Improved Liveness Detection in Dorsal Hand Vein Videos using Photoplethysmography

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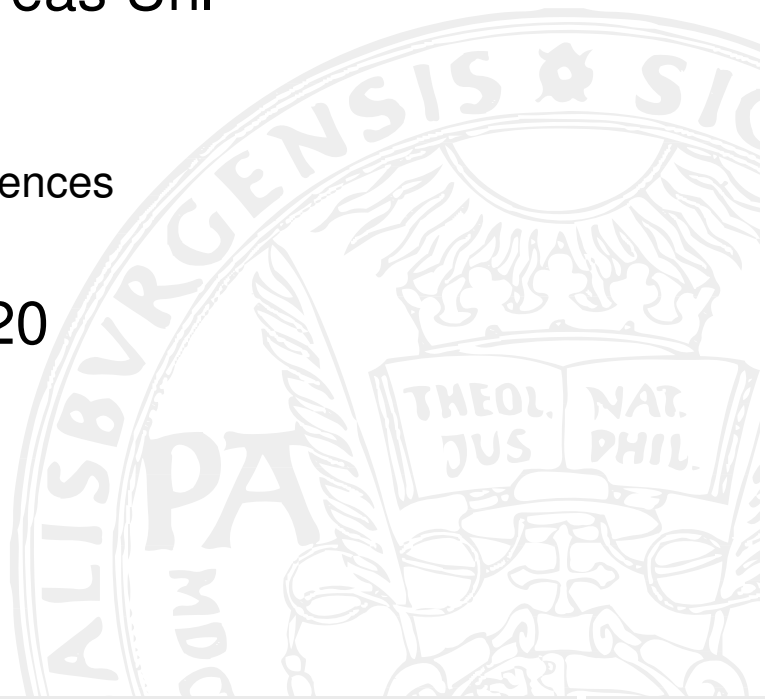

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Hand-Vein Biometrics I

- Pattern of blood vessels under the skin has become an emerging biometric trait due to uniqueness
- Captured through near-infrared (NIR) illumination
- NIR light is absorbed by oxygen-saturated hemoglobin in blood
- Can be used for authentication (similar to fingerprint)

Hand-Vein Biometrics II

Advantages

- Hard to forge since intrinsic trait and only visible through NIR illumination
- No abrasion as with fingerprints
- Invariant to sweat, sunscreen, etc.
- Non-intrusive

Disadvantages

- Special hardware needed (Relatively strong NIR illumination, NIR imaging sensor, ...)
- Vein structure may be influenced by certain diseases or injuries
- In general low contrast and quality

The Presentation Attack Problem

- Scenario: Access to previously captured hand vein data
- Presentation Attacks
  - Printed on paper [1]
  - Shown on smartphone display [2]
- Countermeasures
  - Still Images: Skin texture, image quality, 2D frequency space, CNNs
  - Additional sensors: capacitive sensing, 3D imaging
  - **Differences in adjacent video frames**

