

SEISMIC DETECTION OF ELEPHANT FOOTSTEPS

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BACKGROUND

- Human-Elephant conflicts are a global problem

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- Harm to both people, property and crops

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- Hundreds of casualties in India each year



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- Automated warning system

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1. Zetterqvist, et al. *Elephant DOA Estimation using a Geophone Network*. In FUSION 2023.

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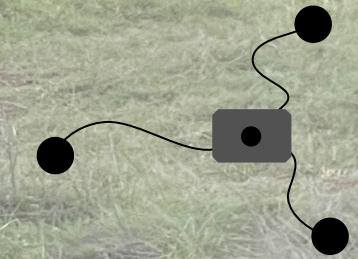
- Automated warning system
- Last year¹, proof of concept
- Now, focus on detection

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SIGNAL MODEL



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$z_i^n(t)$: n th event for geophone i

$e_i(t)$: ambient noise

EVENT DETECTION

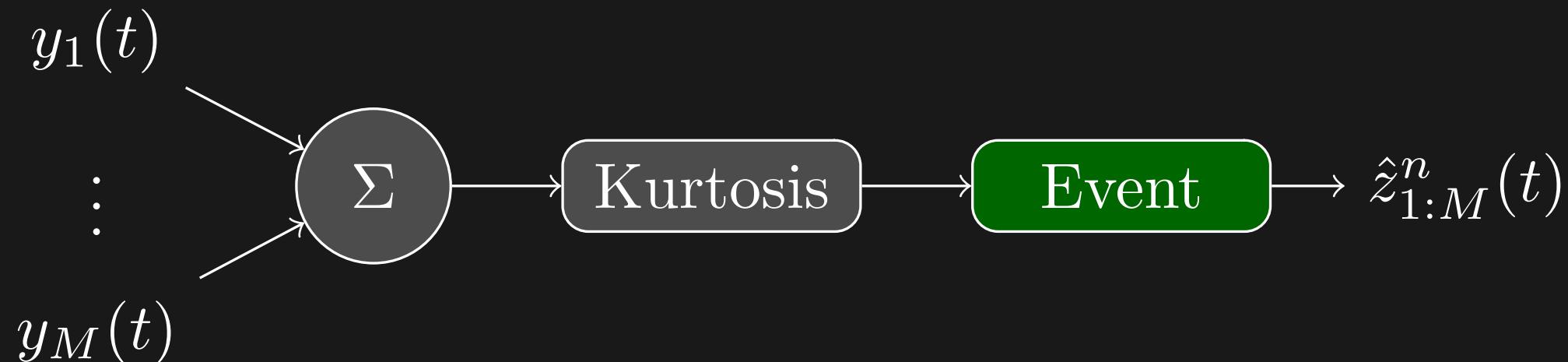
- For event detection we use Kurtosis

EVENT DETECTION

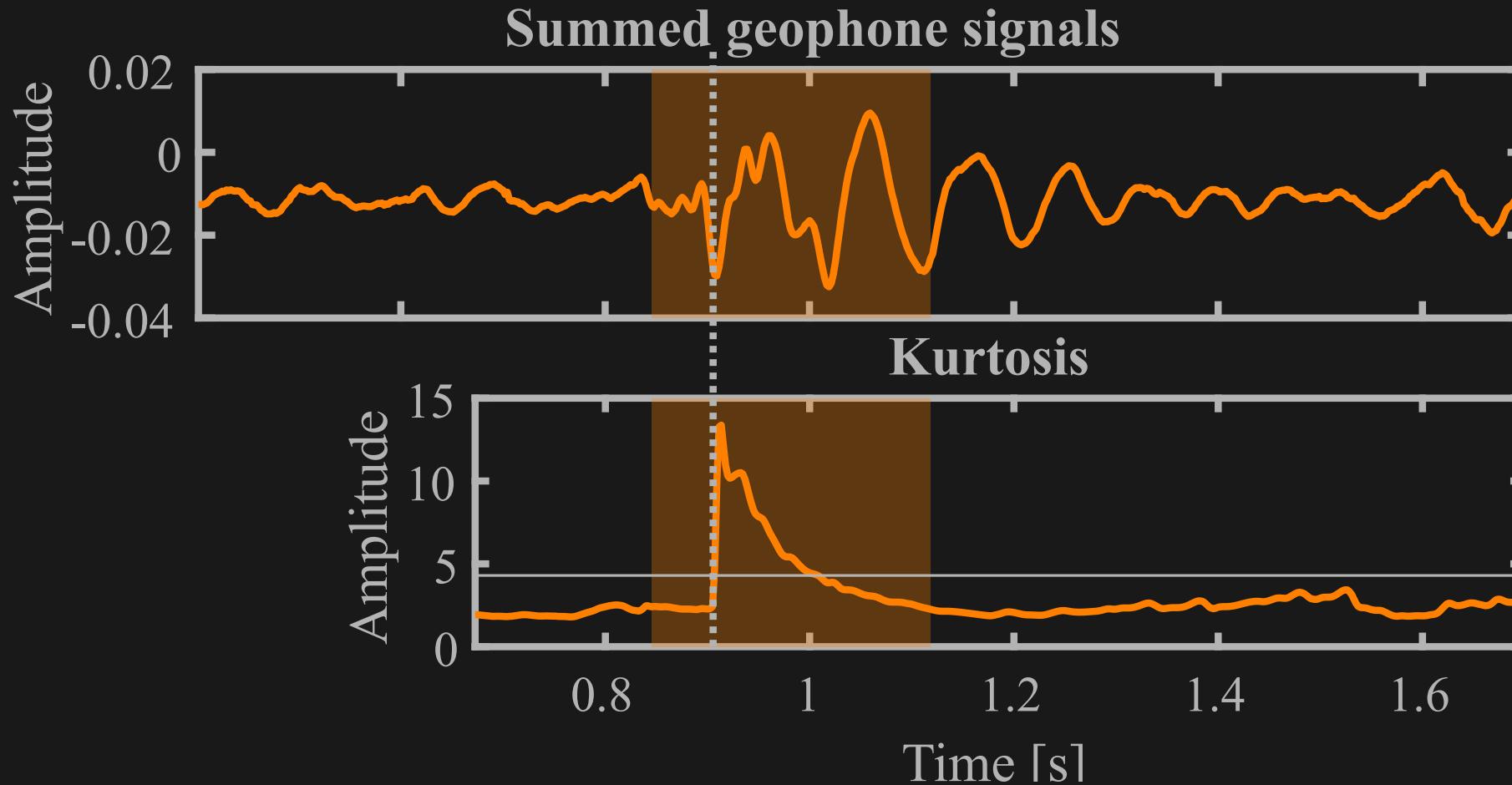
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$$\bullet \quad Q[k] = \frac{\frac{\sum_{l=k-N+1}^k (\bar{y}[l] - \mu[k])^4}{N}}{\left(\frac{\sum_{l=k-N+1}^k (\bar{y}[l] - \mu[k])^2}{N} \right)^2}$$
$$\bullet \quad Q[k] > T \rightarrow \text{Event}$$

