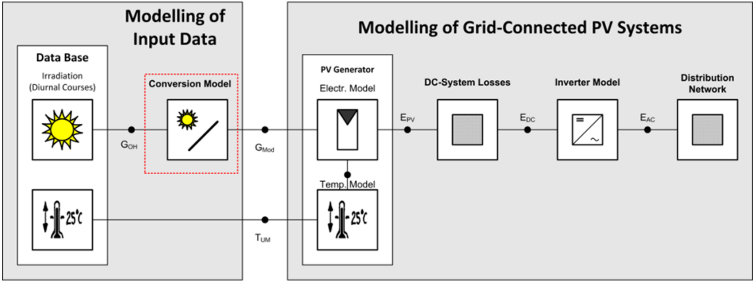
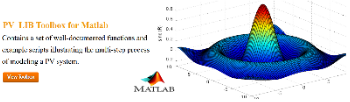
Modelling and Simulation of PV-Systems via Matlab





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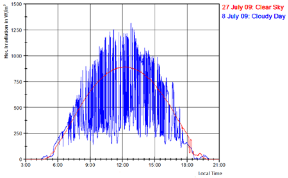
Modelling and Simulation of PV-Systems via Matlab

Technische Hochschule Rosenheim

Short Description

Modelling of the operational behaviour of PV-systems is fundamental for a glance 'under the hood' for single systems as the analyses of specific operational conditions. As well this is important for the understanding of the collaboration of different systems within a network (distribution system – DS or remote area power supply systems- RAPS) or the sizing of PV-systems in applications as PVPS (PV pumping systems) for drink water supply.

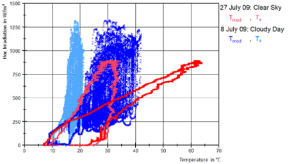
Therefore we will start to raise a library with different models for PV-components. These models will be applied and analysed in first basic PV-systems. We also want to advance the common charts used to analyse the operational behaviour or conditions of PV-systems.



The chart depicts daily insolation values on a clear (red) and cloudy (blue) day. Measurements were taken at the horizontal using the CMP 21 from Kipp & Zonen on the trade fare center Munich

Goals

- \> Survey of models for basic PV-components
  - Algorithms via Science Direct, specialist books, …
  - M-files via PVLib, Mathworks, …
- \> Implementation of the algorithms in Matlab
- \> Development of a setup of models in Matlab
- \> Application of the models in basic systems
- \> Design of interesting graphs for the assessment of the operating behaviour of components and systems



Module temperatures corresponding to the daily energy yield profile

Modelling and Simulation of PV-Systems via Matlab

Technische Hochschule Rosenheim

Tasks and Challenges

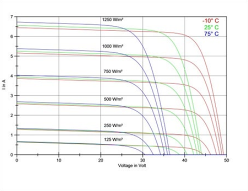
- Research of different sources for models of basic PV-components (results are algorithms or m-files of components) …
- Development of a spectrum of models as m-files for the components
- Validation and comparison of the m-files
- Calculations in fundamental applications and evaluations in graphs
- Documentation (maybe publication) of the results

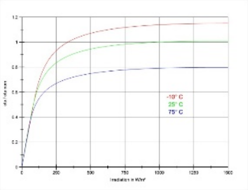
Requirements / Prerequisites

- Interest in Solar Engineering
- Interest and fun with Matlab and modelling
- Interest in scientific work and research
- Teamwork capability
- No previous knowledge of photovoltaics or energy meteorology required

Sources

- World Radiation Monitoring Center (WRMC), Baseline Surface Radiation Network (BSRN), https://bsrn.awi.de/
- Publications on Science Direct
- PV_LIB-Toolbox, https://pvpmc.sandia.gov/applications/pv_lib-toolbox/
- Mathworks Community, Matlab Central, File Exchange
- Publications and graphs by Steve Ransome, http://www.steveransome.com/