Video Database I

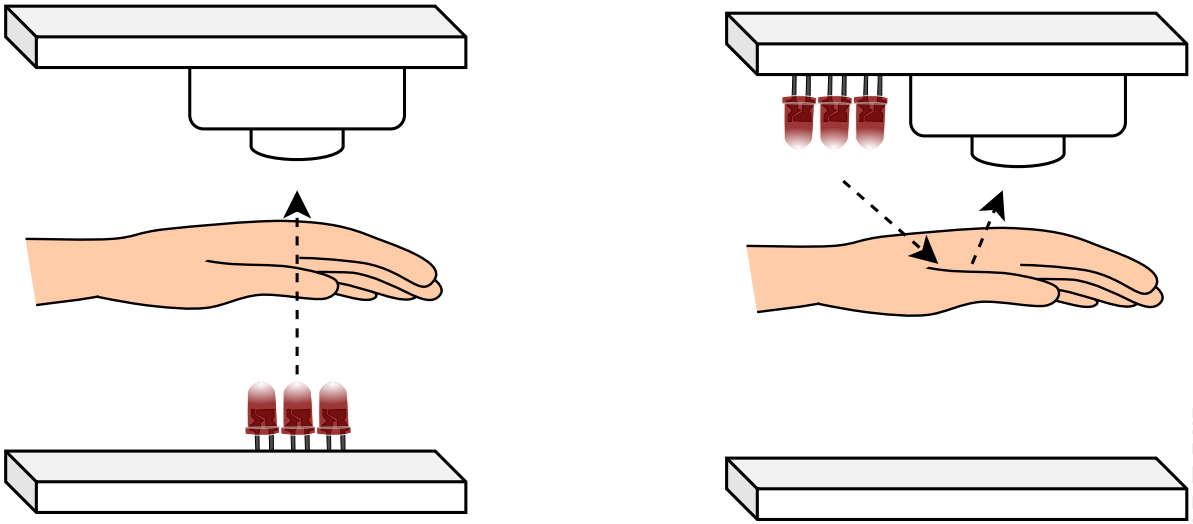


Figure: Modes of operation: Transillumination (left) and Reflected Light.

Video Database II

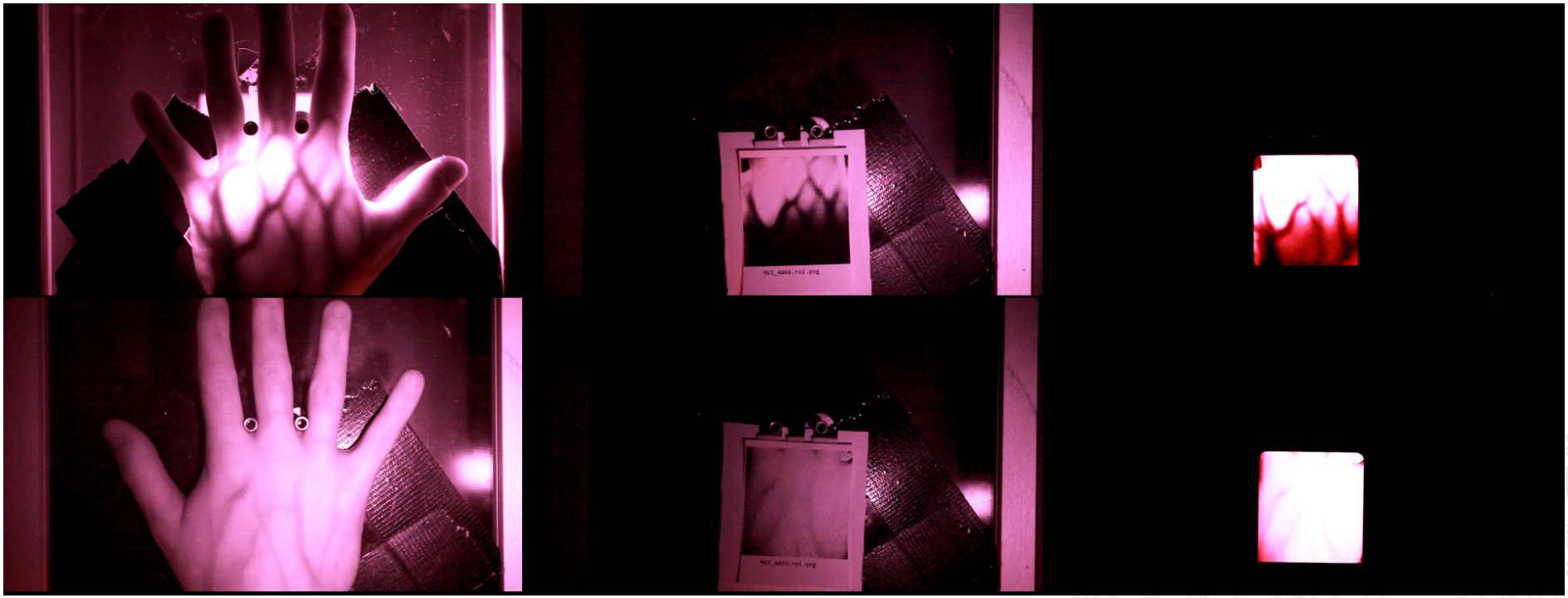
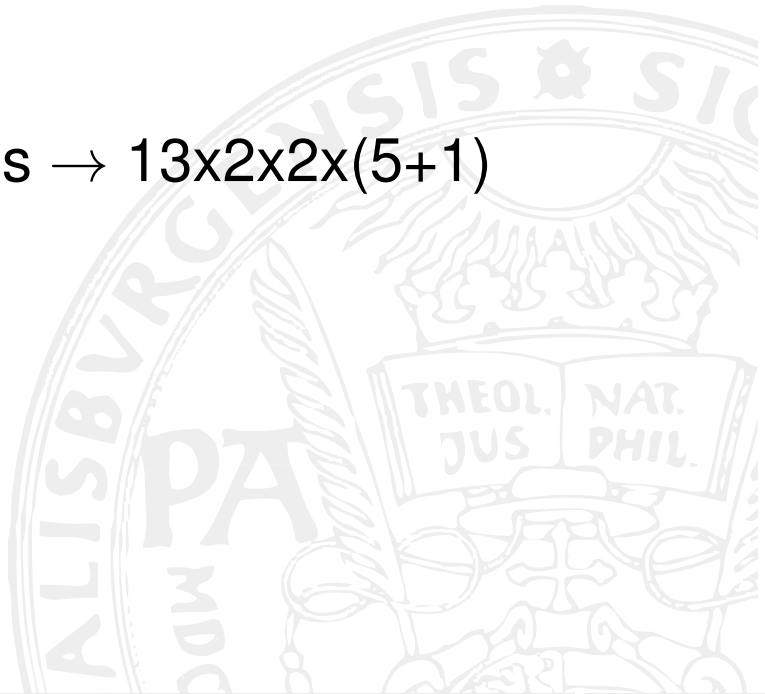


