# Kognitive Sensoren als Voraussetzung für KI-Algorithmen
# Cognitive Sensors as Requirements for AI-Algorithms

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KEEN Abschlusstreffen
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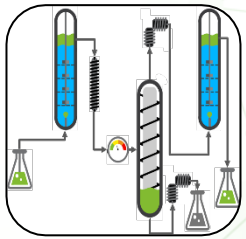
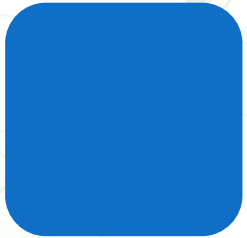
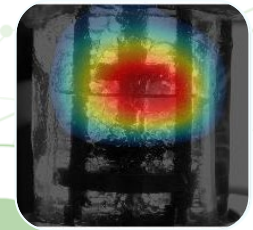






# Overview

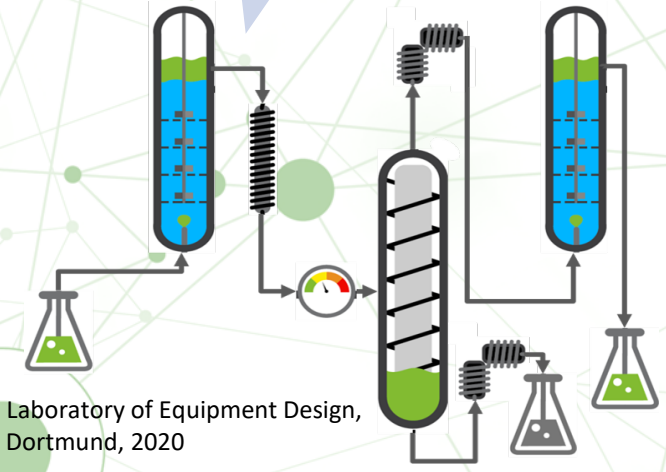
Experimental Setup

Conclusion & Outlook

Motivation

Service Concept

KEEN started



[1] Laboratory of Equipment Design, TU Dortmund, 2020

# Use case Merck - Vision

## Since 2017

- Process monitoring at sublimation with a camera
- Take a photo every 2 minutes

## 2020 KEEN

*„**Zielstellung:** Ziel des TP5 ist die KI-gestützte Informationsgewinnung über Prozesszustände und Produkteigenschaften aus Bilddaten und Zeitreihen in Labor und Produktion.“*

*„**AP5.1**: Erkennung von komplexen Prozessregimes und Produkteigenschaften aus Bild- und Videodaten“*

## 2020 - Idea

- Update the hardware: installation of 4 cameras with an optimized optics to monitor the whole process area
- Analyzing the generated photos with AI as part of KEEN

# Use case Merck - Reality

## 2021

The KEEN project is already completed when enough datasets for the training are collected.

**→ Skip the use case and move the budget to a MTP-Camera**

## 2021 new use case

Development of a Camera-Module with MTP-Interface

The team (TU Dortmund, TU Dresden, Merck KGaA) developed a service and procedure concept using the example of a camera.

The requirements for the concept were a general validity for all cognitive sensors.

## Since 2021

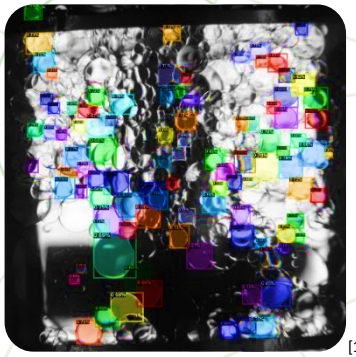
Select suitable components for camera, lens …, PLC, lighting…

Realize the service and procedure concept with the hardware

Adapt the concept to a NIR-Spectrometer-Module

# Motivation

- AI becomes more and more relevant in today's industry
- AI based optical sensors enable new opportunities
- For example, for the online droplet diameter detection



[1]

- ➢ How can we bring AI-sensors to plants in industry environments?
- By realizing them as process equipment assemblies (PEAs)
- ➢ Target: Development of tools and concepts to bring AI sensors to modular plants

