

From object detection to semantic segmentation: Leveraging the AI4EOSC platform for UAS-based thermal image analysis

AI4EOSC Webinar: Accelerating Research with AI4EOSC: Real Use Cases Exploiting the Platform

Elena Vollmer (elena.vollmer@kit.edu)



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Agenda

Motivation

Thermography?

Usage in energy context?

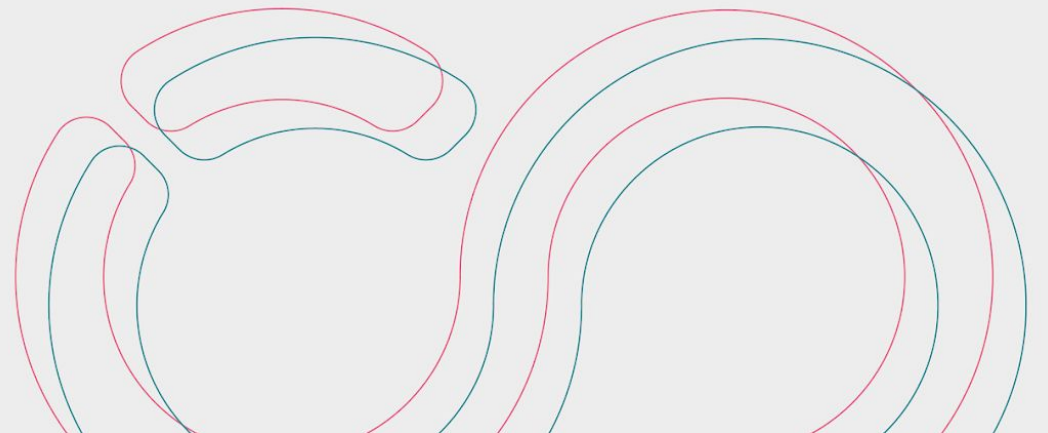
Deep Learning Models

AI4EOSC Platform

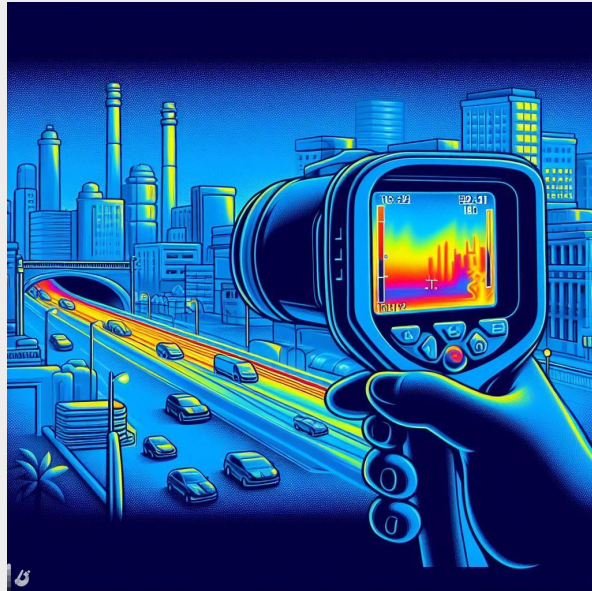


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Motivation



Bing Image Creator from Microsoft
<https://www.bing.com/images/create/>



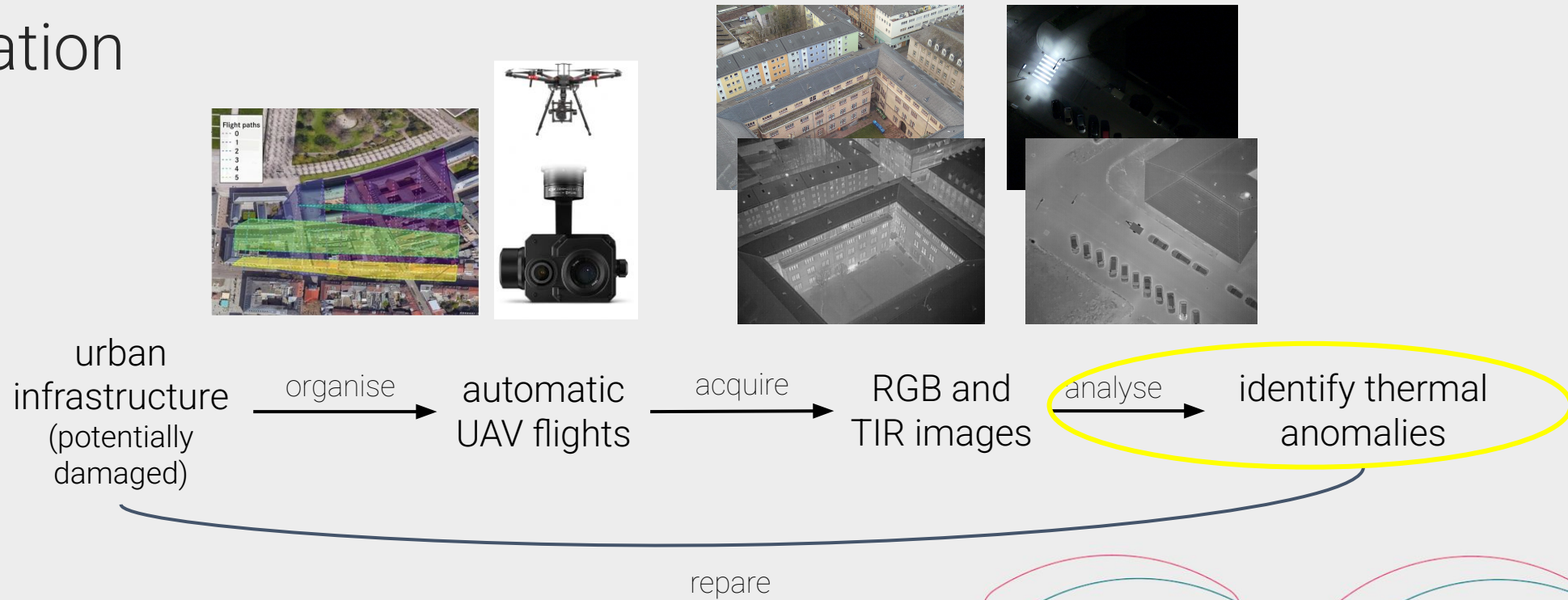
Bing Image Creator from Microsoft
<https://www.bing.com/images/create/>



