LemnaTec

MEMBER OF THE NYNOMIC GROUP

# FIELDAIXPERT

Automatic multi-camera field phenotyping

LemnaTec Customized Solutions for Phenotyping

FIELDAIXPERT

## Automatic multi-camera field phenotyping.
## The largest plant phenotyping robot in the world.

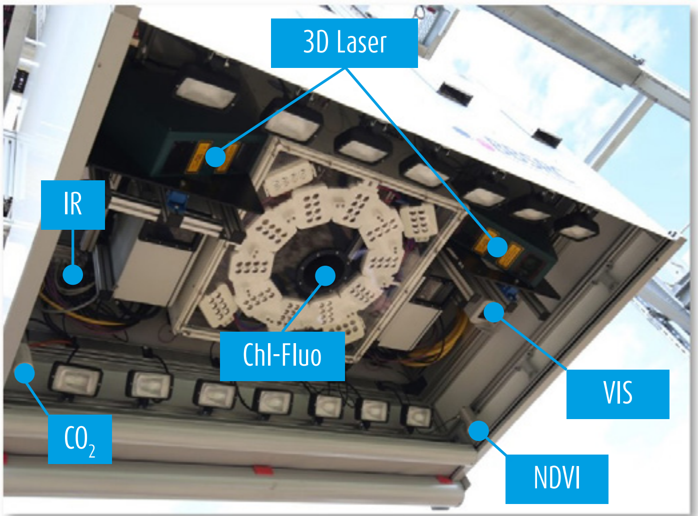
The LemnaTec FieldAIxpert is an automatic sensor-to-plant field phenotyping system that is installed over plot testing sites. It moves on rails installed along a plot site (X-direction), and has a portal structure spanning over the plots. On this structure, the sensor head moves across the plot area (Y-direction), while an axis allows height adjustment of the sensor head (Z-direction). With accurate and repeatable positioning of the sensor head, the system enables time-course imaging and scanning of the plants in the plot area. It is weatherproof and designed to run measurements of the plants throughout the growing season form germination to harvest time.
Inside the plot area, plants can be cultivated in the soil, or they can be placed in containers. Depending on the planting pattern and spacing, the system can record images at canopy level or at single plant level. With continuous and unsupervised operation, the system can monitor plant development throughout the growth period. Programmable imaging patterns enable application-oriented image recording and scanning.

The FieldAIxpert can be equipped with the full range of imaging systems for structural and physiological phenotyping of the growing vegetation. Thereby it enables continuous phenotypic analyses of the developing crops.
The system is delivered with the LemnaTec software suite that not only allows complete control of all technical functions but also provides access to a broad range of phenotypic analysis options. LemnaExperiment handles and analyzes all images and scans acquired with the system, while LemnaGrid and Lemna3D allow flexible programming of analysis pipelines.

- Automated canopy phenotyping system
- Sensor to plant for stationary ground-standing plants outdoor
- Full range of camera types for shoot phenotyping: RGB, chlorophyll fluorescence, hyperspectral imaging, multispectral imaging, NIR/IR imaging, 3D laser scan
- For soil-grown plants or plants in containers
- High resolution and reproducibility
- Fully automated
- Three-directional moving sensor head including all imaging equipment and environmental sensors

## FieldAIxpert Sensor Head

The sensor head mounted on the FieldAIxpert system contains cameras, scanners, and sensors for image recording and scanning, and for measuring data on environmental factors. Light sources required for some of the camera types are included. It combines all equipment in a weatherproof housing. With high precision positioning of the cameras and scanners the system can record phenotypic data of the plot area in time courses.




