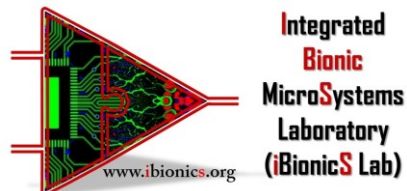


Contact-Free Simultaneous Sensing of Human Heart Rate and Canine Breathing Rate for Animal Assisted Interactions

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North Carolina, USA



Talk Overview

- ❖ Background & Approach
- ❖ Remote **Breathing Rate** Estimation
- ❖ Remote **Heart Rate** Estimation
- ❖ Frequency Tracking & Results
- ❖ Conclusion



Background & Approach

Animal & Canine Assisted Interactions (AAIs & CAIs)

AAIs



[1]

CAIs



Other Contexts



[2]

- ❖ complementary treatment
- ❖ animals as therapeutic agents

- ❖ aim to improve quality of life
- ❖ **neutral** or **positive** effects
(for both subjects)

- ❖ working dogs
- ❖ companion dogs

[1] <https://www.ncmedical.com/animal-assisted-therapy>

[2] <https://www.todayfoundout.com/index.php/2018/01/how-do-they-train-drug-sniffing-dogs/>

Information Sources & Ongoing Needs in CAI

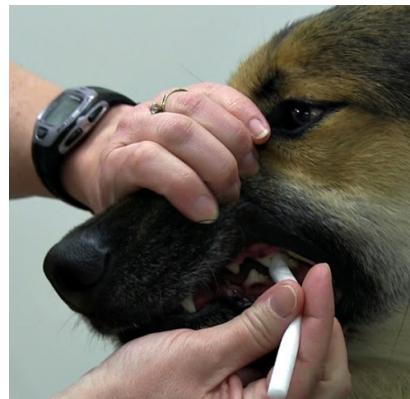
Environment

Context

Psychology

Behavior

Physiology



- ❖ anecdotal
- ❖ subjective
- ❖ qualitative
- ❖ not real-time
- ❖ not continuous

- ❖ obtrusive
- ❖ not ergonomic
- ❖ not dyadic
- ❖ context dependent

Contact-Free Physiological Sensing

in Animals



Al-Naji et al Sensors. 2019.



M. Rubinstein et al Science, 2013.

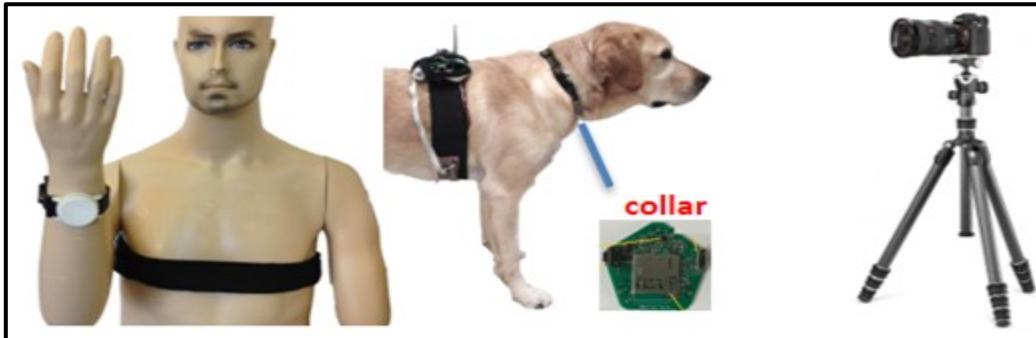
in Humans



J. Mathew et al arXiv. 2021.

Can we do this in a dyadic, CAI context?

Experimental Procedure



Canine Devices

- ❖ Custom smart collar
- ❖ Custom smart harness

Human Devices

- ❖ Custom chest patch
- ❖ Custom wrist-watch
- ❖ Empatica E4 watch

Both (cameras)

- ❖ Lenovo Flex 3 Laptop
- ❖ iPhone 6s (*aux*)
- ❖ Samsung S7 (*aux*)

