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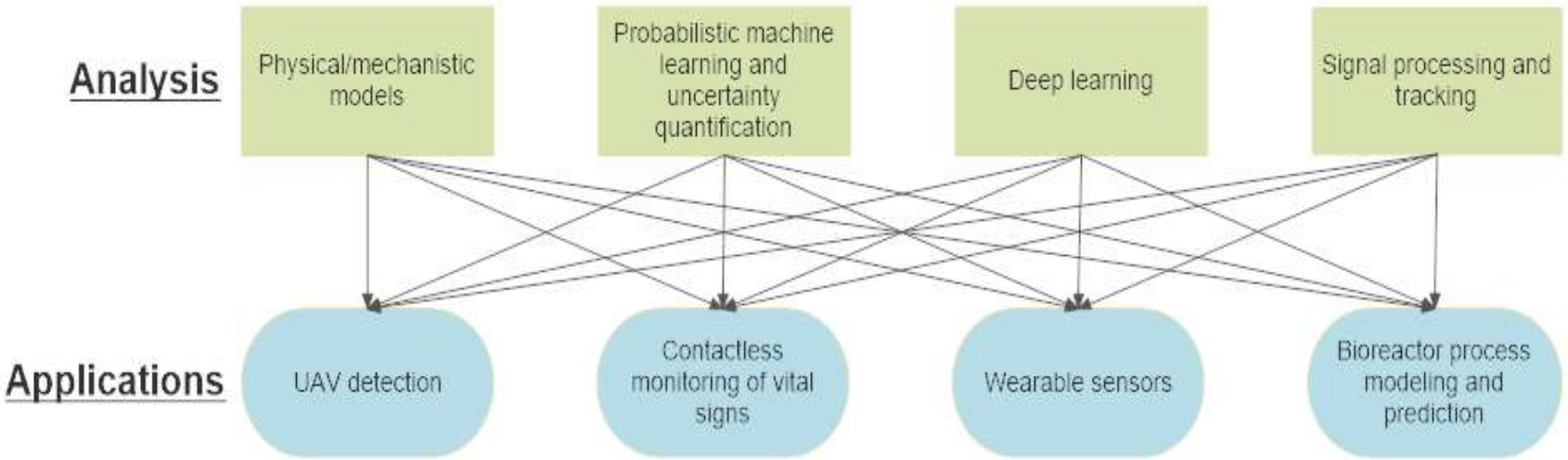
Contactless Cardiac and Respiratory Monitoring

May 16, 2024

Outline

- **Introduction**
- Contactless monitoring
- Selected projects that include video processing
- Selected projects that include radar processing
- Short overview of other projects

UOttawa Computational Analysis and Acceleration Research Group (CARG): Methods and applications

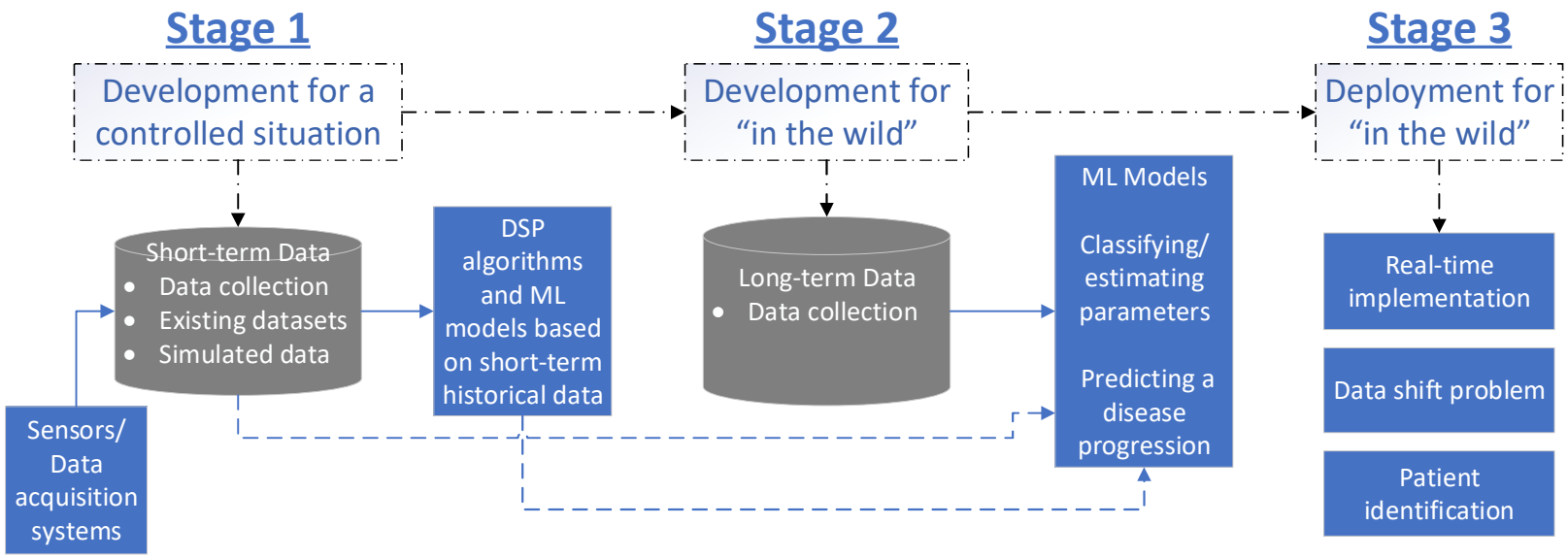


Data!

- "Large, well-designed, well-labelled, diverse and multi-institutional datasets drive performance in real-world settings far more than model optimization."[1]
- Benefits of our own data collection:
  - Researchers have better appreciation of the problem
  - Work with patients/physicians/users and understand their problems
  - Analyze and apply methods that experienced physician use
  - Understand what is different in our data from the available online data
  - Understanding the domain shift

[1] A. Zhang, et al. (2022) Shifting machine learning for healthcare from development to deployment and from models to data. Nature, Biomedical Engineering

Stages of the projects



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What can be monitored at a distance?