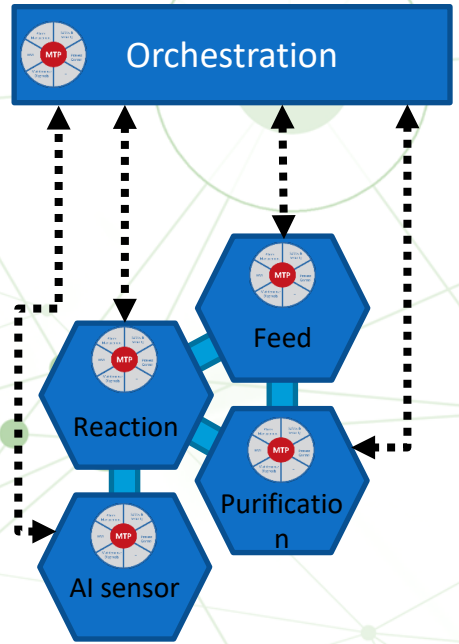
General requirements → Sensor requirements → Tools → Evaluation

[1] Poster L. Neuendorf, Md Jahangir Alam, N.Kockmann "AI-based sensors for extraction coulumn control" ProcessNet JT Fluidverfahrenstechnik, 02-03.05.2022 Frankfurt am Main

# General requirements of modular plants [1]

- Process functions as PEAs
- Fast implementation and high flexibility

- Communication between PEA and orchestration
- Module Type Package (MTP)
  - Service oriented architecture
  - Logic defined in VDI/VDE/NAMUR-2658
  - Manifest file
  - OPC UA server

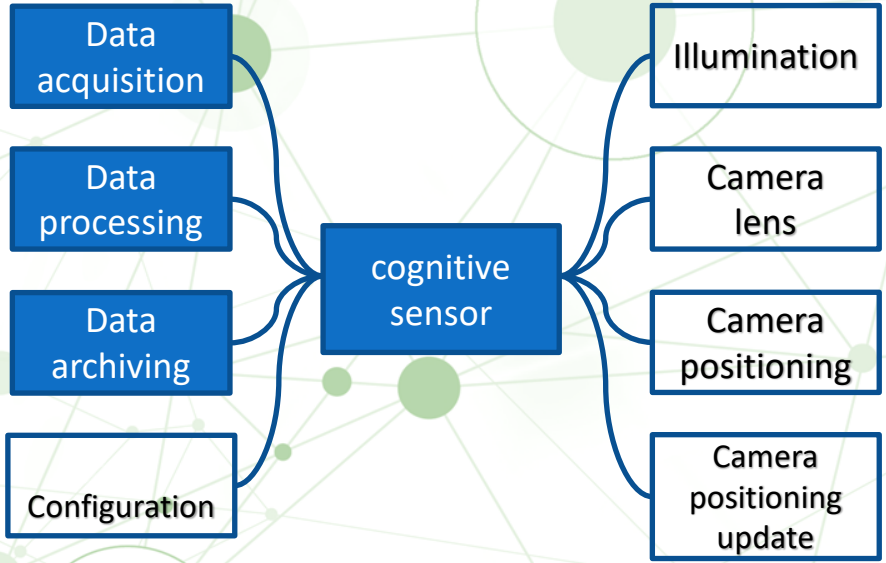



[2]

