

Prediagnostic Cardiovascular Health Monitoring

Michael MacLean, Mickey Smith, Scott Guidoboni

Topics

1. Introduction

- Market
- Plethysmography overview
- Inflection point area ratio

2. Methods - Data Gathering

- Test methods
- Patient demographic

3. Methods/Results - Algorithm

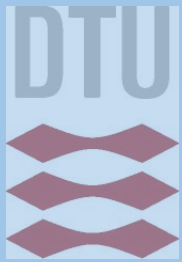
- Moving average filter
- Waveform derivatives
- Calculate critical waveform points
- Exclusion criteria

4. Discussion

- Algorithm faults
- Clinical relevance

5. Conclusion

Introduction

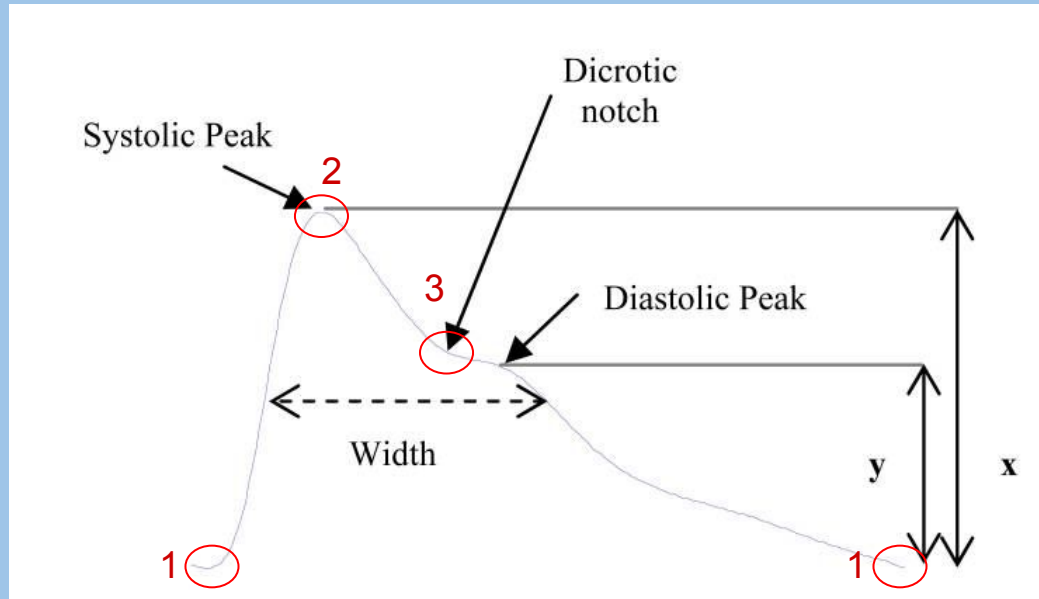


Market Need Cardiovascular Monitoring

Problem People lack a convenient and consistent way to monitor cardiovascular health outside of a medical facility.

Need There is a need for a mobile device that can consistently monitor cardiovascular health during an individual's everyday life.

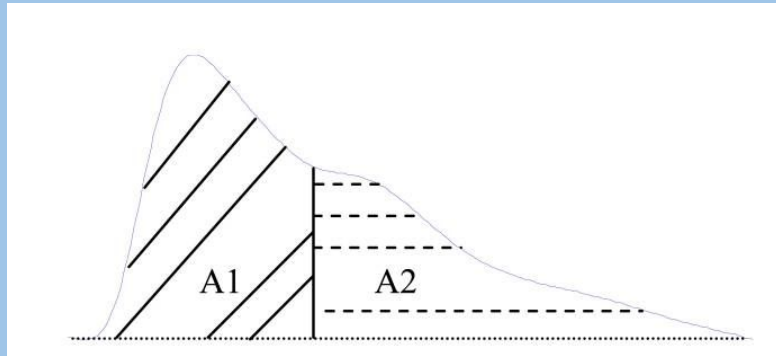
Target PPG Signal



Critical Locations

1. Diastolic Trough
2. Systolic Peak
3. Dicrotic Notch

Solution Inflection Point Area (IPA)



Measure of

Relationship between diastolic and systolic activity [2,3]