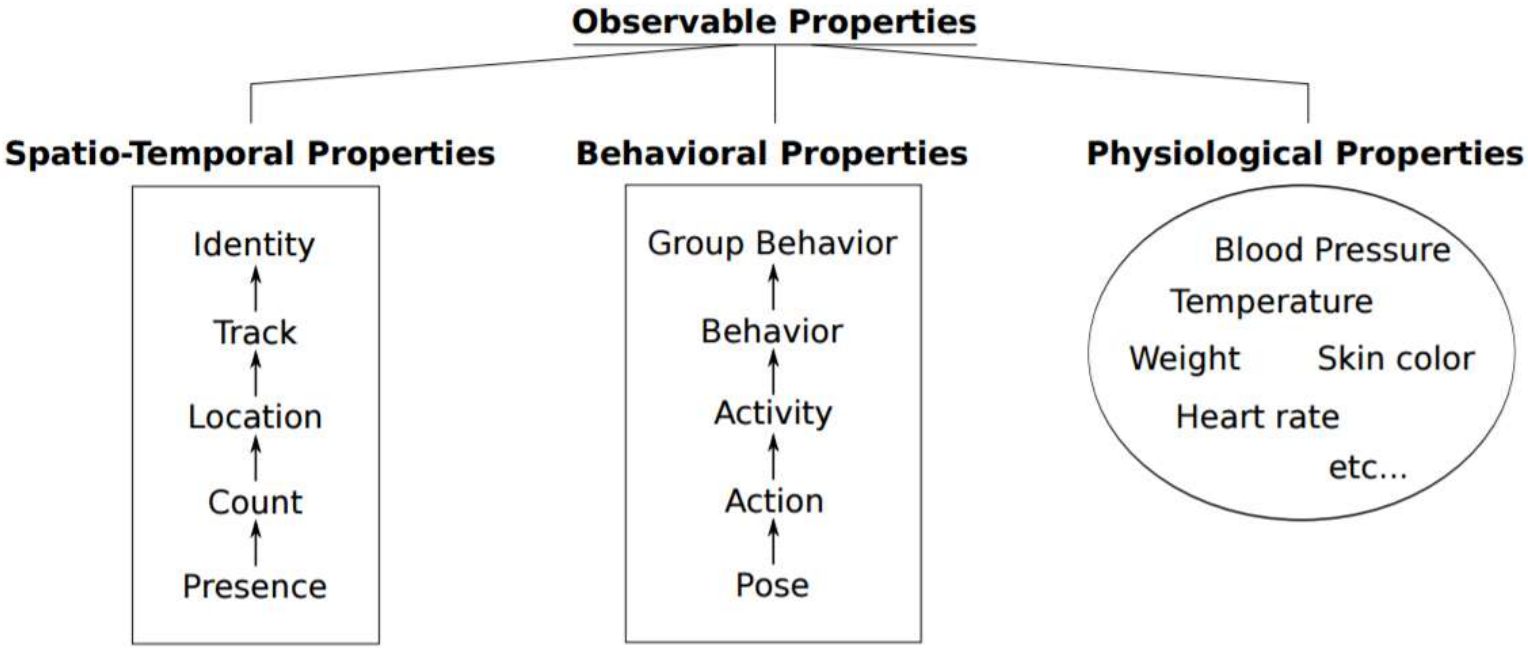

Figure is from Reference: T. Teixeira, at al, "A survey of human-sensing methods for detecting presence, count, location, track and identity," 2015.

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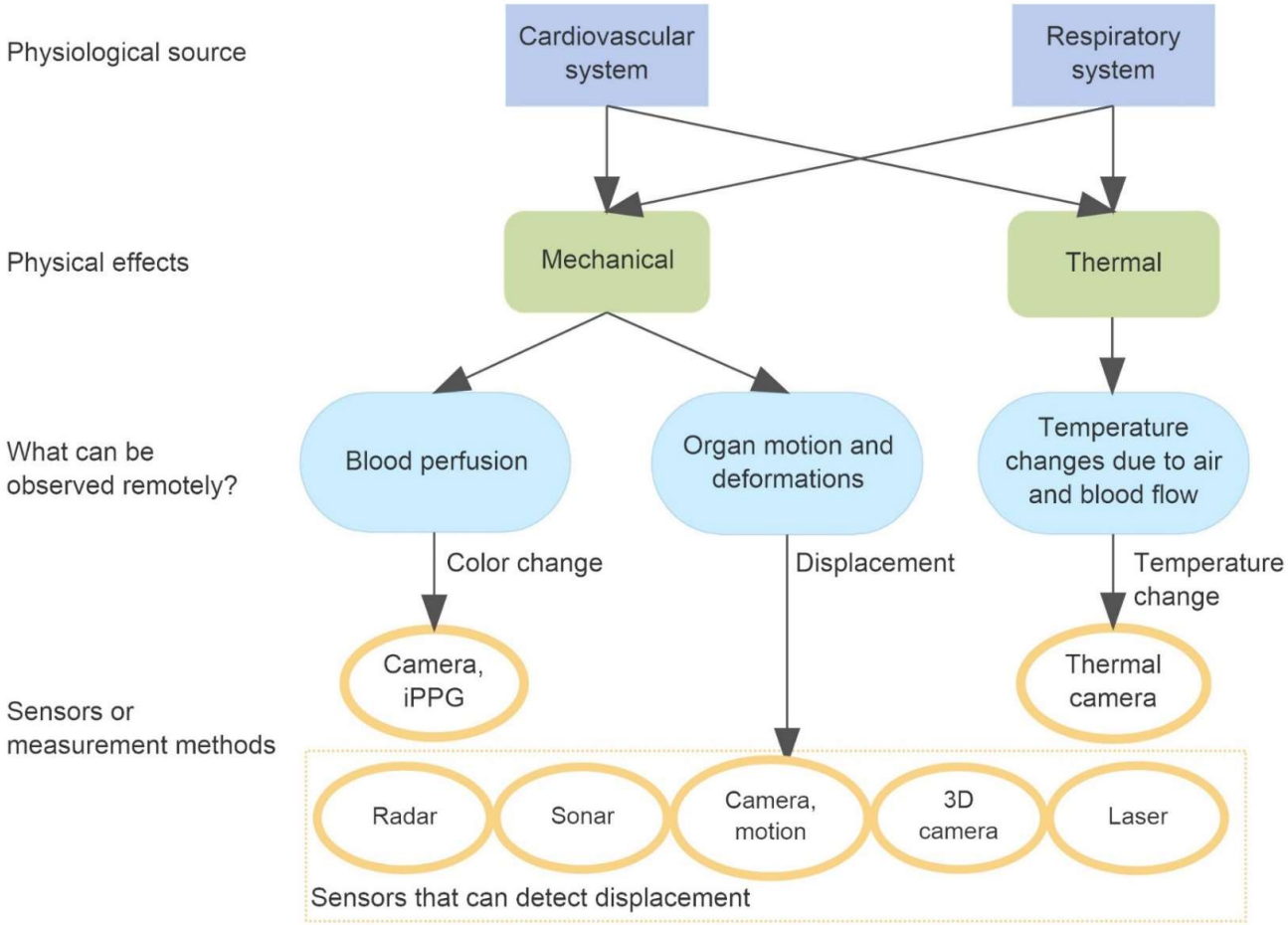
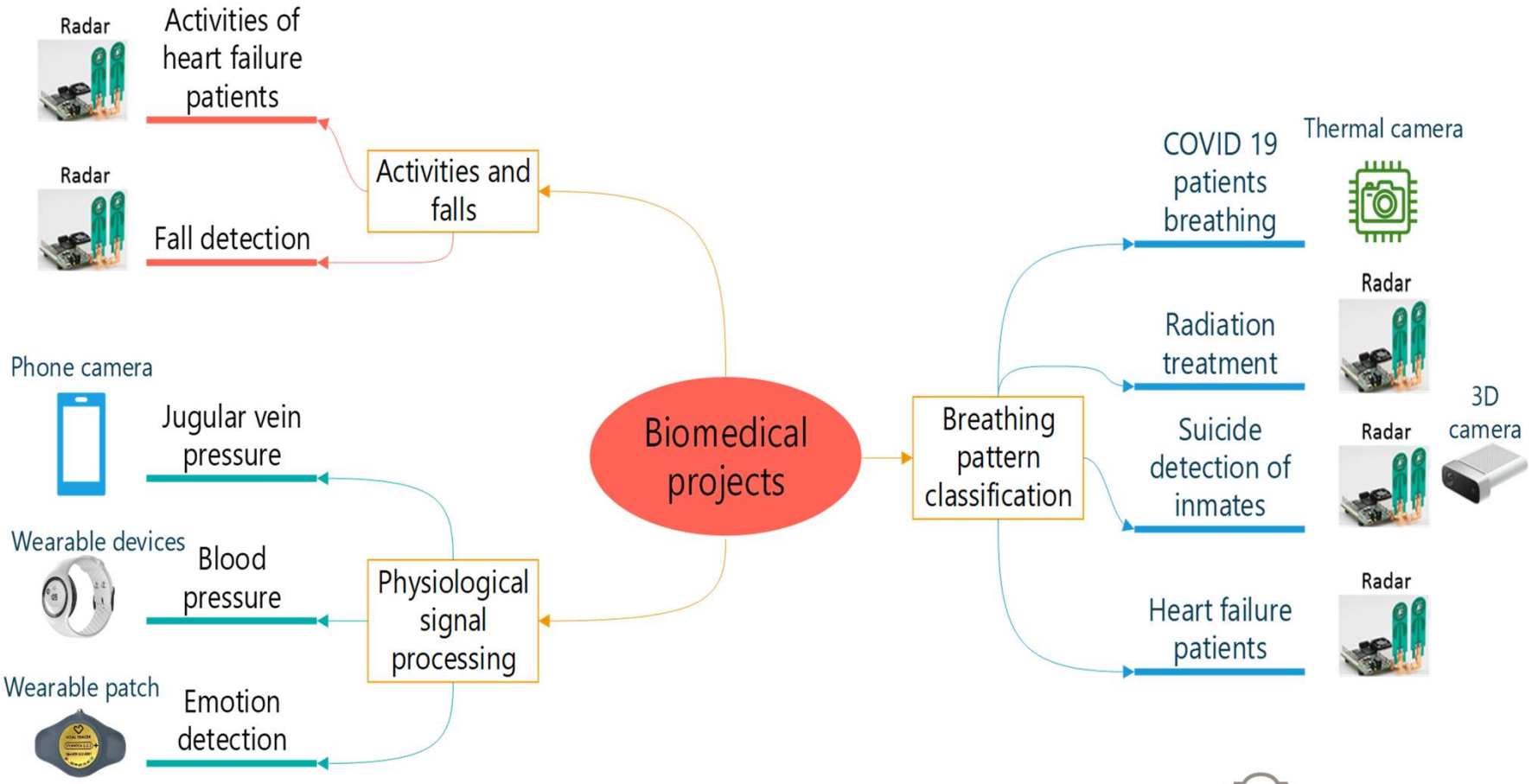
Classification of cardiac and respiratory sensors and operating principles for contactless devices