Figure: Example frames from NIR videos; top row: transillumination, bottom row: reflected light; left: real video frame, middle column: paper attack and right: smartphone attack, respectively. Captured with [3].

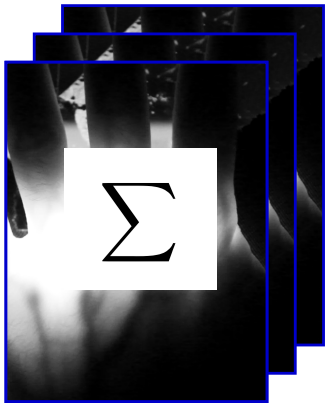
Video Database III

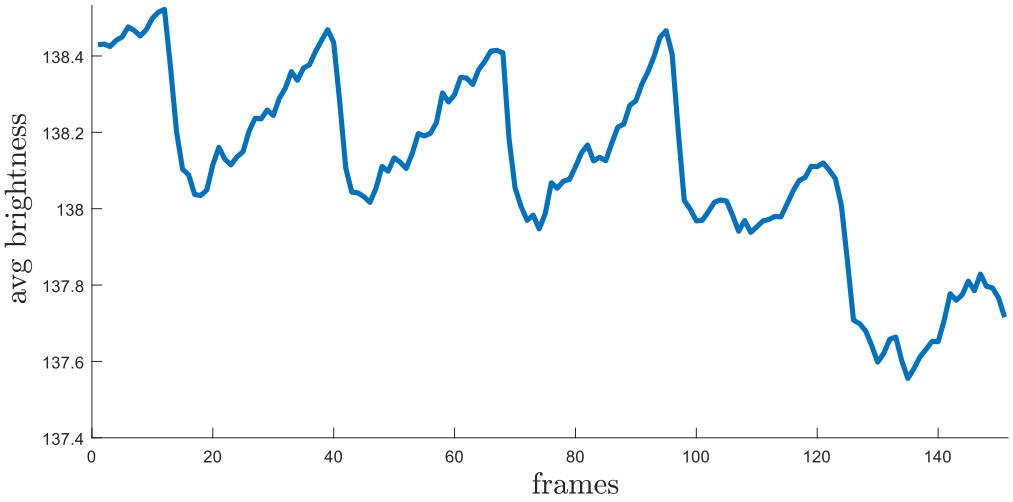
- 13 Persons à 2 Hands
- 2 Illumination Variants
- 5 Presentation Attack Scenarios
- Database in total: 312 Video Sequences $\rightarrow$ 13x2x2x(5+1)



