of crop and livestock products].* 2020. No. 2(103). Pp. 44–57. DOI: 10.24411/0131-5226-2020-10240. (In Russian)

Ракутъко Е. Н. Определение структуры кроны растений при их автоматизированном фенотипировании // Технологии и технические средства механизированного производства продукции растениеводства и животноводства. 2020. № 2(103). С. 44–57. DOI: 10.24411/0131-5226-2020-10240.

22. *Braginsky M.Ya., Tarakanov D.V.* Plant phenotyping by an adaptive image processing system based on convolutional neural networks. *Izdatel'skiy tsentr Sur-GU* [Publishing Center of SurSU]. 2021. No. 2(42). Pp. 6–16. DOI: 10.34822/1999-7604-2021-2-6-16. (In Russian)

Брагинский М. Я., Тараканов Д. В. Фенотипирование растений адаптивной системой обработки изображений на базе сверточных нейронных сетей // Вестник кибернетики. 2021. № 2(42), С. 6–16. DOI: 10.34822/1999-7604-2021-2-6-16.

23. *Röckel F. [et al].* PhenoApp: A mobile tool for plant phenotyping to record field and greenhouse observations. *F1000Res.* 2022. Vol. 11. P. 12.

Information about the authors

Anchekov Murat Inusovich, staff scientist of the laboratory «Molecular selection and biotechnology»,
Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences;
360000, KBR, Nalchik, 224 Kirova street;
murat.antchok@gmail.com, ORCID: <https://orcid.org/0000-0002-8977-797X>

Bzhikhatlov Kantemir Chamalovich, Candidate of Physical and Mathematical Sciences, Head of the Laboratory «Neurocognitive autonomous intelligent systems», Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences;
360002, Russia, Nalchik, 2 Balkarov street;
haosit13@mail.ru, ORCID: <https://orcid.org/0000-0003-0924-0193>

Leshckenov Aslan Muhamedovich, Head of the Laboratory «Agricultural robotics», Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences;
360002, Russia, Nalchik, 2 Balkarov street;
aslan.leshckenov@yandex.ru, ORCID: <https://orcid.org/0000-0001-9516-3213>