[1] M. Bolic, Pervasive Cardiovascular and Respiratory Monitoring Devices: Model-based design, Elsevier, 2023.

CARG's current or recently completed biomedical projects



uOttawa

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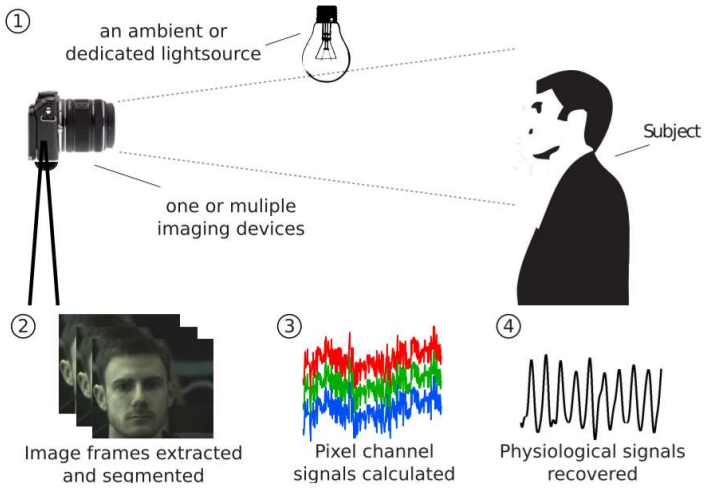
Operating principles of video processing



D. J. McDuff, et al., "A Survey of contactless Optical Photoplethysmographic Imaging Methods," Conf Proc IEEE Eng Med Biol Soc. 2015.

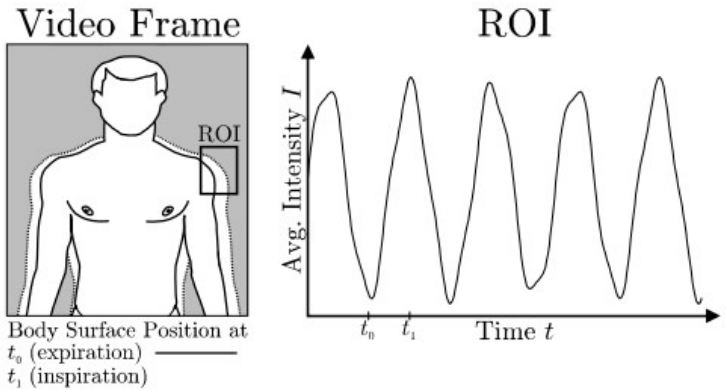
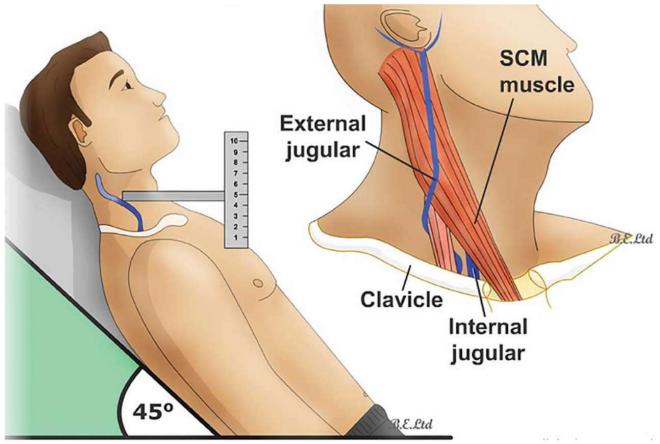
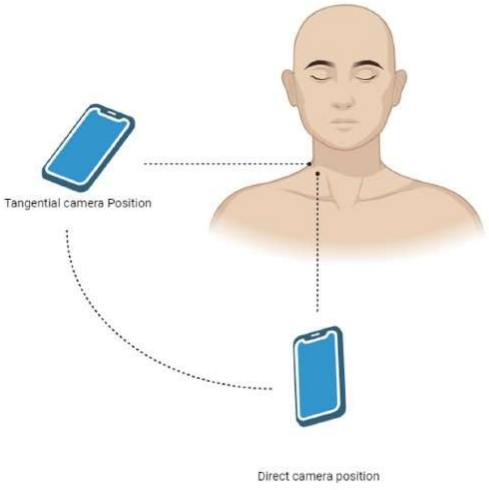


Figure is from : C. Bruser et al. "Ambient and Unobtrusive Cardiorespiratory Monitoring Techniques," 2015.

Vein pressure estimation

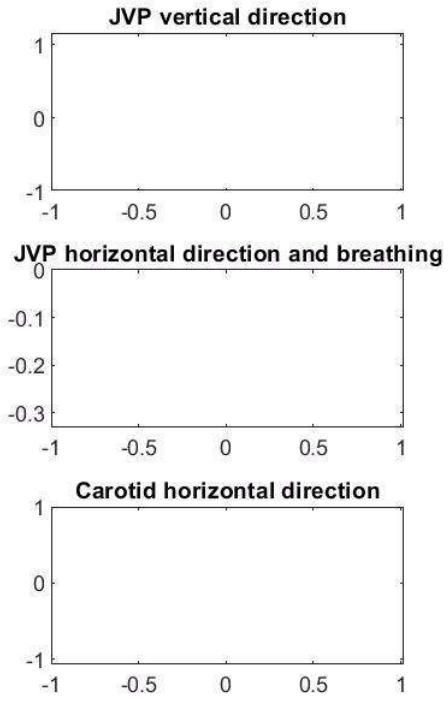
- **The jugular venous pressure**
  - the indirectly observed pressure over the venous system via visualization of the internal jugular vein.
  - It can be used to differentiate different forms of heart and lung diseases.
- **Project**
  - Detection of right atrial pressure via detecting jugular venous pressure in RGB videos
- **Novelty**
  - Smart-phone based – no need for special cameras or lighting
  - AI-based – follow the physician's diagnostic procedure
- **What do physicians observe**
  - Double pulsation during one cardiac cycle
  - Movement of the vein during breathing
  - Different vein height at different postures