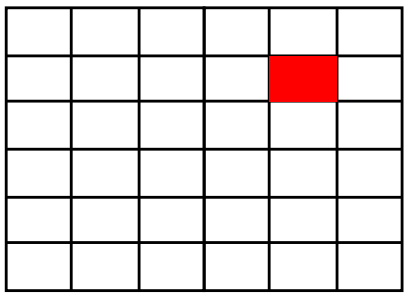
Methods I

Related approaches build upon a common basis:

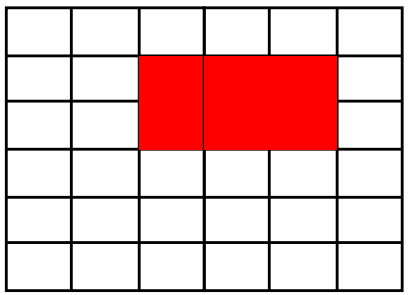




a) Pixel



b) ROI



c) Entire Image

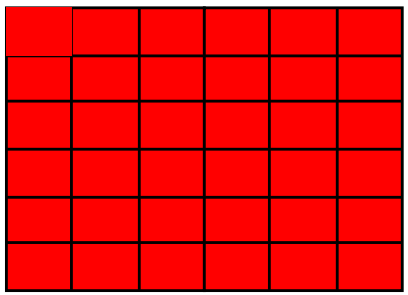
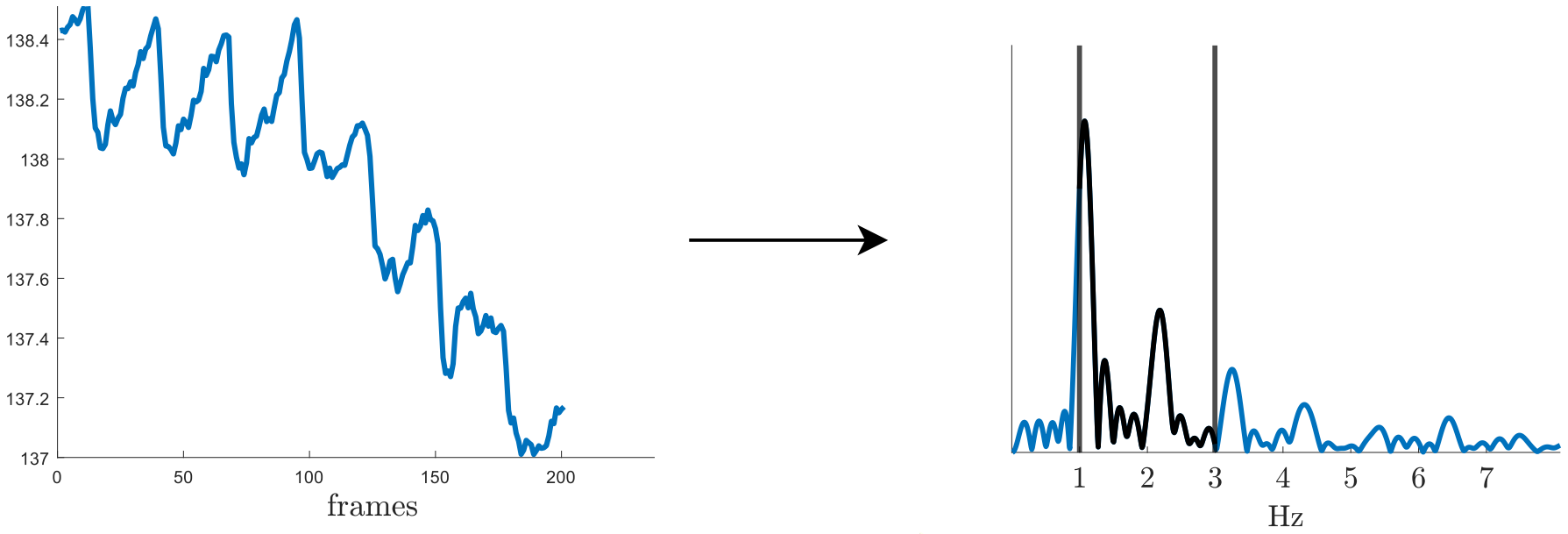