Wearables & Camera Set up

Calm H-C Interaction

Systems Removal

Human Subjects

- ❖ 21 yo female
- ❖ 27 yo male

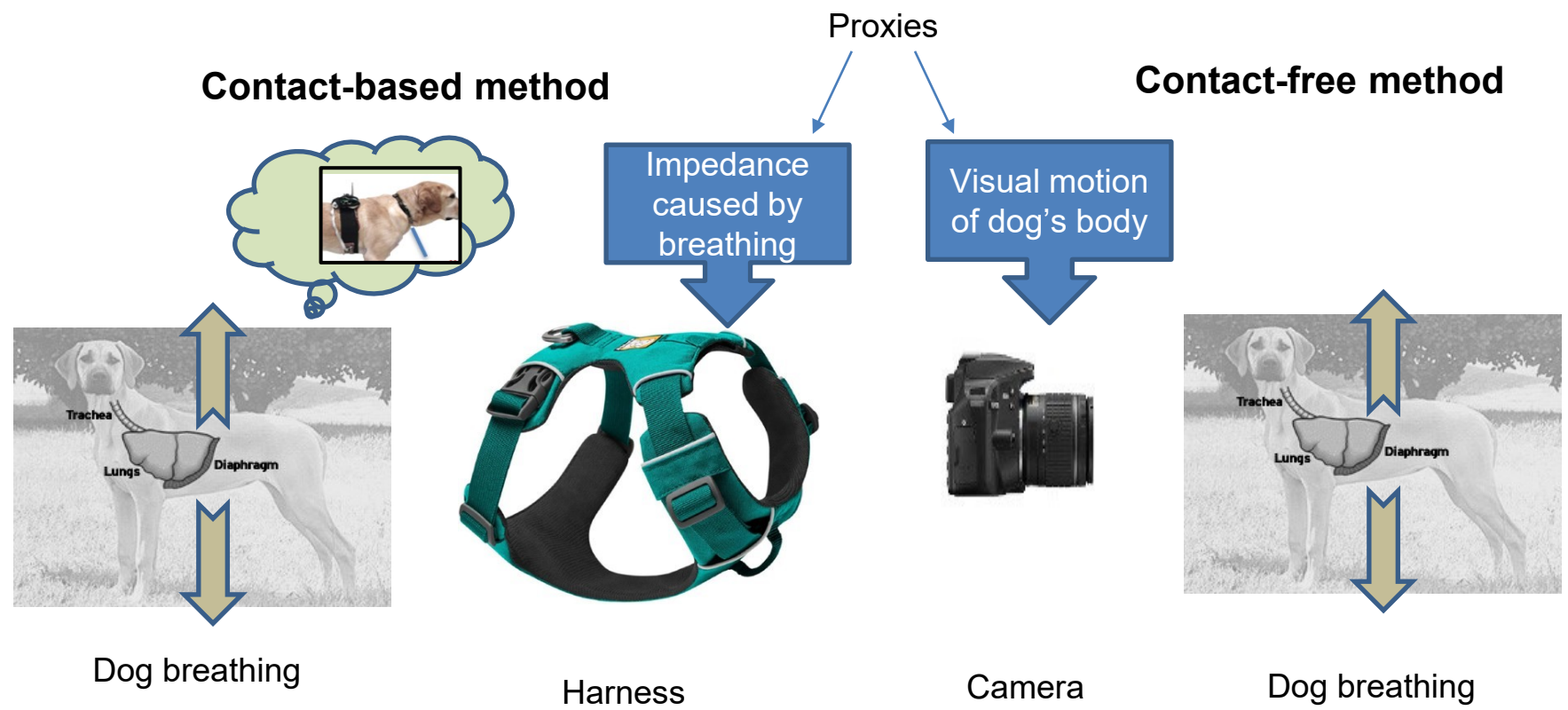
+

Canine Subjects

- ❖ 10 yo male Shih Tzu
- ❖ 5 yo female Pembroke Welsh Corgi

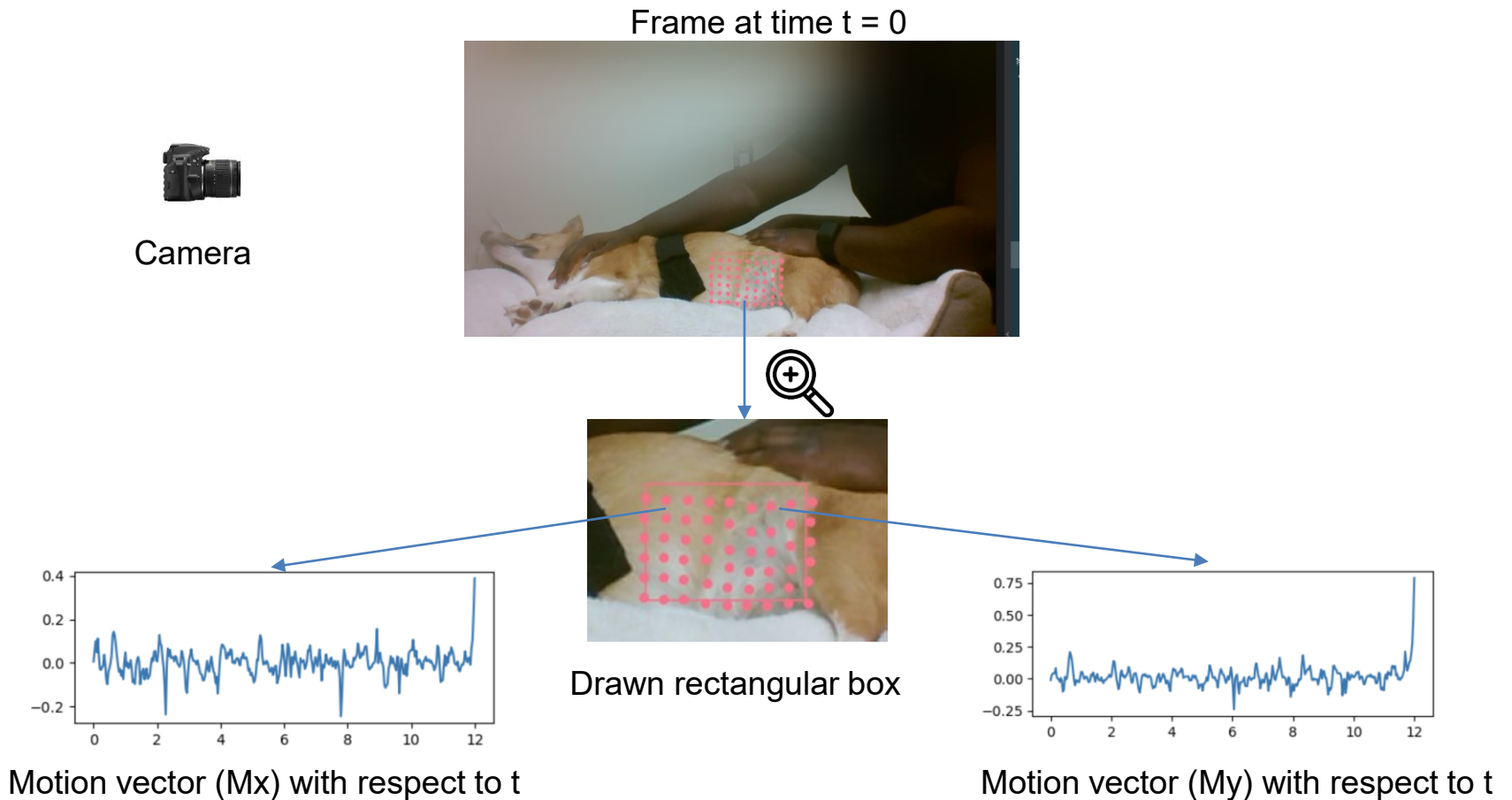
Remote **Breathing Rate** Estimation

Measuring Dog Breathing rate: Contact-Based vs Contactless

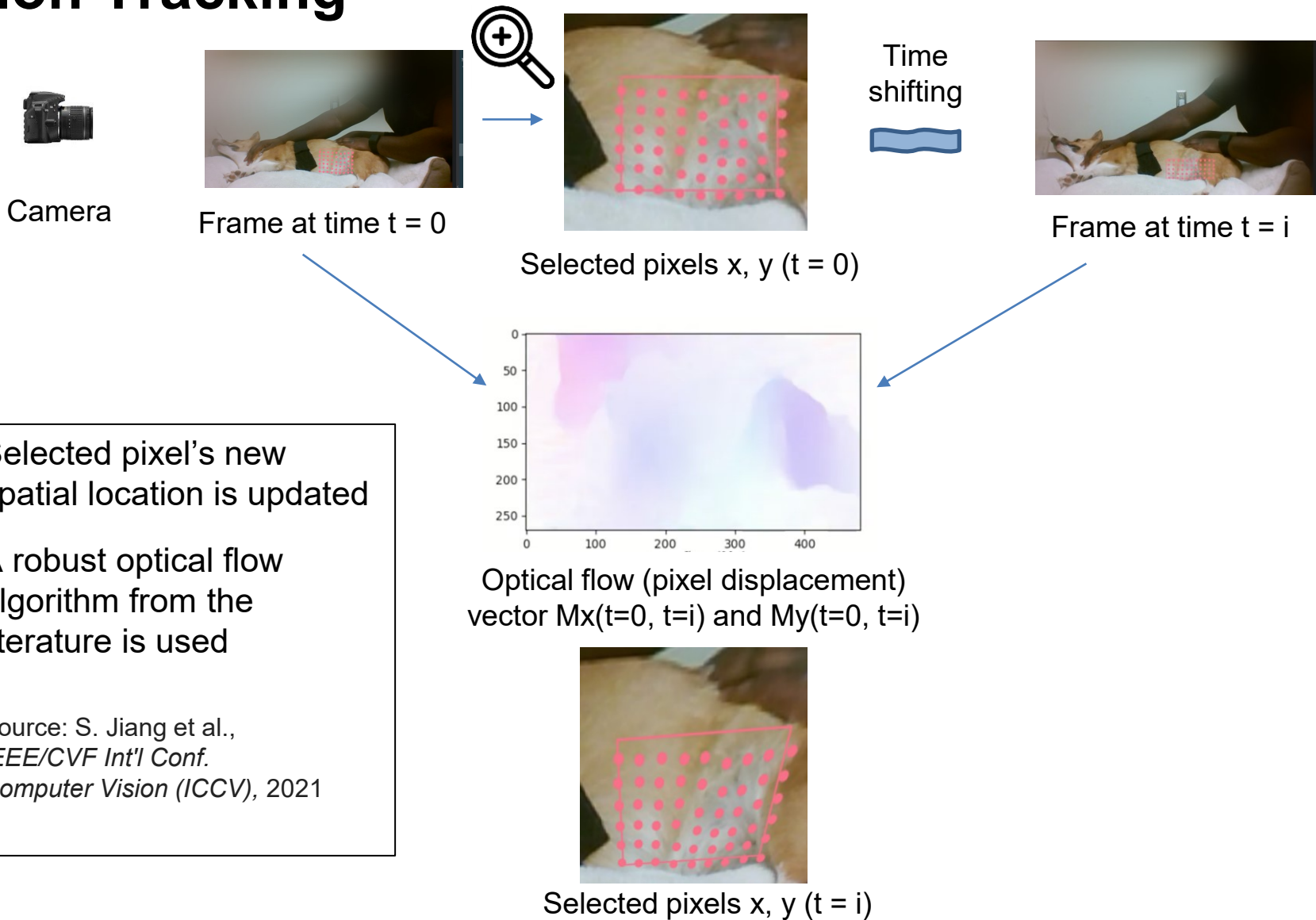


Region Selection

- Rectangular patch drawn on dog's diaphragm region
- Motion vector (M_x , M_y) calculated on each pixel inside the bounding box



Motion Tracking



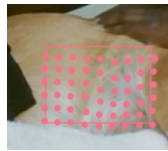
- Selected pixel's new spatial location is updated
- A robust optical flow algorithm from the literature is used
- Source: S. Jiang et al., *IEEE/CVF Int'l Conf. Computer Vision (ICCV)*, 2021

Breathing Signal Estimation

- Spatial displacement between frame at time $t=0$ and $t=i$ provides an estimation of breathing signal
- Breathing signal is submerged within other types of motion signals (movement of dog, patting etc.)