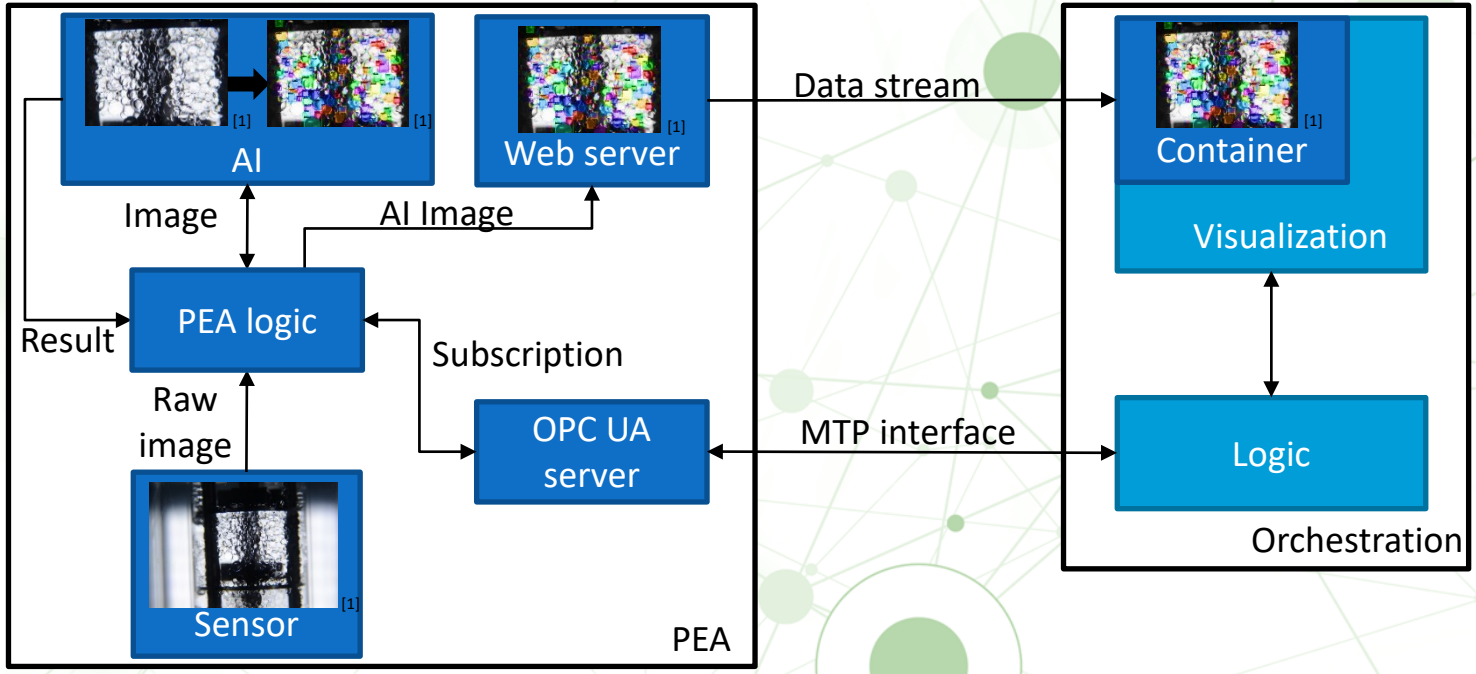
[1] VDI/VDE/NAMUR-2658 "Automation engineering of modular systems in the process industry" 2019 [2] adapted from VDI, ProcessNet, Dechema, „Progress Report Modular Plants" Figure1. 05.2022

# Optical smart sensor / service concept

- Encapsulation of sensor functions as services
- Core services
  - Data acquisition
  - Data processing
  - Data archiving
- Optional services
  - Configuration
  - Illumination
  - Lens
  - Camera positioning