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Motivation



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UAV = unmanned aerial vehicle
RGB = red green blue
TIR = thermal infrared

Deep Learning Models

TBBDet

Thermal Bridges on Building Rooftops Detection

Energy use: **Buildings**

Find thermal bridges on building rooftops
→ support energy **retrofitting** measures

TASeg

Thermal Anomaly Segmentation

TUFSeg

Thermal Urban Feature Segmentation

Energy supply: **District heating networks**

Find thermal anomalies and classify common urban features
→ identify network **leaks** as remaining anomalies



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Deep Learning Models

TBBRDet

Thermal Bridges on Building Rooftops Detection

Energy use: **Buildings**

Find thermal bridges on building rooftops
→ support energy **retrofitting** measures

Single-class
object detection
or instance segmentation



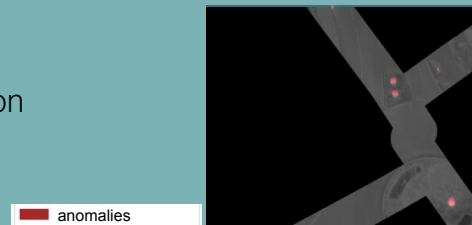
TASeg

Thermal Anomaly Segmentation

Energy supply: **District heating networks**

Find thermal anomalies and classify common urban features
→ identify network **leaks** as remaining anomalies

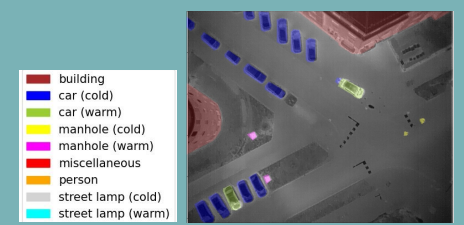
Binary
Semantic
Segmentation



TUFSeg

Thermal Urban Feature Segmentation

Multi-class
Semantic
Segmentation



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Deep Learning Models

TBBDet

Thermal Bridges on Building Rooftops Detection

Energy use: **Buildings**

Find thermal bridges on building rooftops
→ support energy **retrofitting** measures

Single-class
object detection
or instance segmentation

thermal bridges



Dual camera: RGB + TIR
UAV-based: 45° pitch, overlap
Acquisition: daytime in Karlsruhe (DE)



TASeg

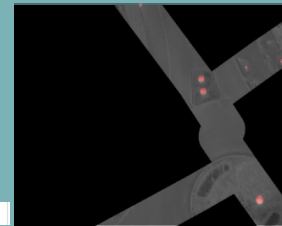
Thermal Anomaly Segmentation

Energy supply: **District heating networks**

Find thermal anomalies and classify common urban features
→ identify network **leaks** as remaining anomalies

Binary
Semantic
Segmentation

anomalies

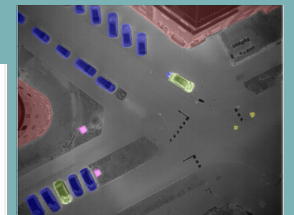


TUFSeg

Thermal Urban Feature Segmentation

Multi-class
Semantic
Segmentation

building
car (cold)
car (warm)
manhole (cold)
manhole (warm)
miscellaneous
person
street lamp (cold)
street lamp (warm)



Dual camera: RGB + TIR
UAV-based: 90° pitch, overlap
Acquisition: nighttime in Munich (DE) and Karlsruhe (DE)



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UAV = unmanned aerial vehicle
RGB = red green blue
TIR = thermal infrared
DE = Germany

Deep Learning Models

TBBDet

Thermal Bridges on Building Rooftops Detection

Data splits: ~720 train, ~200 test

Object detection (and instance segmentation) model(s):

- MaskRCNN ResNet-18 backbone
- MaskRCNN ResNet-50 backbone
- MaskRCNN Swin-T Transformer backbone
- TridentNet*
- Feature Selective Anchor-Free (FSAF)*

MMDetection toolboxes using PyTorch

Mayer, Z. *et al.* Deep learning approaches to building rooftop thermal bridge detection from aerial images. In *Automation in Construction* Vol. 146, p. 104690 (2023). Elsevier BV.
<https://doi.org/10.1016/j.autcon.2022.104690>



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TASeg

Thermal Anomaly Segmentation

Data splits: ~2200 train, ~450 val, ~50 test

Semantic Segmentation model(s):

