



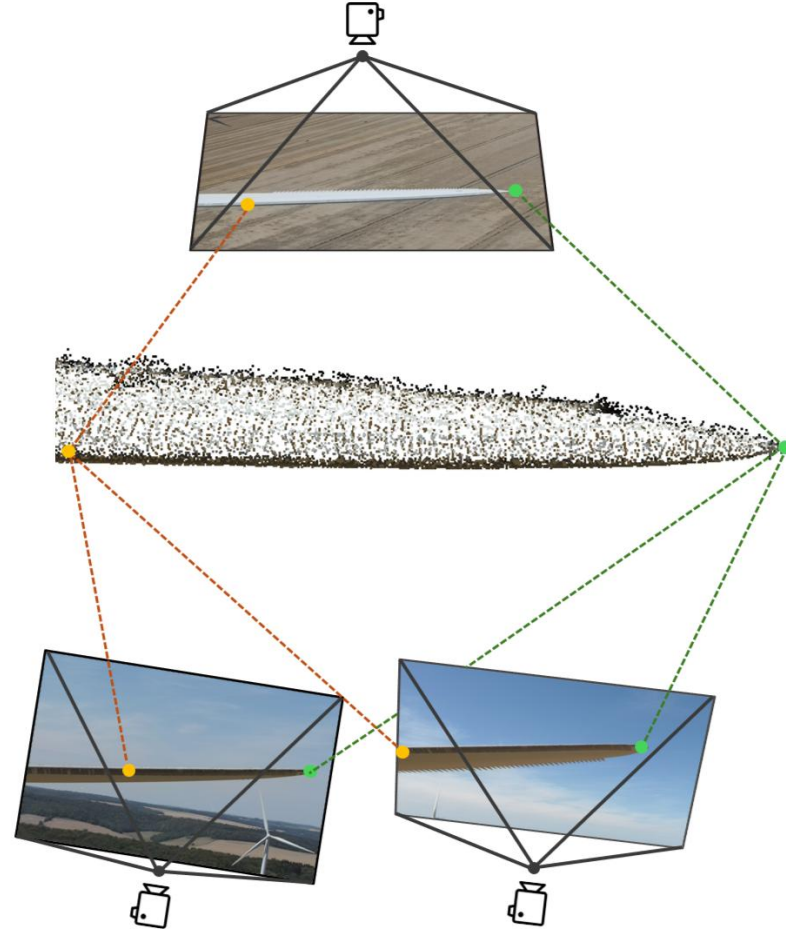
UNIVERSITEIT GENT

Computer Vision for Blade Inspections

Drone-based 3D Reconstruction & Visual-Thermal Fusion

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BLEEPID

Blade Leading Edge Erosion Prediction and Drone-based Inspection

Context

- **Leading edge erosion** impacts aerodynamics
 - Reduces energy output
 - Costly to repair if untreated for too long
- **Goals**
 - **3D reconstruction** from drone RGB images
 - **Wear assessment** on resulting 3D models
- **Localizing and quantifying** erosion can help to:
 - Prevent costly repairs
 - Improve/train predictive erosion models**=> Proactive O&M**

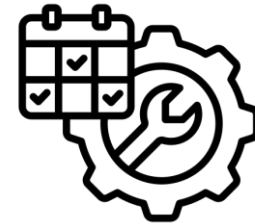
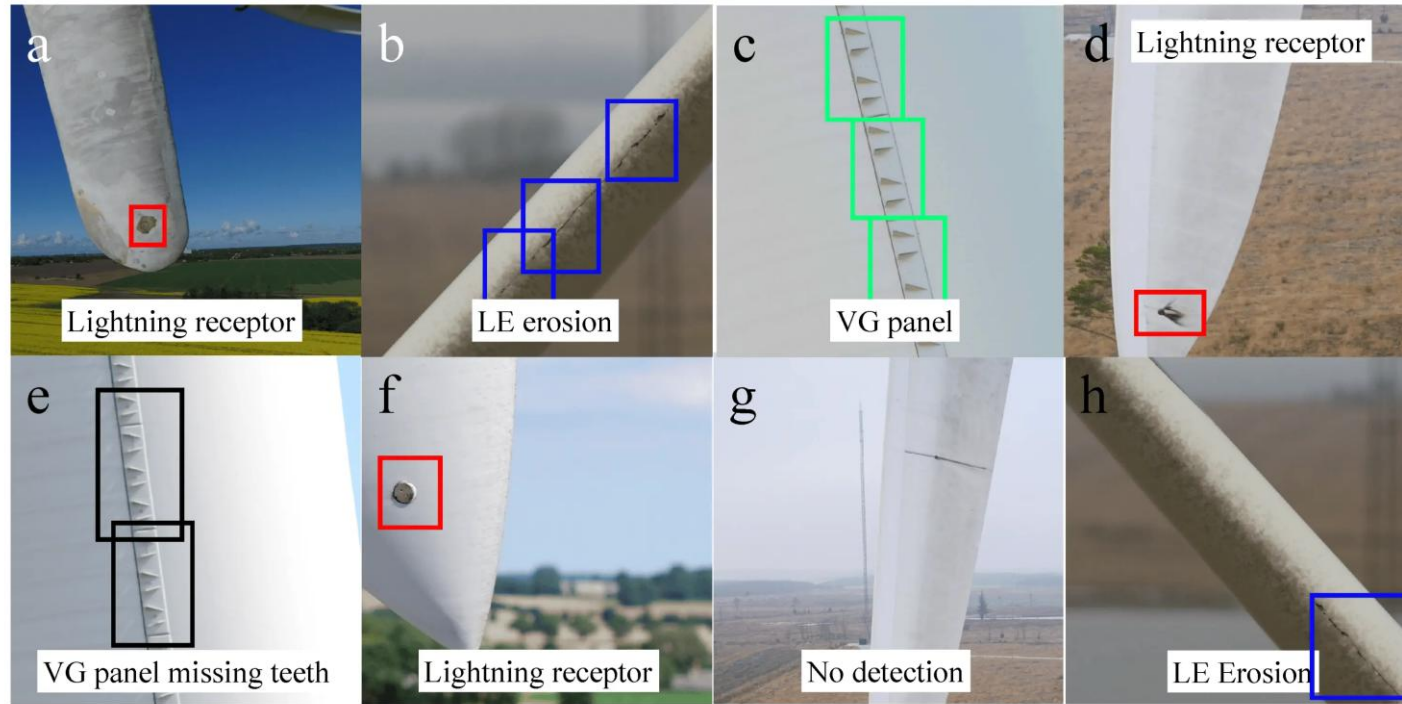
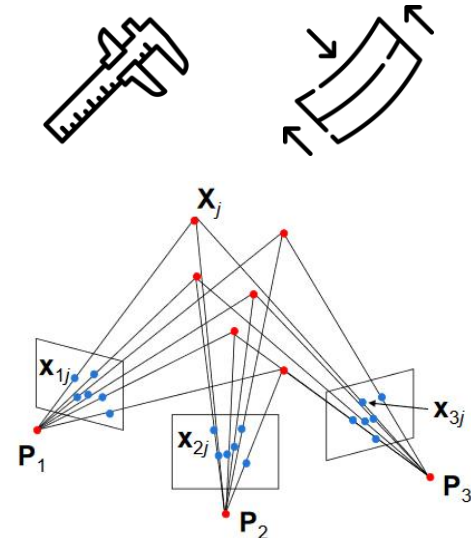