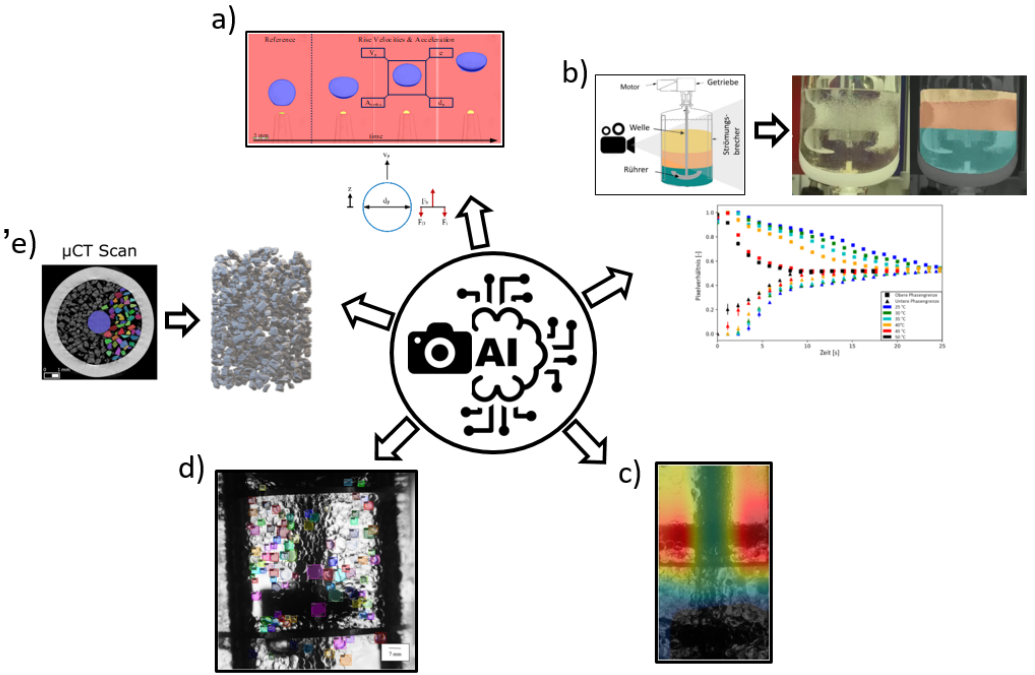
# Complex data stream handling




[1] L. Neuendorf, Md Jahangir Alam, N.Kockmann "AI-based sensors for extraction column control" Poster ProcessNet JT Fluidverfahrenstechnik, 02-03.05.2022 Frankfurt am Main

# AI-based Image Evaluation

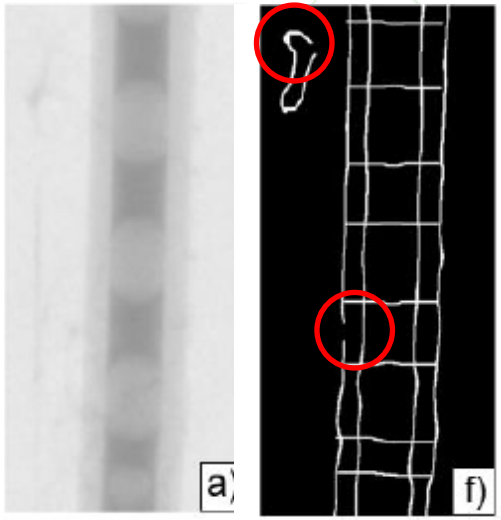
- 7 developed AI-based image analyses, of which 4 as PEAs
  - Coalescence detection
  - Flooding detection
  - Droplet detection
  - Crystal detection




[1] Neuendorf, Baygi, Kolloch and Kockmann, ACS Engineering Au 2022,2 (4), 369-377, DOI: 10.1021/acsengineeringau.2c00014
[2] Neuendorf, Hammal, Fricke, Kockmann, AI-Based Supervision for a Stirred Extraction Column Assisted with Population Balance-Based Simulation; CIT 2023

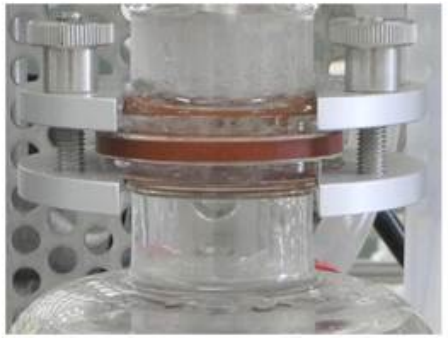
# AI-based Image Evaluation

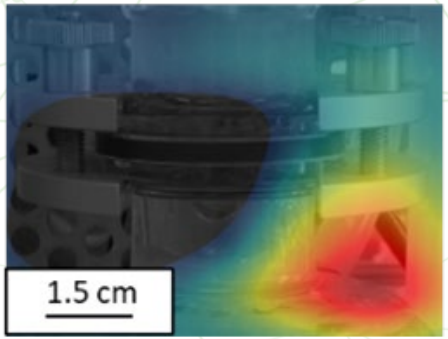
- What were the Learnings of its Usage?
  - More robust to use than edge detection
- How long does the development of such an image processing solution take?
  - BA thesis if data is provided, MA thesis if data is to be generated
  - A day to implement them as PEA



# AI-based Image Evaluation

- Which requirements have to be fulfilled?
  - GPU helps with larger models
  - Python as PEA
- What were the difficulties faced or could be?
  - unbalanced data sets, illumination/changing backgrounds
  - Hardware limitations (Jetson Nano)