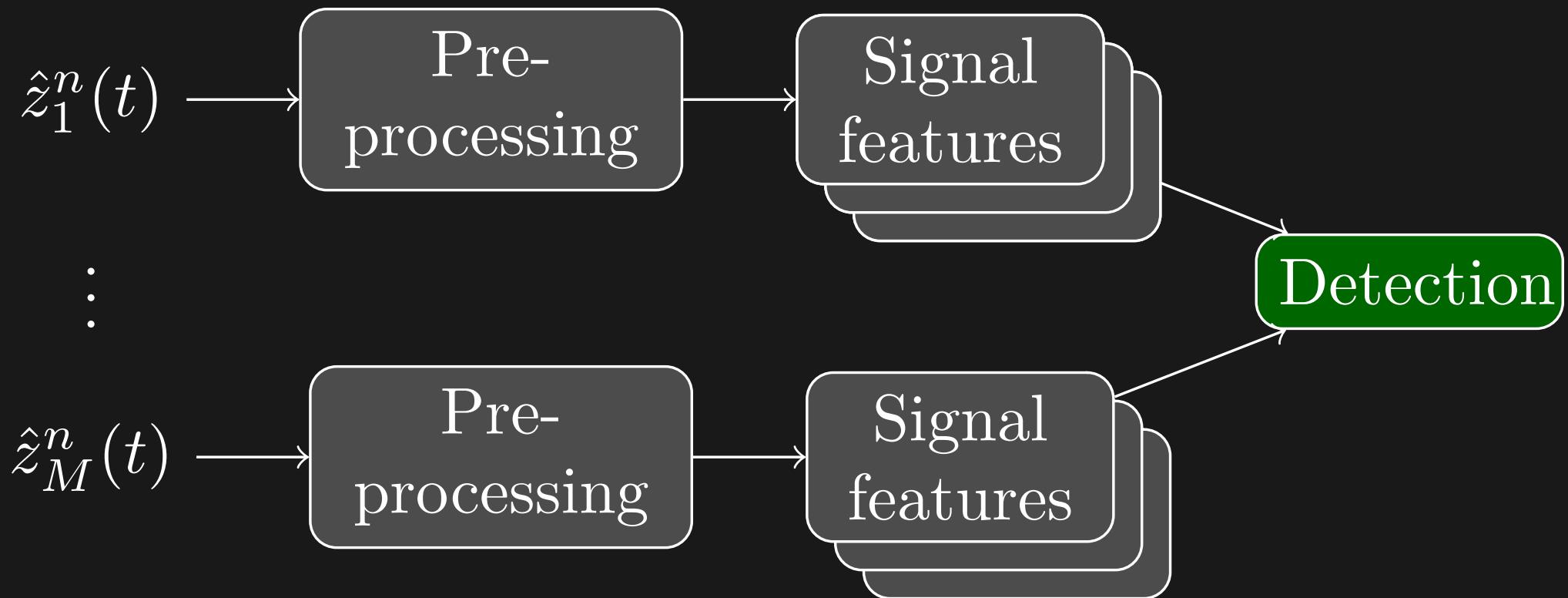
EVENT DETECTION



EVENT DETECTION



ELEPHANT FOOTSTEP DETECTION



PRE-PROCESSING

- Bandpass filter between 4 and 45 Hz
- Normalization

SIGNAL FEATURES

- Standard deviation
- Frequency peak
- Spectral centroid