- SegFormer B0 - B4 backbone
- DeepLabV3+ ResNet-101 backbone
- PSPNet ResNet-101 backbone
- U-Net ResNet-101 backbone

Segmentation_models.pytorch (SMP) and
HuggingFace-Transformers toolboxes using
PyTorch

Vollmer, E. et al.
UNDER REVIEW

TUFSeg

Thermal Urban Feature Segmentation

Data splits: ~630 train, ~160 test

Semantic Segmentation model(s):

- U-Net ResNet-152 backbone

Segmentation_models (SM) toolbox using
Tensorflow;
Energy monitoring using Perun

Vollmer, E. et al., "Enhancing UAS-Based Multispectral Semantic Segmentation Through Feature Engineering," in *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 18, pp. 6206-6216, 2025, <https://doi.org/10.1109/JSTARS.2025.3537330>

* Architectures that only perform
the object detection task

UAV = unmanned aerial vehicle
RGB = red green blue
TIR = thermal infrared
DE = Germany

Deep Learning Models

TBBDet

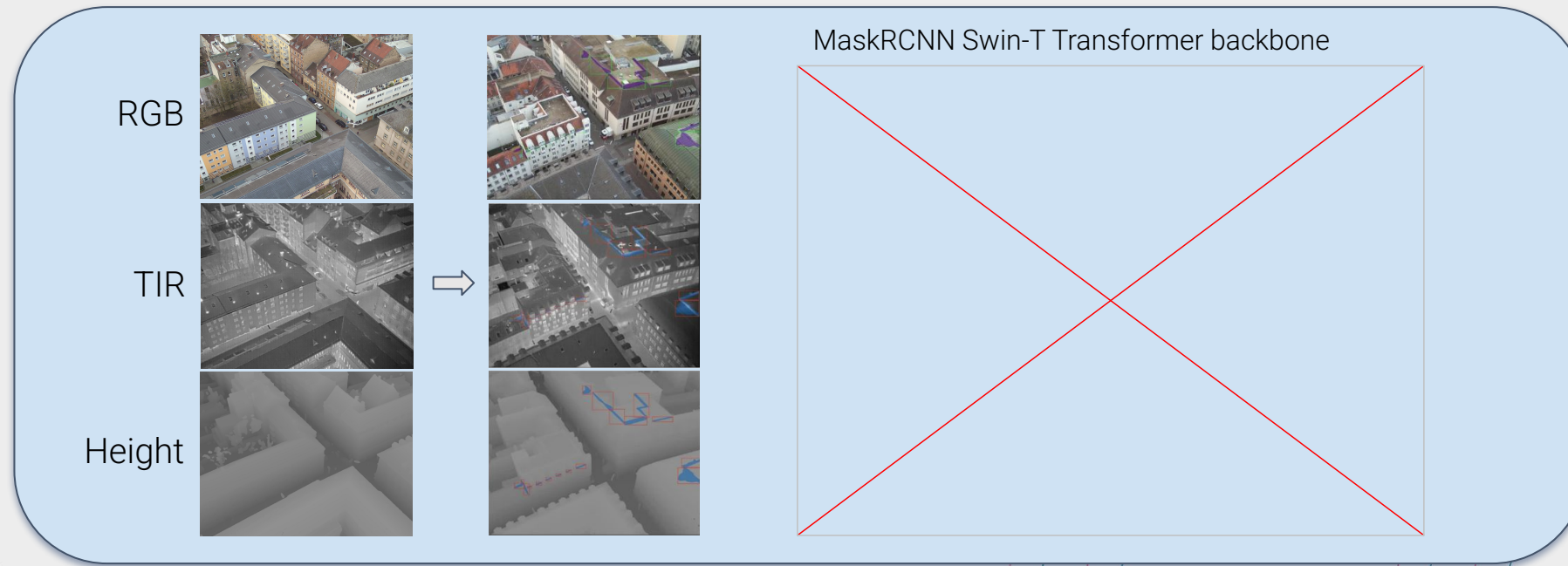
Thermal Bridges on Building Rooftops Detection

TASeg

Thermal Anomaly Segmentation

TUFSeg

Thermal Urban Feature Segmentation



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RGB = red green blue
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Deep Learning Models

TBBDet

Thermal Bridges on Building Rooftops Detection

TASeg

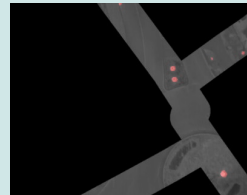
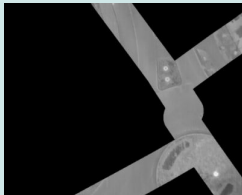
Thermal Anomaly Segmentation

TUFSeg

Thermal Urban Feature Segmentation

SegFormer B2

TIR
masked



TIR
unmasked



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Deep Learning Models

TBBDet

Thermal Bridges on Building Rooftops Detection

TASeg

Thermal Anomaly Segmentation

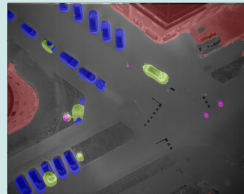
TUFSeg

Thermal Urban Feature Segmentation

RGB



TIR



U-Net ResNet-152 backbone



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AI4

eosc

Dashboards

Statistics

Catalog

Modules

Tools

LLMs

Tasks

Try me

Deployments

Inference

Platform Services

Storage

Experiment tracking

AI Inference workflows

AI4EOSC

External catalogs

Search

thermal

Libraries

Tasks

Platform Categories

Data Types

Tags

Add filter

Thermal Anomaly Segmenter (TASeg)