Image-based damage detection



Beyond image analysis

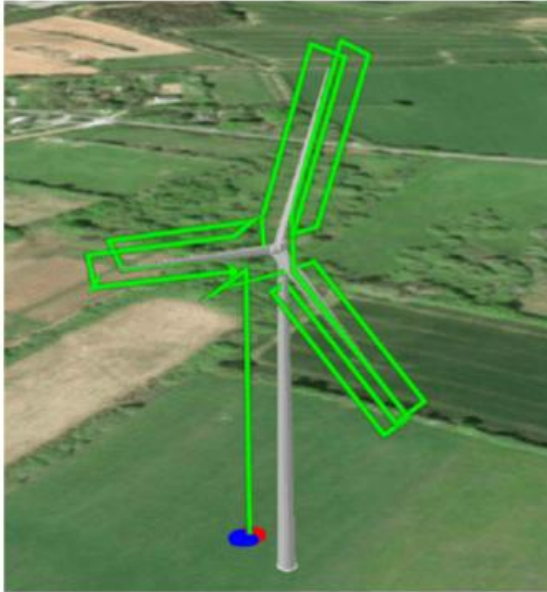
- Limitations of 2D image analysis:
 - **Only detection** of defects, no quantification
 - **No defect localization**
 - Susceptible to **false positives** (e.g., dirt looks like erosion)
- A 3D model enables:
 - **Quantifying** wear (e.g., erosion), blade deformation, ...
 - **Localizing** defects in 3D
 - **Distinguishing** damage from discoloration/dirt
- **Multi-view images enable 3D reconstruction**
 - => we can stick to visual drone inspections
 - => easy integration in existing inspection pipelines



UAV inspections

Typical flight

Trajectory



Example images



Goal

Full coverage while minimizing flight time

Solution

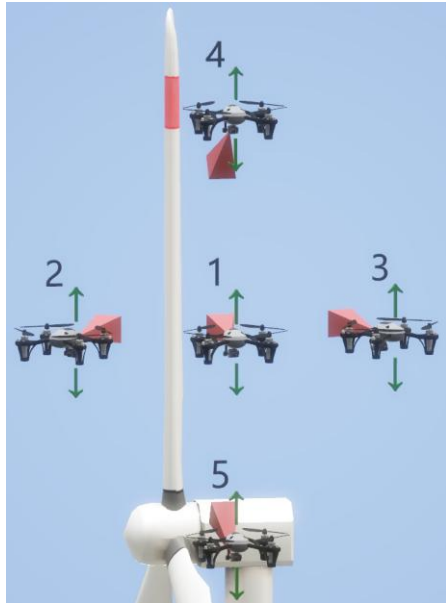
Quick fly-by, minimal overlap

3D reconstruction needs
diverse viewpoints!

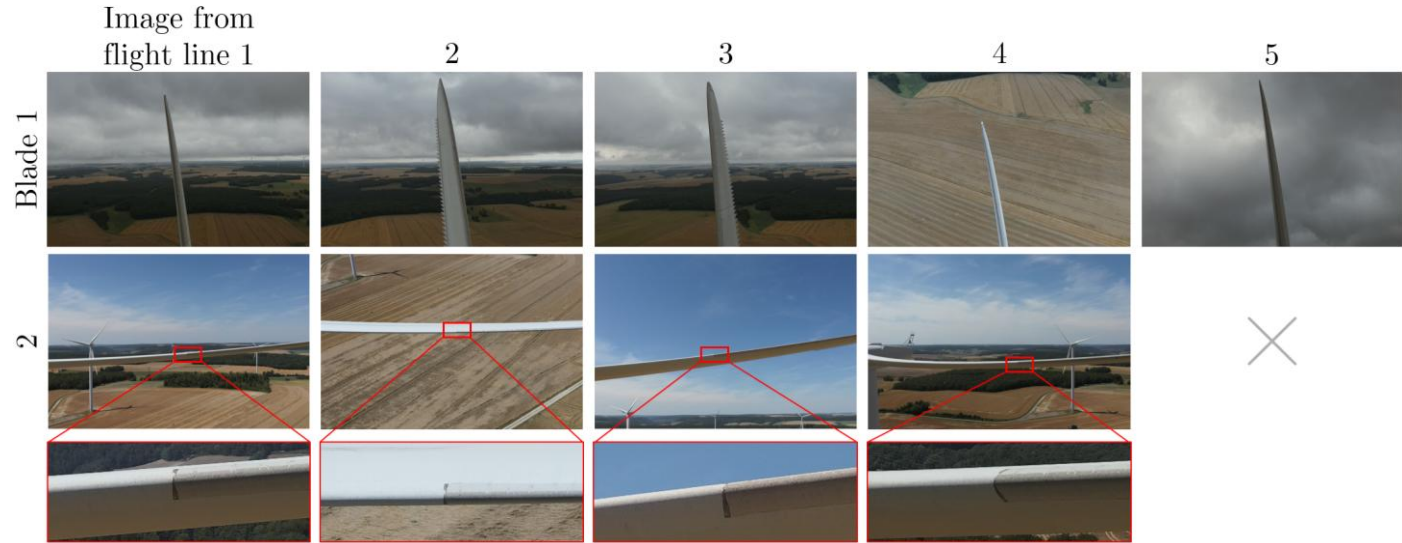
UAV inspections

Custom trajectory (for 3D reconstruction)

Trajectory



Example images

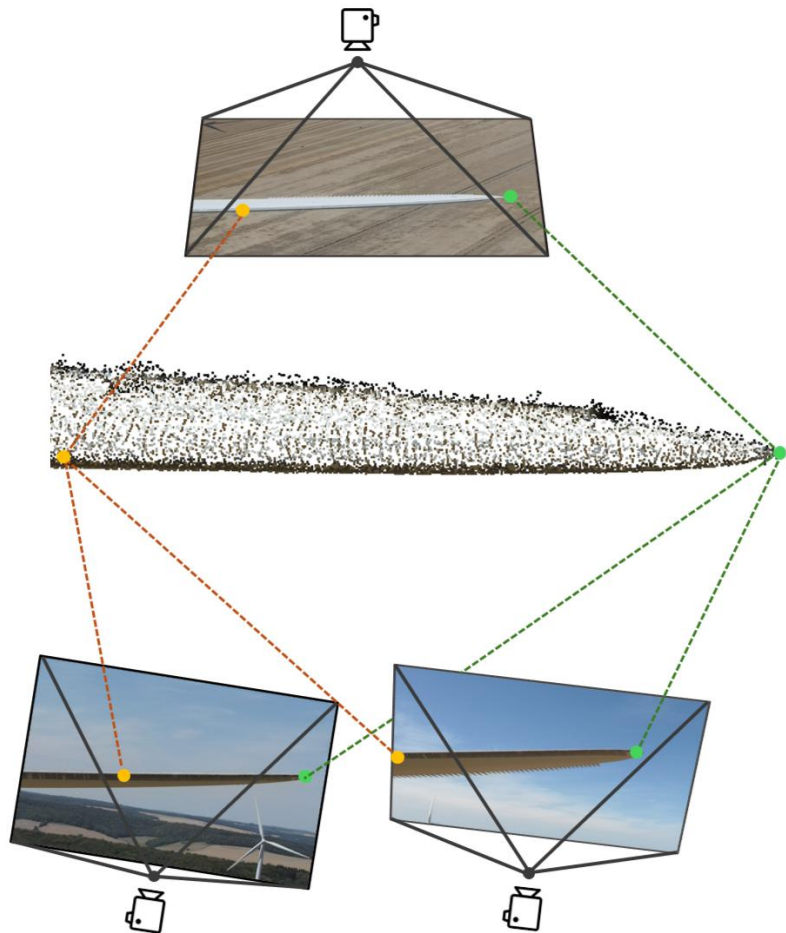


Sparse 3D reconstruction

In a nutshell

■ Phase I

- Detect and **match visual features** across **multiple photos**
- Knowing the drone's position & camera angle, you can **triangulate** the observed points
- The system **jointly estimates** the drone's **flight paths & 3D points** through multi-view geometric constraints
- Output: **3D point cloud** created from thousands of multi-view observations