- Frequency distribution

DIRECTION OF ARRIVAL ESTIMATION

Signal model : $z_i[k] = s [k - \tau_i (\phi[k])] + e_i[k]$

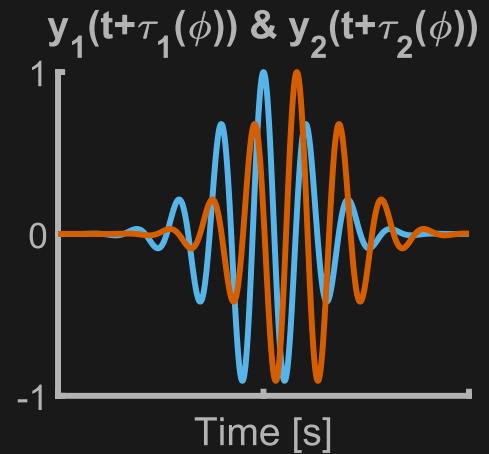
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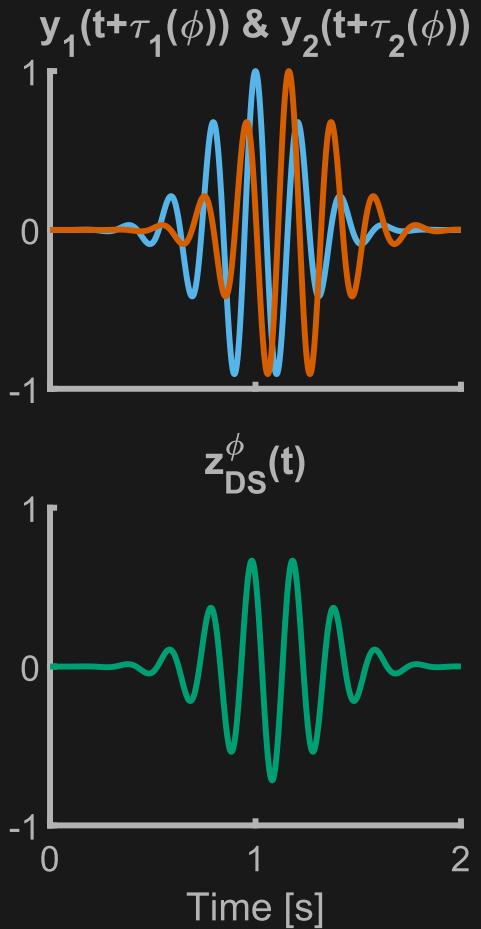
Delay-and-Sum Beamformer:

$$\hat{\phi}[k] = \arg \max_{\phi} \sum_{k=1}^N \left| \frac{1}{M} \sum_{i=1}^M z_i[k + \tau_i(\phi)] \right|^2$$

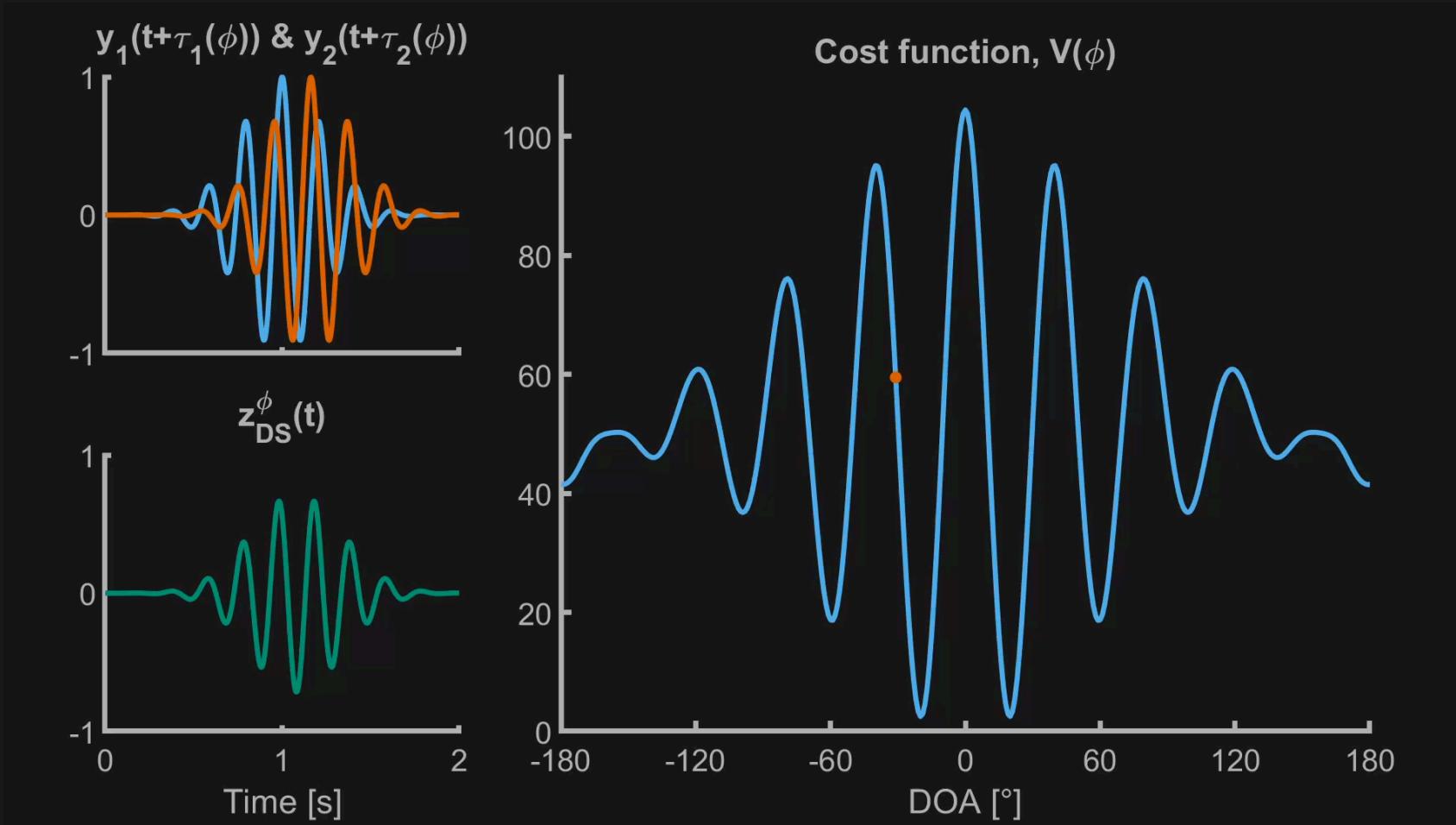
DIRECTION OF ARRIVAL ESTIMATION



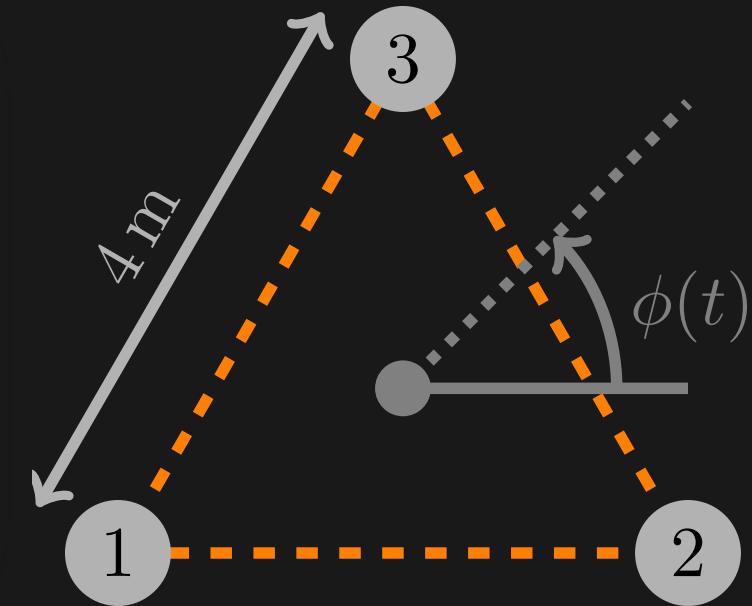