UAS-based thermal urban anomaly semantic segmentation for leak detection in district heating systems

Thermal Bridges on Building Rooftops Detection (TBBDet)

Identify thermal bridges on building rooftops via object detection / instance segmentation models

Thermal Urban Feature Segmentation (TUFSeg)

Identify common thermal urban features in urban landscapes via semantic segmentation

Inference

Platform Services

Storage

Experiment tracking

AI Inference workflows

The AI4EOSC dashboard is a service provided by CSIC, co-funded by AI4EOSC

EU

AI4EOSC

Training the deep learning model(s)

The service is based on the [TUFSeg code](#) for thermal urban feature segmentation. The UNet model can be trained from scratch or using pretrained ImageNet weights. The utilised data can be preprocessed for training in various ways, including vignetting correction for halo effect removal or retinex unsharp filters for contrast increase and deblurring.

Training via this application automatically creates a timestamp folder within the thermal-urban-feature-segmenter/models/ folder.

Data

The dataset that forms the basis of model training is [Thermal Urban Feature Segmentation \(TUFSeg\)](#). It stems from a case study of the cities of Munich and Karlsruhe in Germany and encompasses drone-based multi-spectral (thermal and standard RGB) imagery. The dataset contains **793 images** with a total of **8010 annotations** of common thermal urban features, including buildings, cars, manholes, people, streetlamps, and miscellaneous:

- train (634 images)
- test (159 images)

Due to the small number of images, no validation set is created and instead the data is merely split into train / test.

Inference

Tags

deep learning

semantic segmentation

multi-spectral data

Platform Categories

AI4 trainable

AI4 pre trained

AI4 inference

Additional Resources

GitHub

Ask AI

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EU

AI4EOSC

v3.5.0

Status

Homepage

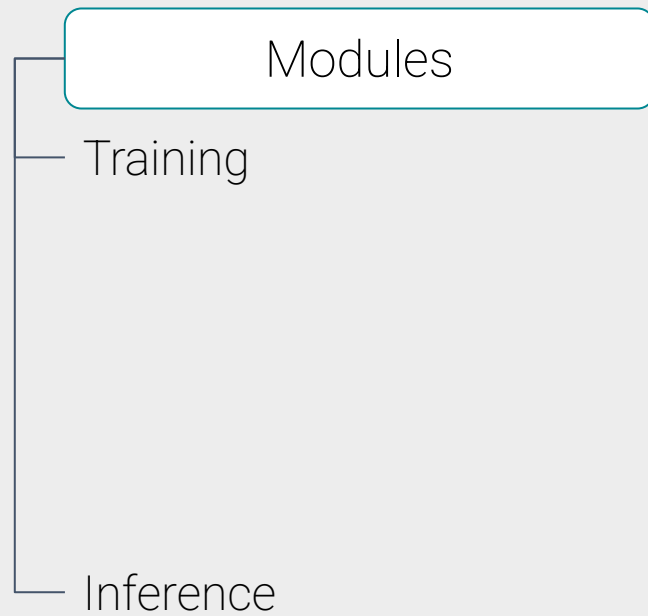
Docs

Terms of use

Privacy policy

Ask AI

Leveraging the AI4EOSC Platform



The screenshot displays the AI4EOSC platform interface. On the left is a sidebar menu with the following items: Dashboard, Statistics, Catalog, Modules (highlighted in teal), Tools, LLMs, Tasks, Try me, Deployments, Inference, Platform Services, Storage, Experiment tracking, and AI Inference workflows. The main content area is titled 'Modules' and shows a search bar with the text 'thermal'. Below the search bar are filters for Libraries, Tasks, Platform Categories, Data Types, and Tags. Three modules are displayed in a grid:

- Thermal Anomaly Segmenter (TASeg)**: UAS-based thermal urban anomaly semantic segmentation for leak detection in district heating systems.
- Thermal Bridges on Building Rooftops Detection (TBBRDet)**: Identify thermal bridges on building rooftops via object detection / instance segmentation models.
- Thermal Urban Feature Segmentation (TUFSeg)**: Identify common thermal urban features in urban landscapes via semantic segmentation.

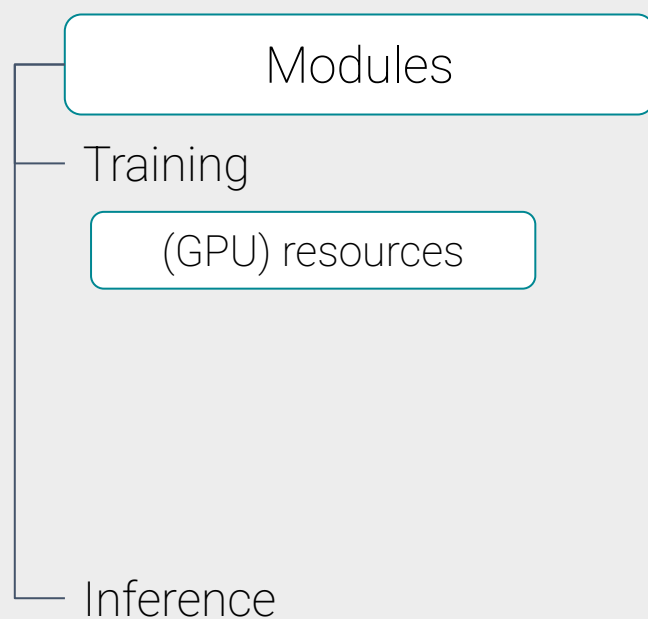
At the bottom of the interface, there is a footer with the text: 'The AI4EOSC dashboard is a service provided by CSIC, co-funded by AI4EOSC'. Below this is the European Union flag and the AI4EOSC logo. On the right side of the footer, there are links for v3.5.0, Status, Homepage, Docs, Terms of use, and Privacy policy. At the bottom right, there is a button labeled 'Ask AI'.