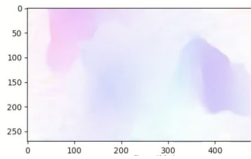
Frame at time $t = 0$



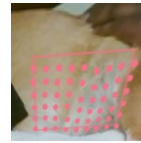
Selected pixels $x, y (t = 0)$



Frame at time $t = i$



Optical flow



Selected pixels $x, y (t = i)$

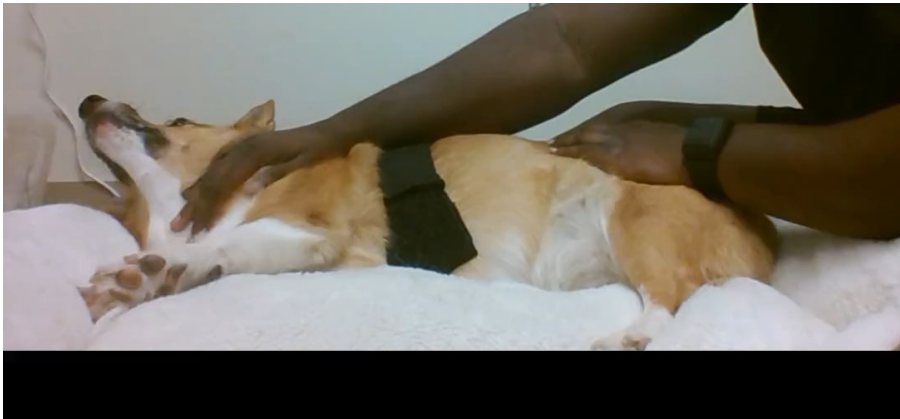


$y (i)$

Displacement

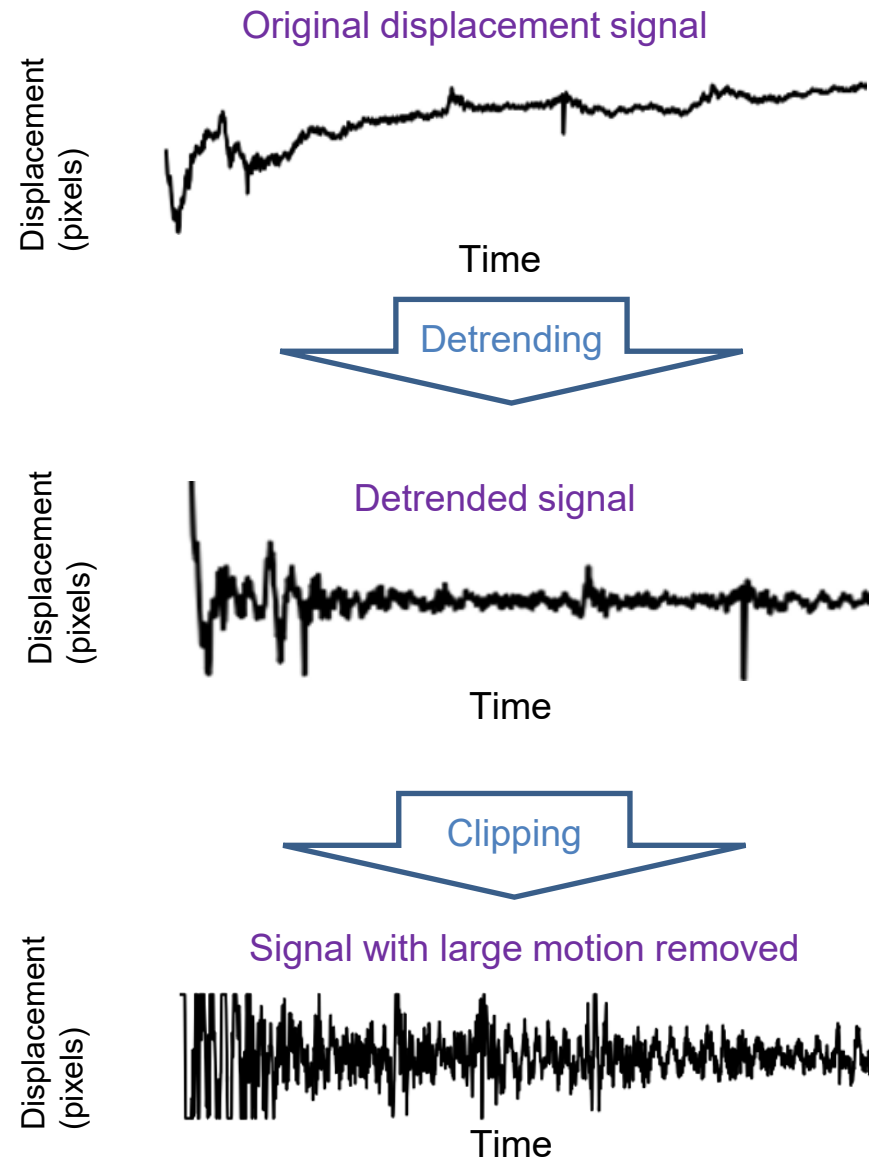


Frame number i



Breathing Signal Enhancing

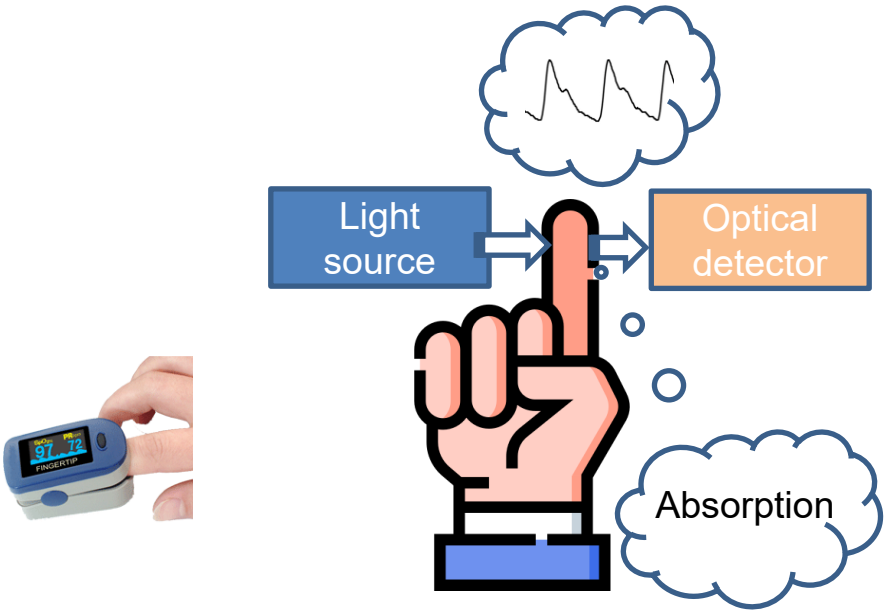
- The original displacement signal is detrended using a window of 2 seconds
- The detrended signal is clipped at 1 pixel to ignore large motions which doesn't originate from breathing



Remote **Heart Rate** Estimation

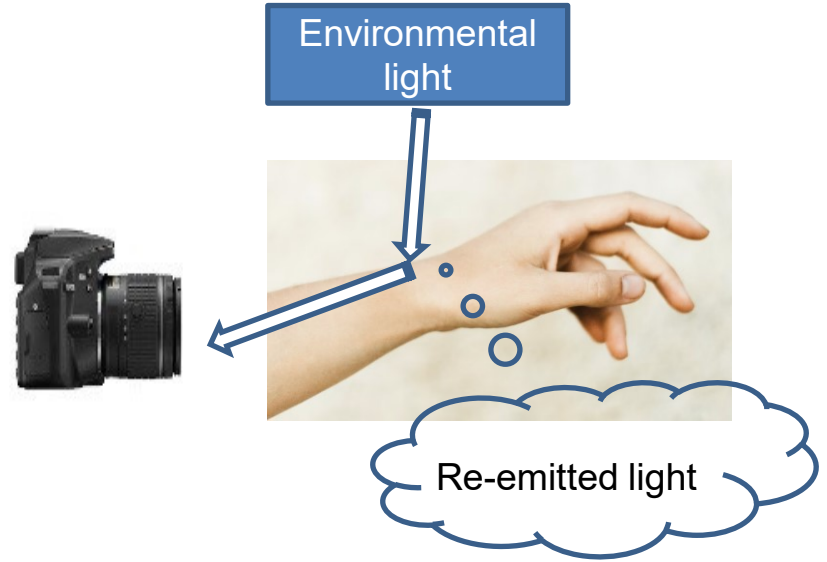
Measuring Human Heart Rate: Contact-Based vs Contactless

