From Sound to Vision: Applying Beamforming to Reduce Parasitic Noise for Fault Detection

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Introduction and Objective:

The propeller blades of unmanned aircraft systems (UAS) 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 UAS by means of acoustics. Previous studies [1 - 4] with single microphones showed first results for UAS but lacked robustness regarding environmental noise.

Fig.1 shows results of a single 10" propeller under laboratory conditions. This approach often fails when used in noisy environments like an open-air field. Our new approach deploys multiple microphones and a new algorithm aiming for improved accuracy.

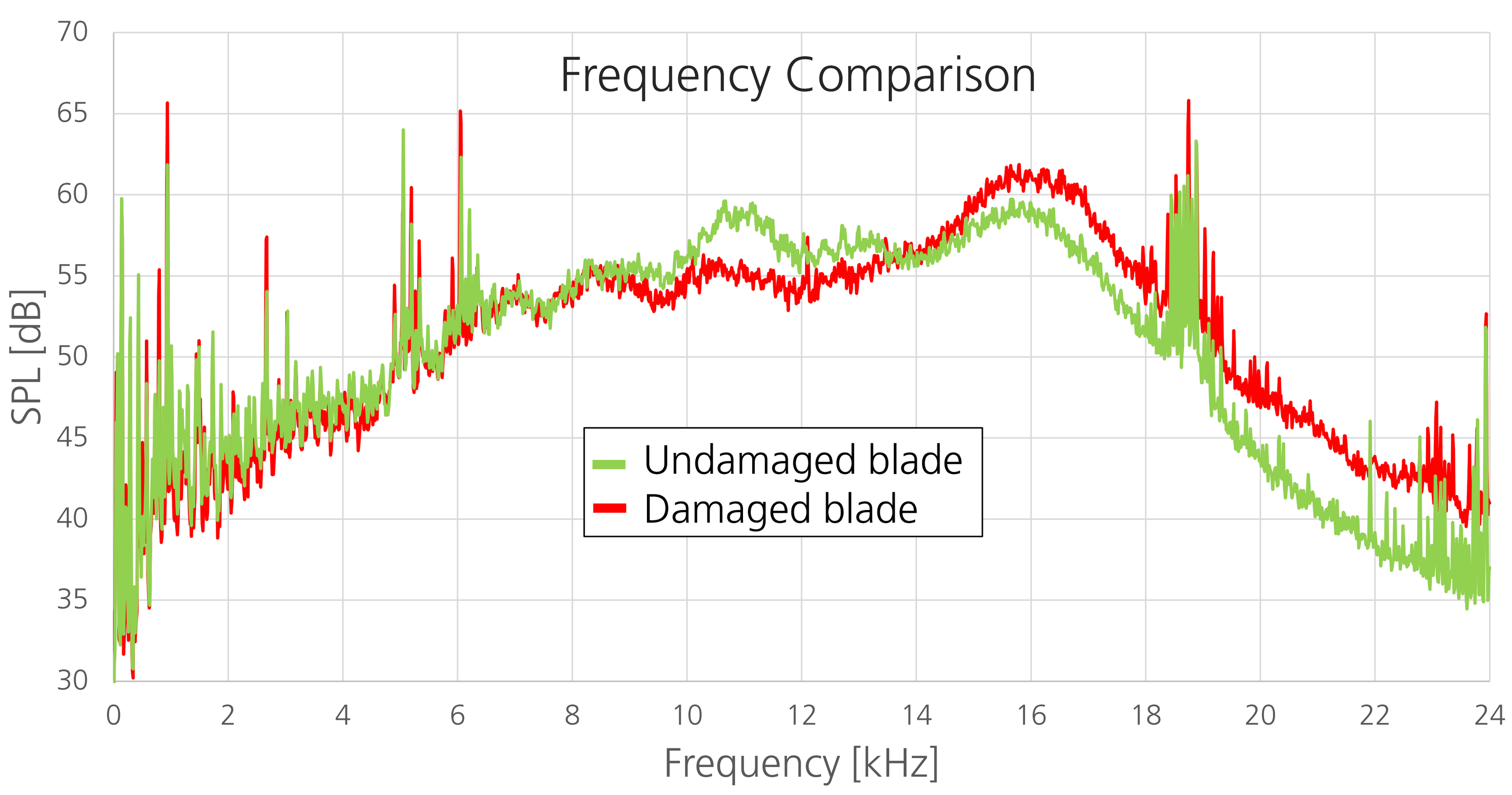

Fig. 1: Frequency response of two 10" propellers measured with an acoustic camera at a distance of 55cm from the propeller top.