DIRECTION OF ARRIVAL ESTIMATION



DIRECTION OF ARRIVAL ESTIMATION



EXPERIMENTAL SETUP



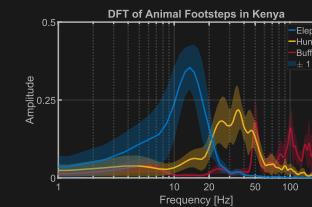
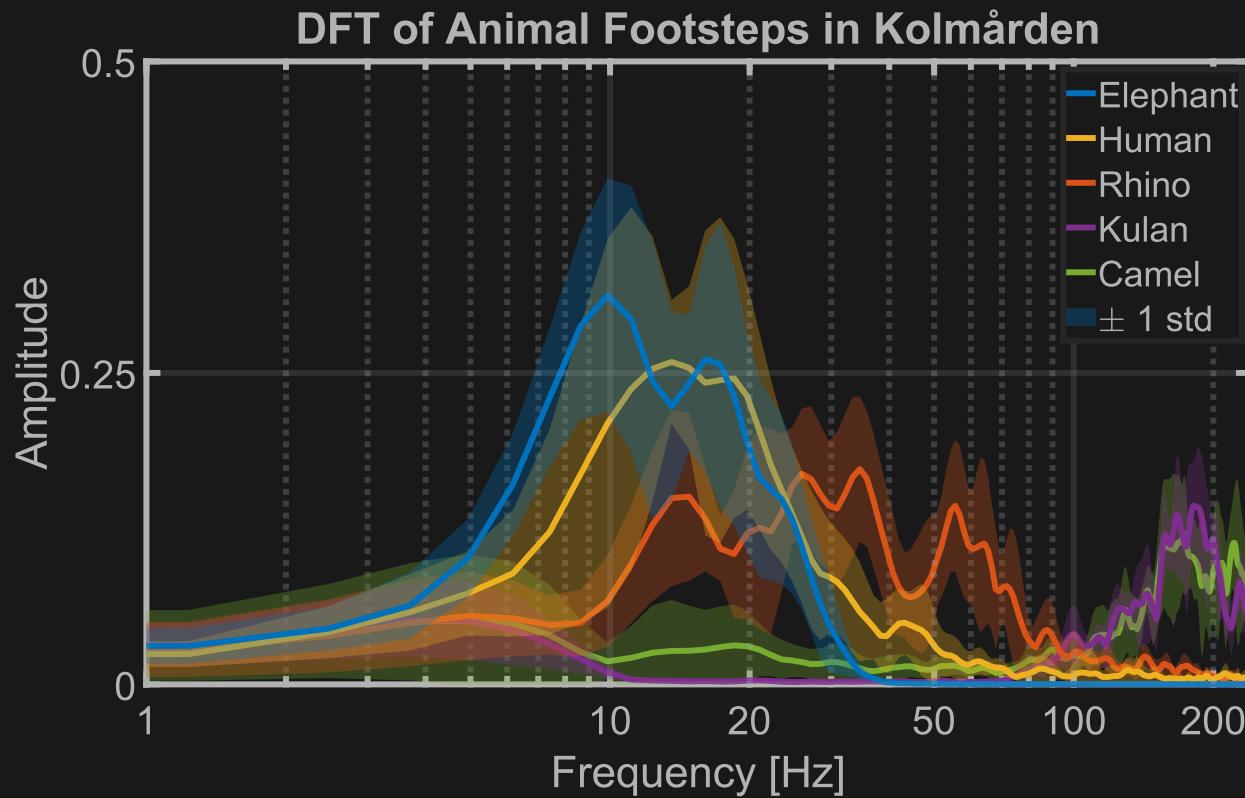
EXPERIMENTAL SETUP