Correlated with

Blood pressure

Peripheral resistance

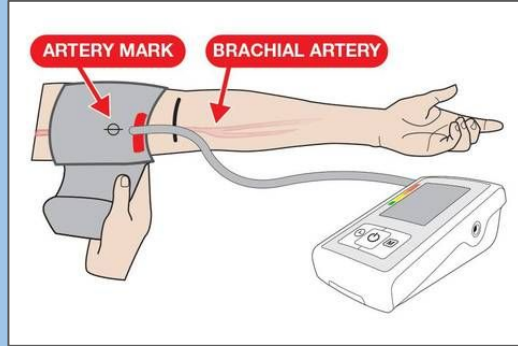
Vascular distensibility

$$IPA = \frac{A2}{A1}$$

Methods - Data Gathering

Data Gathering Protocol

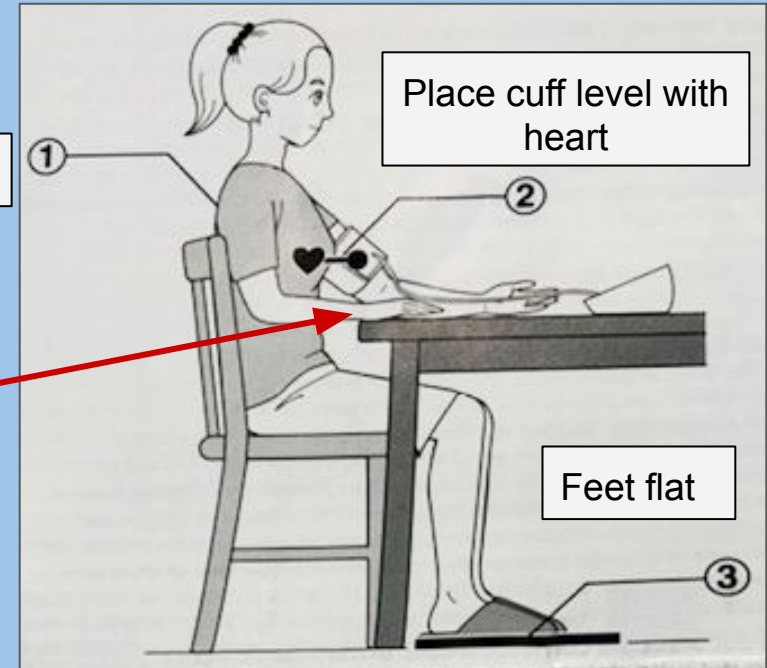
seconds	minutes,seconds	Action
0	0	Start test (when empatica indicates start)
30	30s	take first BP
109	1min 49s	take second BP
188	3min 8s	take third BP
218	3min 58s	stop test



Back against chair



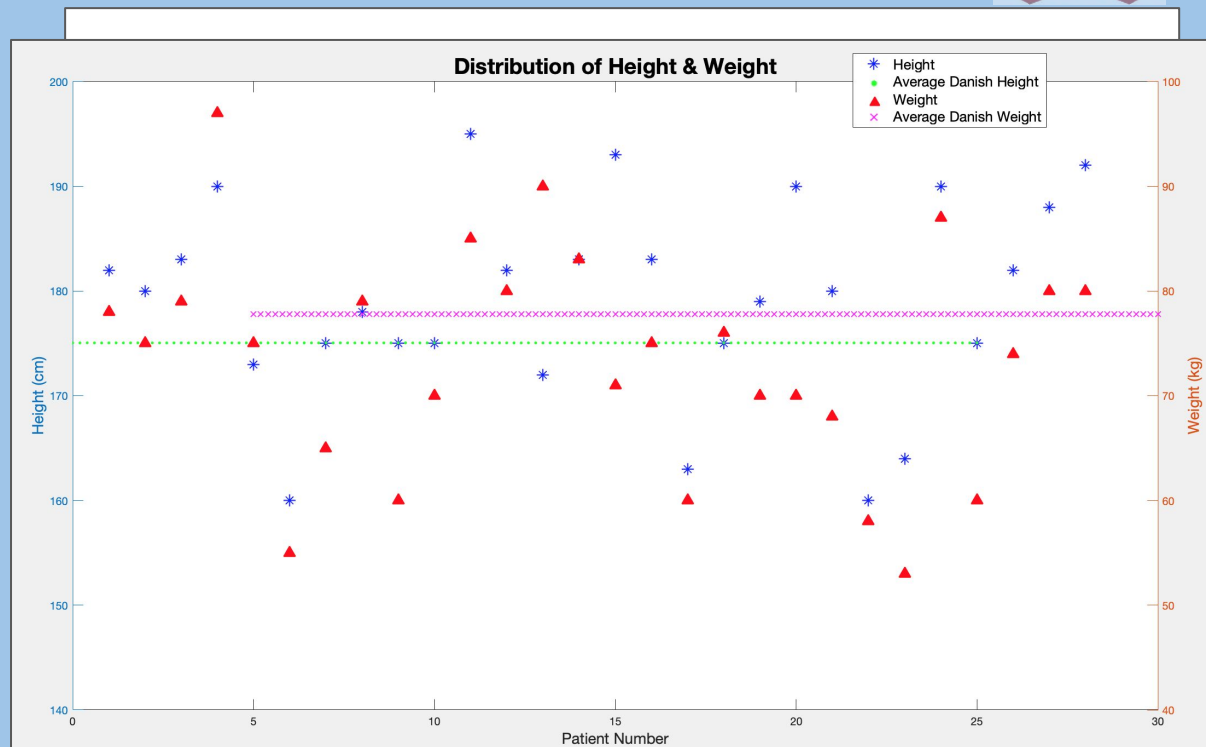
[1]



