Acoustic Fault Diagnosis for UAV Propeller Blades

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Introduction and Objective:

The propeller blades of unmanned aircraft vehicle (UAV) are prone to damage and wear and tear, which can cause mechanical stress on the components, performance degradation and a decreased flight stability. The aim is to automate the maintenance process of the propeller blades without the need of interacting with the UAV by means of acoustics.

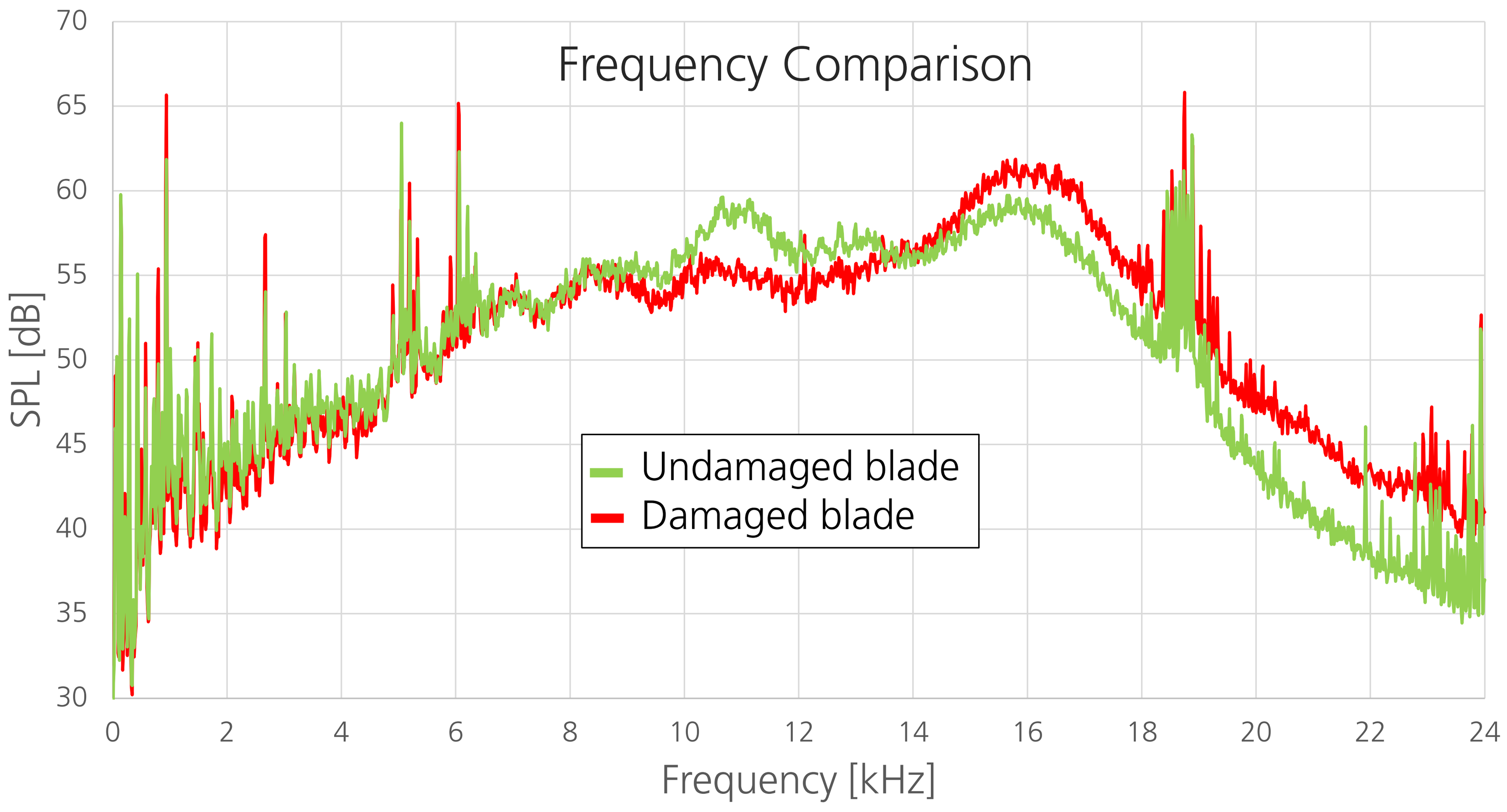

Fig. 1: Differences in acoustic signature shown by means of frequency response of two 10” propellers measured at a distance of 55cm from the propeller plane.