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Leveraging the AI4EOSC Platform



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Dashboard Statistics

Catalog

Modules

Tools

LLMs

Tasks

Try me

Deployments

Inference

Platform Services

Storage

Experiment tracking

AI Inference workflows

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Configure training: **Thermal Urban Feature Segmentation (TUFSeg)**

Modules / Thermal Urban Feature Segmentation (TUFSeg) / Deploy

Show help

General configuration Hardware configuration Data configuration

Hardware options

Number of CPUs
4

Number of GPUs
1

GPU model
Tesla V100-PCIE-32GB

RAM memory (in MB)
40000

Disk memory (in MB)
50000

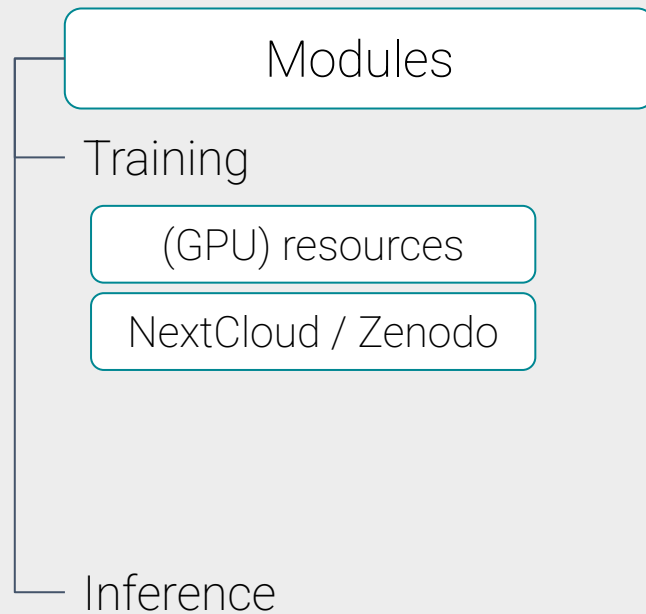
Back Next

Ask AI



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Leveraging the AI4EOSC Platform



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Dashboard Statistics Catalog Modules Tools LLMs Tasks Try me Deployments Inference Platform Services Storage Experiment tracking AI Inference workflows

Configure training: **Thermal Urban Feature Segmentation (TUFSeg)**

Modules / Thermal Urban Feature Segmentation (TUFSeg) / Deploy

General configuration Hardware configuration Data configuration

Storage configuration

Storage service: share.services.ai4os.eu

Advanced settings

Dataset configuration

Name

Datasets

zenodo doi + HTTP

Zenodo community

Artificial Intelligence for the European Open Science Cloud (AI4EOSC)

Zenodo dataset

Thermal Urban Feature Segmentation - Multispectral (RGB + Thermal) UAS-based images from Germany with annotations ✓

Hyperspectral (RGB + Thermal) drone images of Karlsruhe, Germany - Raw images for the Thermal Bridges on Building Rooftops (TBBR) dataset

Thermal Bridges on Building Rooftops - Hyperspectral (RGB + Thermal + Height) drone images of Karlsruhe, Germany, with thermal bridge annotations

Plant leaves image segmentation dataset

This module has a suggested dataset. Click here to add it.

Source Force pull Actions

Add dataset

Back Submit

Ask AI

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Leveraging the AI4EOSC Platform

Modules

Training

(GPU) resources

NextCloud / Zenodo

Inference

Swagger

DEEP as a Service API endpoint ^{2.3}

Hybrid DataCloud

This is a REST API that is focused on providing access to machine learning models. By using the t HTTP calls.

Currently you are browsing the [Swagger UI](#) for this API, a tool that allows you to visualize and int

- [Project website](#).
- [Project documentation](#).
- [Model marketplace](#).

API documentation

versions

GET /v2/ Get V2 API version information

GET / Get available API versions

debug

GET /v2/debug/ Return debug information if enabled by API.

models

GET /v2/models/ Return loaded models and its information

GET /v2/models/tufsegm_api/ Return model's metadata

POST /v2/models/tufsegm_api/train/ Retrain model with available data

GET /v2/models/tufsegm_api/train/ Get a list of trainings (running or completed)