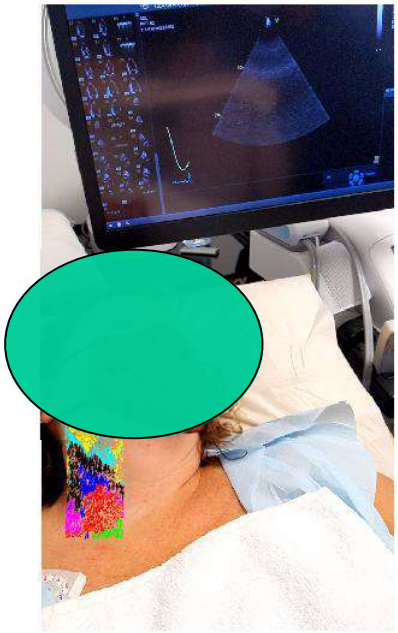




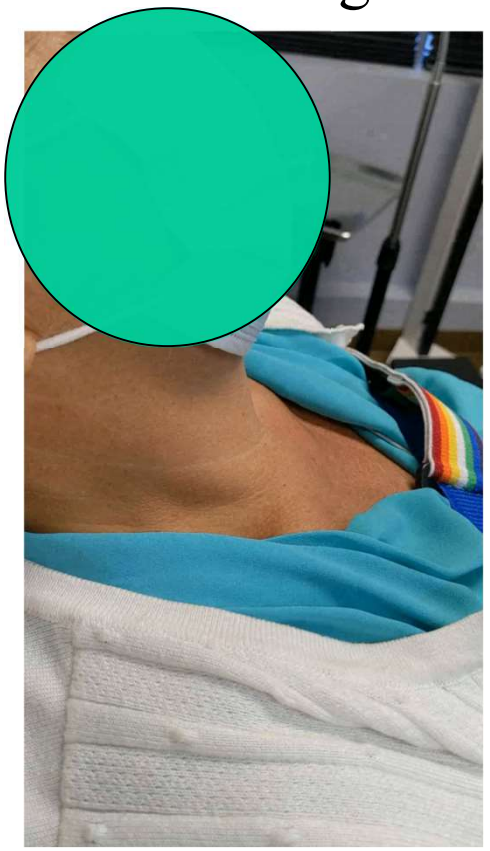
Example of videos

Optical flow – extracting pixel motion

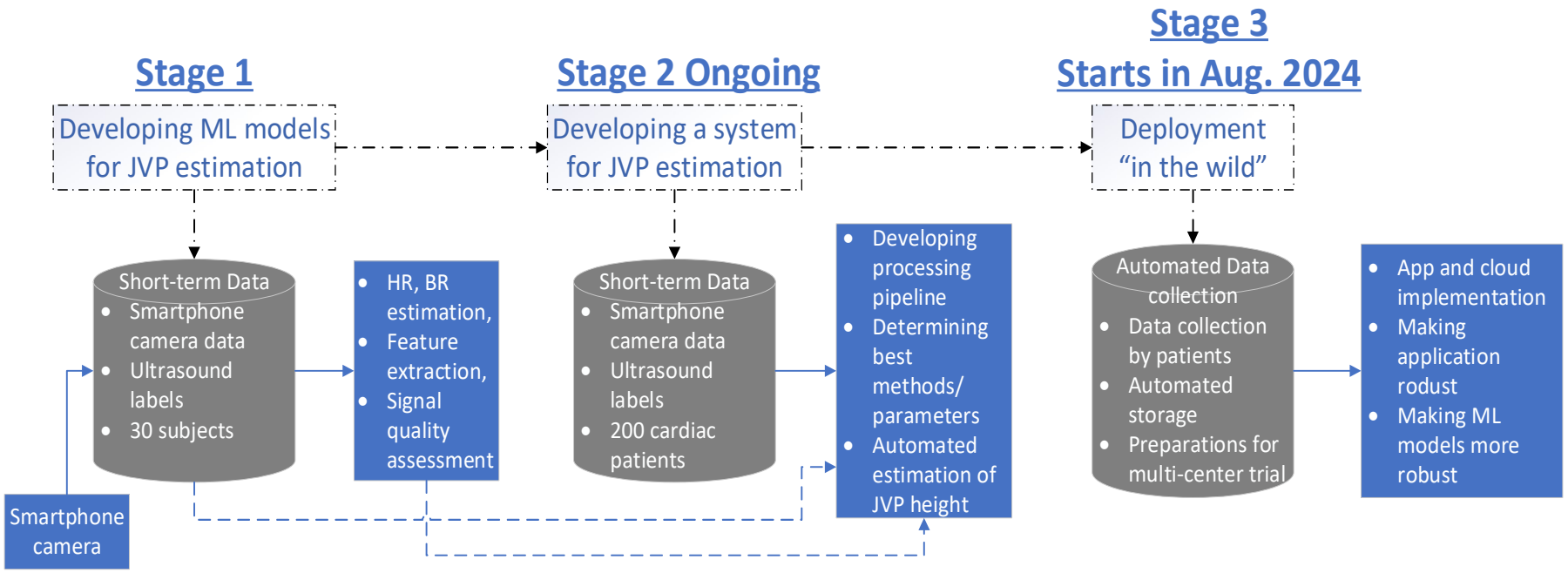




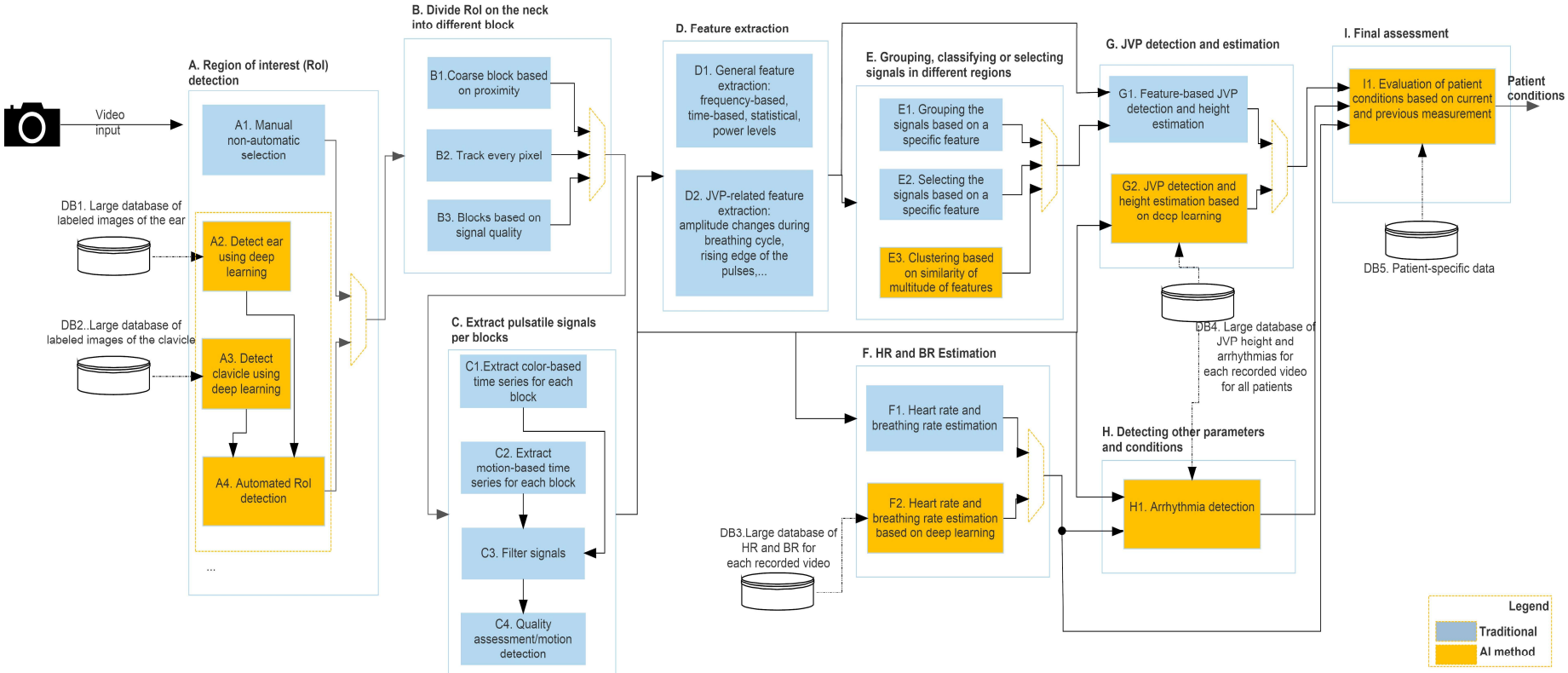
Eulerian magnification



Project stages

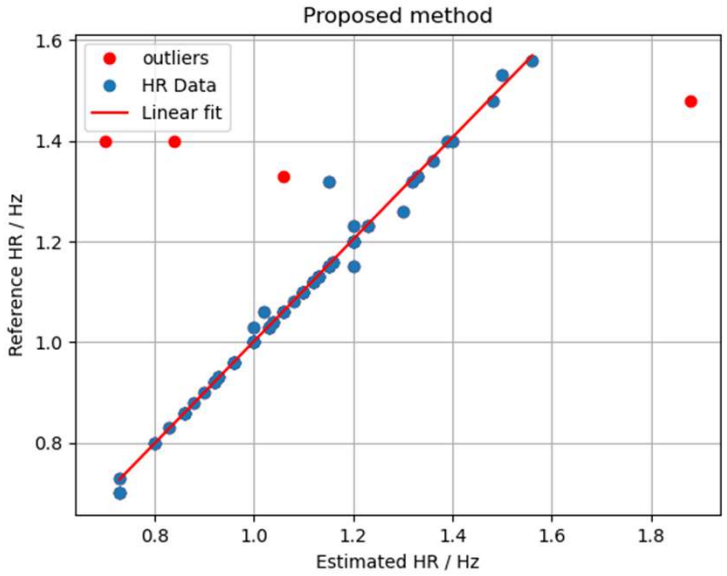


JVP processing stages

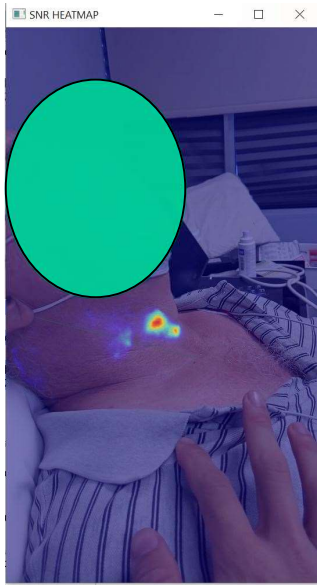


Results

Heart rate estimation accuracy



JVP height estimation

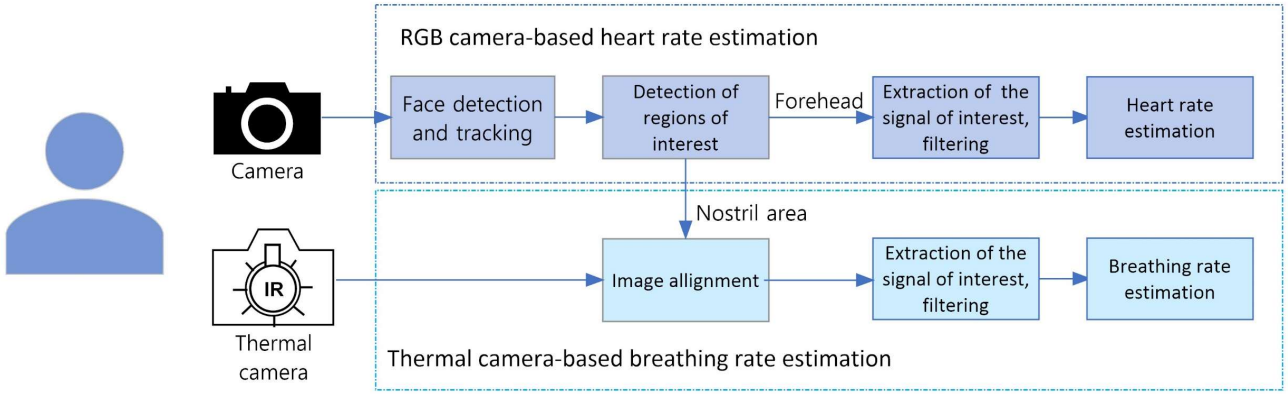


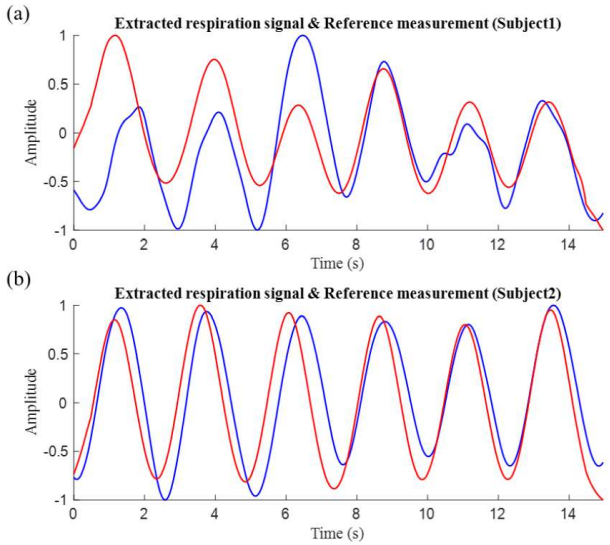
T. Zhang, et al., "Non-Contact Heart Rate and Respiratory Rate Estimation from Videos of the Neck," accepted for presentation at EMBC conference, 2024.

Ongoing work and future direction

- Sometimes there are not good quality signals from the neck
- Features are not consistent throughout the subjects
- The models have problems with atrial fibrillation patients
- It is difficult to train ML model based on time series when we have so many time series per recording per subject.
- Quantification of JVP height in relation to the neck based on the locations of detected jugular venous waveforms within the neck region. The pulses are propagated through the skin on the neck.

Camera-based breathing and cardiac monitoring





F. Yang, S. He, S. Sadanand, A. Yusuf and M. Bolic, "Contactless Measurement of Vital Signs Using Thermal and RGB Cameras: A Study of COVID 19-Related Health Monitoring," Sensors, MDPI, 2022.