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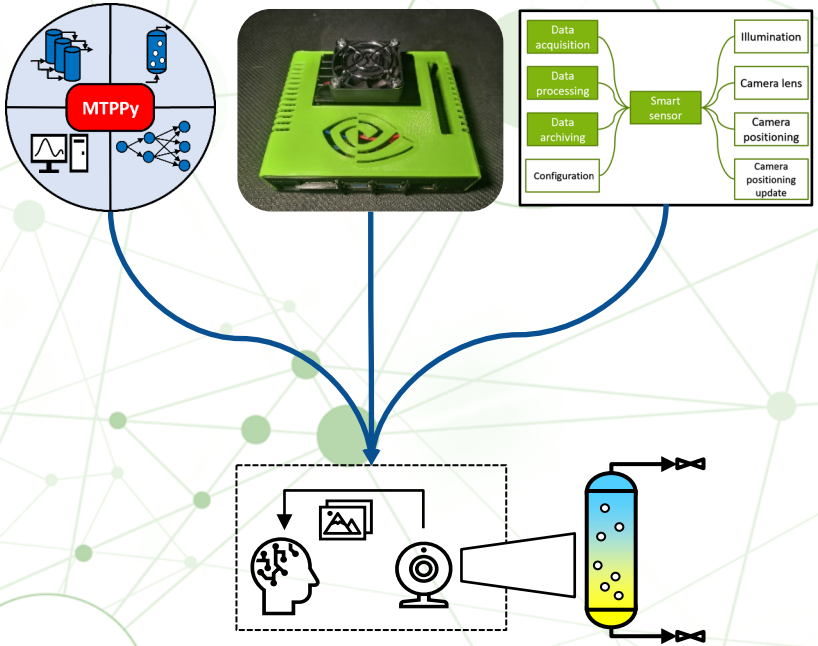
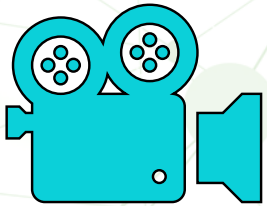