Contact-based method



Photoplethysmography (PPG) device

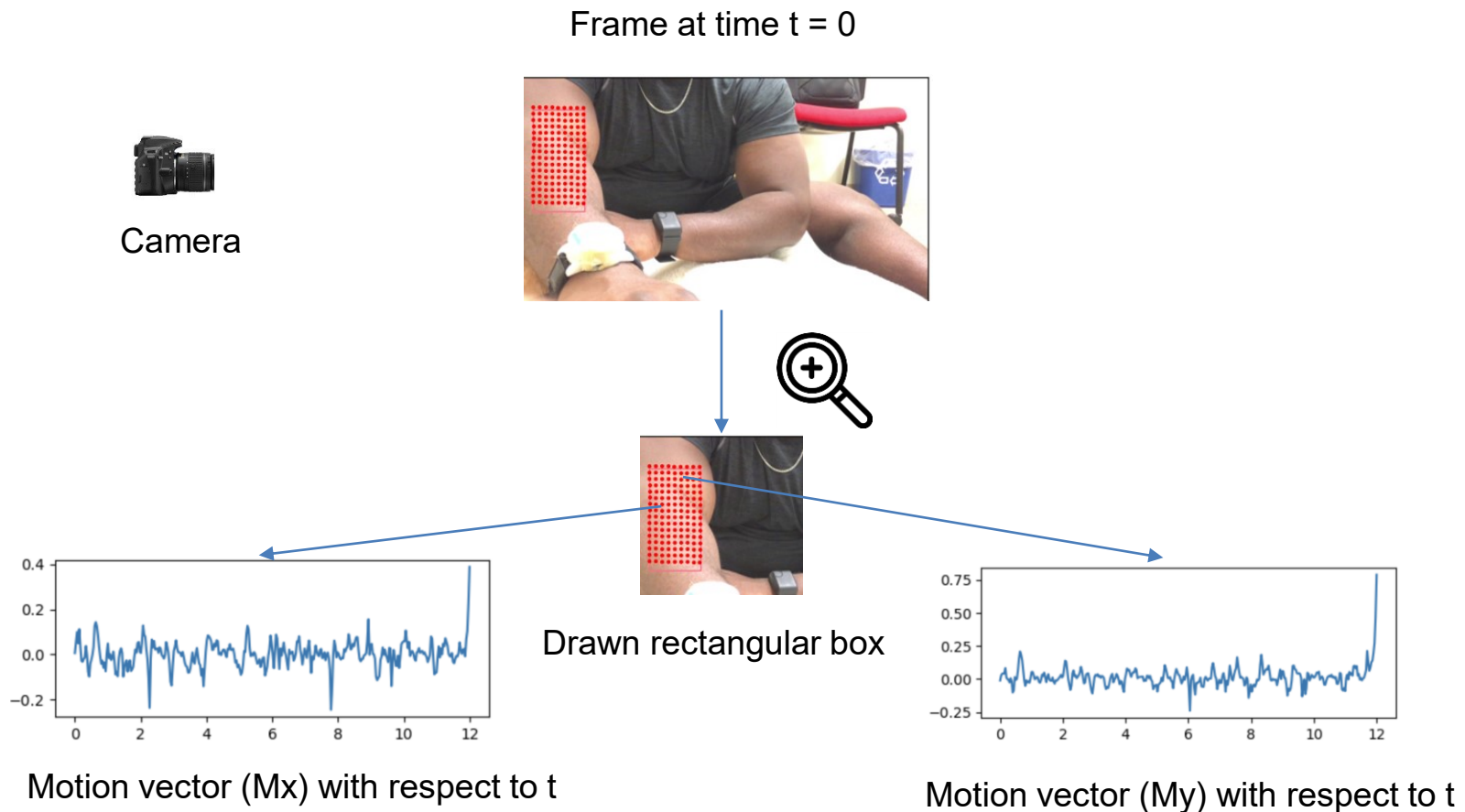
Contact-free method



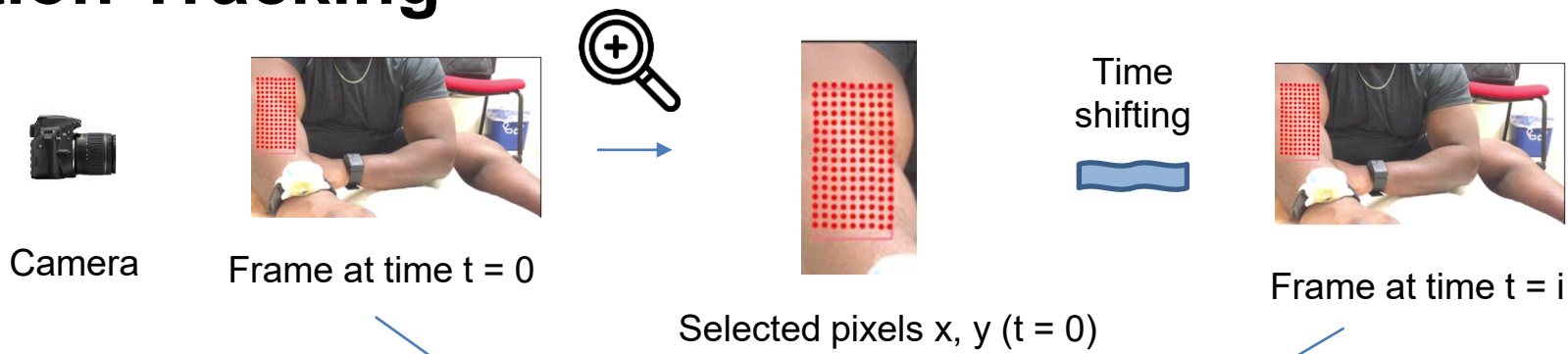
Camera

Region Selection

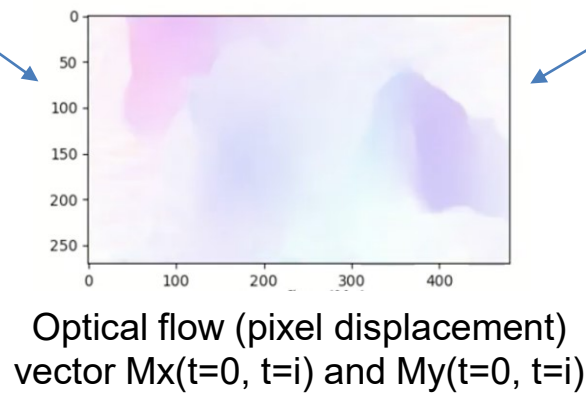
- Rectangular patch drawn on human's hand/ legs/ face
- Motion vector (M_x , M_y) calculated on each pixel inside the bounding box