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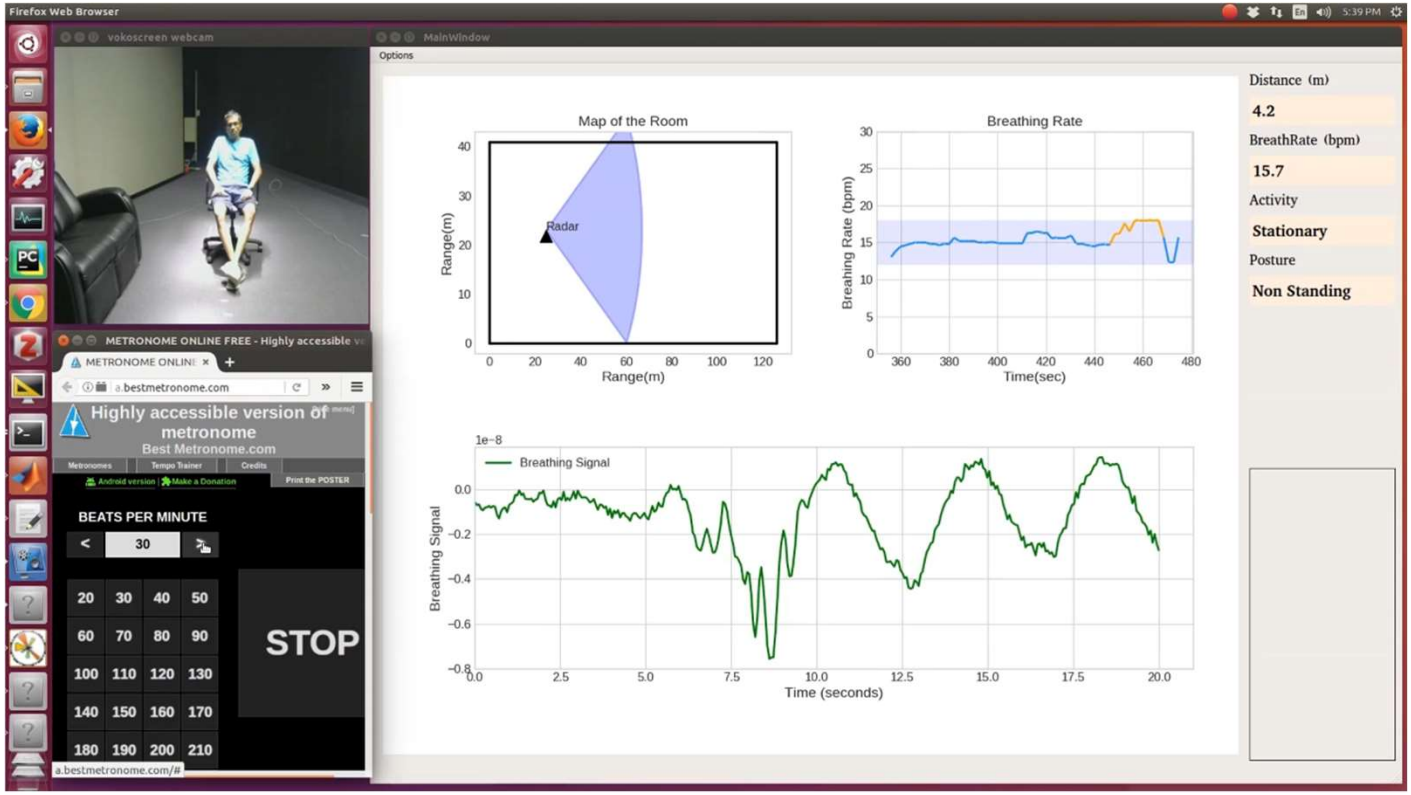
Processing radar signals



Radar-based heart failure monitoring

Project

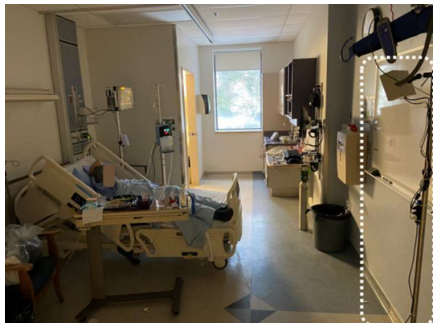
- Monitoring heart failure patients with radar
- Monitoring elderly people in nursing home with radar

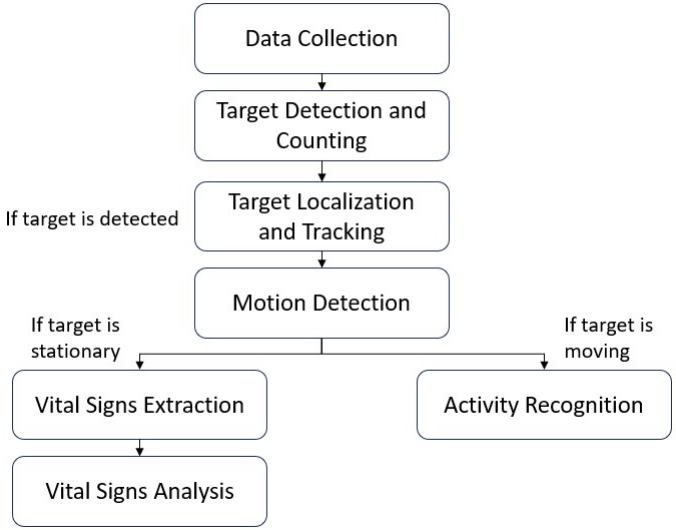
Objective

- Implementing passive and contactless activity recognition and vital sign monitoring