# MTP-Camera Hardware

**Power Supply**
Turck
PSU67-11-2440/M
24V DC

**PLC**
Turck
TBSEN-L5-PLC-11
Programming with codesys

**Lens Controller**
Gardasoft
TR-CL180



**Smart Kamera**
Matrox Iris GTR
Programming with Matrox Design Assistant

**Electrically tunable lens**
Optotune
EL-16-40-TC


**Switch**
Cisco

**Lighting**
depends on application

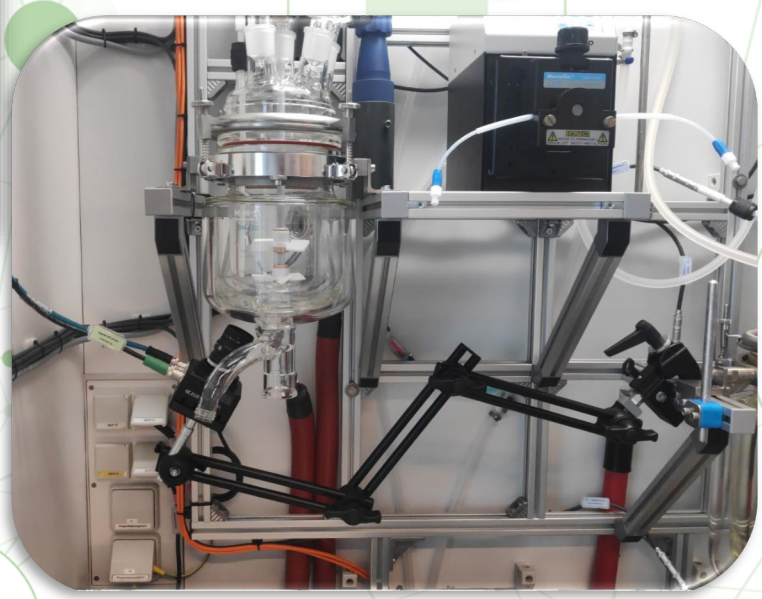
# MTP-Camera


Controller lens

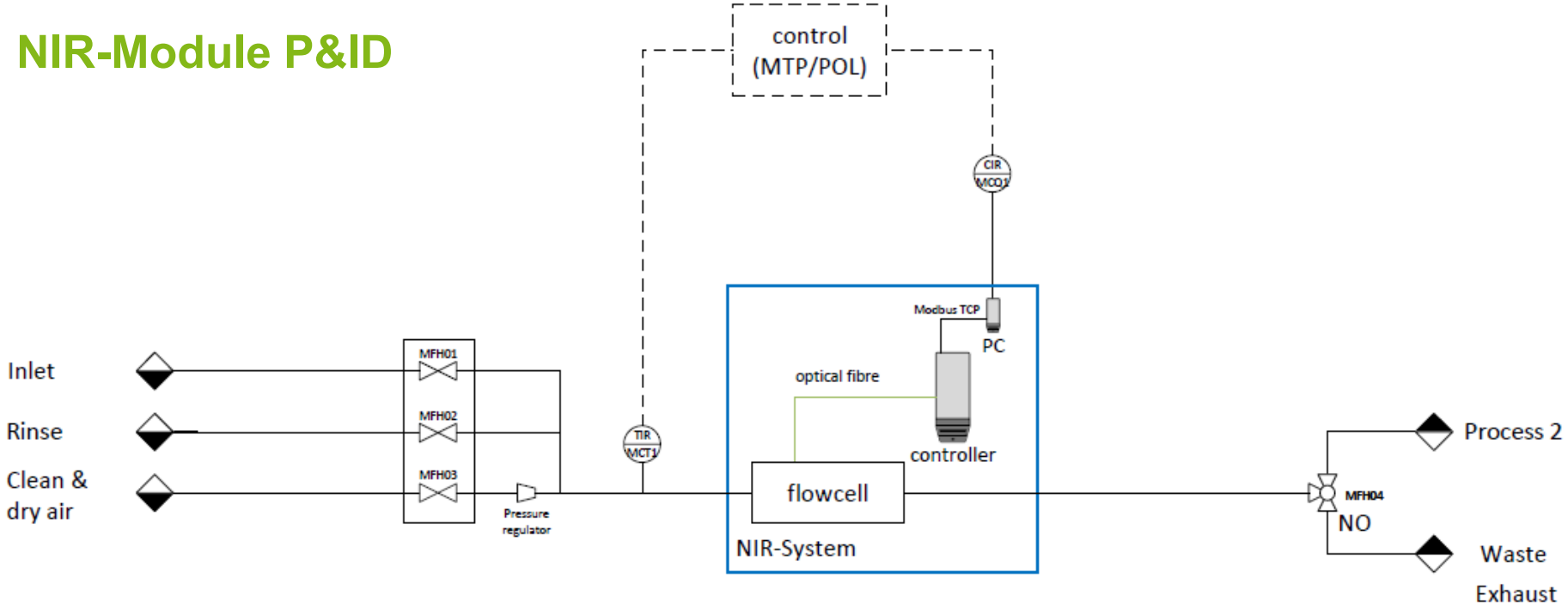
PLC

Power Supply

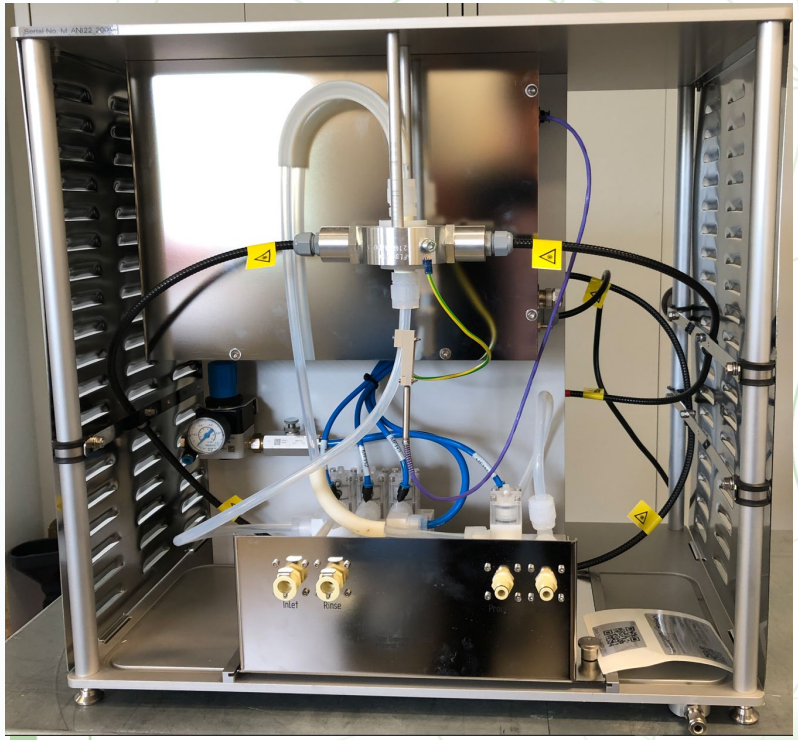