- RGB camera
- Thermal Infrared camera
- NIR camera
- Hyperspectral Imagers
  - VNIR (400 - 1000 nm)
  - SWIR (900 - 1700 nm)
- Chlorophyll Fluorescence imaging system
- 3D Laser Scanners
- $CO_2$ sensor
- Environmental sensors

- All cameras, scanners, and sensors combined in a sensor head
- Sensor head on axis system reaches all points in the dedicated plot area
- High-precision repeatable positioning of the sensor head
- Weatherproof housing of electronics

## Product Properties

- Up to 30 m width, variable length and height – currently largest installation has 400 m lenght
- Installation on field sites
- Design and construction based on an industrial portal crane system
- X-axis is guided along a rail system underpinned by concrete piles driven into the ground to allow natural drainage
- X-direction: length is only limited by cabling requirements; existing customer installations reaches 500 m length
- Y-direction: customized width, e.g., 10 m, 20 m or 30 m
- Z-axis serves to lift the container with the sensor equipment up and down
- Precise movement of all 3 axes

# Software Suite

The FieldAIxpert is delivered with a comprehensive software suite. The software enables the users to provide sample information and control cameras and lights. After imaging all data are stored and accessible for image and data processing.

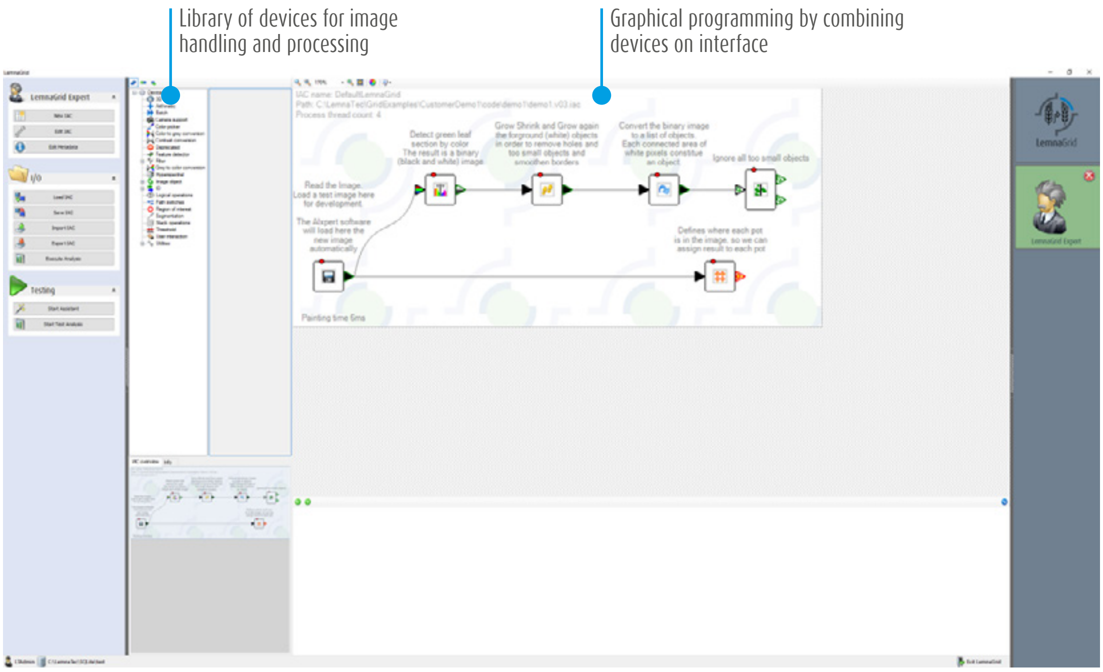
LemnaControl is the interface with which users operate the system. With LemnaControl, users carry out all settings that are required for image recording with the system. In particular, this comprises settings for the camera(s) and lights included in the system. All settings can be combined and scheduled to configure recordings. The available functions are tailored to the corresponding hardware. Each hardware system delivered by LemnaTec comes with its own control software adapted for the functions of that system.

The LemnaGrid app uses an intuitive graphical programming environment, which allows for easy integration of different image analysis algorithms. LemnaGrid phenotyping software offers high flexibility  for user programming. The image processing pipeline extracts desired properties/features from the original image and stores results in a dedicated storage system. LemnaGrid can include functions of state-of-the-art machine learning tools, next to standard image analysis to detect and extract features of interest. Guided by the LemnaGrid graphical user interface, users can build their own analytical pipeline with pre-defined devices.