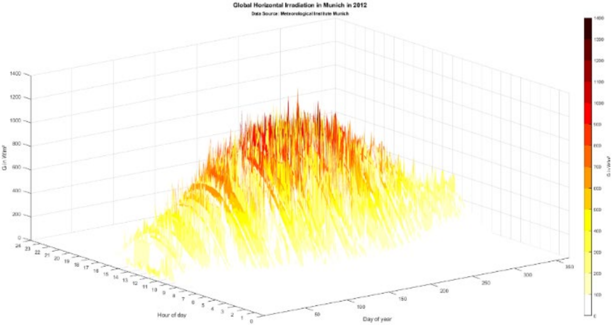


I(*V*) curve (above) and Irradiation / eta curve (beneath) for a mc-Trina PV- module for various temperatures

pvlib

PVPerformance MODELING COLLABORATIVE

Energy Meteorology: Irradiance Volatility (IV) & Irradiance Enhancement (IE)
Analysis of Irradiance Data Sets (BSRN, DWD, MIM – LMU, …)



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Analysis of Irradiance Data Sets (BSRN, DWD, MIM – LMU, …)

Technische Hochschule Rosenheim

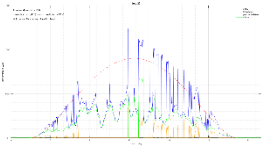
Short Description

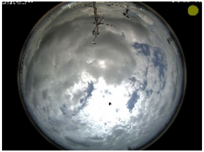
For the optimum system behavior of photovoltaic plants, knowledge of the energy meteorological and site-specific parameters is essential for their design. The analyses focus on quantifying these parameters and understanding their correlation to cloud conditions (cloud types, cloud height and cloud cover).

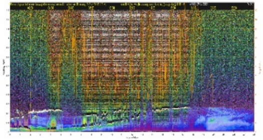
Therefore the extended high-resolution and long-term weather data sets of the BSRN , the German Weather Service (DWD) and the Meteorological Institute Munich (MIM) of the Ludwig-Maximilians-University have to be evaluated.

Goals

- Preparations and preliminary work :
  - Different Data Sets of BSRN, DWD, MIM, CMS, …
  - Reference characteristic curves with libRadtran …
- Incorporation in previous publications
- Data preparation and visualisation in Matlab
- Search for characteristics and correlations
- Design of interesting graphs for the assessment of the data
- Roundup of the results for a publication







The three figures show for one exemplary day different daily insolation values (above), a All-Sky-Image reflecting the weather and cloud situation (middle) and a ceilometer image describing the cloud heights of that day (Src.: MIM & LMU)

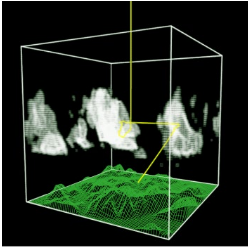
Analysis of Irradiance Data Sets (BSRN, DWD, MIM – LMU, …)

Tasks and Challenges

- Preparation of and incorporation in the different data sources
- Calculation of reference diurnal values with libRadtran
- Search for fundamental characteristics and correlations (multivariate data analysis as one possible method)
- Development of interesting multi-dimensional graphs
- Documentation (maybe publication) of the results

Requirements / Prerequisites

- Interest in Weather and Solar Engineering
- Interest and fun with data, data analysis and multi-dimensional graphs
- Interest in scientific work and research
- Teamwork capability
- No previous knowledge of photovoltaics or energy meteorology required



Mode of operation of the reference program libRadtran - library for radiative transfer (Src.: MIM, LMU)

Sources

- World Radiation Monitoring Center (WRMC), Baseline Surface Radiation Network (BSRN), https://bsrn.awi.de/
- DWD data set (22 locations: irradiance values over 10 years in a minutely resulution, 7 of the locations with synoptical data, cloud data in hourly resolution, …)
- Data sets of the Meteorological Institute Munich, Ludwig-Maximilians-Universität München and our reference program libRadtran, http://www.libradtran.org
- Different data sets by CMS Dr. Schreder GmbH, Kichbichl (Austria)

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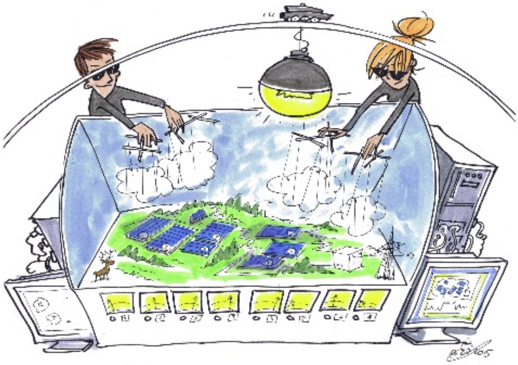
Implementation of Methods for Cloud Detection Based on Image Data from All-Sky-Imagers