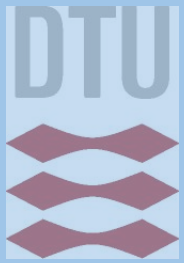
Data Statistics

Includes

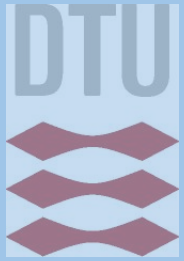
- 28 subjects: 23 men & 5 women
- Age range: 21-30 y/o
 - Excludes clinical patient
- Height range: 160-195 cm
- Weight range: 53-97 kg [8]



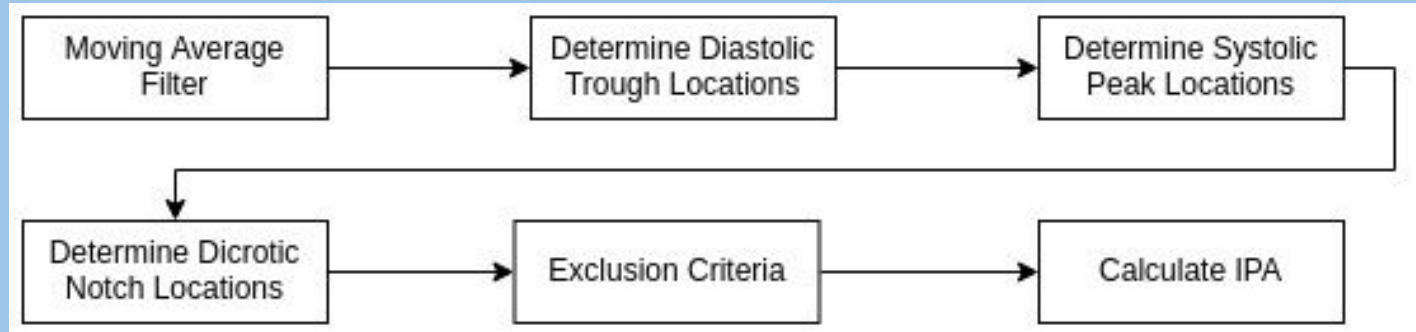
Retrieving Data