Figure: Idea of Average Pixel Illumination.

Methods II

- Exception: [4] used ”Eulerian motion magnification” $\rightarrow$ [5] used the described spoofing database to show that this method can still be fooled
- In [6], the peaks and valleys of the time series were used as classification criteria
- [7, 8, 9] reported the observation that this processing step contains information about heart rate by transforming the time series to Fourier domain
- Bok et al. [10] constructed classifier out of Fourier domain, although for finger vein videos

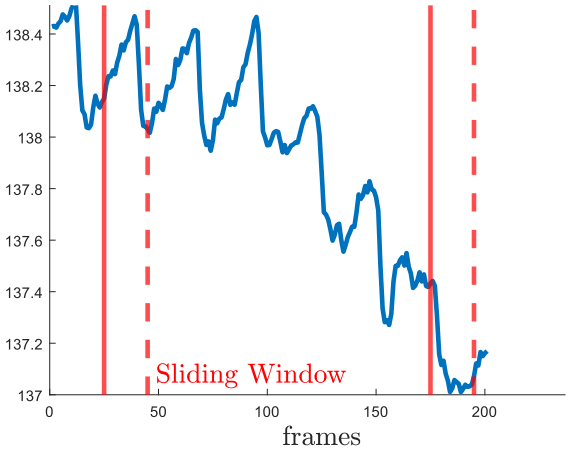
Reference Method: Bok et al.



$$Feature\ Vector \in R^{50}$$

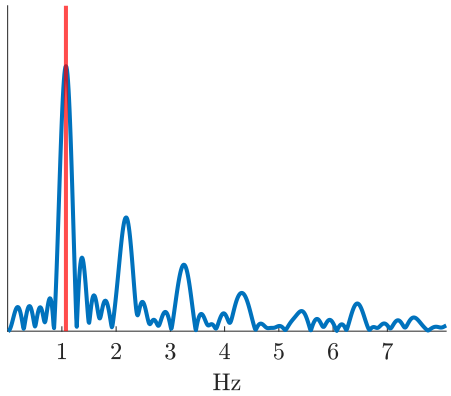
Figure: Feature Vector Construction Bok et al.

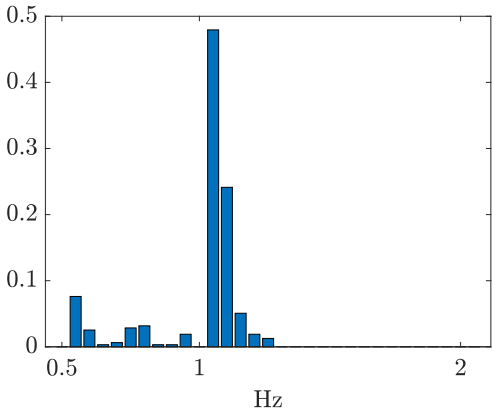
Introduced Method 1



$PerWindow:$

$Highpass\ Filtering$
$Zero\ padding$
$Fourier\ transform$





$Histogram\ Majority - voting$

$Feature\ Vector \in R^{30}$

Figure: Feature Vector Construction Method 1.