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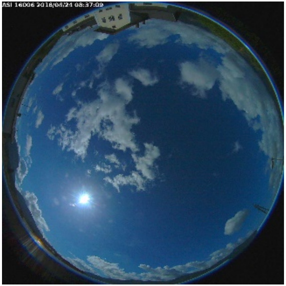
Implementation of Methods for Cloud Detection Based on Image Data from All Sky Imagers

Technische Hochschule Rosenheim

Short Description

In contrast to conventional power plants, photovoltaic systems are affected not only by seasonal but also by natural fluctuations caused from weather events. In particular, cloud formations are responsible for volatile power generation. Short-term forecasts make an important and significant contribution to improve the integration of renewable energies into the electrical grid by forecasting the fluctuations in power generation for small time horizons. Previous forecasting methods (satellites and numerical weather models) will in future be usefully supplemented by All Sky Imager (ASI), as these enable high-resolution irradiation forecasts in terms of time and space. For this purpose, at least two ASIs will be installed at the PV power plants, which will picture the sky with a fisheye-lens. To derive the spatial radiation, the image data will be evaluated in a first step. **For this purpose the clouds in the all sky images must be detected and separated from other objects (e.g. sun, houses on the horizon, ...).**



Exemplary All-Sky-Image from a measuring site in Kirchbichl, Austria.

Goals

- Implement and compare different cloud detection methods in Matlab or Python
- Evaluation of existing methods using a test dataset
- Compare own implemented methods with a commercial software
- Optional: Developement of an own technique for the determination of cloud cover
- Critically and objectively deal with research tasks and issues

Implementation of Methods for Cloud Detection Based on Image Data from All Sky Imagers

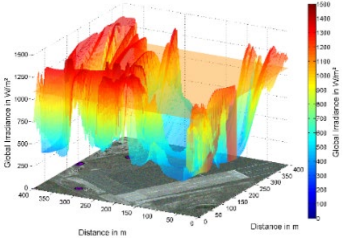
Technische Hochschule Rosenheim

Tasks and Challenges

- Literature research of publications and the current status of technology
- Implementation of cloud recognition algorithms (preferably in Matlab or Python)
- Applying, comparing and evaluating the algorithms for the test dataset
- Optimization of existing methods for more robust results
- Possibility to develop an own algorithm (for example using Machine Learning)
- The results can be published as a scientific poster
- Challange: To be able to differentiate clouds from other objects (like the sun, trees,…) Moreover, there are already many publications on this topic.

Requirements / Prerequisites

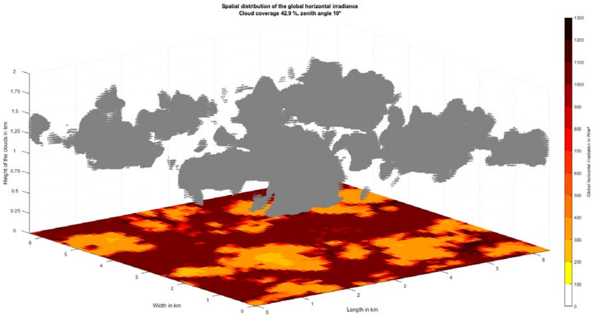
- Programming knowledge
- Scientific work and research
- Basics in image processing
- Mathematical fundamentals
- No previous knowledge of photovoltaics or energy meteorology required



Geospatial distribution of global horizontal irradiance (GHI) for a measuremet grid on Hawaii. This graphic illustrates the volatile effects of clouds on solar radiation.

Technische Hochschule Rosenheim

Calculation of Cloud Heights Based on Two All-Sky-Imager



Simulierte räumliche und zeitliche Verteilung der solaren Einstrahlung mit Cumulus-Wolken.

