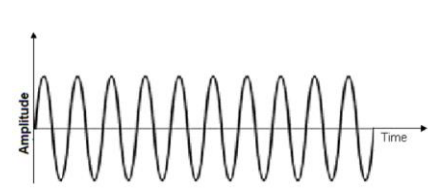# Radar-based Detection and Classification of Vulnerable Road Users

Tetiana Lavrenko[1,2], Timo Gessler[1], Thomas Walter[1], Hubert Mantz[1], and Michael Schlick[2]

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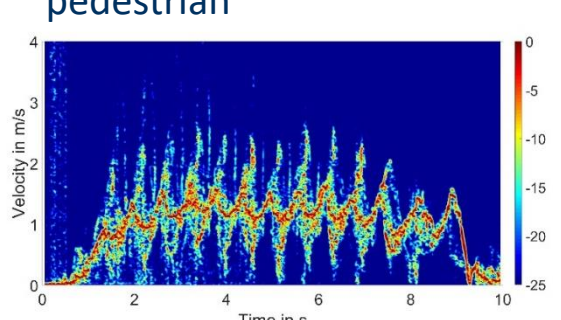
Motivation

Continuous wave radar

Doppler-spectrum of a walking pedestrian
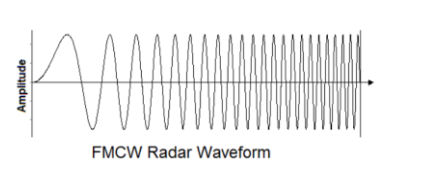
- Continuous
- Unmodulated transmit waveform

- Time information
- Velocity information

🙂 **Clear gait pattern**
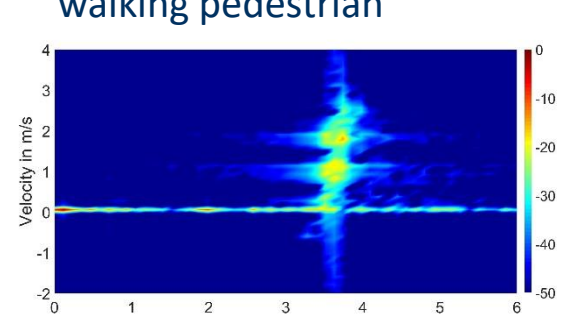
😕 **Little information, computationally expensive**

Frequency modulated continuous wave radar

Range-Doppler-spectrum of a walking pedestrian

- Linearly modulated pulses (chirps) over time
- Frequency modulation

- Time information
- Distance information
- Velocity information
- Angular information
- DoA – Direction of arrival