Smart Camera with tunable lens



# NIR-Module P&ID

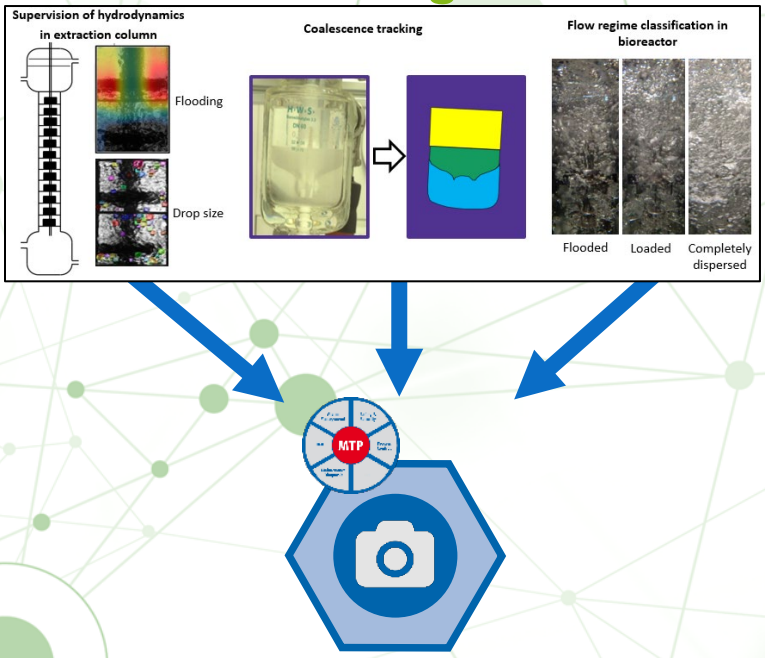


# Module

# Conclusion Cognitive Sensoren as Requirement for AI-Algorithms

- MTP standard provides a suitable framework to integrate advanced imaging analytics
- Unified service specification for camera system developed and validated



# Outlook Camera

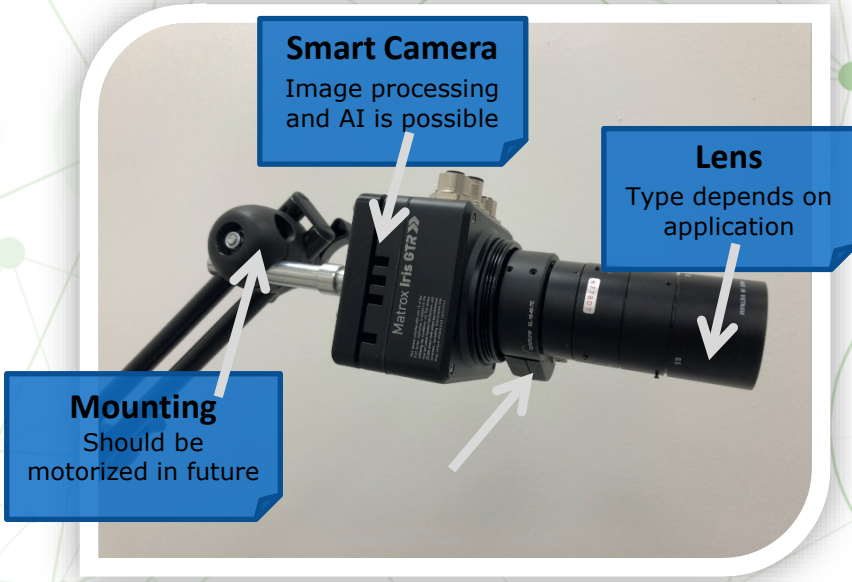
Transfer and visualisation of complex data streams

GMP conformity

Illumination automation

Robotic Arm (TU Dresden)