Approach:

The acoustic camera records the UAV (Fig. 3) in 3 different environments. Functional beamforming creates a sound profile for the individual propeller blades (Fig. 4). The sound profiles are classified as damaged or undamaged using a Convolutional Neural Network (Fig. 5).

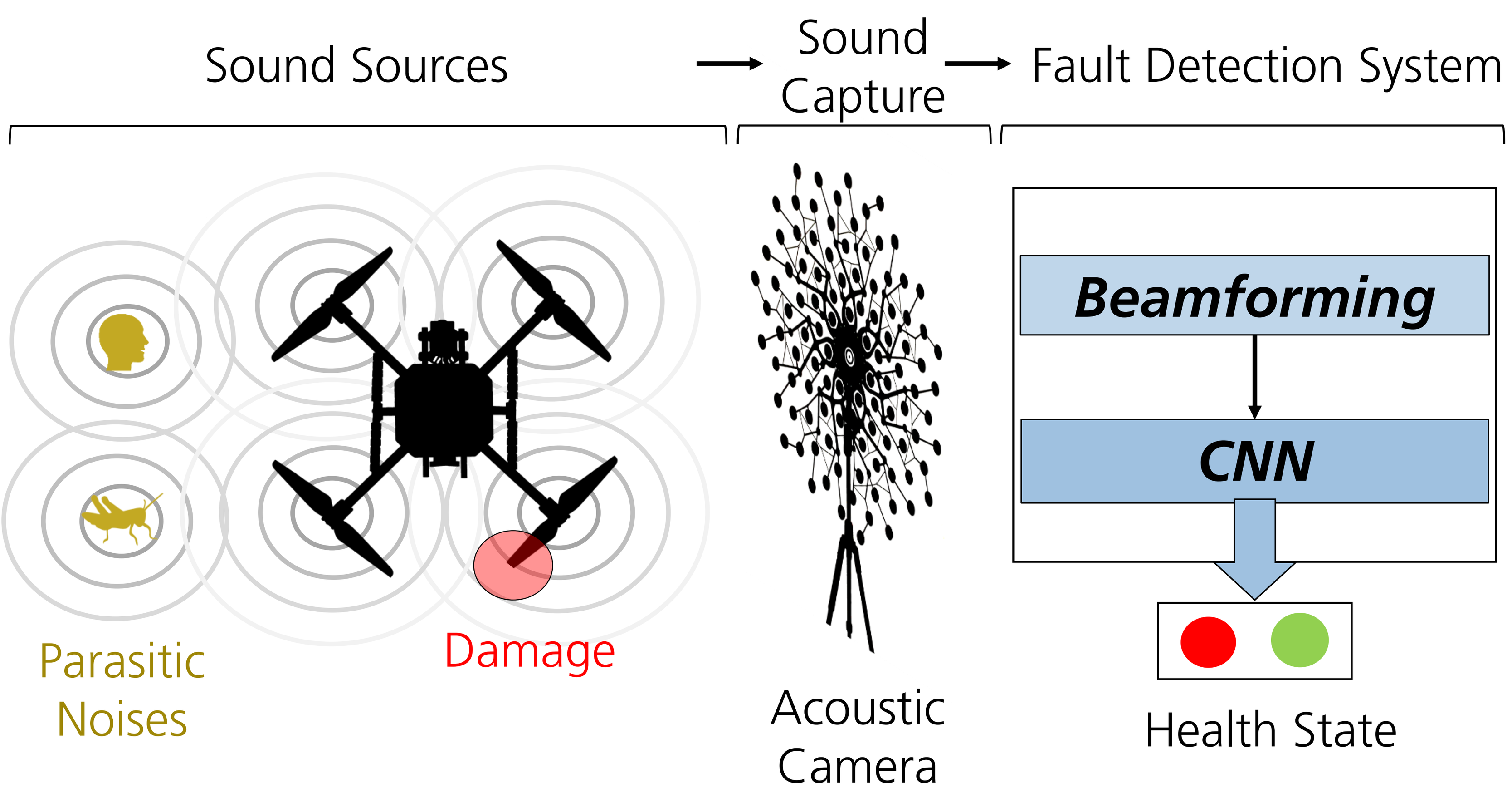

Fig. 2: Principle system overview from sound source to propeller health state

Results:

With over 99% accuracy the results are promising with an outlook of reliable usage on a drone landing platform to provide an automatic assessment of the propeller blade health state.