Motion Tracking

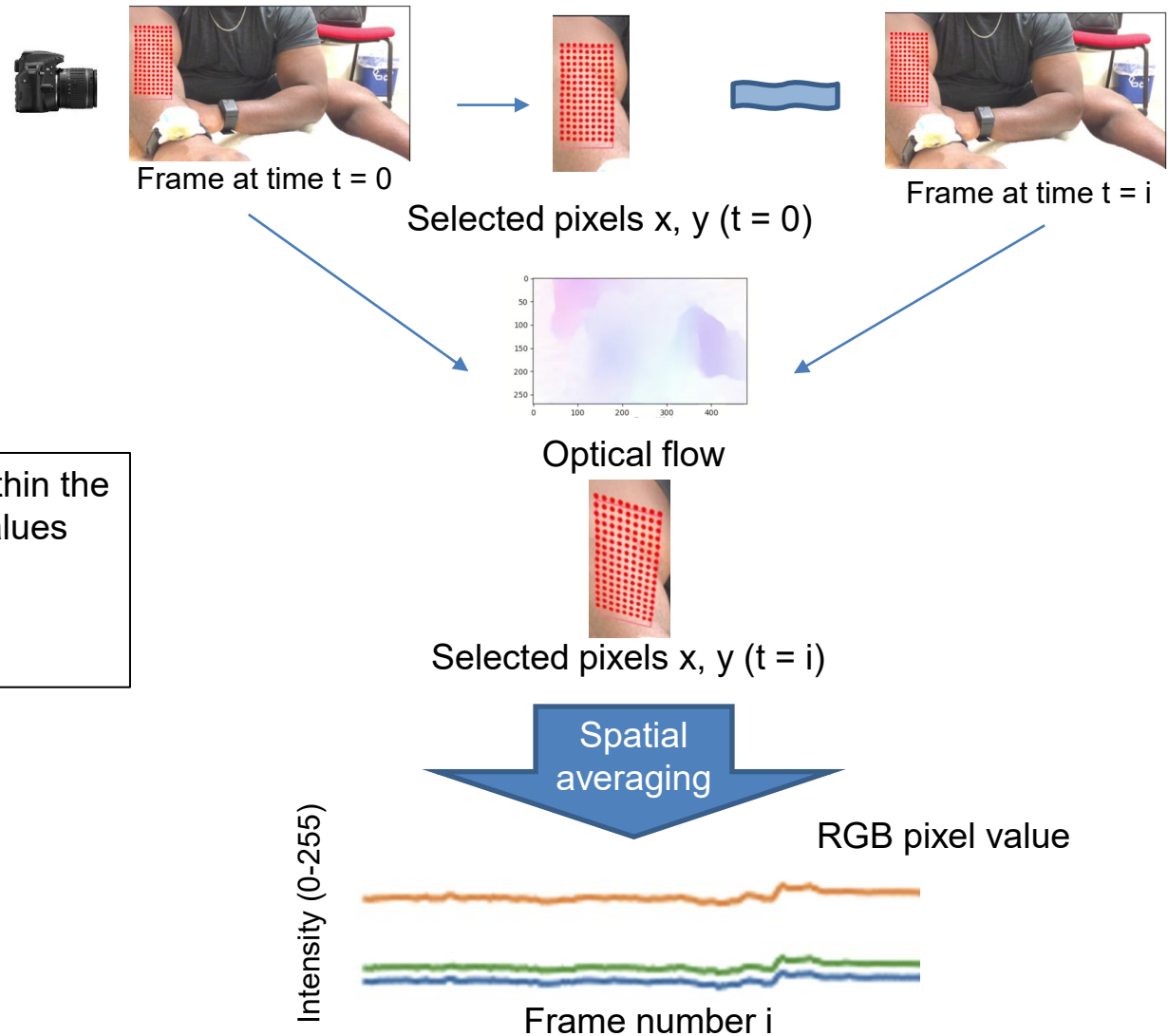


- Selected pixel's new spatial location is updated
- A robust optical flow algorithm from the literature is used
- Source: S. Jiang et al., IEEE/CVF Int'l Conf. *Computer Vision (ICCV)*, 2021



Selected pixels $x, y (t = i)$

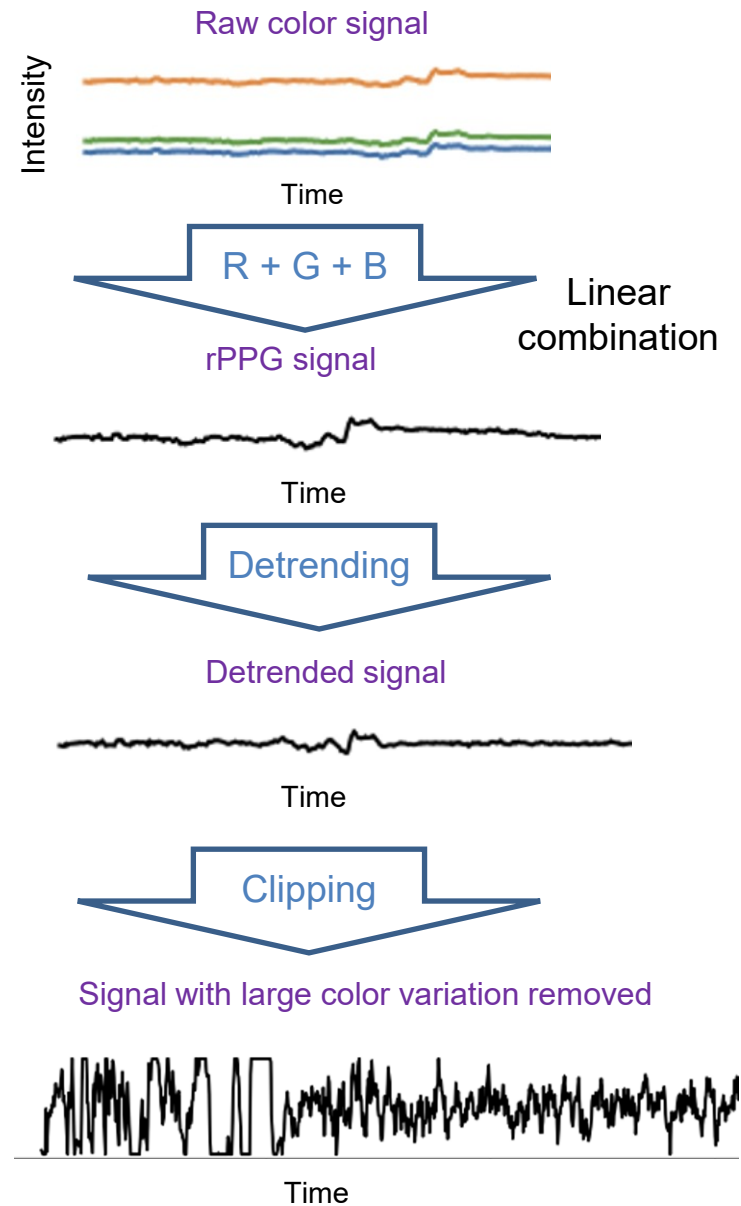
rPPG Signal Estimation



- rPPG signal is submerged within the time varying RGB intensity values recorded by the camera
- Very low signal-to-noise ratio

rPPG Signal Enhancing

- The three-color signals (red, green and blue) are merged by a linear combination
- The obtained rPPG signal is detrended using a window of 2 seconds
- The detrended signal is clipped