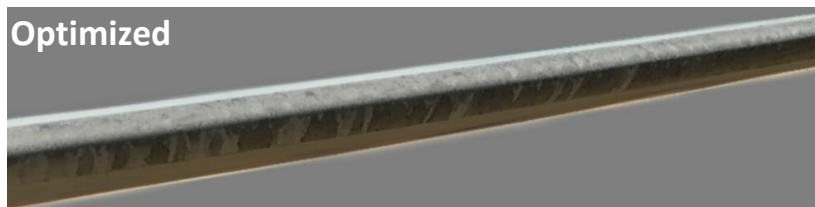
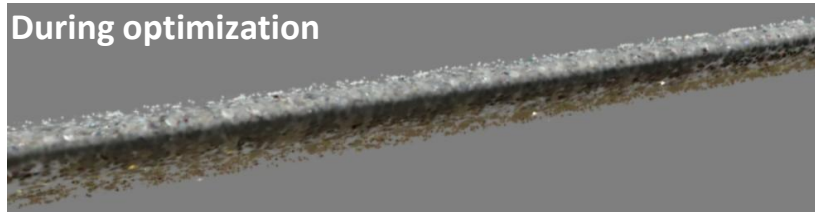


Dense 3D reconstruction

In a nutshell

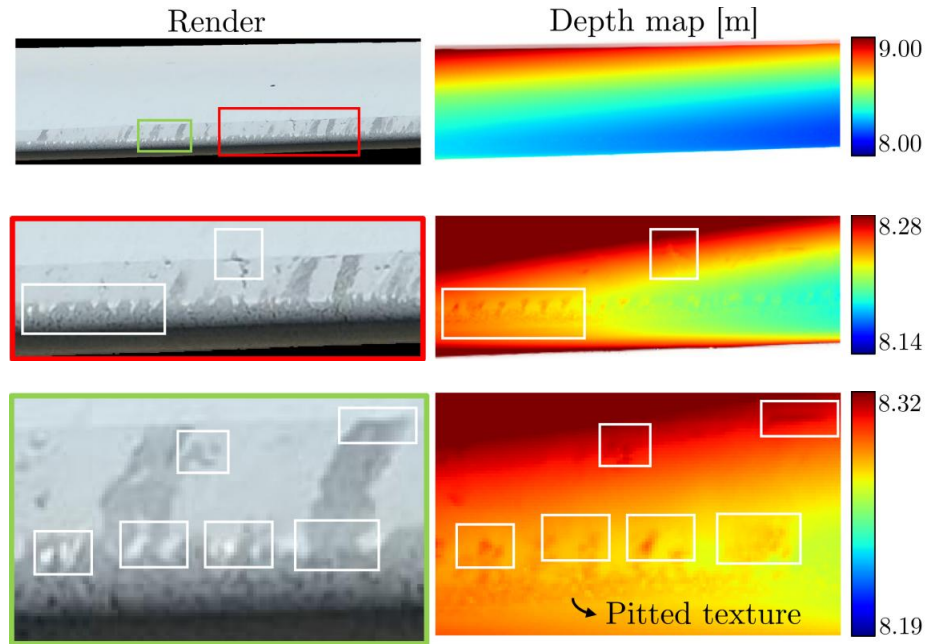
■ Phase 2

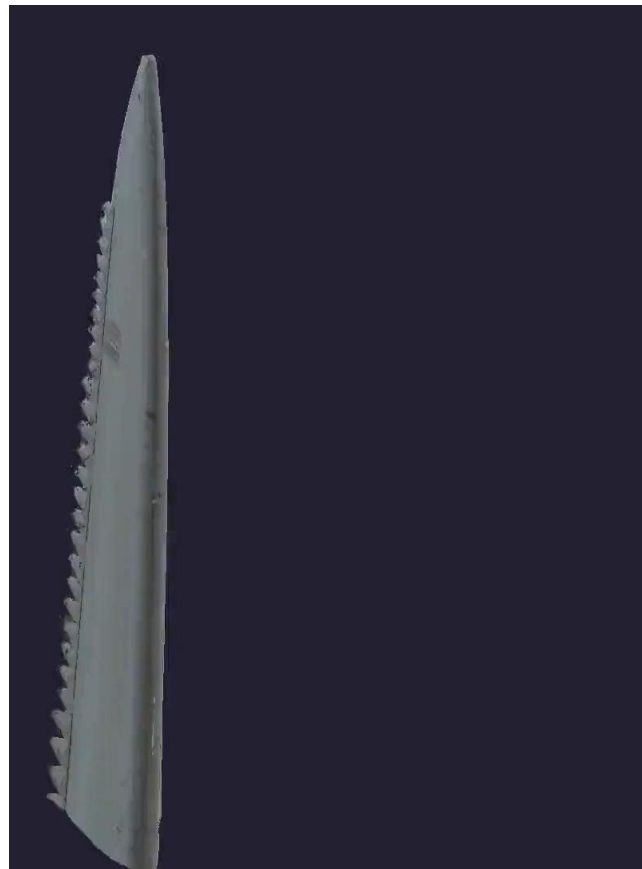
- Model is **densified**, guided by the initial 3D reconstruction