Methods V

Observation from Wei et al. [11]

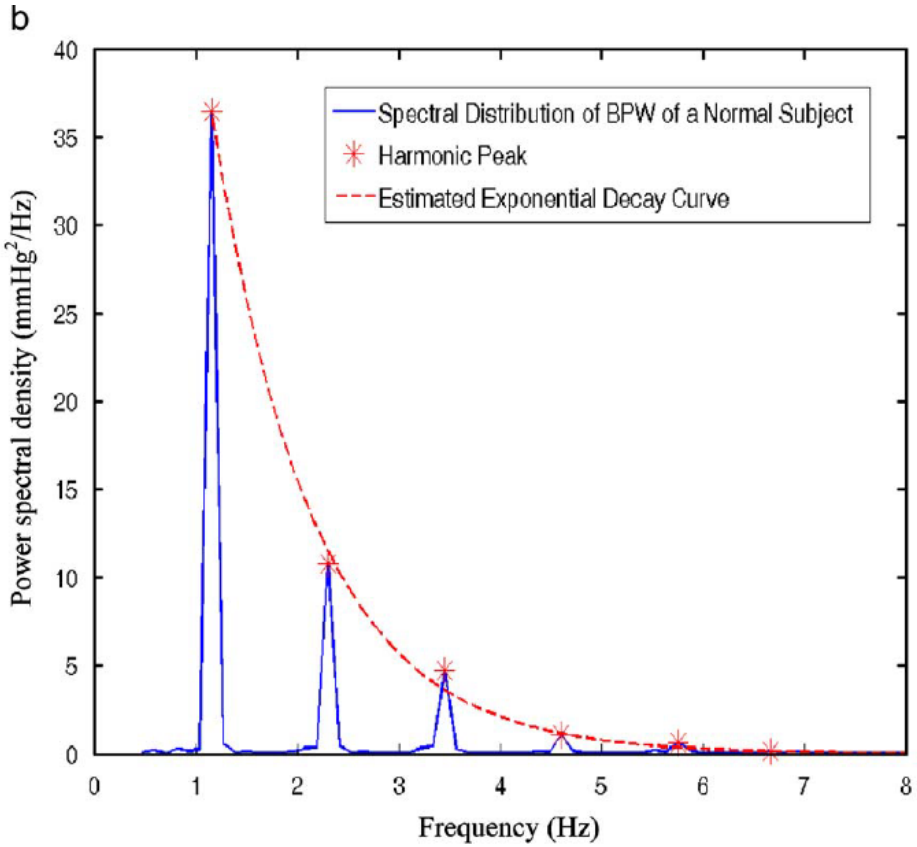
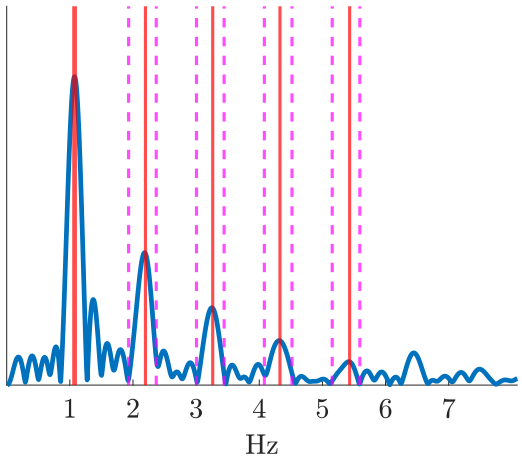
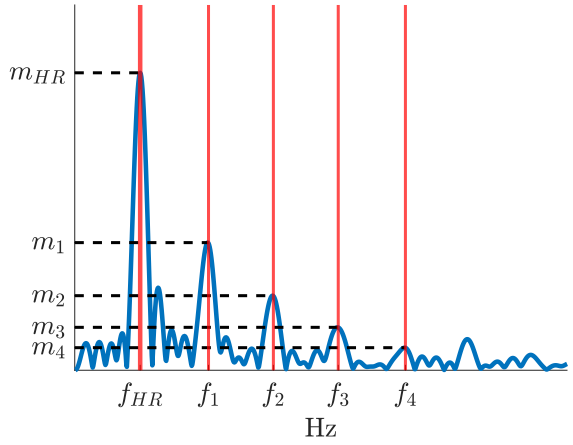


Figure: Blood pressure measurement in Fourier space have harmonics that can be modelled through exponential decay. Figure taken from [11].