🙂 **Much information**

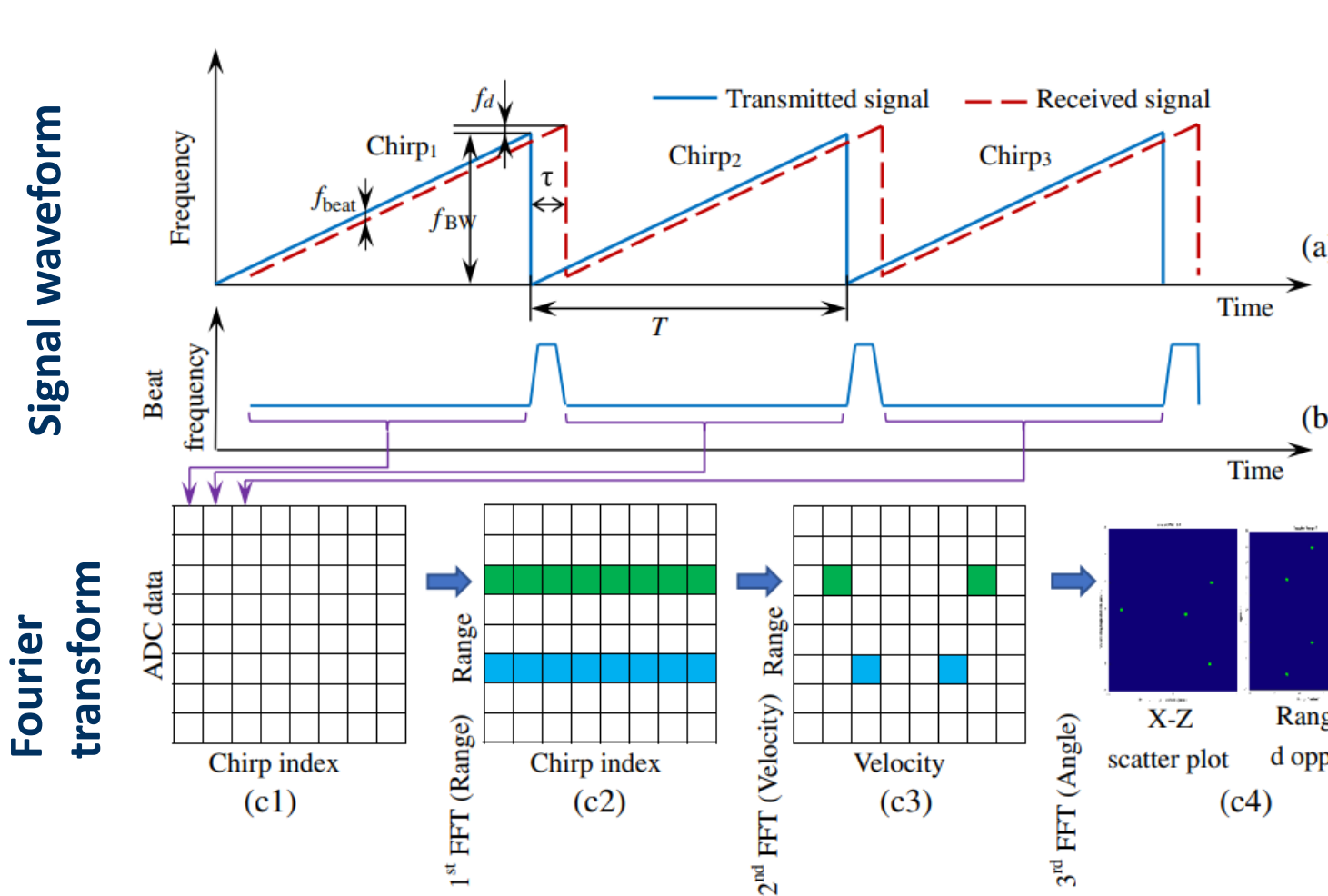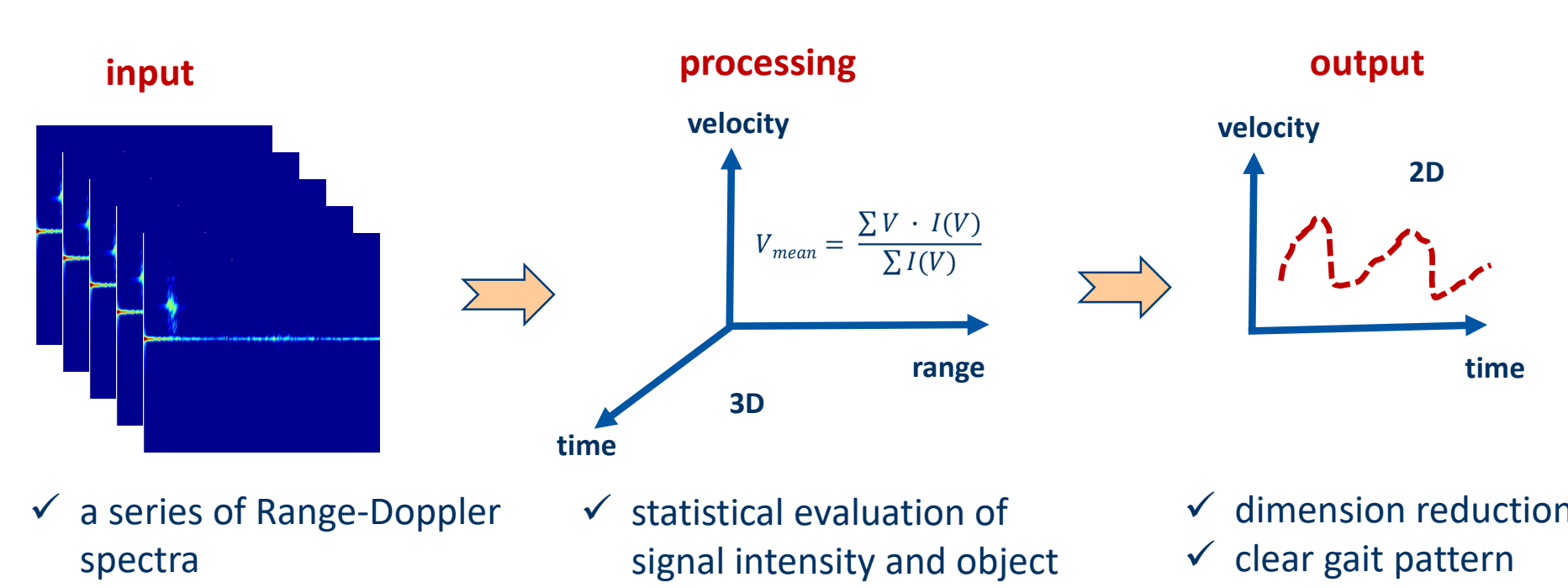😢 **No clear gait pattern**