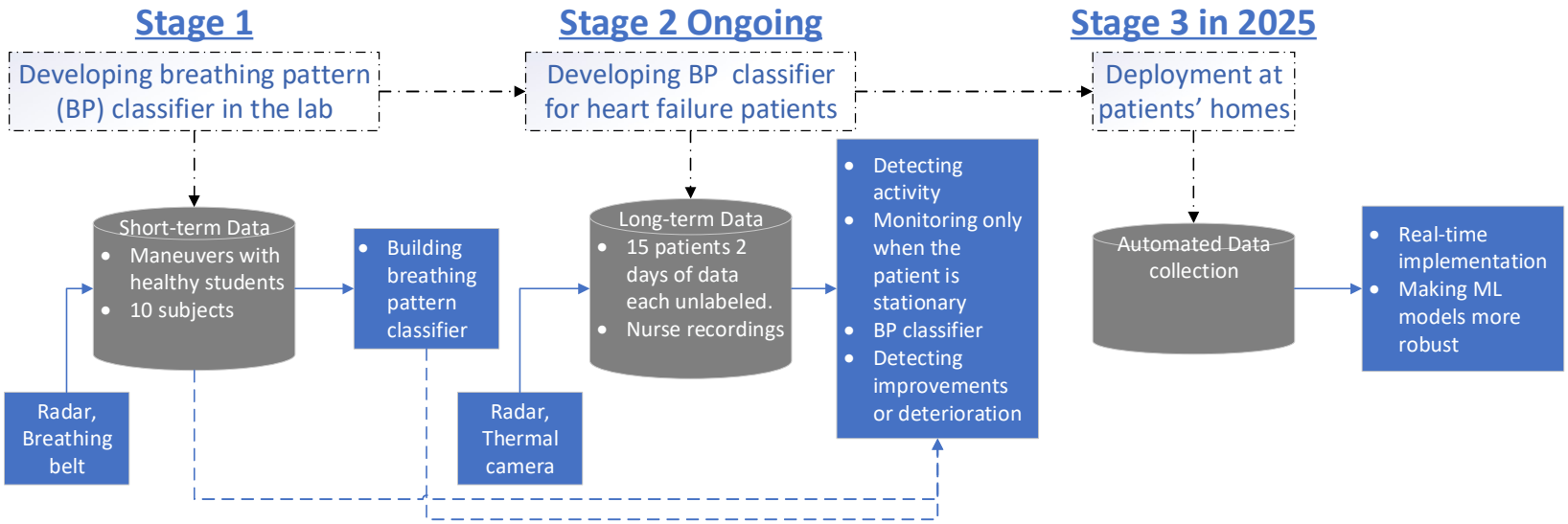
Motivation

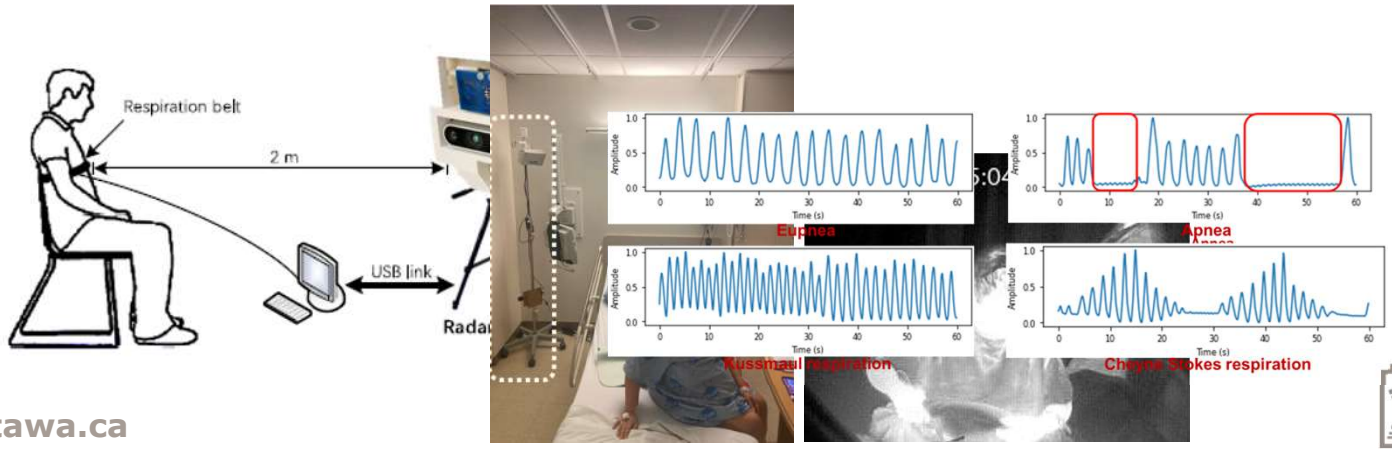
- To develop a privacy-preserving daily health monitoring solutions that can detect heart failure decompensation, falls as well as report on activities of people





Project stages

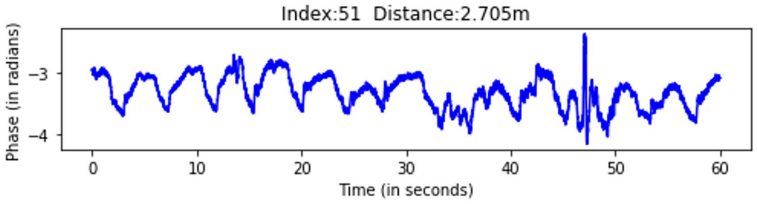




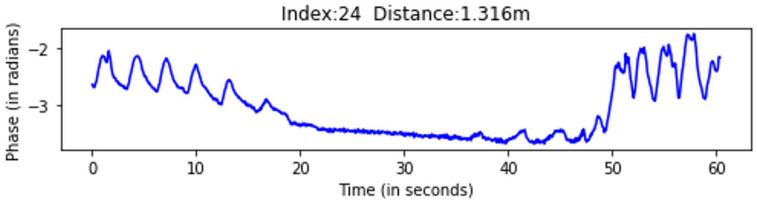
Hospital Ward

Results

- Patient data:

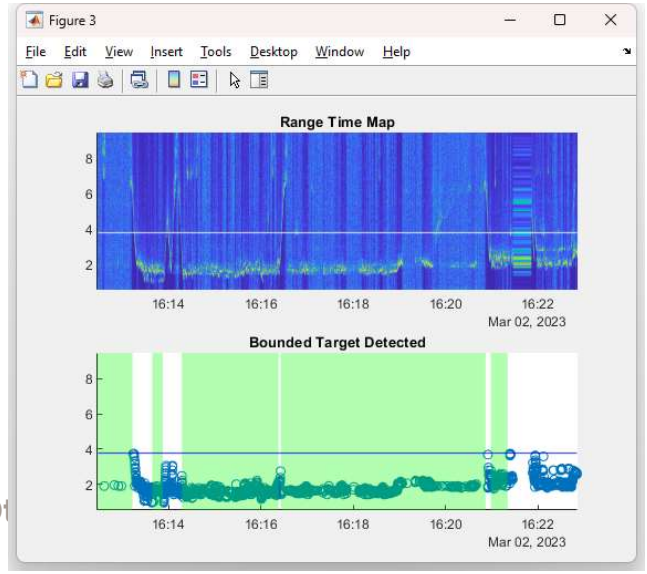


Normal breathing pattern



Abnormal breathing pattern

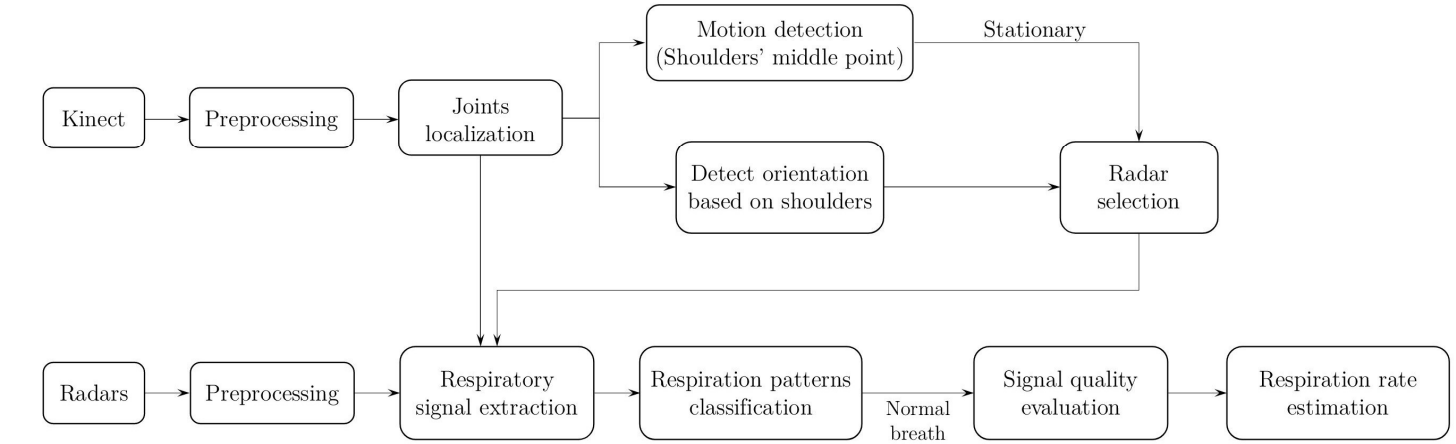
Activity detection: Large (white) and Small (green) movements

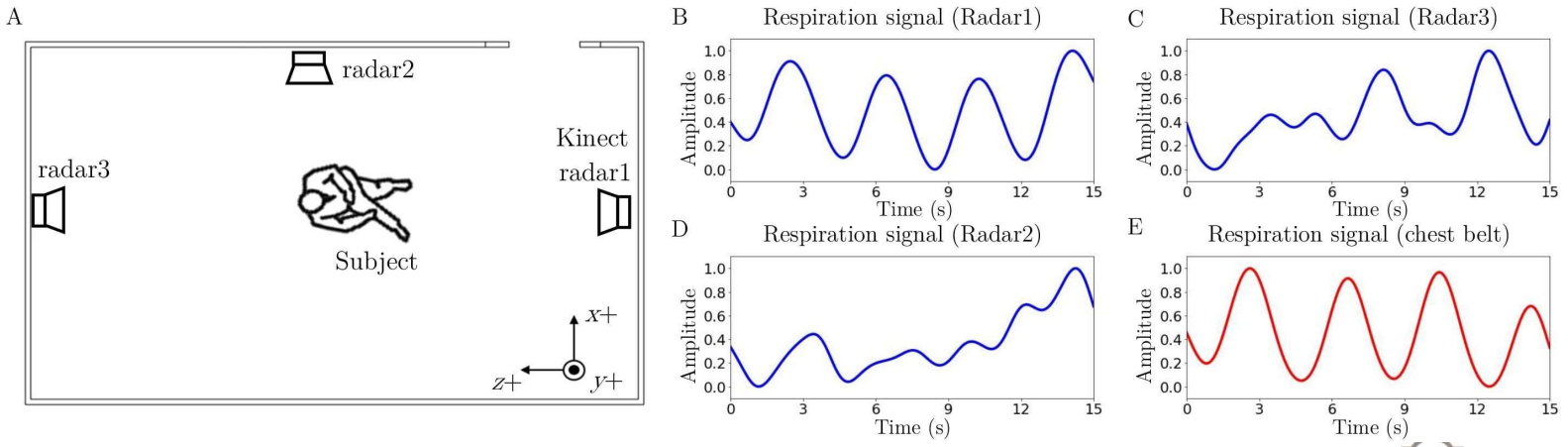


Breathing pattern classification results in the lab - Random forest

	precision	recall	f1-score	support
Eupnea	0.86	0.74	0.79	84
Cheyne Stokes	0.55	0.81	0.66	32
Kussmaul	1	1	1	34
Apnea	0.73	1	0.85	11
Moving	0.84	0.77	0.8	93