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Calculation of Cloud Heights Based on Two All-Sky-Imager

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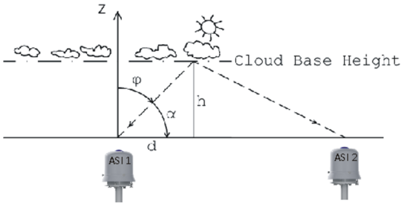
Short Description

In contrast to conventional power plants, photovoltaic systems are affected not only by seasonal but also by natural fluctuations caused from weather events. In particular, cloud formations are responsible for volatile power generation. Short-term forecasts make an important and significant contribution to improve the integration of renewable energies into the electrical grid by forecasting the fluctuations in power generation for small time horizons. Previous forecasting methods (satellites and numerical weather models) will in future be usefully supplemented by All-Sky-Imager (ASI), as these enable high-resolution irradiation forecasts in terms of time and space. For this purpose, at least two ASIs will be installed at the PV power plants, which will picture the sky with a fisheye-lens. **To calculate the shadow of the clouds on the earth's surface, the cloud heights are necessary in addition to the position of the sun.**

Goals

- ⇒ Implementation of an existing technique for determining cloud heights in All-Sky-Images
- ⇒ Set up different criteria to find the same cloud in images of ASI 1 and ASI 2
- ⇒ Compare and objectively evaluate alternatives for determining cloud heights



Schematic illustration of the method for calculation cloud heights using two All Sky Imagers. (Src.: Instruction Manual 'Cloud Base Height Software', distributed by EKO)

Calculation of Cloud Heights Based on Two All-Sky-Imager

Technische Hochschule Rosenheim

Tasks and Challenges

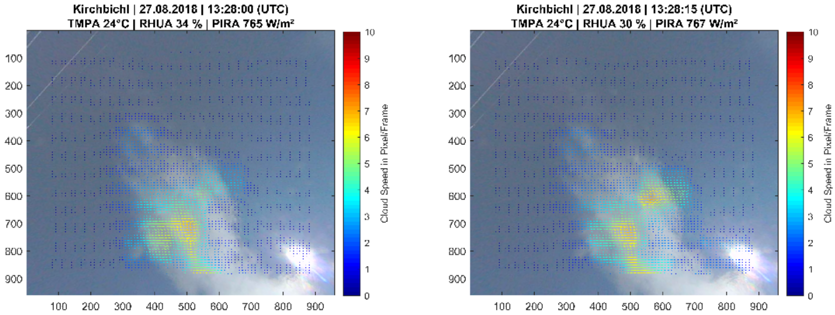
- Literature research of publications and the current status of technology
- Implementation of the triangulation technique to determine cloud heights for individual cloud objects in the All Sky Images (preferably in Matlab)
- Determine the accuracy of the determined cloud heights
- Comparison of own calculations with a commercial software
- Search for other methods and possibilities for height determination
- The results can be published as a scientific poster
- Challenge: Serveral clouds can have different heights in one image

Requirements / Prerequisites

- Programming knowledge
- Scientific work and research
- Basics in image processing
- Mathematical fundamentals (Geometry in particular)
- No previous knowledge of photovoltaics or energy meteorology required

Technische Hochschule Rosenheim

Object Tracking in All-Sky-Images to Determine Cloud Speed and Direction



Computed cloud motion vectors into rectified images from an All Sky Imager.
The colorbar gives information about the speed of the clouds.

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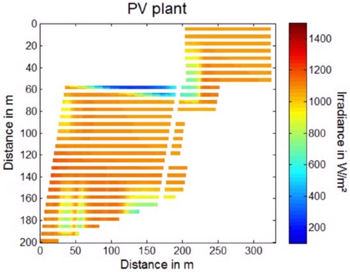
Object Tracking in All-Sky-Images to Determine Cloud Speed and Direction

Technische Hochschule Rosenheim

Short Description

In contrast to conventional power plants, photovoltaic systems are affected not only by seasonal but also by natural fluctuations caused from weather events. In particular, cloud formations are responsible for volatile power generation. Short-term forecasts make an important and significant contribution to improve the integration of renewable energies into the electrical grid by forecasting the fluctuations in power generation for small time horizons. Previous forecasting methods (satellites and numerical weather models) will in future be usefully supplemented by All Sky Imager (ASI), as these enable high-resolution irradiation forecasts in terms of time and space. **The camera systems photograph the clouds using a fisheye lens. To predict the cloud position, the speed and direction of the clouds must be calculated (Cloud Motion Vectors, CMV). In addition to optical flow methods, object tracking techniques can be used.**



Temporal and areal distribution of irradiation on a PV power plant.