Proposed Approach:

The acoustic camera CAE Systems Bionic M112 [5] records the UAS (Fig. 2). This installation enables beamforming to reduce the impact of parasitic noises and to localize damages of all propellers simultaneously.

Fig. 2: Experimental setup – the acoustic camera is mounted above the UAS, which is in parking position on ground level.

Fault Detection System

A new fault detection system is proposed in Fig. 3. Acoustic images of the UAS propellers are generated from the acquired data and are fed to a neural network for training.

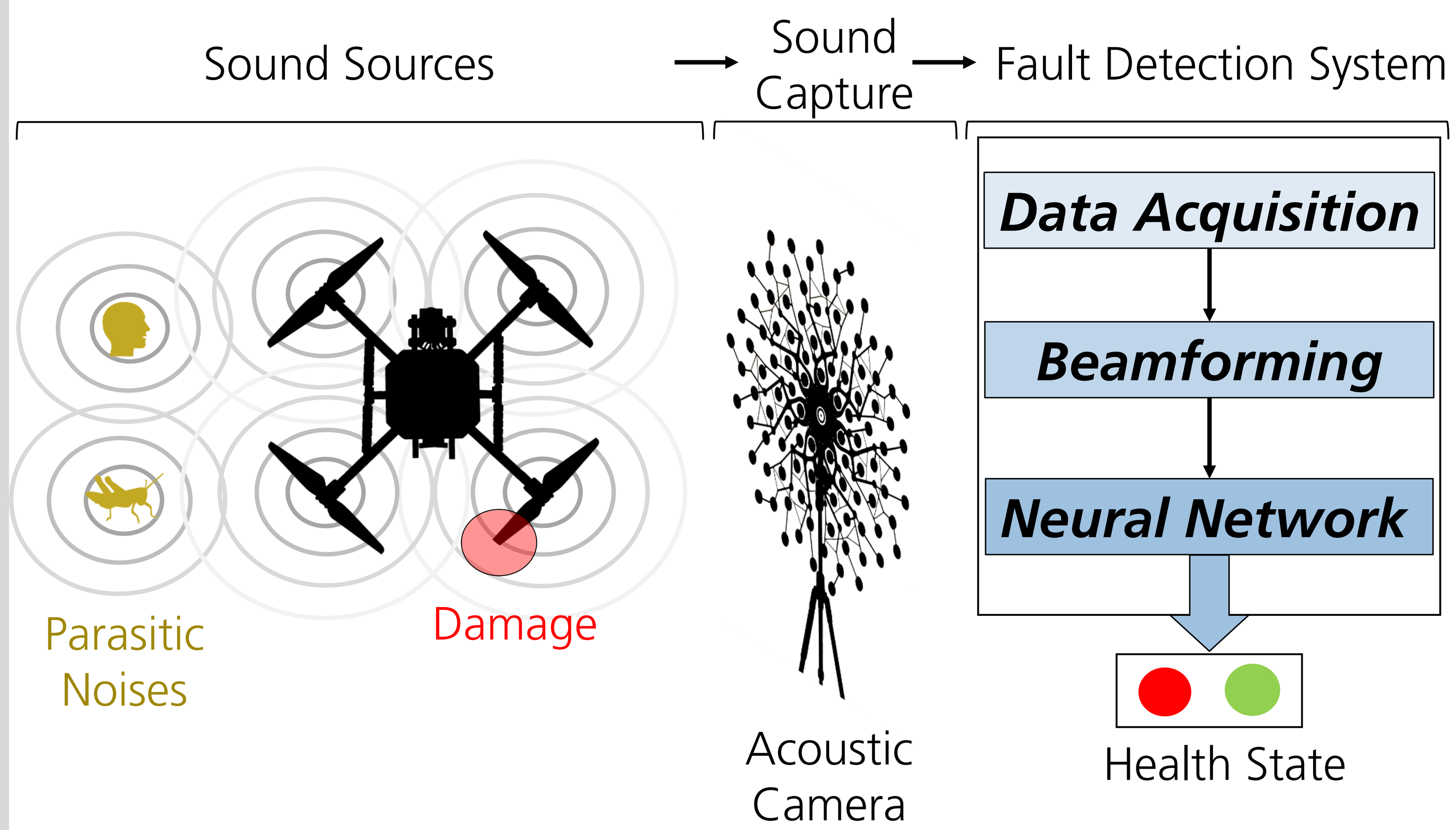

Fig. 3: Principle system overview from sound source to propeller health state

Beamforming:

The free and open-source Python library Acoular [6] provides beamforming algorithms e.g. delay-and-sum and rotating beamforming. The sound profiles of the individual propeller blades of the UAS are isolated (Fig. 4). Initial tests with Acoular showed satisfying results.

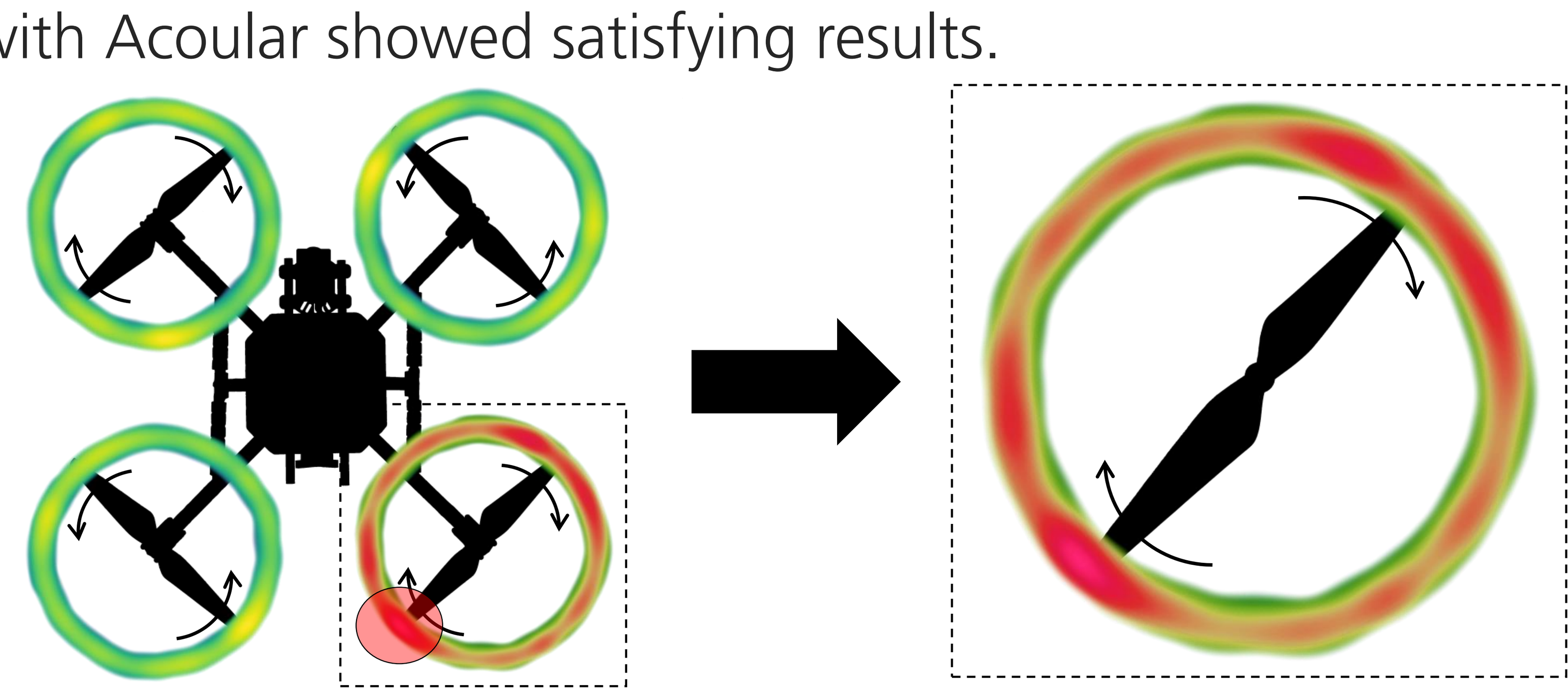

Fig. 4: Beamforming is applied to a full quadcopter UAS and then evaluated for each propeller.