Results

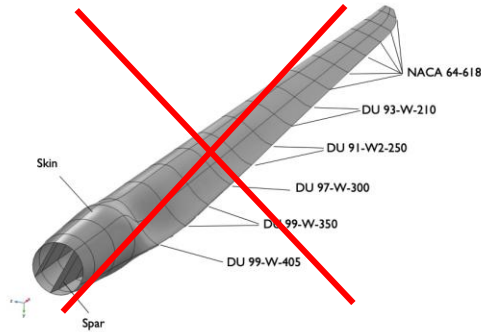
Achieved surface detail





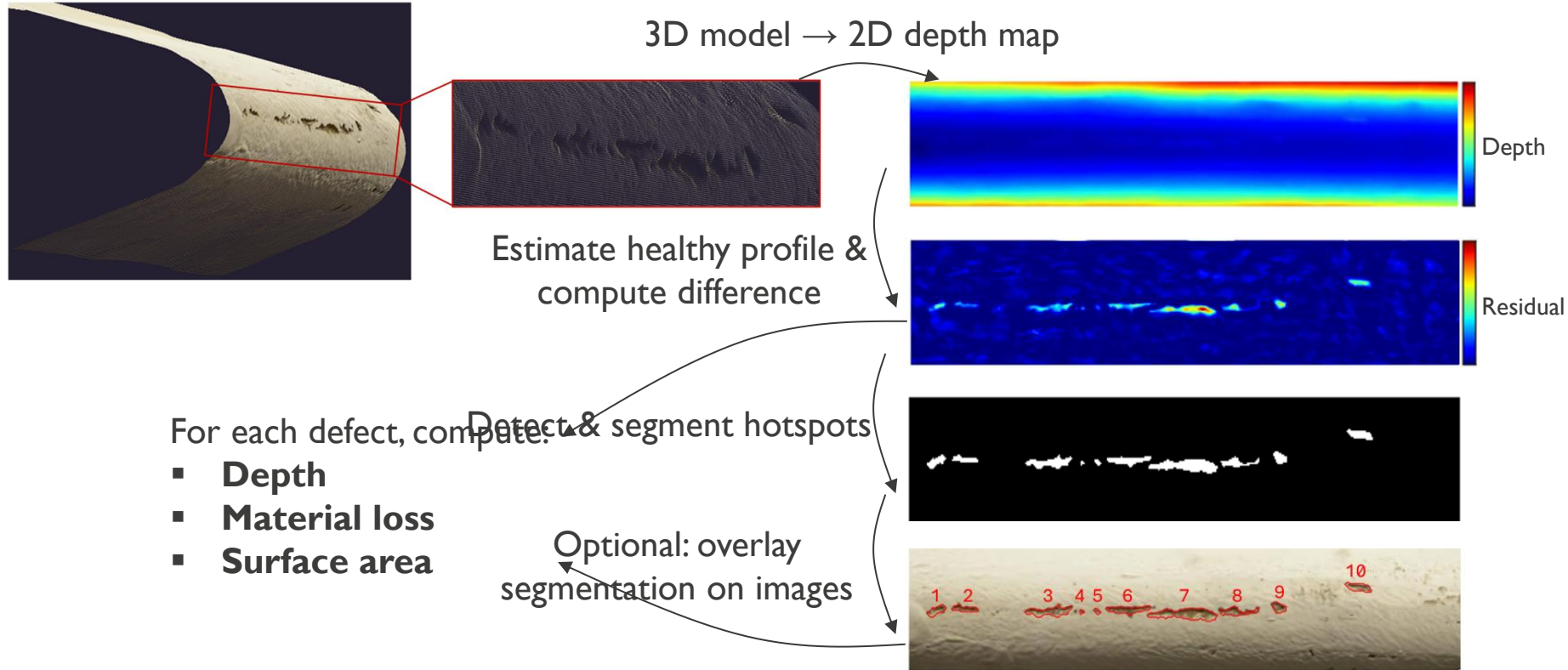
Wear assessment

- **Goal:**
 - **Segmentation and quantification of surface wear**
- **Main challenge:**
 - **Lack of a reference model**



Wear assessment

In a nutshell



AI4Blades

Wind[•] TECHNOLOGY EUROPE WORKSHOP 2025 19-20 JUNE ISTANBUL



**Create your own research question and methodology
related to improving AI for RGB+thermal wind blade inspection**

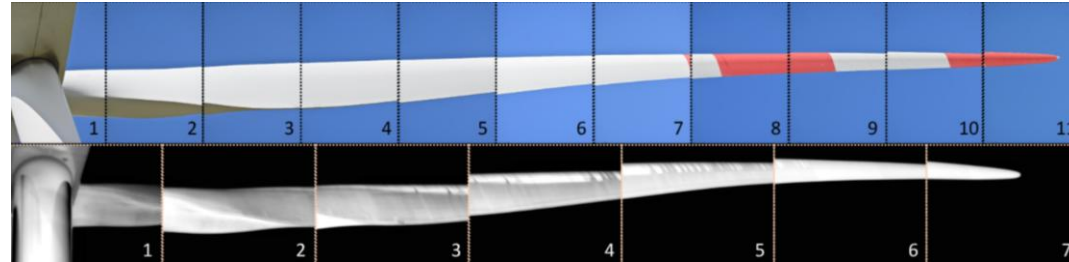
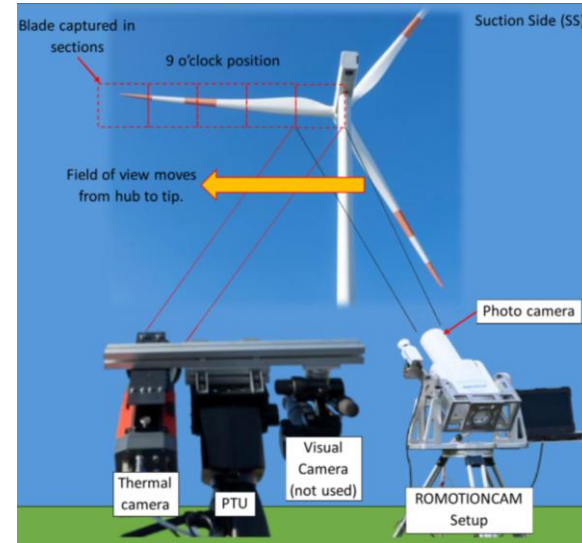
Public dataset

■ Acquisition

- Ground-based inspection
- RGB + thermal camera
- Turbine in operation

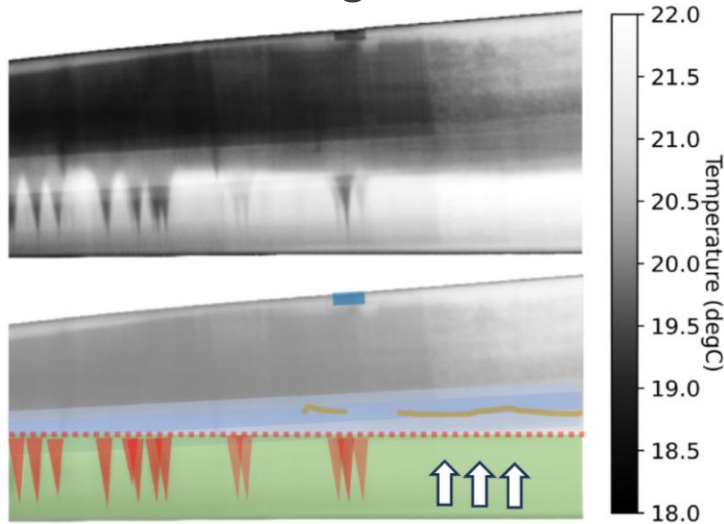
■ Description

- 30 turbines
- Images (RGB, thermal)
- Metadata:
 - Weather & temperature
 - Position along blade (for each image)



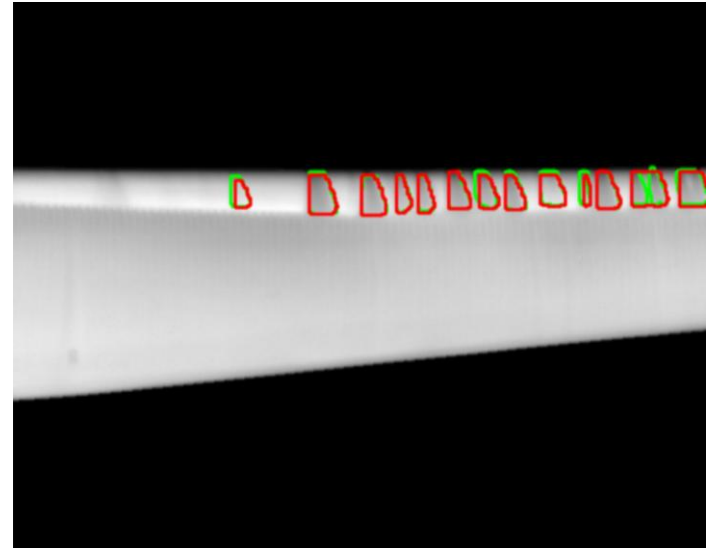
Private data & trained AI model

Thermal image annotations



laminar flow ●, TTP ●, Transition line - - -, air flow □
inner structure ■, surface scratch —, repair patch ●

Thermal turbulence pattern (TTP) detector



**ENABLING VISUAL-THERMAL
FUSION VIA MULTIMODAL
IMAGE ALIGNMENT**

LIMITATIONS

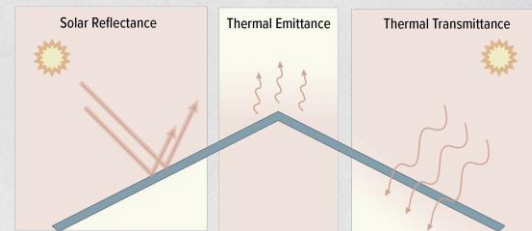
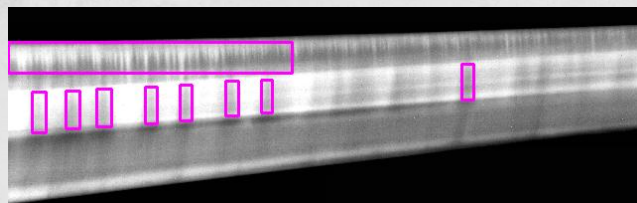
OF THE KI-VISIR TTP DETECTOR