Goals

- Implementation of a robust method for cloud tracking
- Comparison of object tracking with optical flow from results of a master thesis
- Determine cloud edges and the centre of area of clouds

Object Tracking in All-Sky-Images to Determine Cloud Speed and Direction

Technische Hochschule Rosenheim

Tasks and Challenges

- ⇒ Literature research of publications and the current status of technology
- ⇒ Implementation and application of common techniques (preferably in Matlab)
- ⇒ Comparison of results from object tracking with optical flow (already existing results from a master thesis)
- ⇒ Challenge: There are different types of clouds that can suddenly form or dissolve in the image and gradually disappear beyond the edge of the all sky image. In addition, the clouds can move at the different heights in various directions simultaneously.

Requirements / Prerequisites

- ☼ Programming knowledge
- ☼ Basics in image processing
- ☼ Mathematical fundamentals
- ☼ Scientific work and research
- ☼ Critical review of results
- ☼ No previous knowledge of photovoltaics or energy meteorology required

Use Artificial Intelligence (AI):
Machine Learning (ML) to Predict Solar Radiation

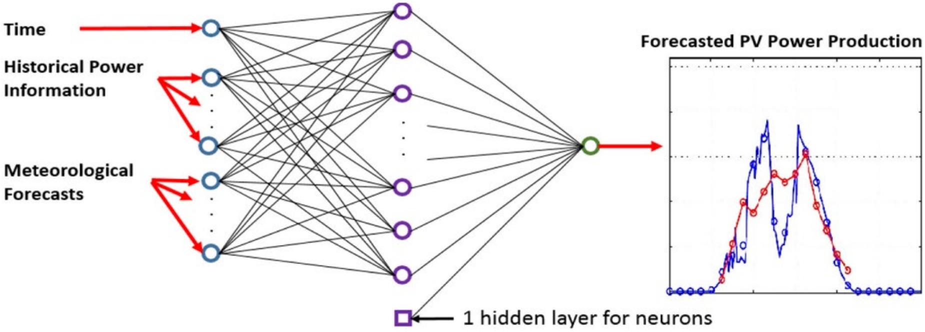


Illustration by: Zhaoxuan Li, SM Mahbobur Rahmen, Rolando Vegan and Bing Dong

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Use Machine Learning to Predict Solar Radiation …

Technische Hochschule Rosenheim

Short Description

In contrast to conventional power plants, photovoltaic systems are affected not only by seasonal but also by natural fluctuations caused from weather events. In particular, cloud formations are responsible for volatile power generation. Short-term forecasts make an important and significant contribution to improve the integration of renewable energies into the electrical grid by forecasting the fluctuations in power generation for small time horizons. Previous forecasting methods (satellites and numerical weather models) will in future be usefully supplemented by All-Sky-Imager (ASI), as these enable high-resolution irradiation forecasts in terms of time and space. **Many calculations and sub-steps are required until the finished solar power forecast from image information from ASI is available. The results can be optimized with machine learning methods. This leads to significantly more reliable yield forecasts. In other areas, machine learning has become indispensable…**

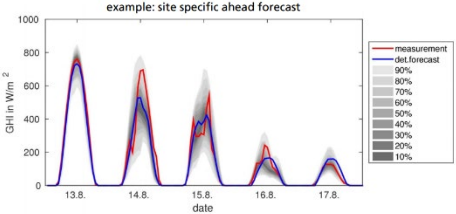
Goals

- Learning the basics in machine learning
- Review and demonstrate the potentials of ML
- Select one component of the forecast yourself and apply ML
- Publish results in a scientific poster

Use Machine Learning to Predict Solar Radiation …

Tasks and Challenges

- ⇨ Literature research of publications and the current status of technology
- ⇨ Create of the basics for machine learning in solar power forecasting
- ⇨ Application of ML to a sub-area of the forecast (free choice)
- ⇨ Scientific analysis
- ⇨ Challenge: very dynamic topic area with many new developments day by day



