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AVATARS - Advanced virtuality and augmented reality approaches in seeds to seeds

***Thomas Altmann*[1]**

Amine Abbadi[2]
Matthias Enders[2]
Marius Kloft[3]
Andrea Bräutigam[4]
Olaf Sacher[5]
Ljudmilla Borisjuk[1]
Hardy Rolletschek[1]
Jozephus Schippers[1]
Hans-Peter Braun[6]
Evgeny Gladilin[1]
Mary-Ann Blätke[1]
Matthias Lange[1]

[1] Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Seeland OT Gatersleben, Germany

[2] NPZ Innovation GmbH, Hohenlieth Holtsee, Germany

[3] RPTU Kaiserslautern-Landau, Kaiserslautern, Germany

[4] University of Bielefeld, Bielefeld, Germany

[5] Breakpoint One, Berlin, Germany

[6] Leibniz University of Hannover, Hannover, Germany

Background:

Advanced molecular omics analyses and high-throughput phenotyping provide unprecedented opportunities for crop improvement. Researchers and breeders need novel analysis tools to cope with the enormous data volumes and complexities. The AVATARS project uses a FAIR data ecosystem, performs integrated data analyses, modelling, and deep learning, and employs advanced virtuality and augmented reality for data visualization and exploration.

Objective:

Seed germination ability of winter oilseed rape (Brassica napus L.) is affected by strong G x E interactions and is highly variable even in modern varieties. To support seed germination stability improvement and its prediction from complex data, four academic and two industrial partners join their expertise in plant breeding, non-destructive plant and seed phenotyping, image analysis, molecular omics analyses, network analysis and modelling, data management, deep learning, and virtual reality.

Methods:

Highly comprehensive data collected in multi-environment field trials are interrogated using deep learning methods. Spatially and temporally resolved omics data are investigated and data and results are made accessible in a novel virtual reality environment. A time-resolved 3D seed model based on high-resolution MRI and histological data will serve as a canvas for an interactive display of organ-specific transcriptome, proteome, and metabolome data, as well as epigenetic information obtained during seed formation. The omics data are of three genotypes grown and phenotyped under field-like conditions simulated in IPKs PhenoSphere, a novel plant cultivation and phenotyping facility capable of fully controlling environmental conditions.

Results:

Two growth seasons were completed in the PhenoSphere with contrasting weather conditions, benign and detrimental to seed formation, that reveal relevant environmental influences on structural and topological features and on metabolic and regulatory networks. Field trials were conducted across four seasons (2019-2023) in two to four locations per year, on up to 400 genotyped breeding lines. Drone images during the growing season and properties of seeds analysed by TD-NMR, hyperspectral imaging, X-ray CT, and germination assays for both, the field trials and the PhenoSphere material, provide the input data for novel deep learning algorithms to predict germination ability. Established gene regulatory and metabolic networks provide a backdrop onto which the complex omics datasets will be mapped for detailed visualization. All data are curated and integrated in a central data hub providing efficient data access for analyses and visualization. Co-ordination and communication and education efforts flank the scientific core of AVATARS. They reach out to scientific target groups in fundamental and applied research, plant breeding, and computer vision and to students, science journalists and the general public. The created VR edutainment medium “Plant Journey” for school kids was presented at the Science Expo 2019 in Hannover. It is used in the public relations of the partners and is disseminated via software and media distribution platforms.

Conclusions:

AVATARS embarks on a highly interdisciplinary and innovative Data Science approach to tackle a scientifically and economically relevant topic. It integrates use of ultra-high-throughput genotype and phenotype data for AI (deep learning) to predict the quality of seed charges with detailed systems biological investigation to elucidate the underlying molecular-physiological processes.