	APZ	AC	EC
Accuracy	0.9986	0.9972	0.9830
F1-Score	0.9977	0.9943	0.9767

Sound Capture:

The CAE Systems Bionic M112 is used to record the UAV at 12.5 kHz in 3 different environments: laboratory (APZ), anechoic chamber (AC) and echoic chamber (EC).

	Recorded time (s)		
	APZ	**AC**	**EC**
Undamaged	1200	2400	1200
Damaged	1200	1200	1200

Fig. 3: The acoustic camera is mounted above the UAS, which is in parking position on ground level.

Beamforming:

Recordings are cut into 1 s segments, functional beamforming is applied to create the sound profiles of the individual propeller blades(Fig. 4).

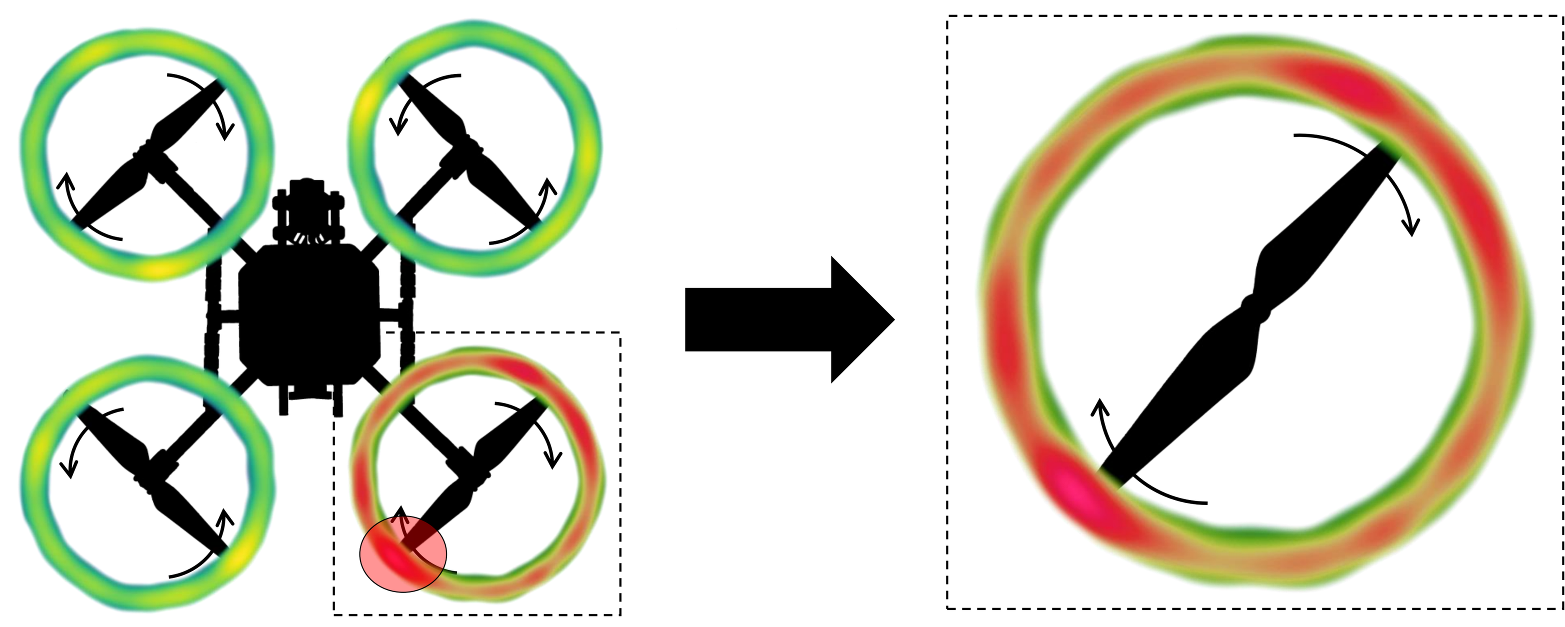

Fig. 4: Beamforming is applied to a full quadcopter UAS and then evaluated for each propeller.

Convolutional Neural Network (CNN):

A CNN is used to classify the single propeller sound profiles as damaged or undamaged. A hyperparameter gridsearch found different hyperparameters for each environment.