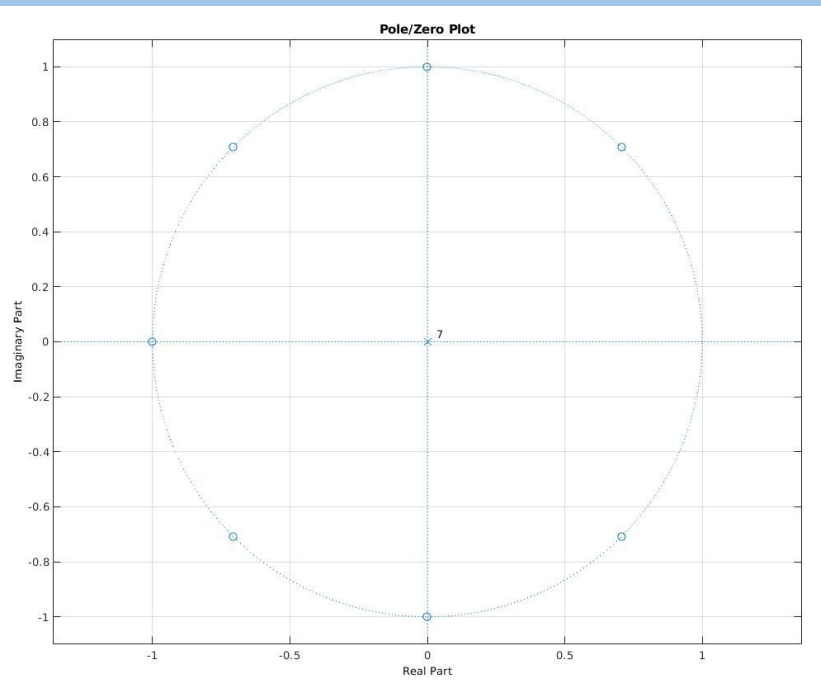
Storing Data



Methods/Results - Algorithm

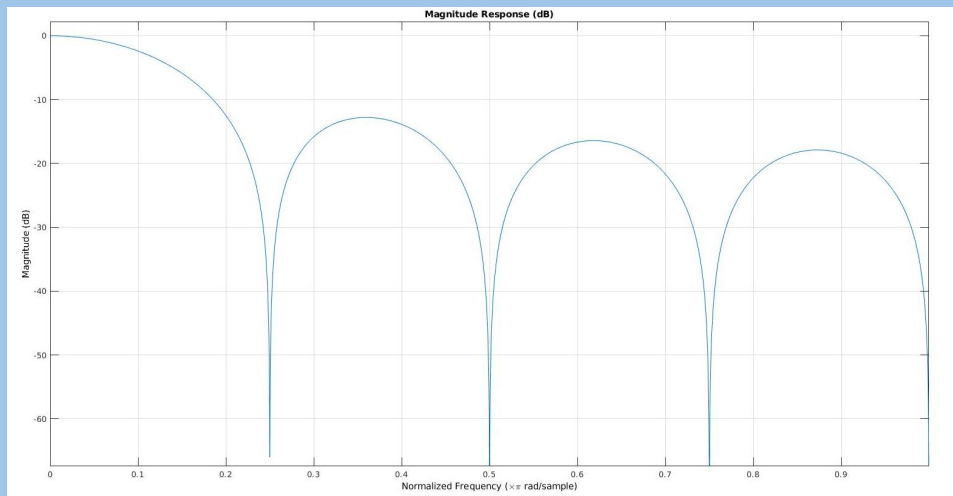


Filtering Moving Average Filter

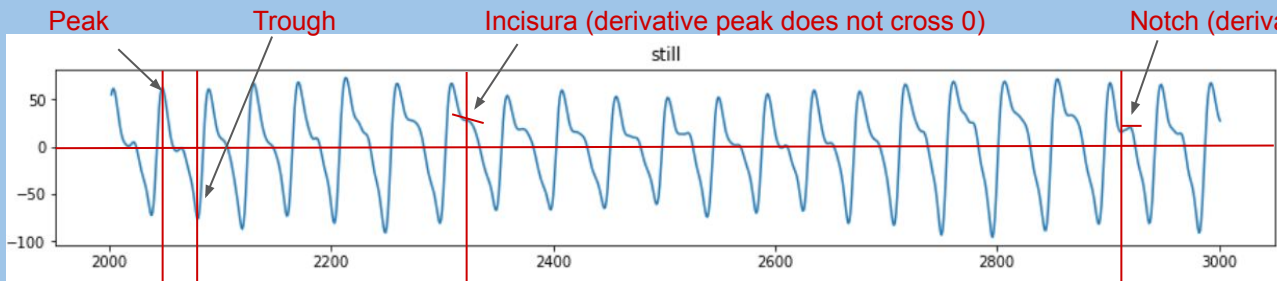


Goal

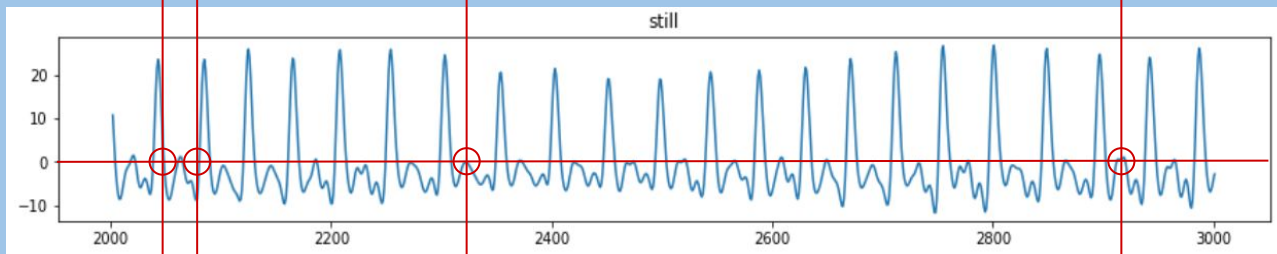
First step Smooth the signal to remove small peaks/troughs that cause false positives