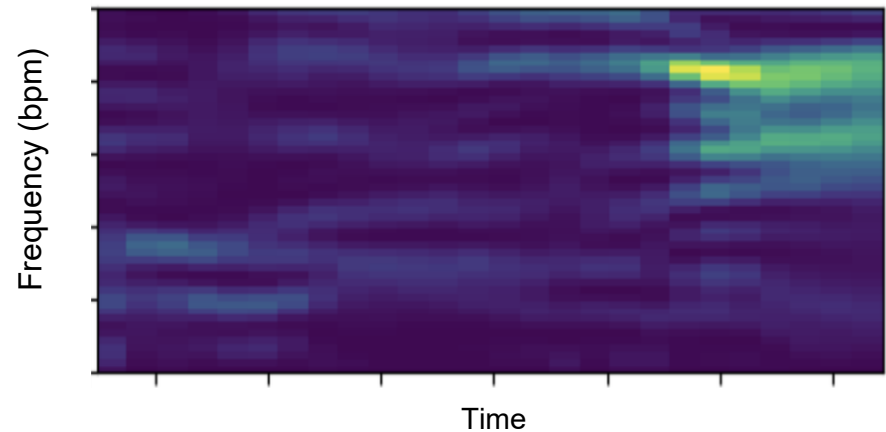


Frequency Tracking and Results

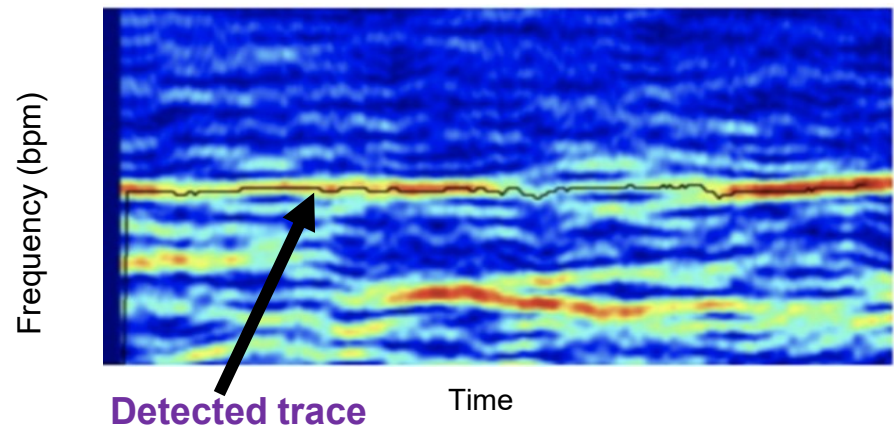
Robust Frequency Tracking

- Crude frequency estimation doesn't provide any good traces of heart/breathing rate
- We use a robust frequency estimation algorithm from the literature that can robustly track multiple traces
- Source: Qiang Zhu et al., *IEEE Transactions on Information Forensics and Security*, 2020.

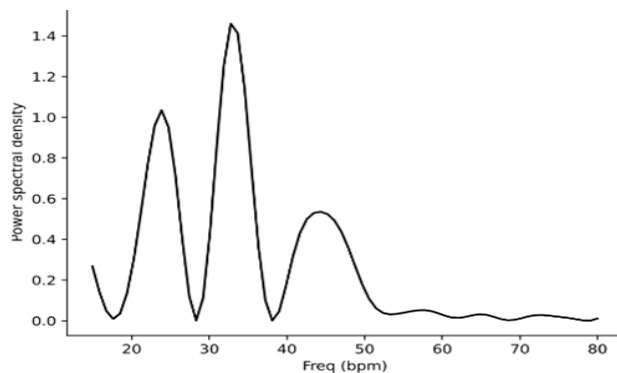
Frequency traces obtained by crude algorithm



Frequency traces obtained by robust frequency tracking algorithm

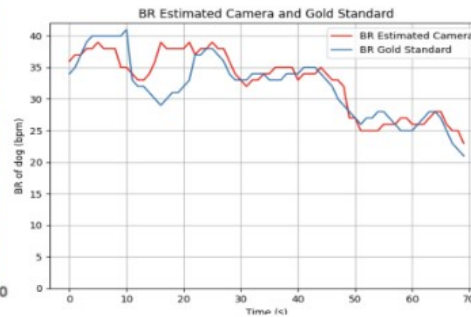
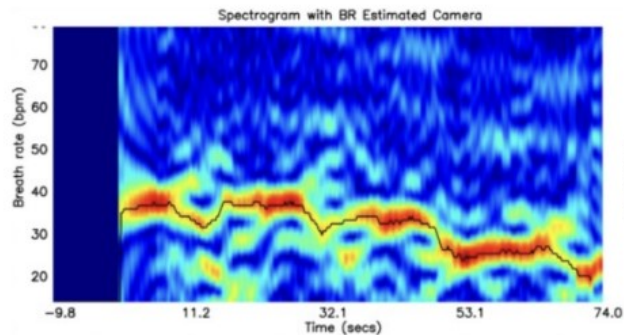


Sample PSD obtained from a 5 sec signal

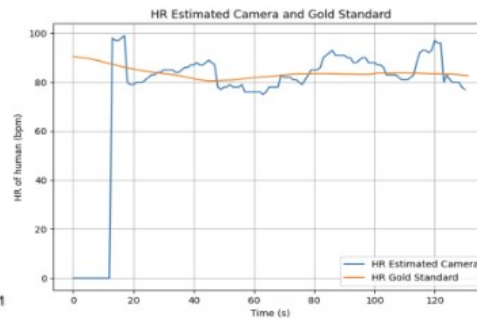
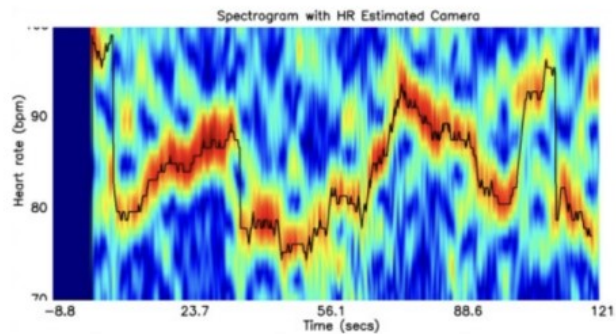