Hyperspectral cameras



# Outlook Cognitive Sensors

Transfer and visualisation of complex data streams

Combining image based AI with Other sensor data

GMP conformity

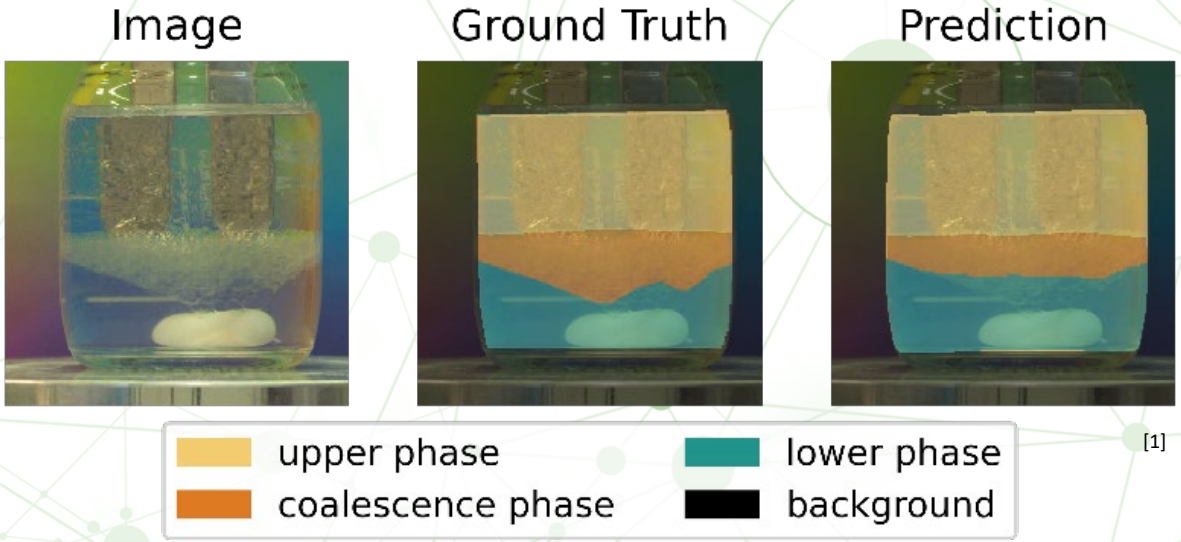
Unified, standard MTP interface for spectrometers

Integration of advanced analytic equipment (NMR, Raman, MIR, NIR) in modular plants using MTP

# Vielen Dank !

# Evaluation

- Realized PEAs
  - Coalescence detection
  - Flooding detection
  - Droplet detection




[1]

[1] L. Neuendorf, P. Müller, C. Bergeest, N. Kockmann, A. Meijer, C. Schlander, P50 - Künstliche Intelligenz (KI)-basierte optische Sensorik für flüssig-flüssig Systeme, 10.5162/16dss2022/P50

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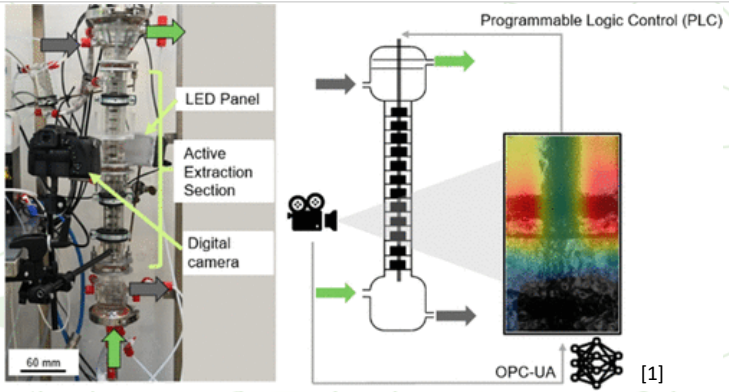


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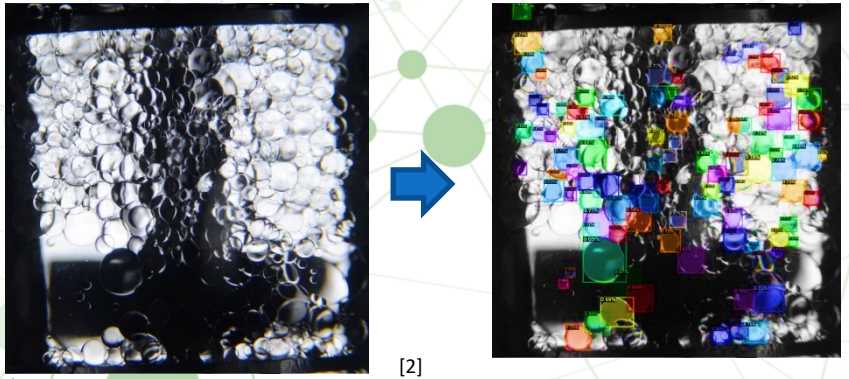

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[1] Neuendorf, Baygi, Kolloch and Norbert Kockmann, ACS Engineering Au 2022,2 (4), 369-377, DOI: 10.1021/acsengineeringau.2c00014
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