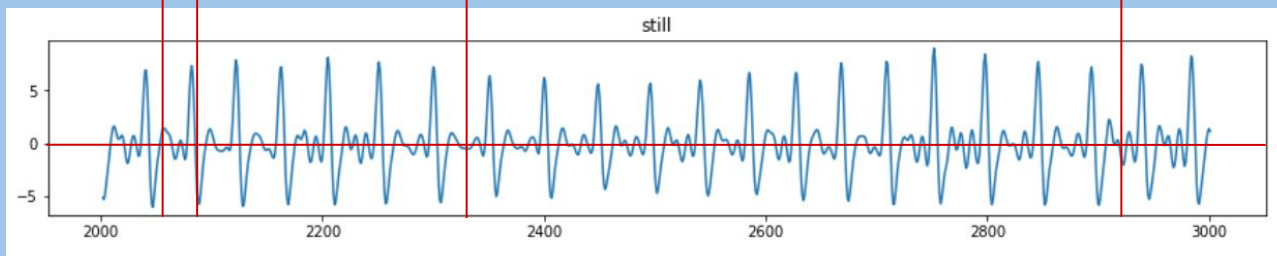
PPG Waveform Derivatives



Original Signal

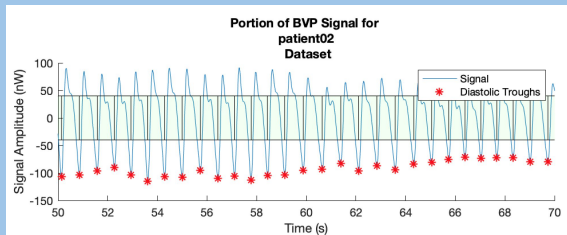


First Derivative

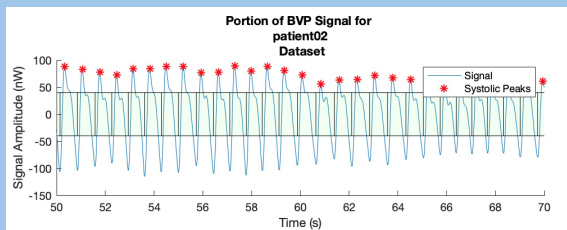


Second Derivative

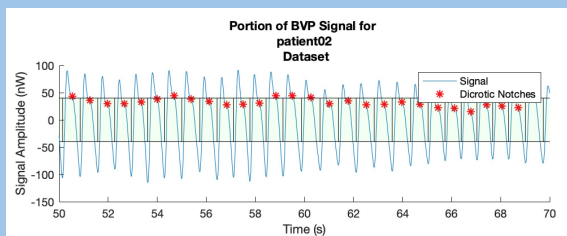
Critical Points



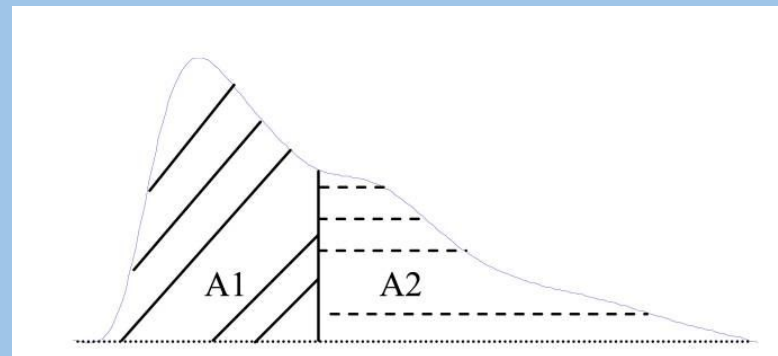
Diastolic Troughs



Systolic Peaks



Dicrotic Notches



$$IPA = \frac{A2}{A1}$$

[2,3]