	APZ	AC	EC
Learning rate	0.0005	0.005	0.002
Size	8-16-16	4-16-16	16-16-16
Epochs	42	24	38

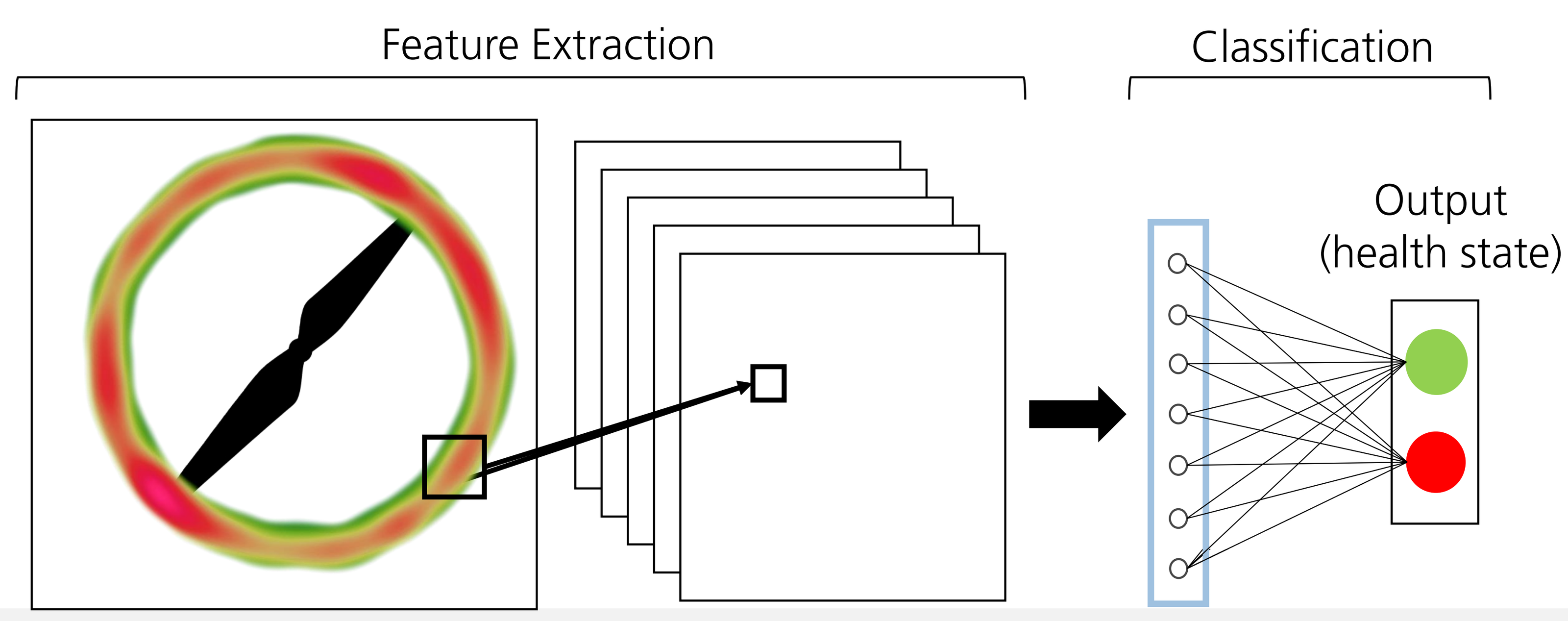

Fig. 5: Convolutional neural network.

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Related Publications:

- Gomez, M.S. et al. (2022), “Non-destructive Evaluation of the Condition of a UAV’s Propellers by means of Acoustics”, *Proceedings of SPIE - The International Society for Optical Engineering. SPIE Smart Structures and Nondestructive Evaluation*, 06.-09. March 2022, Long Beach, USA.
- Gomez, M.S. et al. (2023), “Acoustic non-destructive testing of UAS’s propellers during pre-departure and post-flight checks”, *ECNDT2023*, 03.-07. July 2023, Lisbon, Portugal.
- Steinhoff, Leon et al. (2023) “Development of an Acoustic Fault Diagnosis System for UAV Propeller Blades”. Deutscher Luft- und Raumfahrtkongress 2023, 2023-09-19 - 2023-09-21, Stuttgart, Deutschland.
- Steinhoff, Leon et al. (2024) “Development of an Acoustic Fault Diagnosis System for UAV Propeller Blades” CEAS Aeronautical Journal, 1 - 13. Springer.