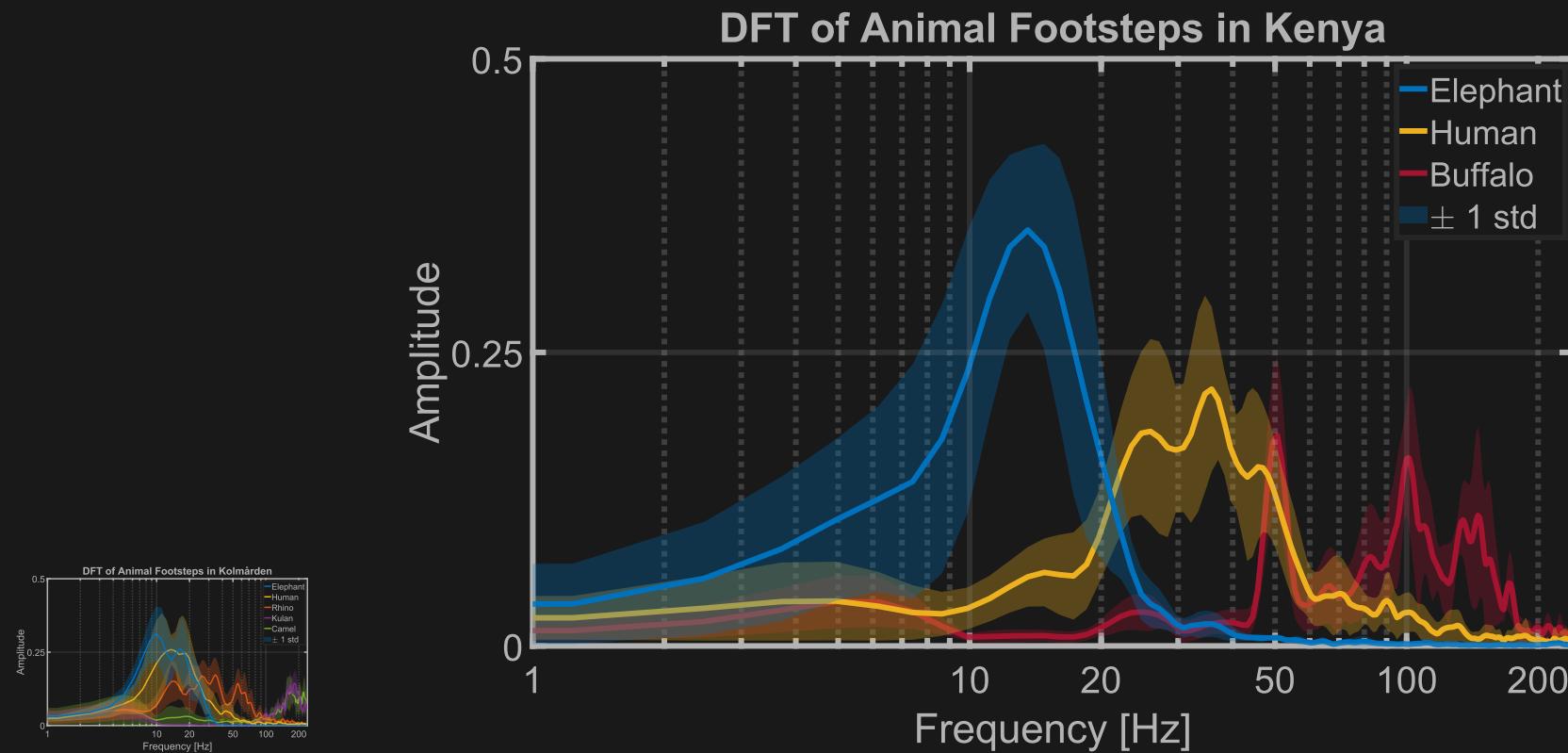
DATA COLLECTION

Animal	Kolmården	Kenya
Elephant	Asian	African
Human	✓	✓
Rihno	✓	-
Kulan	✓	-
Camel	✓	-
Buffalo	-	✓

SIGNAL FREQUENCY



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SIGNAL FEATURES

Kolmården

Feature	Mean	σ
Standard Deviation	0.08821	6.5e-4
Frequency peak	13.2	3.72
Spectral Centroid	19.1	3.62
Frequency Ratio	603.1	478.9

SIGNAL FEATURES

Feature	Kolmården	Kenya		
	Mean	σ	Mean	σ
Standard Deviation	0.08821	6.5e-4	0.08812	9.3e-4
Frequency peak	13.2	3.72	12.9	3.15
Spectral Centroid	19.1	3.62	18.3	3.53
Frequency Ratio	603.1	478.9	48.1	27.4

DETECTION RESULTS

- **Accuracy:** Proportion of correct predictions

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- **F1 score:** Harmonic mean of precision and recall