Measured irradiance (red curve) and forecast (blue) with uncertainty ranges (grey) (Src.: Elke Lorenz, Fraunhofer ISE)

Requirements / Prerequisites

- ☼ Programming knowledge
- ☼ Basics in image processing
- ☼ Mathematical fundamentals
- ☼ Scientific work and research
- ☼ Critical review of results
- ☼ No previous knowledge of photovoltaics or energy meteorology required

Technische Hochschule Rosenheim

Installation and Commissioning of Two Instruments to Measure Soiling on PV

Construction of a soiling measuring station in Spain (left). The right picture shows the DustIQ. Both measuring instruments are available at the university for setup and commissioning (Source: meteocontrol GmbH)

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Installation and Commissioning of Two Instruments to Measure Soiling on PV

Short Description

Contamination by deposits, such as sand or pollen, considerably affect the power output of photovoltaic modules. Especially in dry regions, the contamination of the systems plays a decisive role. But at what time does an expensive cleaning of the systems pay off? This requires measurement technology that determines the PV contamination. There are various technologies and approaches for this purpose. In this thesis two measurement systems shall be set up and commissioned. One of these devices is the DustIQ from Kipp & Zonen, a relatively new device on the market. The other device is from Campbell Scientific. It compares the yields of a cleaned and a soiled module.

Goals

- Both measuring devices should continuously measure the soiling and store the data centrally
- Own developments of graphics in Matlab allow a fast and uncomplicated evaluation (based on results of a previous project work)
- Proper technical documentation of the measurement setup for the technical staff
- Development of an automatic cleaning function for a PV module (so that the reference module does not have to be cleaned by hand)

Installation and Commissioning of Two Instruments to Measure Soiling on PV

Tasks and Challenges

- ⇒ Literature research of publications and the current status of technology
- ⇒ Installation of both measuring stations at a suitable location on the campus
- ⇒ Commissioning and measurement recording
- ⇒ First measurement data evaluation
- ⇒ Evaluation of the two systems regarding different criteria (costs, effort, measurement data, accuracies, problems, ...)
- ⇒ Share / discuss results and experiences with industry partners
- ⇒ Share experiences using DustIQ with Kipp & Zonen (They would like to publish an article about our measuring station on their website)

Requirements / Prerequisites

- ☼ Experience in working with measurement technology
- ☼ Technical skills
- ☼ Fundamentals of measurement technology
- ☼ Fundamentals of photovoltaics

BIM: Building Information Modeling and the Use of Drones

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BIM: Building Information Modeling and the Use of Drones

Technische Hochschule Rosenheim

Short Description

Drones offer an enormous potential: In the building industry, drones are being used more and more for 3D planning, especially for inventory control. Drones with the appropriate hardware can measure terrain profiles, facades or roof surfaces in very high resolution and with a minimum of time and cost. The aerial photographs are perspective rectified and photogrammetrically evaluated. This produces two-dimensional views from which 3D models can be generated. And this opens up a number of different possibilities - more detailed and extensive information can be found on the following website: https://www.autodesk.de/solutions/bim/aec-case-studies-architecture/5d-institut

Goals

- establish a basis
- Setup of soft- and hardware
- Drone flight for test recordings and following processing in revit
- Working with Flight Simulator
- Identify potentials, challenges and weaknesses

BIM: Building Information Modeling and the Use of Drones

Technische Hochschule Rosenheim

Tasks and Challenges

- ⇒ Literature research of publications and the current status of technology
- ⇒ Create bascis (hard- and software)
- ⇒ Check requirements for technology and software
- ⇒ If necessary, purchase missing hardware and software; request offers
- ⇒ Agreement on requirements for drone recordings and BIM across faculties
- ⇒ First test recordings with the drone and evaluation in existing software (revit)
- ⇒ Presentation of the results across different faculties

Requirements / Prerequisites

- ☼ Great interest in drones
- ☼ Experience with CAD desirable, but not required
- ☼ Good technical knowledge
- ☼ Interest in interdisciplinary cooperation
- ☼ Contribute your own ideas
- ☼ Fun with innovative and trendsetting topics