- Does not know the cause of the TTP
TTP $\neq$ defect: can be caused by dirt or by design
- Does not consider weather & position
Context can help in challenging scenarios ^[2, 3]
- Operates on raw thermograms
Solar reflections may pollute the useful signal

➔ Contained in RGB images

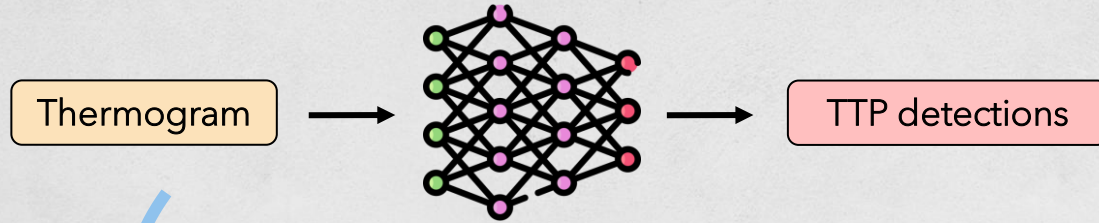
➔ Contained in metadata

➔ Reflectance can be estimated from images of the other blades ^[4]



MODEL IMPROVEMENTS

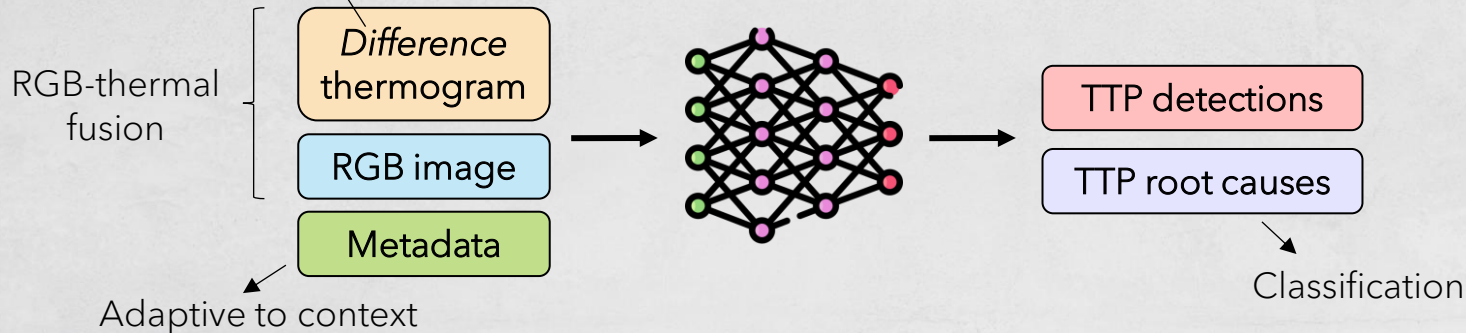
Original model



Requires multimodal & cross-blade alignment

Reflectance-free

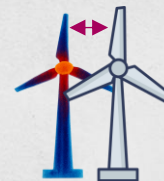
Improved model



RESEARCH QUESTION

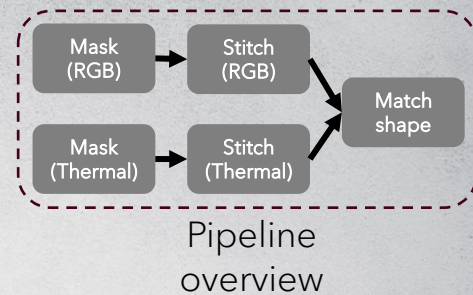
How can we **align**

- RGB and thermal images of a blade, and
- thermal images of **different** blades?



ALIGNMENT

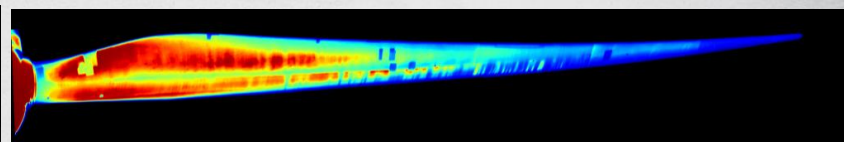
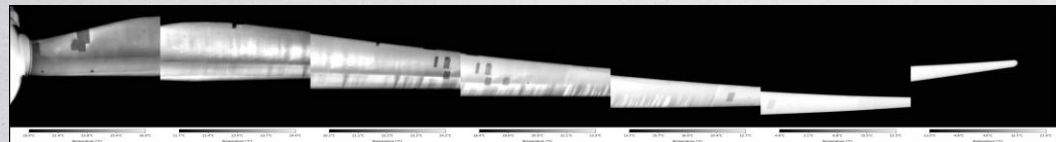
MULTIMODAL EXAMPLE



