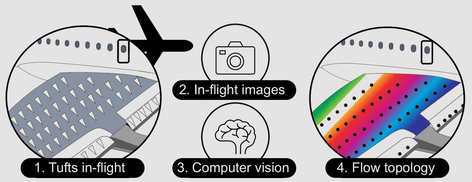
Learning Fluid Flow Visualizations from In-Flight Images with Tufts

A. Main Idea



1. Install tufts and fly an aerial system.
2. While flight, take image streams of tufts.
3. Apply semantic segmentation.
4. Visualization of flow topology.

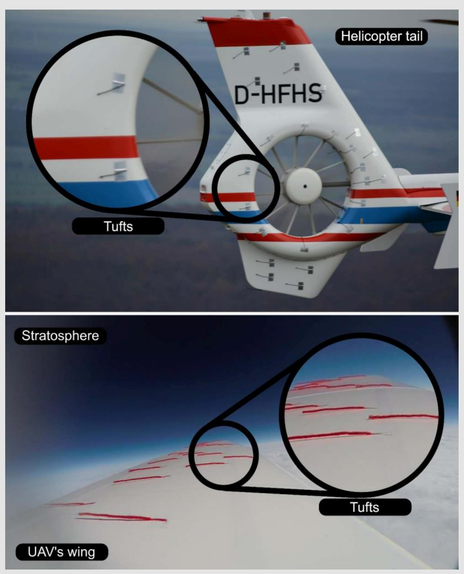
This is advantageous because:

- Automation brings flexibility, reproducibility, lack of human bias, and scalability to vast number of images and tufts per image.
- Augments wind tunnel testing and numerical simulations like CFDs.

B. Task Definition

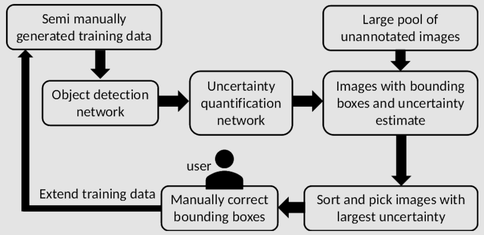
Semantic segmentation of individual tufts to monitor them individually over time.

Challenges: failures of classical methods and lack of annotations for learning.



C. The Proposed Method

- **Detection of Tufts**



An active learning approach based on uncertainty sampling.

- **Classification of Tufts**

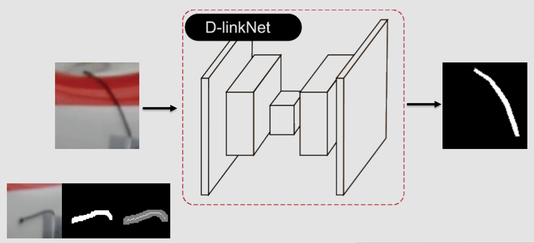
Combines uncertainty estimates,

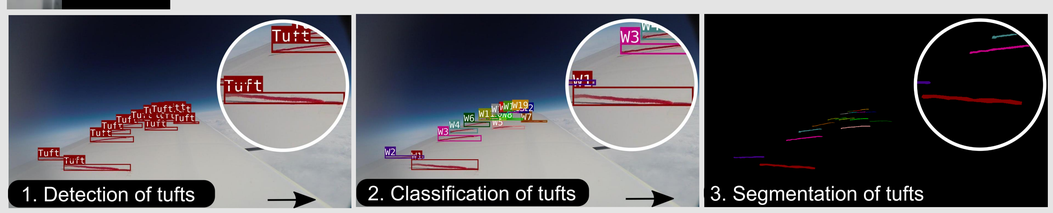
$$p(\boldsymbol{y}^*|\boldsymbol{x}^*, \mathcal{D}) = \int p(\boldsymbol{y}^*|\boldsymbol{x}^*, \boldsymbol{\theta}) p(\boldsymbol{\theta}|\mathcal{D}) d\boldsymbol{\theta},$$

image matching and hungarian algorithm for label propagation:

```
/* Key-frame based Image matching
for all the K images in the key-frames do
    T_i, C_i ← image_matching(I_{S,i}, I_T) ∀i ;
end
T ← arg min({C_i}_{i=1}^K) ;
{c_j}_{j=1}^L ← label_propagation(b, T) ;
```

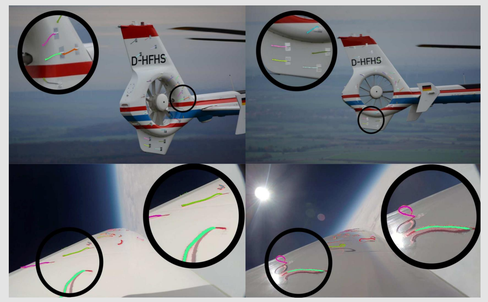
- **Segmentation of Tufts**





D. Main Results

	Mask RCNN	Cascaded RCNN	Ours
Helicopter	23.422±2.1822	11.198±2.4028	**60.729±2.1894**
UAV	34.032±1.2945	18.254±0.5844	**58.343±2.4532**



- Data collection at the scale of two real-world applications, i.e., aeroacoustics of helicopter flights, and incompressible aerodynamics of stratospheric flights.
- A working demonstration at the scale of real world application, for the first time to our knowledge.
- No semantic segmentation masks required for training. Some bounding box annotations and one image with class information annotated.

E. Key Take Aways

Probabilistic approaches facilitate the learning process without requiring any manual annotations of semantic segmentation masks for real-world applications of AI4Science domain.

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video website paper