Gait Pattern Pedestrian vs. Bicyclist

series of range-Doppler spectra

- ✓ periodic
- ✓ dominated by torso and limb movements

time-dependent series of mean velocity

series of range-Doppler spectra

- ✓ linear
- ✓ dominated by torso

time-dependent series of mean velocity

Methodology

First step: low level signal processing (figure after *)

Standard approach

Signal waveform

Fourier transform

One Range-Doppler spectrum not enough Information for pattern!

Second step: high level signal processing

Proposed approach

input

processing

$$V_{mean} = \frac{\sum V \cdot I(V)}{\sum I(V)}$$
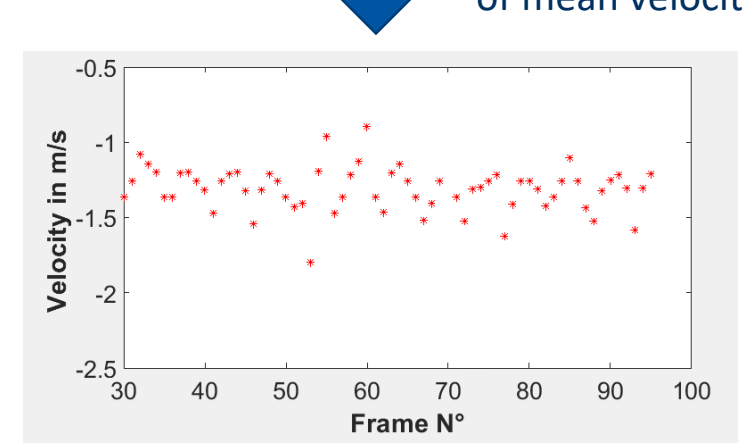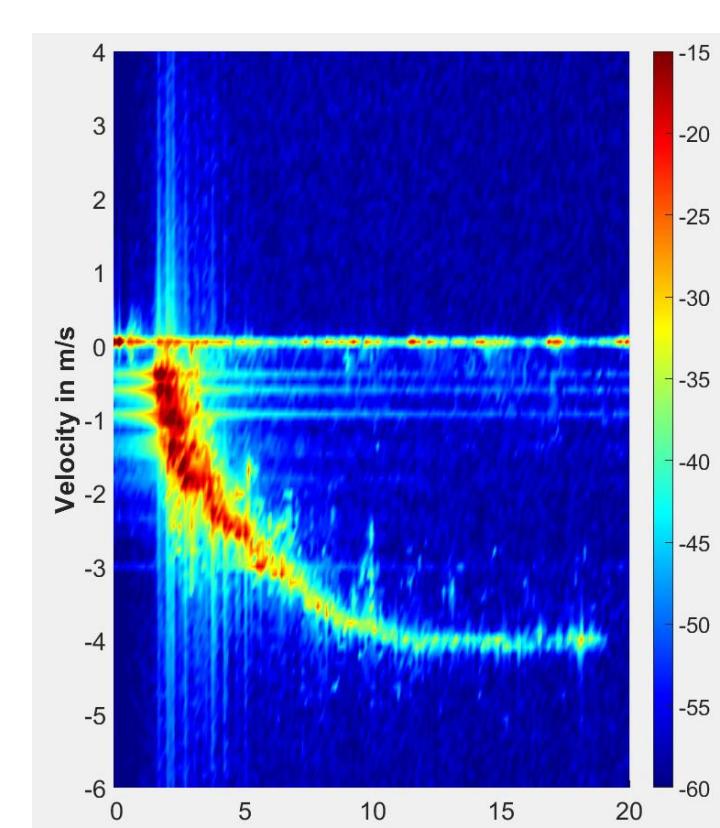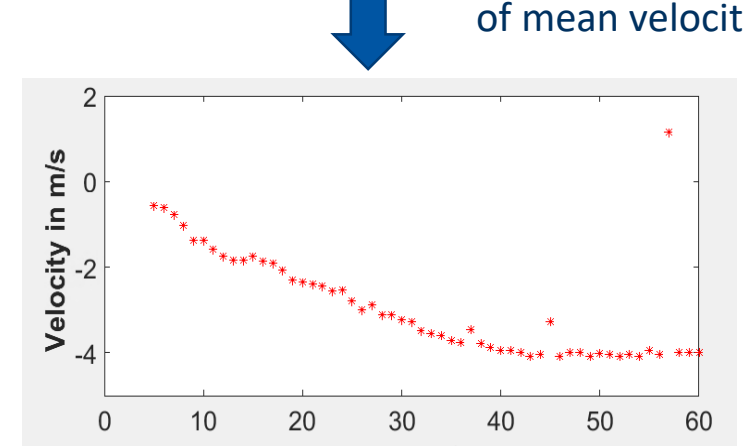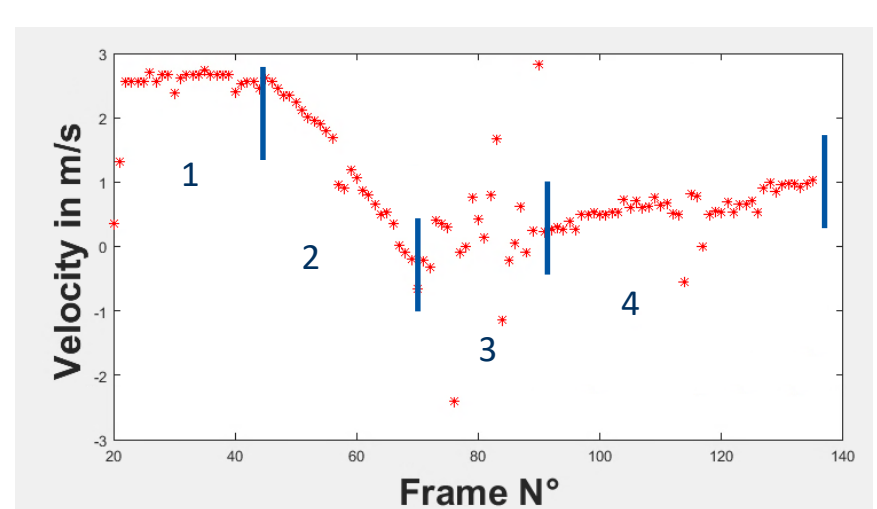
output

- ✓ a series of Range-Doppler spectra
- ✓ statistical evaluation of signal intensity and object velocity
- ✓ dimension reduction
- ✓ clear gait pattern

Movement Analysis

The proposed approach can be used to analyse the movement behaviour (here bicycle)

1 – movement with a constant velocity
2 – slowing down towards the sensor
3 – noise, too close to the sensor
4 – accelerating towards the sensor

Reference

* Long, Ningbo & Wang, Kaiwei & Cheng, Ruiqi & Yang, Kailun & Weijian, Hu & Bai, Jian. (2019). Assisting the visually impaired: Multitarget warning through millimeter wave radar and RGB-depth sensors. Journal of Electronic Imaging. 28. 1.10.1117/1.JEI.28.1.013028.

Summary

In this work, a new approach to interpret unique spectral signatures of pedestrians and cyclists is proposed. Doppler-Range spectra which result from the local dynamic of the moving body parts are used to extract statistical parameters of the movement pattern. The gait pattern is therefore represented by a time-dependent velocity distribution. These calculations are based on a probabilistic approach of the detection.

Acknowledgements