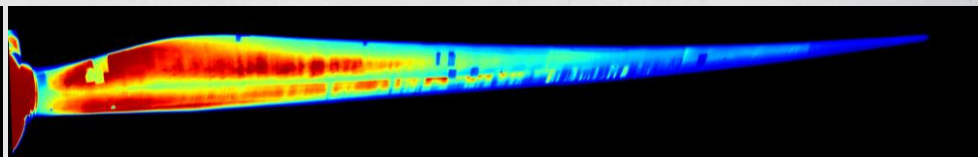
1) Mask and stitch all RGB images



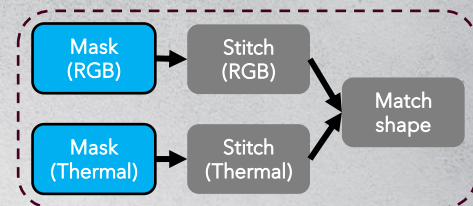
2) Mask and stitch all thermal images



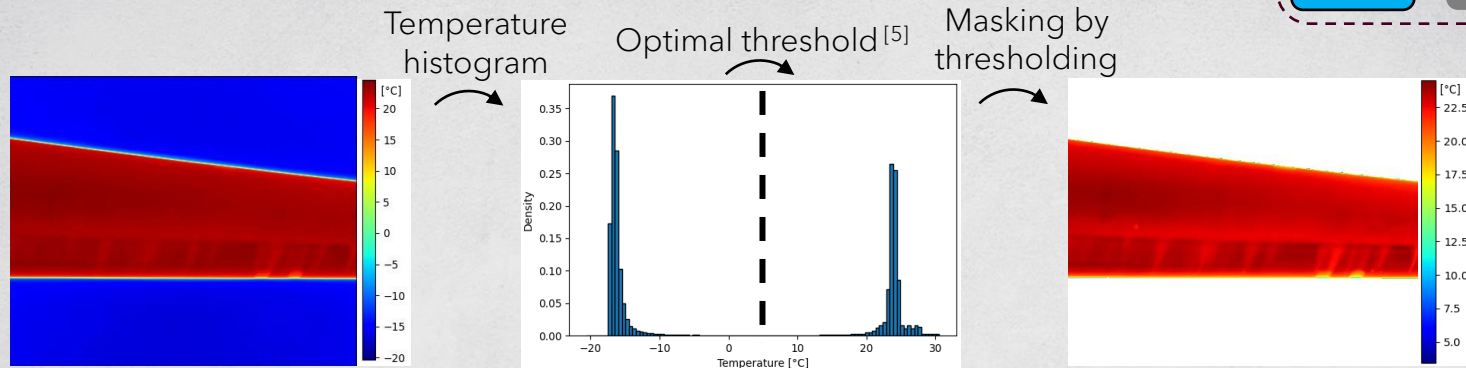
3) Align the blade shapes



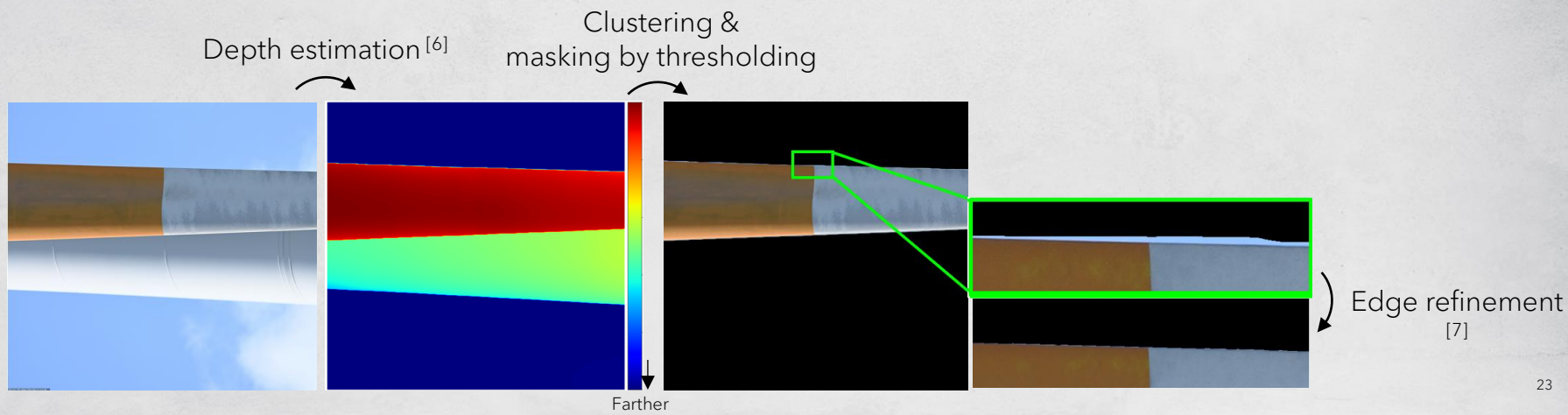
BACKGROUND MASKING



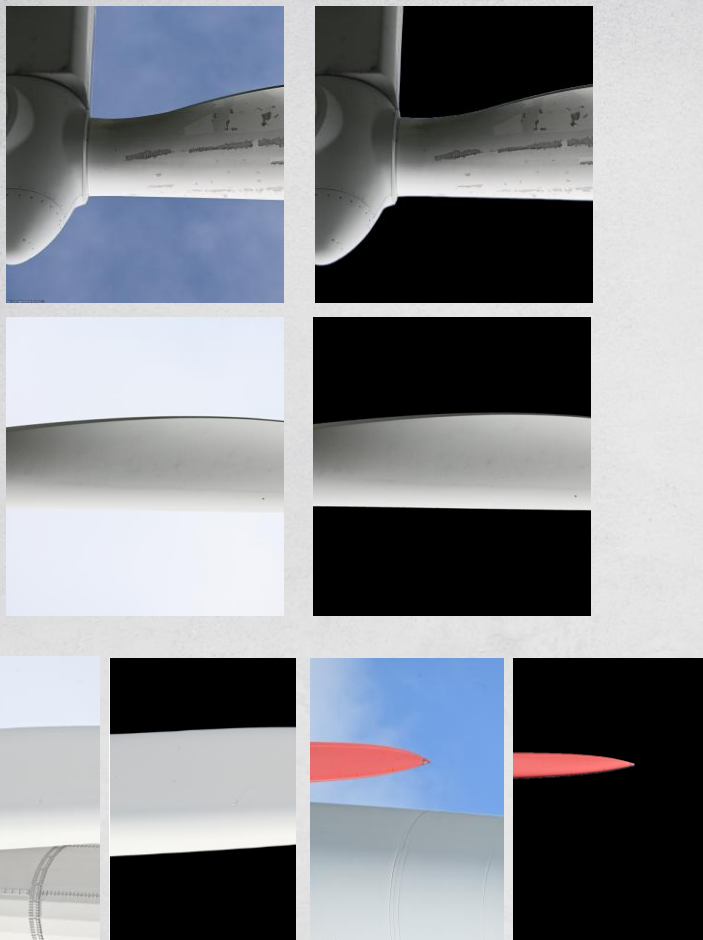
Thermal



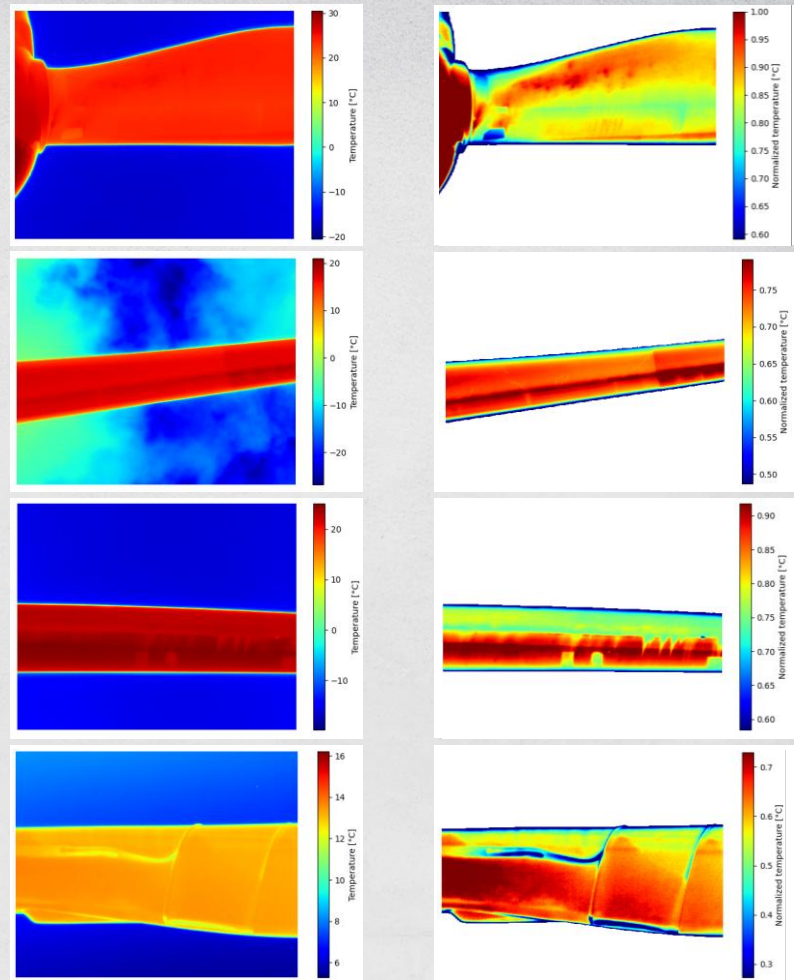
RGB



RGB

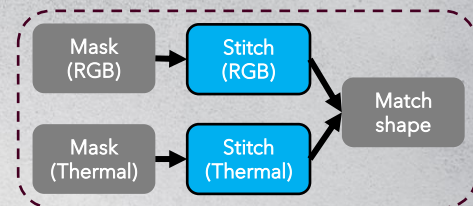
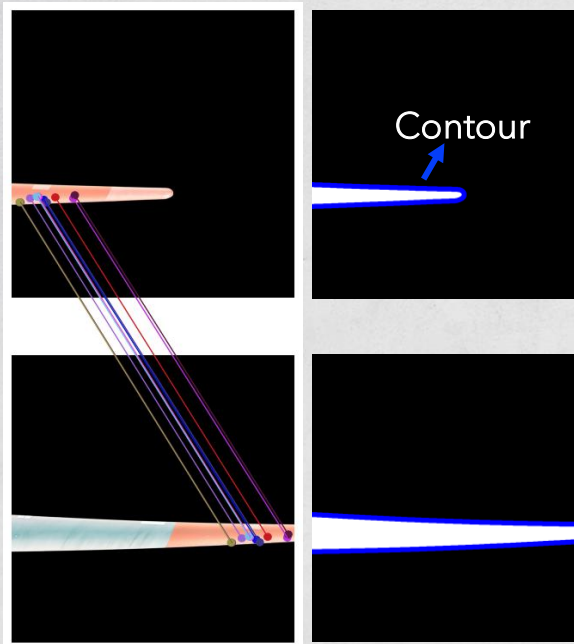