DETECTION RESULTS

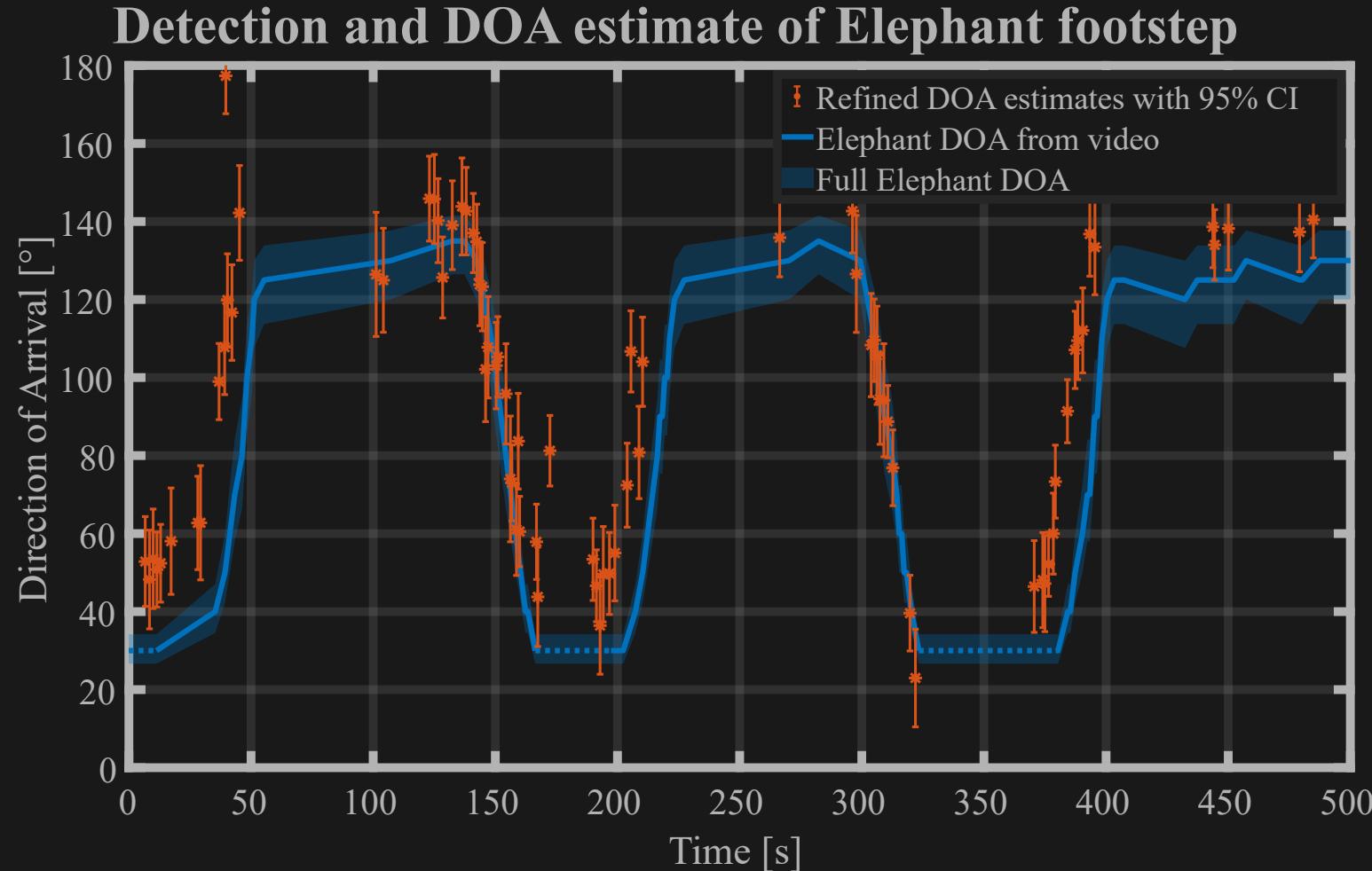
Evaluation scores from Kolmården Wildlife Park.

$\pm\sigma(s)$	Accuracy	Recall	Precision	F1 score
1	0.86	0.30	1	0.46
1.5	0.89	0.54	0.89	0.67
2	0.89	0.61	0.81	0.7

COMPARISON

	Proposed algorithm				Last year			
Animal	TP	TN	FP	FN	TP	TN	FP	FN
Elephant	8	0	1	2	10	0	8	0
Human	0	10	0	0	0	9	1	0
Rhino	0	10	0	0	0	9	1	0
Camel	0	10	0	0	0	10	0	0
Kulan	0	10	0	0	0	10	0	0
Total	8	40	1	2	10	38	10	0

DOA RESULTS



CONCLUSIONS

- Proposed algorithm reduces false alarms

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- High accuracy for elephant detection
- Direction of arrival estimation is accurate

THANK YOU!