GET /v2/models/tufsegm_api/train/{uuid} Get status of a training

DELETE /v2/models/tufsegm_api/train/{uuid} Cancel a running training

POST /v2/models/tufsegm_api/predict/ Make a prediction given the input data

POST /v2/models/tufsegm_api/train/ Retrain model with available data Cancel

Parameters

Name	Description
mlflow_username string (query)	MLFlow username for experiment tracking (password will be requested via terminal). Leave blank if you don't want to use MLFlow.
backbone string (query)	Model backbone to use. Default is 'resnet152'.
weights string (query)	Encoder weights to load (pretrained or not). Default is 'imagenet'.
dataset_path string (query)	Path to the dataset. Available paths are: • local: [] • remote: ['/storage/tufsegm/data', '/storage/tufsegm/remote_data', '/storage/tufsegm/test_unzipping_data', '/storage/tufsegm/zipped_data']
save_for_viewing boolean (query)	Save additional data such as segmentation masks in .png for user viewing. ATTENTION: This will fill up additional space!
test_size number(\$float) (query)	Percentage of the dataset to be used for testing and to calculate evaluation metrics with.
channels integer(\$int32) (query)	Process the data either in standard 4 channels (RGBT) or as 3 channels (greyRGB+T+T).
processing string (query)	Use original data (basic) or apply preprocessing filters (vignetting removal, retinex and unsharp).
img_size string (query)	Use original image size (640x512) or downscale. ATTENTION: The original size requires a lot of RAM memory (> 25000) otherwise training will fail.
epochs integer(\$int32) (query)	Number of epochs to train the model.
batch_size integer(\$int32) (query)	Batch size to load the data.
lr number(\$float) (query)	Learning rate.
seed integer(\$int32) (query)	Global seed number for training.

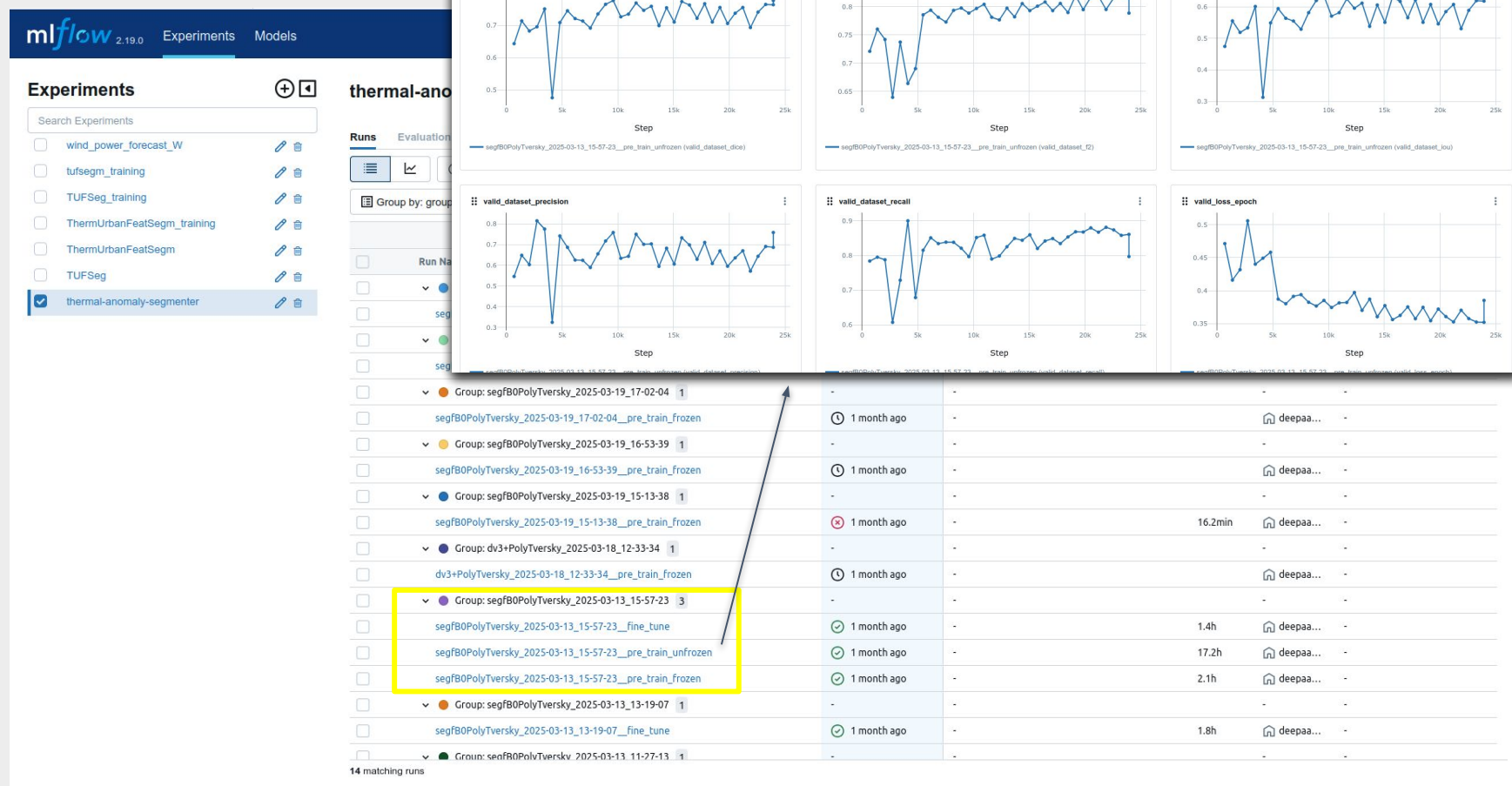
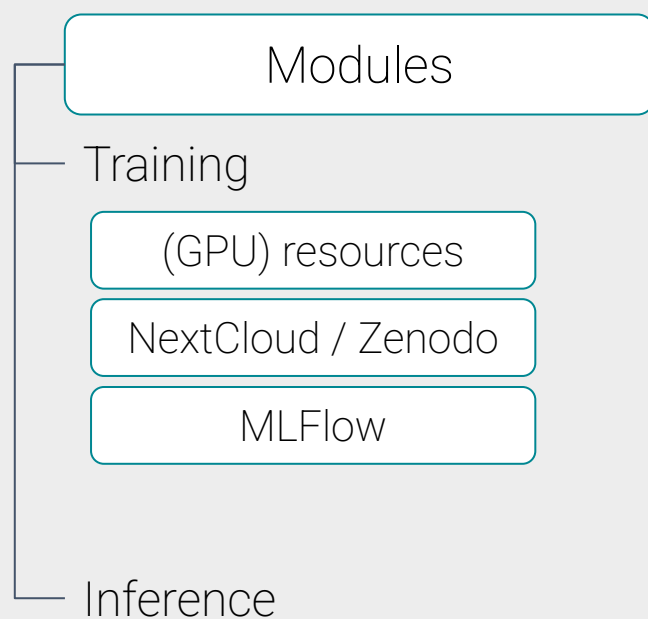
Execute