Thermal

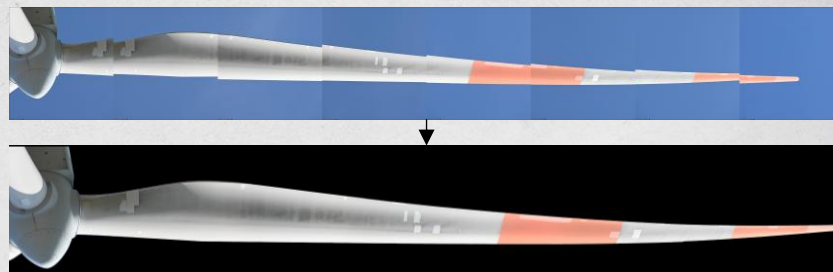


STITCHING

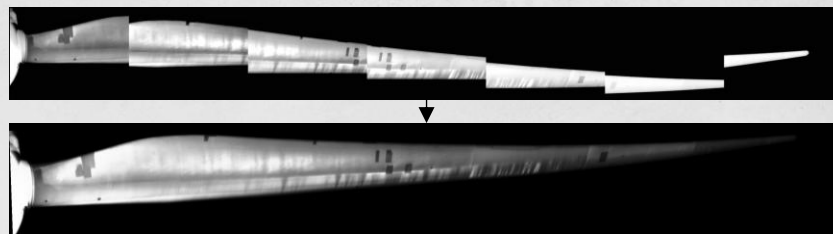
Place subsequent images to maximize
keypoint & contour alignment^[8]



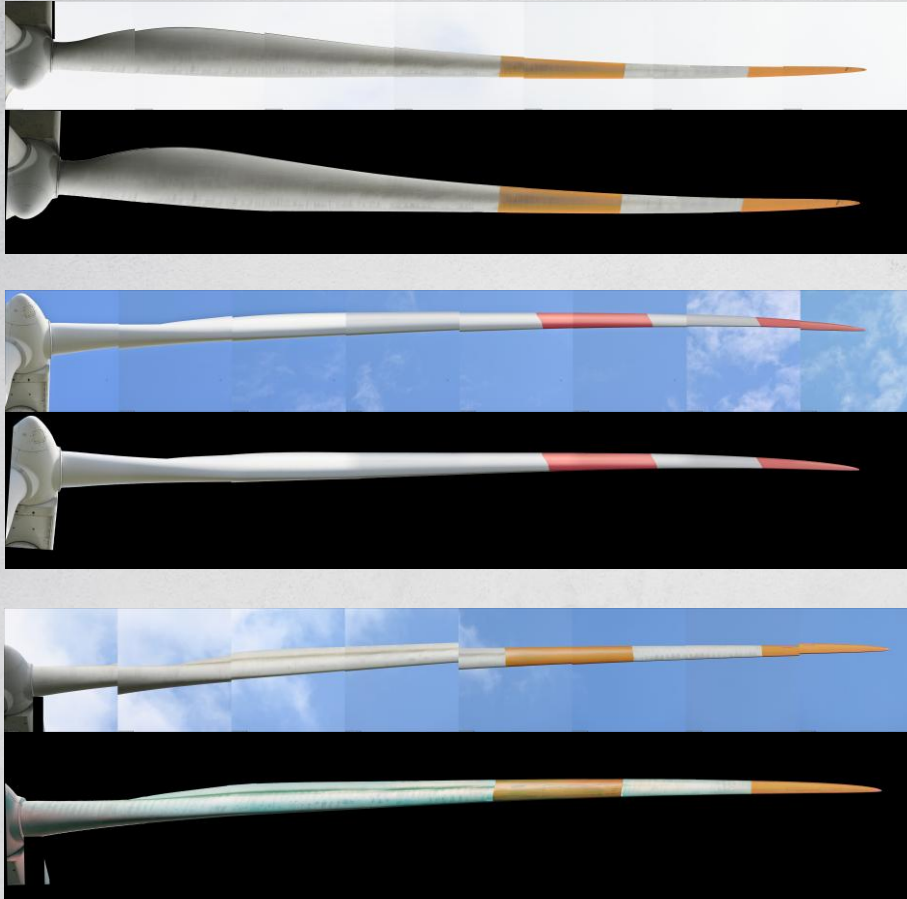
Repeat for all images



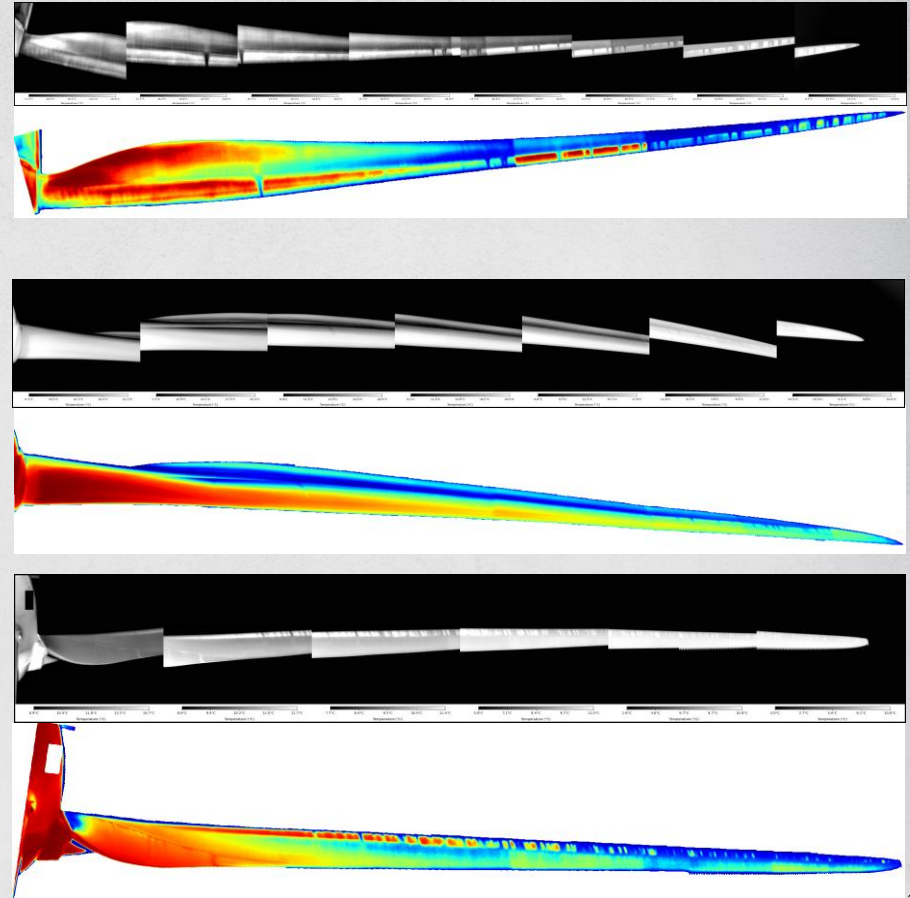
Thermal: same pipeline, but first
normalization & histogram equalization