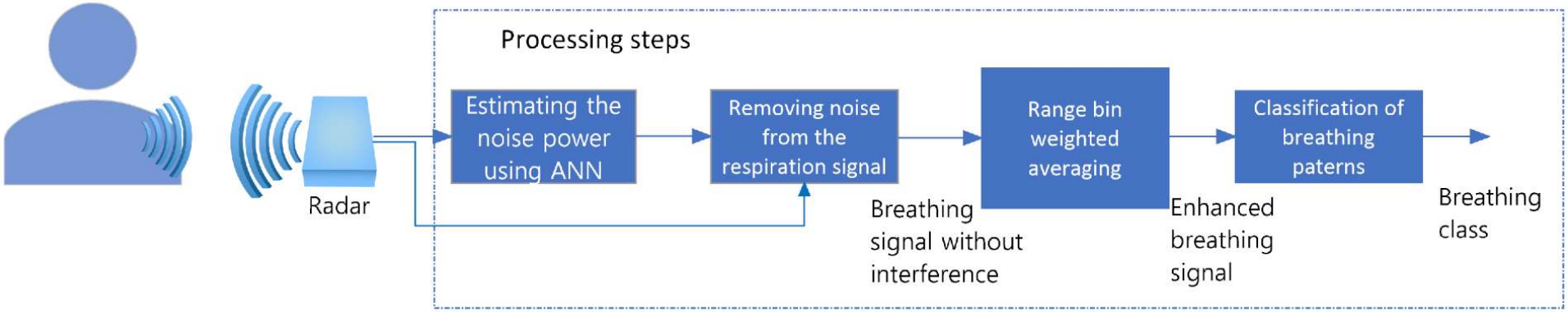
Monitoring inmates

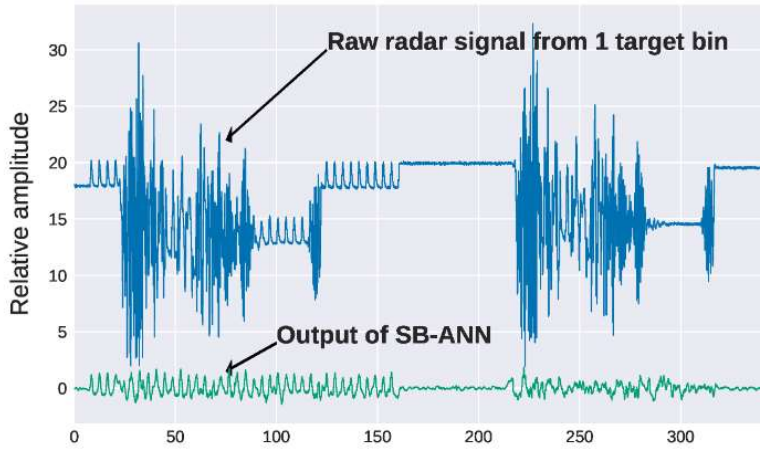




S. He, Z. Han, C. Iglesias, V. Mehta, M. Bolic, "A Real-Time Respiration Monitoring and Classification System using a Depth Camera and Radars," Frontiers in Physiology, 2022.

Classifying breathing during radiation treatment





		No-Gantry Noise		Gantry Noise	
		Sensitivity	Specificity	Sensitivity	Specificity
SB-ANN	No breathing	0.86	0.97	0.86	0.86
	Hold breathing	0.73	0.89	0.47	0.87
	Regular breathing	0.90	0.96	0.66	0.87
	Deep inspiration	1	0.99	0.83	0.98
	Overall accuracy	0.85		0.72	

Fallatah, A. et al., 2022. "Monitoring Respiratory Motion during VMAT Treatment Delivery Using Ultra-Wideband Radar" *Sensors* 22, no. 6: 2287.

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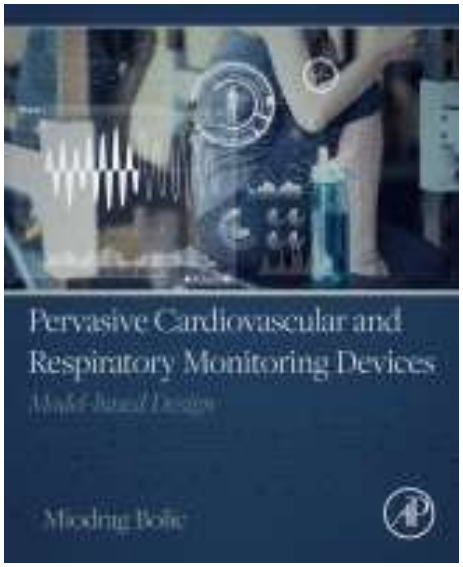
Other projects

UAV-related project

- Completed
  - Multiple intruder UAS detection using UAV interceptors, with Thales and NRC
  - Detecting UAS intruders using ground sensors, with CS Group Canada and NRC
- Current
  - Power line detection
  - BVLoS infrastructure inspection
  - Multitarget UAV detection, classification and tracking
- Starting this summer
  - Comprehensive simulator of interceptor-based solution for multiple UAS intruder detection, tracking and intent-detection
  - Detecting intruder UAVs that communicate over 5G networks, with CS Group Canada

Wearable devices

- Simulation and modeling of biomedical devices
- Uncertainty quantification and sensitivity analysis



Acknowledgements

- Funding agencies
  - NSERC, OCI, Mitacs
  - National Research Council Canada
  - Local industry
- My graduate students and researchers

UOttawa Computational Analysis and Acceleration Research Group (CARG)

Major areas	Sub-topic	Researchers and Graduate Students	Collaborators
UAV Detection	Detection and classification of objects using UAVs	• Fardad Dadboud (Ph.D.) • Hamid Azad (Research Assoc.) • Meng Lian (Ph.D) • Mohammad Akhlaque (M.Eng)	National Research Council Canada, University of Victoria
	Detecting UAVs using 5G networks	• Dr. Kesav Kaza (postdoc) • Daniel Charron (M.Sc.)	National Research Council Canada
Biomedical wearables	Blood pressure monitoring	• Shan He (Ph.D.)	Kyushu Univ, Japan
	Emotion recognition	• Mehak Dhothar (M.Sc.) • Hitham Jleed (Research assoc.) • Rongchen Guo (collaborator)	Orbmedic Inc., UOttawa Psychology
Biomedical contactless	Monitoring breathing and detecting falls using radars	• Zixiong Han (Ph.D.) • Saad Rhanmouni (M.Eng.)	Heart Institute, Ottawa
	Monitoring using cameras and thermal cameras	• Mohamad Hosein Davoodabadi Farahani (Ph.D.) • Tianyu Zhang (Ph.D) • Yang Hu (Meng.)	Orleans Cardiopulmonary Group
AI Bioreactor	Scientific machine learning	• Cristovao Iglesias (Ph.D) • Somaiyeh Khodadadi (collab.)	National Research Council Canada