Criteria for Calculation

Pulse width

HR < 240 bpm

HR > 20 bpm

Amplitude

Above min threshold

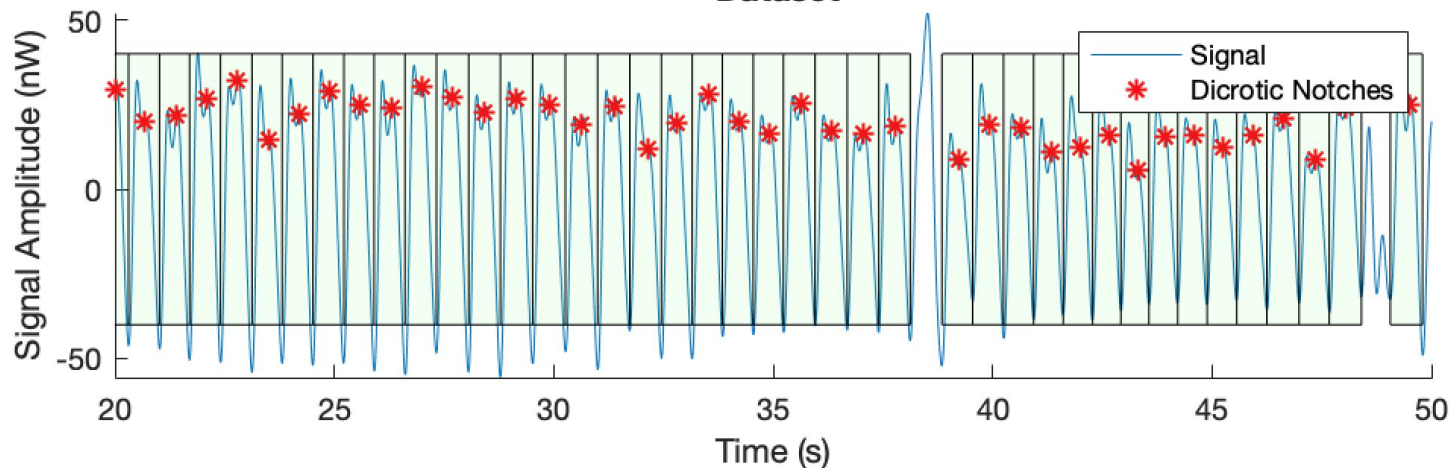
Below max threshold

Morphology defects

$0 < \text{peaks detected} \leq 2$

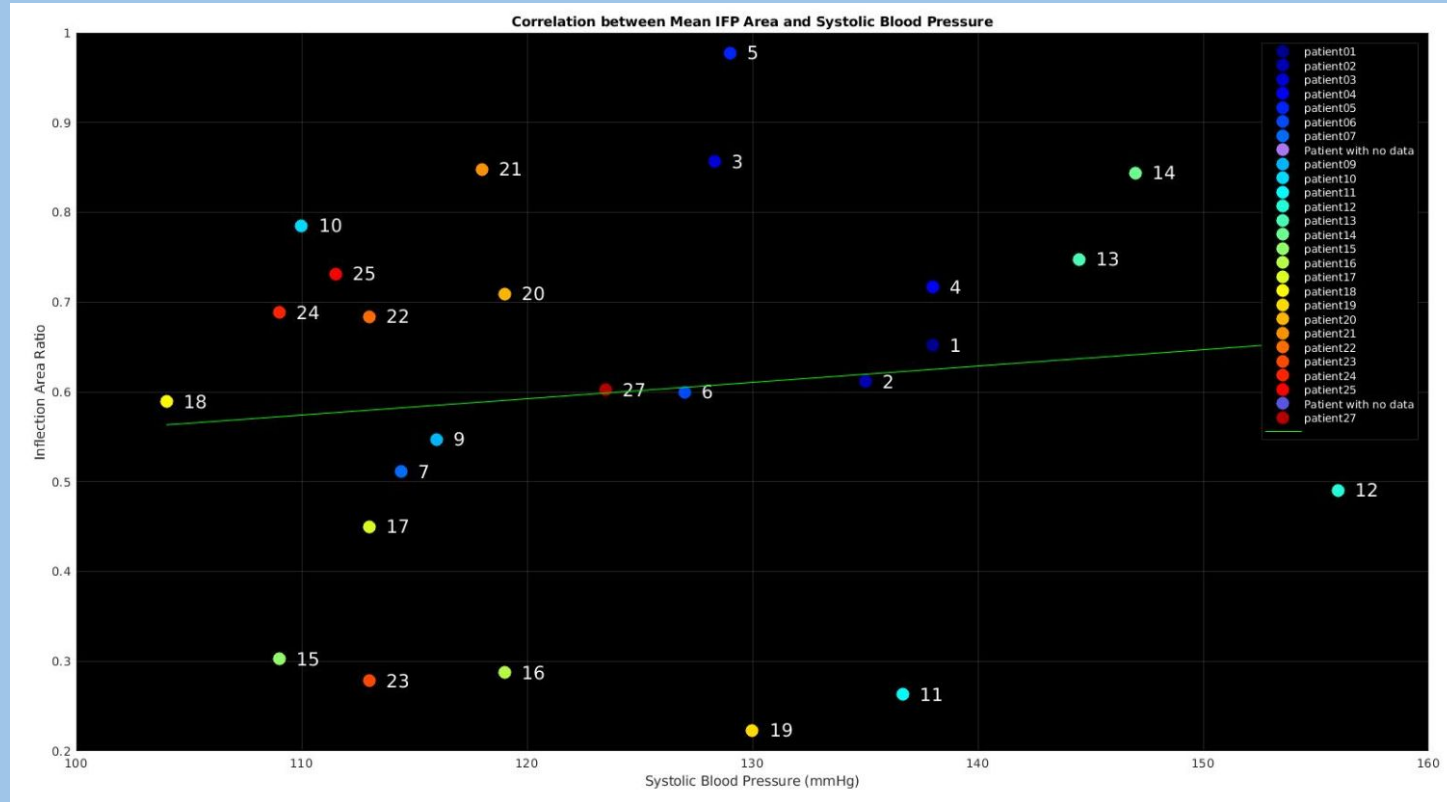
Single dicrotic notch

Portion of BVP Signal for