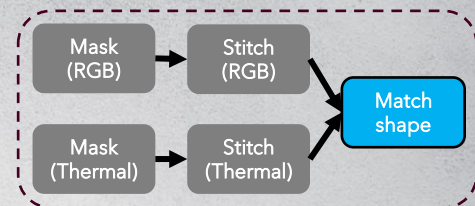
RGB



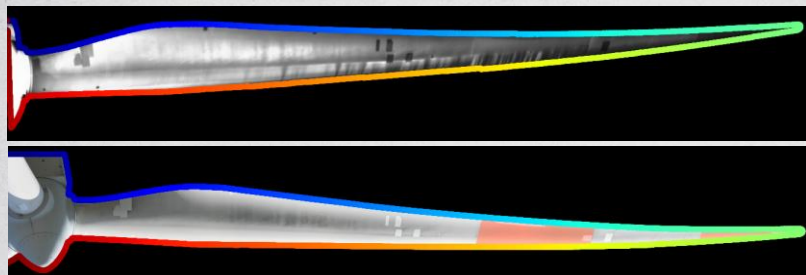
Thermal



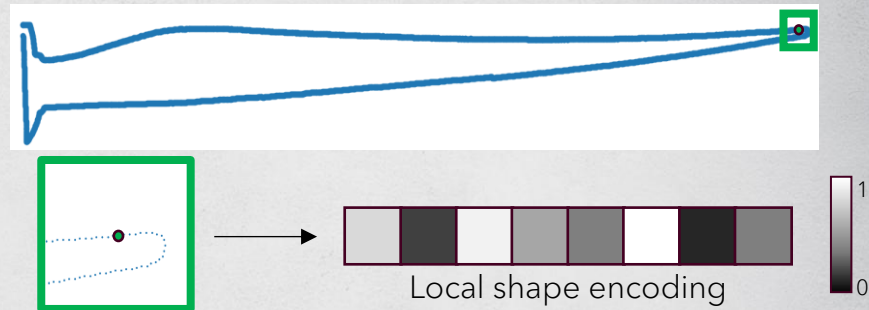
SHAPE MATCHING



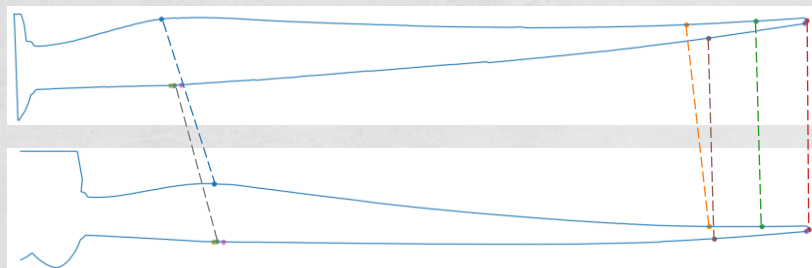
1) Extract contours in both images



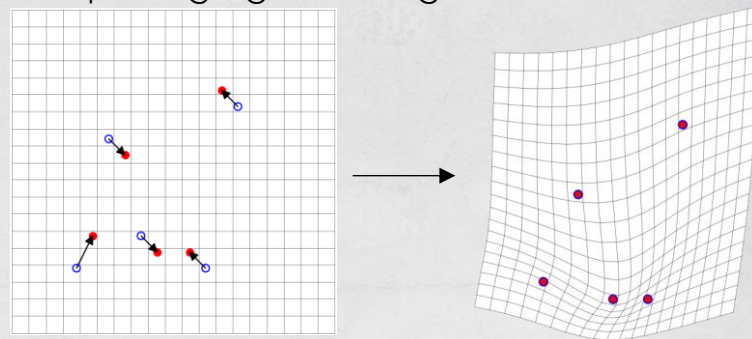
2) Compute contour descriptors ^[9]



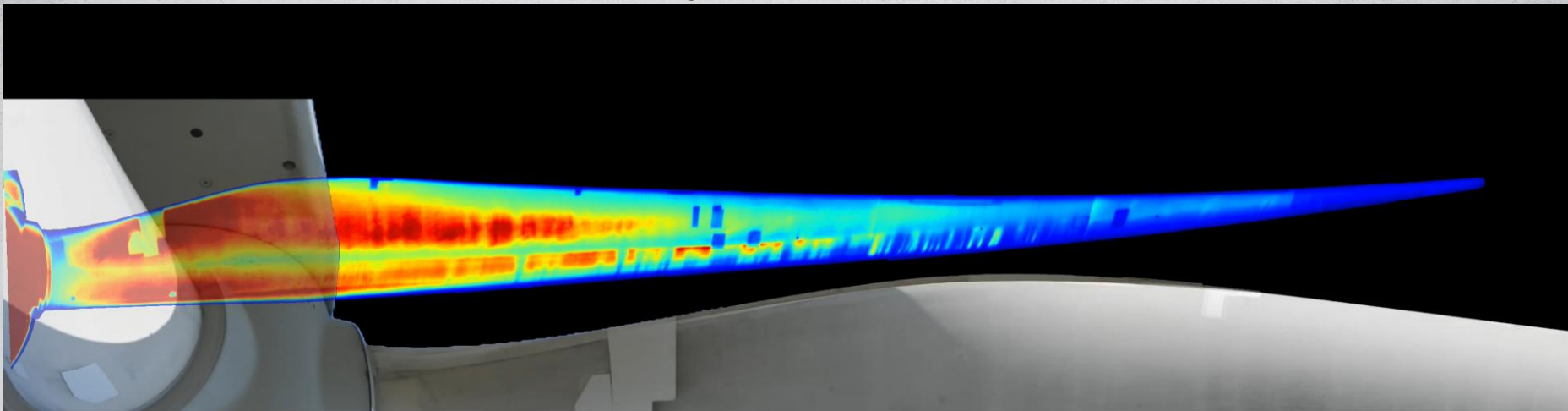
3) Match points on the contours



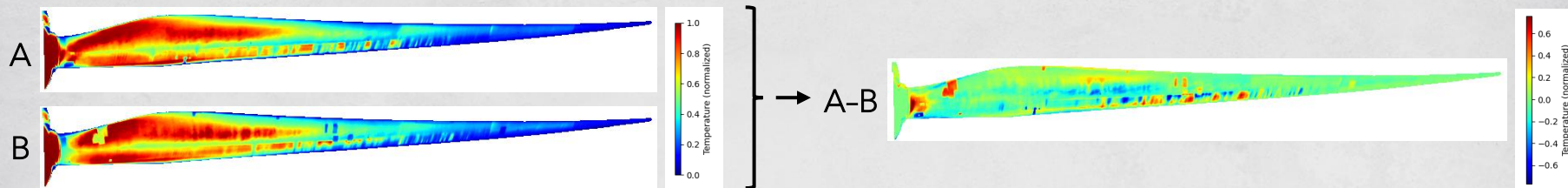
4) Warp image grid to align the matches ^[10]



Multimodal alignment: Warp animation



Cross-blade alignment → Difference thermograms



CONCLUSION



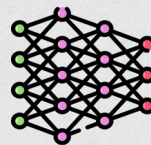
Multimodal alignment

→ Root cause analysis of TTP



Cross-blade alignment

→ Filtered thermograms



Tailored neural network

→ Exploiting all information





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embracing a better life