Neural Network:

The proposed machine learning algorithm is a convolutional neural network (Fig. 5) as it is well suited for image recognition. Different multi-layer architectures are investigated and compared, considering accuracy, precision and runtime.

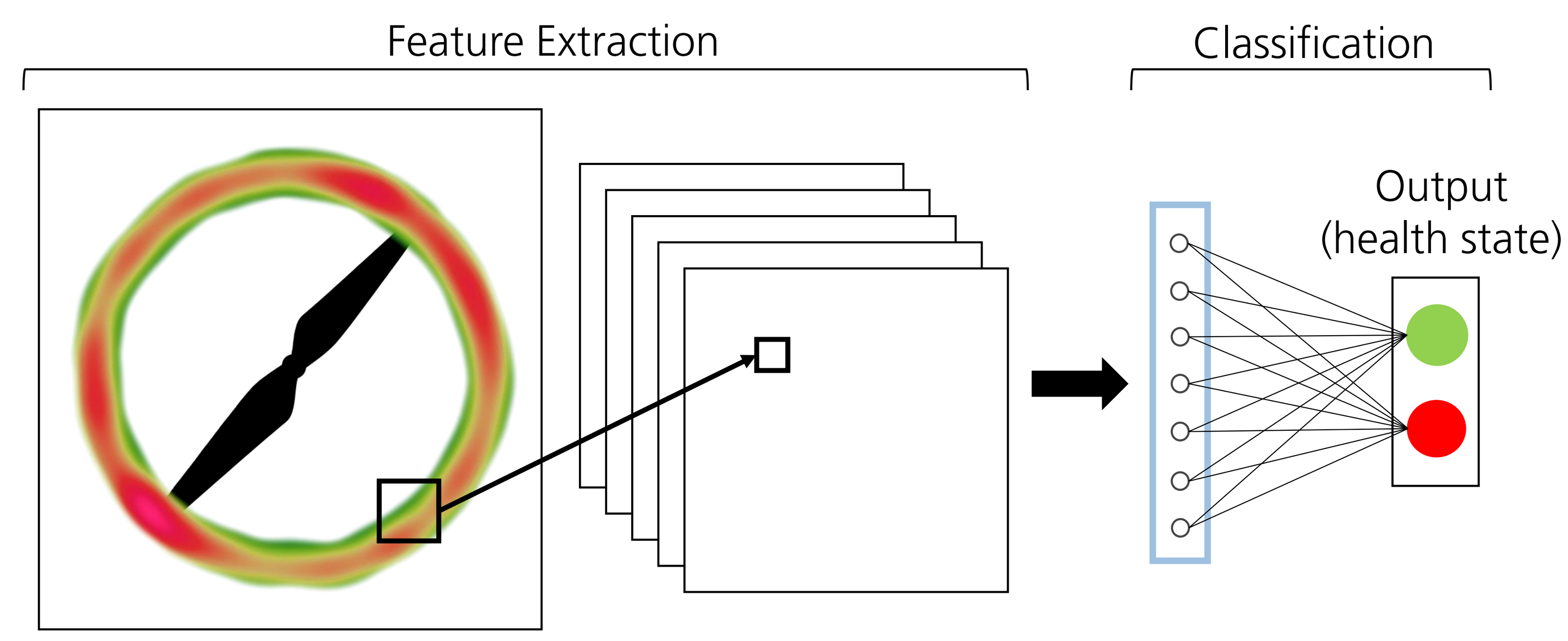

Fig. 5: Architecture of the suggested convolutional neural network.

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[6] Acoular - Acoustic testing and source mapping software, URL: http://www.acoular.org (02.2023)