patient20
Dataset

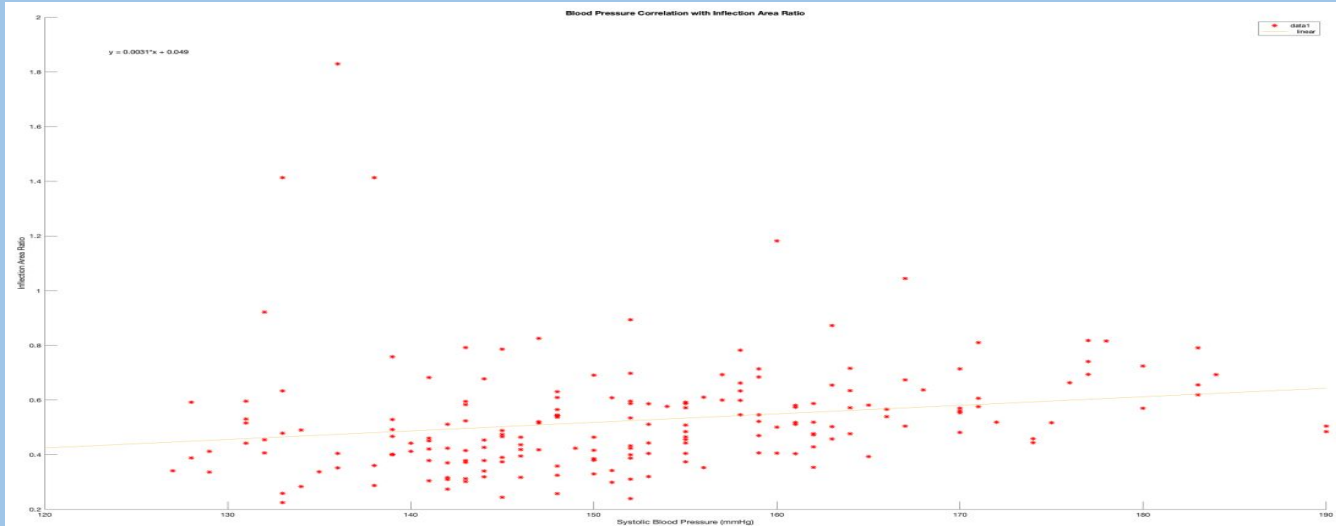
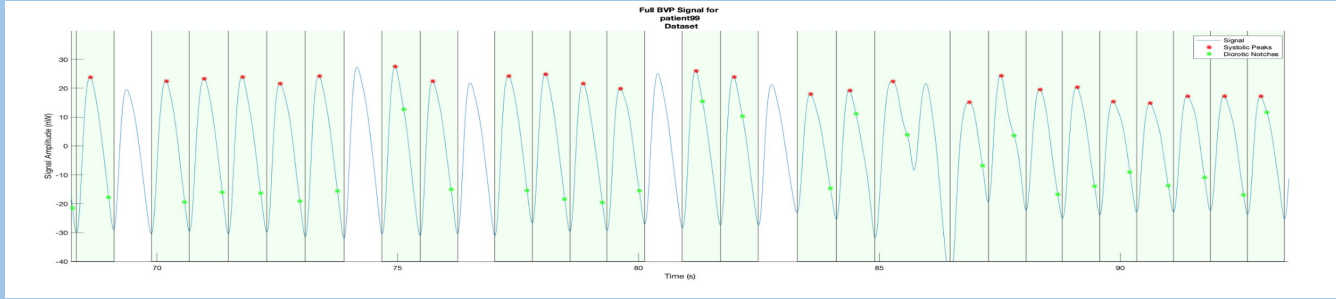


Discussion/Statistical Analysis

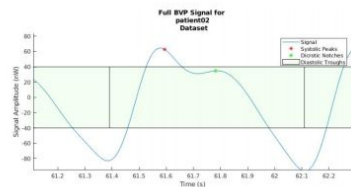
Statistical Analysis (Healthy Participants)



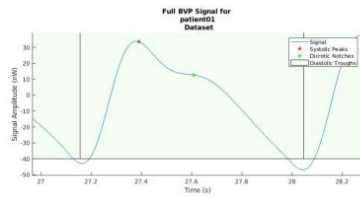
Statistical Analysis (Post-Surgery)