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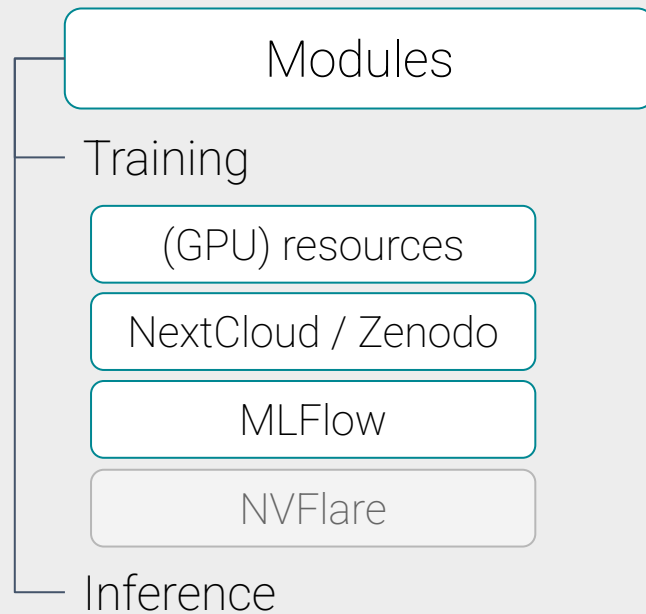
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Leveraging the AI4EOSC Platform



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Leveraging the AI4EOSC Platform



Federated learning with NVFlare

NVFlare Dashboard and Federated learning server

NVIDIA FLARE (NVIDIA Federated Learning Application Runtime Environment) is a domain-agnostic, open-source, extensible SDK that allows researchers and data scientists to adapt existing ML/DL workflows to a federated paradigm. It enables platform developers to build a secure, privacy-preserving offering for a distributed multi-party collaboration.

Management Tools

- Provisioning
- Orchestration
- Monitoring

NVIDIA FLARE Runtime

Federated Specification

- Training Flows
- Evaluation Flows
- Learning Algorithms
- Privacy Preserving Algorithms

Learner Configuration

Authenticate, Train, Evaluate, and Update Models

- PyTorch
- TensorFlow
- NumPy
- MONAI

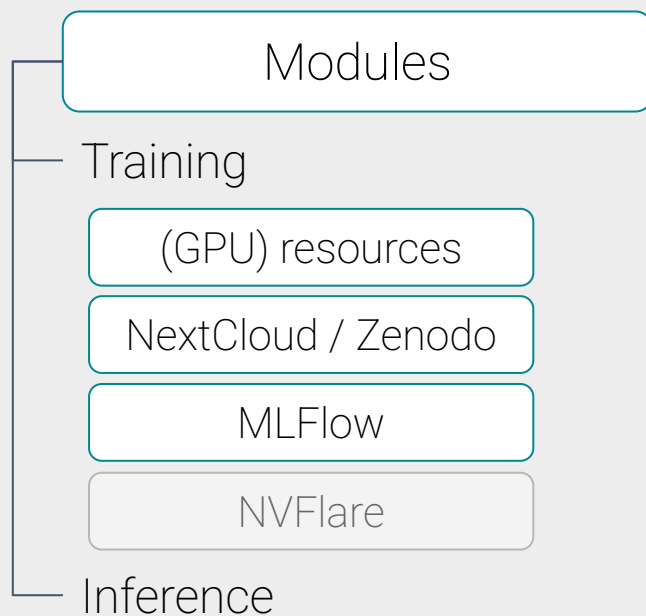


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Duda, L. et al. Comparative Study of Federated Learning Frameworks NVFlare and Flower for Detecting Thermal Bridges in Urban Environments. At EGI Conference (2024). Lecce, Italy.
<https://publikationen.bibliothek.kit.edu/1000174831>

Leveraging the AI4EOSC Platform



Swagger

DEEP as a Service API endpoint 2.3.2

Hybrid DataCloud

This is a REST API that is focused on providing access to machine learning models. By using the DEEP API, you can interact with the models via HTTP calls.

Currently you are browsing the [Swagger UI](#) for this API, a tool that allows you to visualize and interact with the API.

