MAP ESTIMATION OF AIR-FLOW DIPOLE SOURCE POSITIONS USING ARRAY SIGNAL PROCESSING

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In nature, fish have the ability to form flow-based maps to assist localizing predator or prey using the lateral-line system. Yet it is not fully understood what techniques are used by fish to draw these flow maps. Biologists try to figure out fish techniques by investigating different hypotheses [1]. Inspired by the lateral line of fish, we propose in this paper model based array signal processing techniques used to visualize the air-flow maps. The results show an ability to visualize the flow field generated by a dipole source using lateral-line system.

Array signal processing uses sensors organized in patterns or arrays to determine extra information from the received signals i.e. source position, orientation and strength [2]. In this work, the sensors are artificial hairs arranged in linear array shape similar to the lateral line in fish. The main target is visualizing the air-flow over the surrounded area and thus determining the exact position of the source. This localization technique differs from other techniques [3] in localizing the source even in positions located outside the maximum detection range of the array system and while maintaining high robustness.

The source localization algorithm, used here, is based on calculating a template for the expected array response using the dipole source model (equ. 1), for each point in the grid [2,3].

$$V_{x,//}(x) = s\,\omega a^3 \frac{\left(2x^2 - D^2\right)}{\left(x^2 + D^2\right)^{5/2}} \qquad (1)$$

where $V_{x,//}$ denotes the response of each sensor at its position in the x-axis, ω is the angular vibration frequency, a is the sphere diameter, s is the sphere displacement amplitude and D is the distance between the centre of the sphere and sensor reference line (x-axis).

Fig. 1 shows a schematic drawing of the lateral-line system. The actual array response over all sensors outputs is used to calculate an estimate of the covariance matrix R. Once R is computed, beamforming technique based on Capon's algorithm [4] is used and the associated output power (P_{BF}) at each grid point is calculated according to:

$$P_{BF} = \frac{1}{\left(a^H R^{-1} a\right)} \qquad (2)$$

where a denotes the array response to dipole source at each grid point and a^H is the Hermitian of a.

The resulted power level at each grid point is used to visualize the area of interest and thus to determine the position of the dipole source as shown in Fig. 2.

As a conclusion, the use of array signal processing techniques in combination with the lateral-line system make it possible to determine the source position even in the outside range of the array system. Future work will focus on modeling and implementing of different array signal processing algorithms using the artificial lateral-line system. Once this is achieved, flow maps can be acquired and hence the number of sources as well as their positions can be determined.

References

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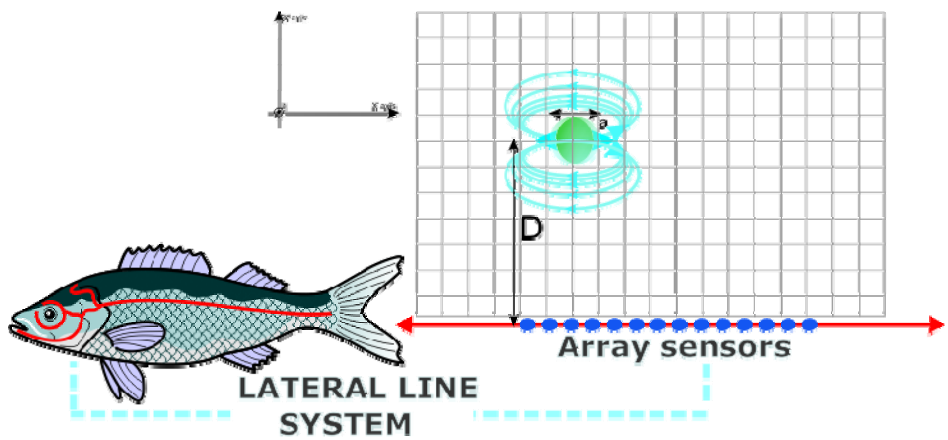

Fig. 1. Schematic drawing of the lateral-line system.

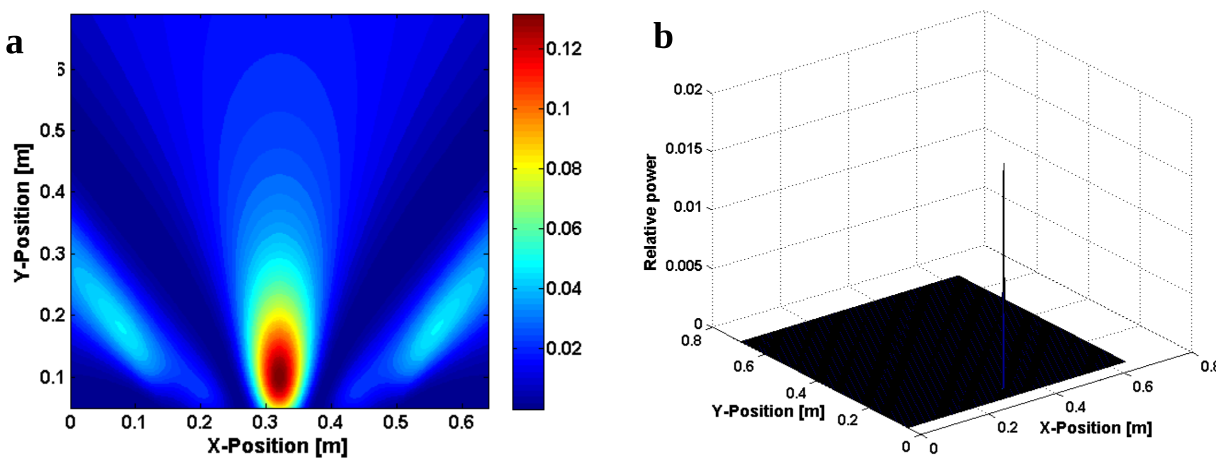

Fig. 2. Dipole source imaging at X= 0.2 m and Y= 0.1 m. a) 2D imaging of dipole source position. b) 3D image of dipole source position.