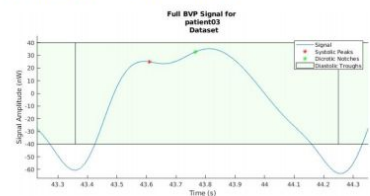
Algorithm Faults/Waveform Morphology



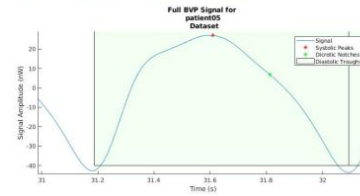
(a) A traditional waveform with a dicotic peak, type 1, IPA = 0.60



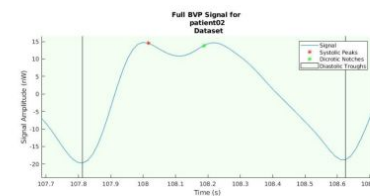
(b) A traditional waveform with only a dicotic incisura, type 2, IPA = 0.62



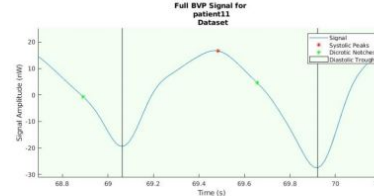
(c) A left justified waveform with a left peak, type 3, IPA = 1.16



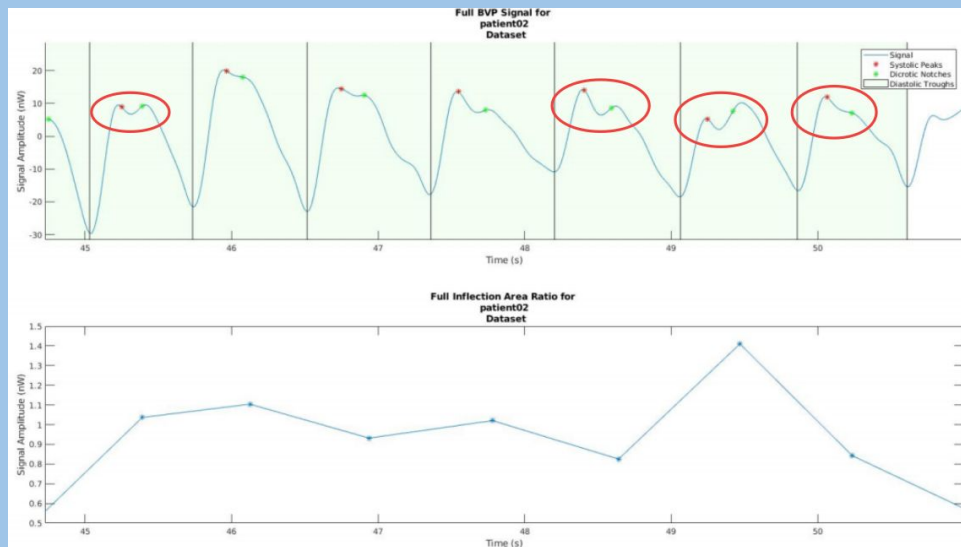
(d) A left justified waveform with a left incisura, type 4, IPA = 0.25



(e) A waveform with two peaks of roughly equal height, type 5, IPA = 1.04



(f) A relatively smooth waveform, type 6, IPA = 0.24



Conclusion

IPA/Program untapped potential

- Machine learning feature generation
- IPA as standalone biometric
- Use as consumer prediagnostic tool

IPA vs. invasive metrics correlations

- Vascular distensibility
- Peripheral resistance
- Heartbeat irregularity

Poor PPG signal repeatability

Citations

- [1] Empatica. Empatica E4 Technical Specifications, 11 2014. Rev 001.
- [2] Wearable device revenue worldwide 2016-2022 — statistic.
- [3] L. Wang, E. Pickwell-Macpherson, Y.p. Liang, and Y.t. Zhang. Noninvasive cardiac output estimation using a novel photoplethysmogram index. 2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2009.
- [4] Mohamed Elgendi. On the analysis of fingertip photoplethysmogram signals. Current Cardiology Reviews, 8(1):14–25, Jan 2012.
- [5] John Allen. Age-related changes in the characteristics of the photoplethysmographic pulse shape at various body sites. Physiological Measurement, 24(2):297–307, 2003.
- [6] Jae Mok Ahn. New aging index using signal features of both photoplethysmograms and acceleration plethysmograms. Healthcare Informatics Research, 23(1):53, 2017.
- [7] Omron. Omron Model M2 Basic: Instruction Manual, 02 2010. Rev 002. [8] Average height of men and women worldwide