Example of BR/HR Estimated Camera

- Remote breathing rate estimation result follows that of gold standard measurement
- Camera estimated heart rate estimation is also comparable with gold standard reading



MeRate: 6.4 %, RMSE 2.9 bpm



MeRate: 5.1 %, RMSE 5.2 bpm

Results (**Breathing Rate**)

- BR estimation: RMSE **6.9** bpm, SD of error **4.1** bpm, MeRate **6.5%**

Evaluation of canine BR estimation

Contact-less BR est. setting (Canine)	RMSE (bpm)	SD error (bpm)	MeRate
Standardization	8.0	5.2	11.2%
Detrending + Standardization	6.1	4.7	9.7%
Detrending + Clipping + Standardization	6.2	4.9	9.7%

- Detrending boosts the performance significantly
- Clipping doesn't

Results (Heart Rate)

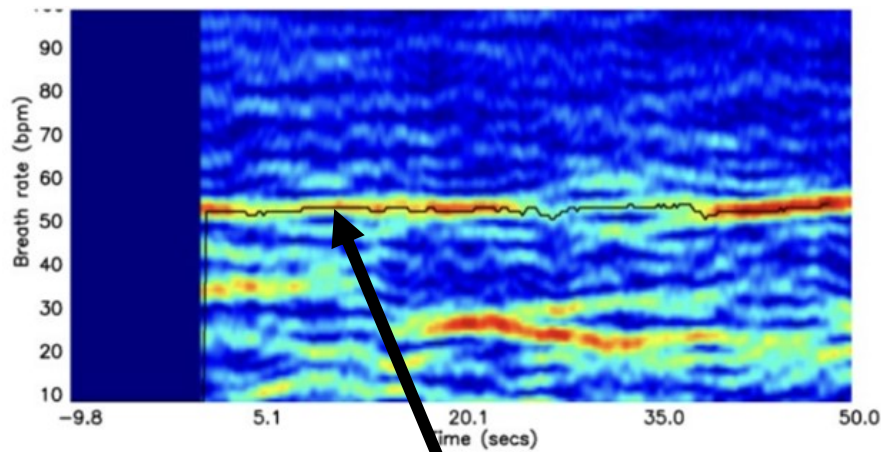
- HR estimation: RMSE **6.1** bpm, SD of error **4.7** bpm, MeRate **9.7%**

Evaluation of human HR estimation

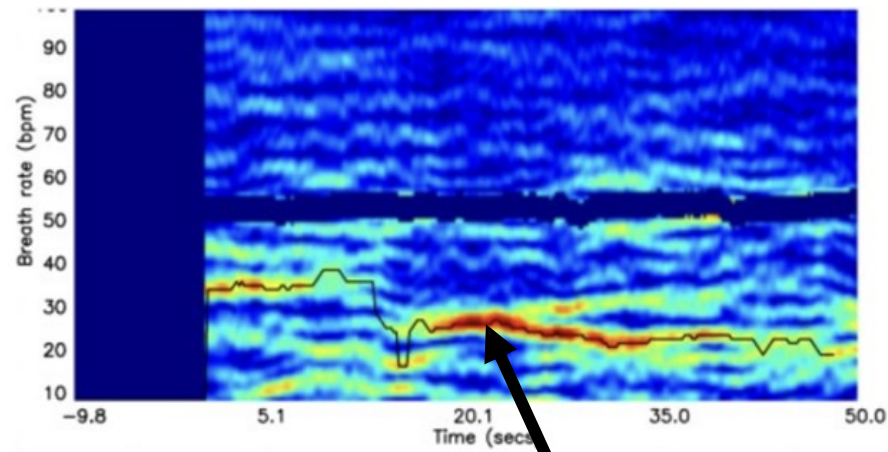
Contact-less HR est. setting (Human)	RMSE (bpm)	SD error (bpm)	MeRate
Standardization	8.0	4.7	7.4%
Detrending + Standardization	6.9	4.1	6.5%
Detrending + Clipping + Standardization	7.0	4.2	6.5%

- Detrending boosts the performance significantly
- Clipping doesn't

How Robust is Our Method?



Most significant trace: frequency of patting



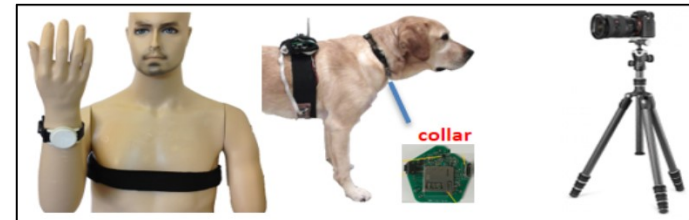
Second most significant: dog breathing rate

Conclusion

Canine Assisted Interactions

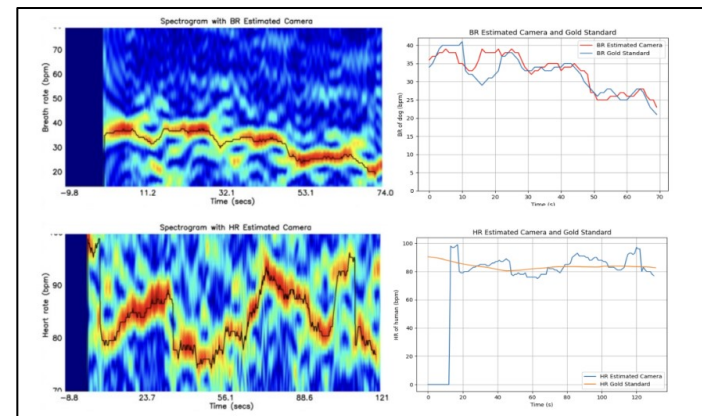


Our Approach & Results



Other Methods

- ❖ obtrusive
- ❖ not ergonomic
- ❖ not dyadic
- ❖ context dependent



Contact-free, physiological sensing in a dyadic, CAI context? Yes.

Acknowledgments



- ❖ Supported by the US Science Foundation grant numbers CCSS-1554367 & ECC-1160483.



- ❖ Supported by IBM Faculty Awards.

Thanks for listening!

Future Work & Extensions



- ❖ more **subjects**
- ❖ new **signals**
- ❖ add'l **animals**
- ❖ other **contexts**



- *Animal Shelters*
- *Televet. / Vet. Surgery*
- *Citizen Science*