- [Project website](#)
- [Project documentation](#)
- [Model marketplace](#)

[API documentation](#)

versions

- [GET /v2/](#) Get V2 API version information
- [GET /](#) Get available API versions

debug

- [GET /v2/debug/](#) Return debug information if enabled by API.

models

- [GET /v2/models/](#) Return loaded models and its information
- [GET /v2/models/tufsegm_api/](#) Return model's metadata
- [POST /v2/models/tufsegm_api/train/](#) Retrain model with available data
- [GET /v2/models/tufsegm_api/train/](#) Get a list of trainings (running or completed)
- [GET /v2/models/tufsegm_api/train/{uuid}](#) Get status of a training
- [DELETE /v2/models/tufsegm_api/train/{uuid}](#) Cancel a running training
- [POST /v2/models/tufsegm_api/predict/](#) Make a prediction given the input data

POST /v2/models/tufsegm_api/predict/ Make a prediction given the input data

Parameters

Name	Description
model_dir string (query)	Model to be used for prediction. Results will be saved to a "predictions" folder in the selected model directory. Currently existing model paths are: <ul style="list-style-type: none"> local: ['/srv/thermal-urban-feature-segmenter/models/2023-11-20_20-35-52'] remote: ['/storage/tufsegm/models/2023-09-11_12-02-35', '/storage/tufsegm/models/2023-09-21_11-42-18', '/storage/tufsegm/models/2023-11-20_20-35-52', '/storage/tufsegm/tests/models/2024-04-24_17-57-17']
input_file string (query)	Insert a .npy path of a four channels file to infer on. Provide this in either one of two ways: <ul style="list-style-type: none"> local path (in 'data/') f.e.: 'images/KA_01/DJI_0_0001_R.npy' remote path on Nextcloud f.e.: '/storage/.../KA_01/DJI_0_0001_R.npy'
display boolean (query)	Plot the resulting prediction to the console. false
accept string (header)	Return format for method response. application/json

Execute



Leveraging the AI4EOSC Platform

Modules

Training

(GPU) resources

NextCloud / Zenodo

MLFlow

NVFlare

Inference

GradIO

application/json image/png

tufsegm_api

This is a temporary deployment that will automatically delete itself after 10 minutes. To access more permanent inference options, [become a member of one of the supported projects](#). Take into account that this deployment runs on *limited resources*, therefore some resource-intensive functionalities (like processing videos or very big images) might not work as expected.

Input_file
DJI_1_0604_R.npy 42.9 MB

Input a 4-channel .npy file to infer upon.

model_dir
Choose a model to use for inference. Results will be saved to a "predictions" folder in the selected model directory.
/srv/thermal-urban-feature-segmenter/models/2023-11-20-20-35-52

Plot the resulting prediction to the console.
☐ display

Clear Submit

output

Inference Results - data/DJI_1_0604_R.npy
Original four channel image

RGB Thermal

Processed image channels used as model input

Channel 1 Channel 2 Channel 3

Segmentation mask

- building
- car (cold)
- car (warm)
- manhole (cold)
- manhole (warm)
- miscellaneous
- person
- street lamp (cold)
- street lamp (warm)

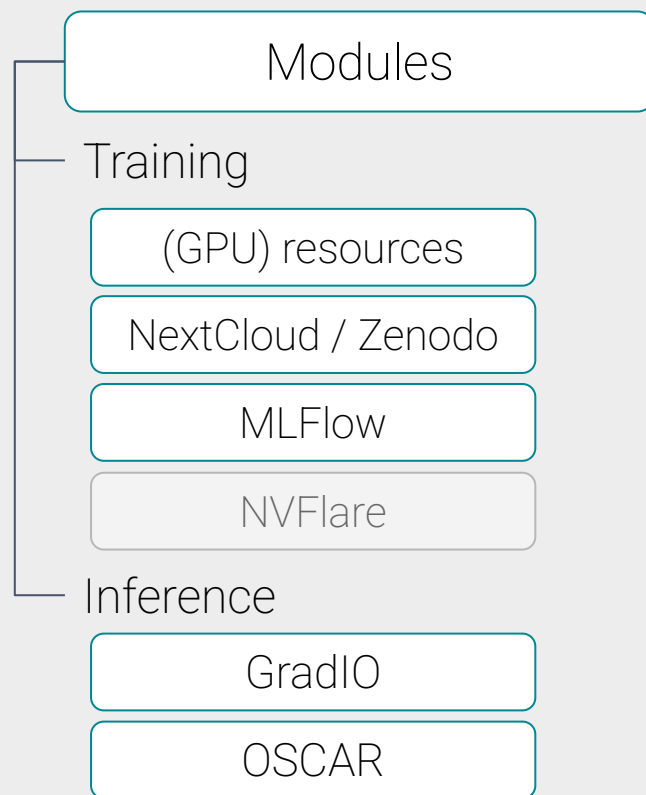
Flag



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Leveraging the AI4EOSC Platform



The screenshot displays the AI4EOSC platform interface. On the left, a sidebar shows navigation options: Services, Buckets, Notebooks, and Info. The main area lists various buckets, including 'thermal-bridges-rooftops-detector' and 'thermal-bridges-rooftops-detector-c28d9f63e4'. Two callout boxes provide detailed views of these buckets. The top callout shows the 'thermal-bridges-rooftops-detector' bucket with a file named 'DJI_0004_R_score0.5.png'. The bottom callout shows the 'thermal-bridges-rooftops-detector-c28d9f63e4' bucket with a file named 'DJI_0006_R_score0.5.png'.



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Thank you for your attention!

Questions?

Elena Vollmer (elena.vollmer@kit.edu)



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