Introduced Method 2

Like before: Fourier transform for every window





Use Means & Medians over all windows as Feature Vector.
Note: Actually use Quotient w.r.t
f_{HR} & m_{HR}

$$(\overline{m_{HR}}, \overline{m_1} \dots \overline{m_4}, Md(m_{HR}), Md(m_1) \dots Md(m_4),$$
$$\overline{f_{HR}}, \overline{f_1} \dots \overline{f_4}, Md(f_{HR}), Md(f_1) \dots Md(f_4))$$

$$Feature\ Vector \in R^{20}$$

Figure: Feature Vector Construction Method 2.

Experimental Results I

Evaluation metrics according to ISO/IEC 30107-3:2017

- Attack Presentation Classification Error Rate (APCER): proportion of attack presentations incorrectly classified as bona fide presentations in a specific scenario

- Bona Fide Presentation Classification Error Rate (BPCER): proportion of bona fide presentations incorrectly classified as presentation attacks in a specific scenario

Experimental Results II

RBF Kernel C=10, $\gamma = 0.001$

Spoof Method		Bok et al.		Method 1		Method 2	
		APCER	BPCER	APCER	BPCER	APCER	BPCER
Transill.	Paper	**10.31**	30.77	11.54	15.38	11.54	**3.85**
	Paper Mov.	**4.35**	37.50	26.92	11.54	11.54	**0.00**
	SP	**0.00**	89.42	3.85	7.69	**0.00**	**0.00**
	SP Mov.	77.36	89.42	**0.00**	19.23	19.23	**0.00**
	SP Zoom	59.43	17.31	**3.85**	19.23	11.54	**0.00**
Refl. Light	Paper	**0.00**	80.37	53.85	61.54	7.69	**23.08**
	Paper Mov.	49.06	5.61	**23.08**	**3.85**	42.31	7.69
	SP	63.55	6.54	7.69	**3.85**	**3.85**	**3.85**
	SP Mov.	23.08	6.54	3.85	**0.00**	**0.00**	3.85
	SP Zoom	15.24	7.48	3.85	**0.00**	**0.00**	3.85

Table: The table shows the SVM results with a RBF kernel, BoxConstraint of 10 and a γ value of 0.001 as proposed in [10]. Best results are highlighted **bold**.

Experimental Results III

Linear SVM Kernel

Spoof Method		Bok et al.		Method 1		Method 2	
		APCER	BPCER	APCER	BPCER	APCER	BPCER
Transill.	Paper	11.34	18.27	**7.69**	26.92	11.54	**0.00**
	Paper Mov.	**7.61**	16.35	26.92	19.23	11.54	**7.69**
	SP	13.21	54.81	7.69	26.92	**0.00**	**0.00**
	SP Mov.	17.92	57.69	11.54	11.54	**3.85**	**0.00**
	SP Zoom	27.36	40.38	7.69	11.54	**0.00**	**0.00**
Refl. Light	Paper	12.84	71.03	61.54	53.85	**0.00**	**3.85**
	Paper Mov.	25.47	**1.87**	15.38	3.85	**3.85**	7.69
	SP	46.73	6.54	7.69	19.23	**3.85**	**3.85**
	SP Mov.	28.85	6.54	3.85	**3.85**	**0.00**	**3.85**
	SP Zoom	18.10	5.61	**3.85**	**0.00**	**3.85**	3.85

Table: The table contains results with a simple linear kernel. Best results are highlighted **bold**.

Conclusion

Contribution

- Evaluated an existing Presentation Attack Detection Method for finger vein biometrics on a custom dorsal hand vein data set.
- Proposed two additional methods for PAD, employing spectral analysis of the average pixel illumination per frame.
  - Superior with respect to the reference method
  - High time consumption

Future Work

- Reduce computational cost of proposed algorithms
- Acquire more data samples

Thank you for your attention!

Thank You!
Q & A

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