### Analysis devices include:

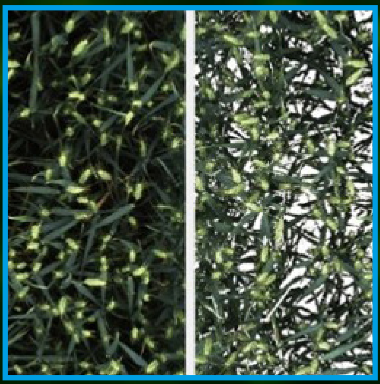
- filters
- threshold functions
- image converters
- object detectors
- feature detectors
- color analysis tools
- region of interest function
- combinatory functions
- and many more

All devices – graphically represented by boxes – can be combined on a interface by aligning the boxes to pipelines. Along such workflows, each function can provide insights in the progress of the analysis by feeding out an intermediate image. Image processing pipelines can include branches and parallel paths that combine to a final result. For 3D data, the app Lemna3D is used for programming analytical pipelines. Similarly as in LemnaGrid, users can do graphical programming on an interface by combining devices from a library of functions.

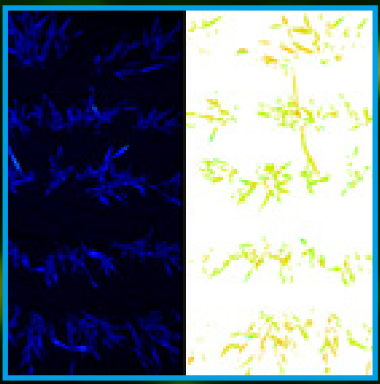


LemnaExperiment serves to manage experiments and measurements, and to schedule and run analyses. Moreover, it enables viewing, visualizing, and exporting results. It provides capabilities to access and browse through recorded images and to display metadata for samples and measurements. As core function, LemnaExperiment selects recordings for analysis and assigns an image analysis pipeline –written in LemnaGrid or in Lemna3D – to a given set of recordings. After assignment, the analyses are run in the background by the Analysis Executor. Parameters of interest can be selected in LemnaExperiment so that they are displayed in the analysis output.

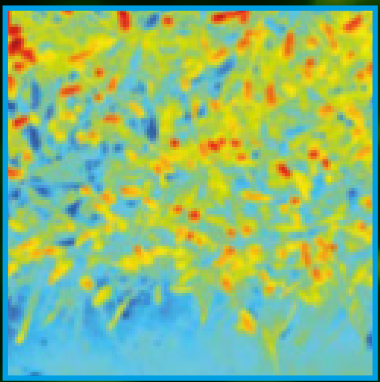
# Application Examples



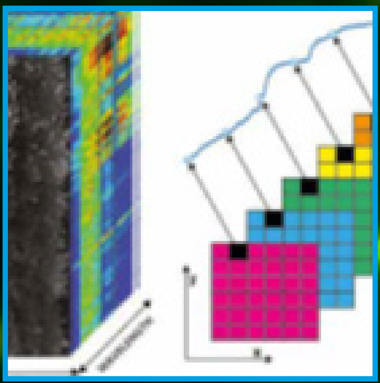
**Plant growth and development**
monitoring plant phenotypic features and ground cover from seedling emergence to maturity enables analyzing genotype-phenotype relations as well as environmental impact on phenotypic traits.



**Screening photosynthetic parameters**
Chlorophyll fluorescence as indicator of photosynthesis allows measurements of the status and activity of photosystem II at whole plant and canopy scale. Application cases can be for instance in genetic studies, for stress response assessments, or in plant pathology.



**Stress assessments**
Canopy temperature measurement via infrared imaging allows analyses of water use and transpiration as well as investigations on biotic or abiotic stress.



**Phyisological phenotyping**
Hyperspectral analyses for physiological phenotyping enables various assessments of physiological responses of the plants in genetic or environmental context. Spectral imaging data can be used to calculate many vegetation indices.

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