

# Outpatient System for multipoint monitoring of the IPG signal

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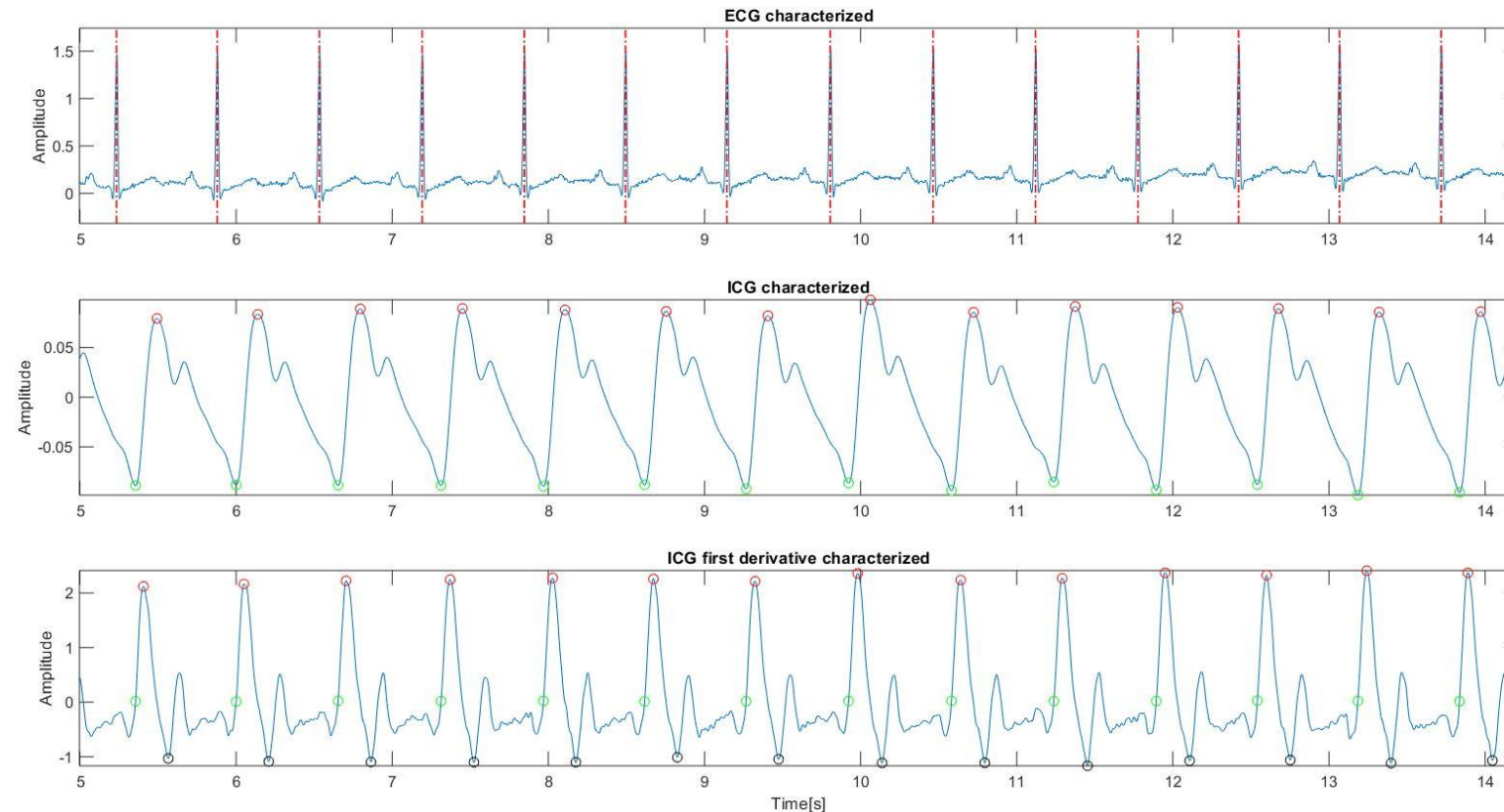
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## Motivation

- **Main Goal:** Allow the monitoring of the cardiovascular system through measurements in the most comfortable places for each patient.
- Study the variability of the IPG (*Impedance Plethysmography*) signals when measured in different spots of the body and the evolution of the Pulse Wave when propagating.
- Development of a system able to measure IPG, ECG and PPG signals.
- Obtention of approximated values of the Stroke Volume from IPG signals.

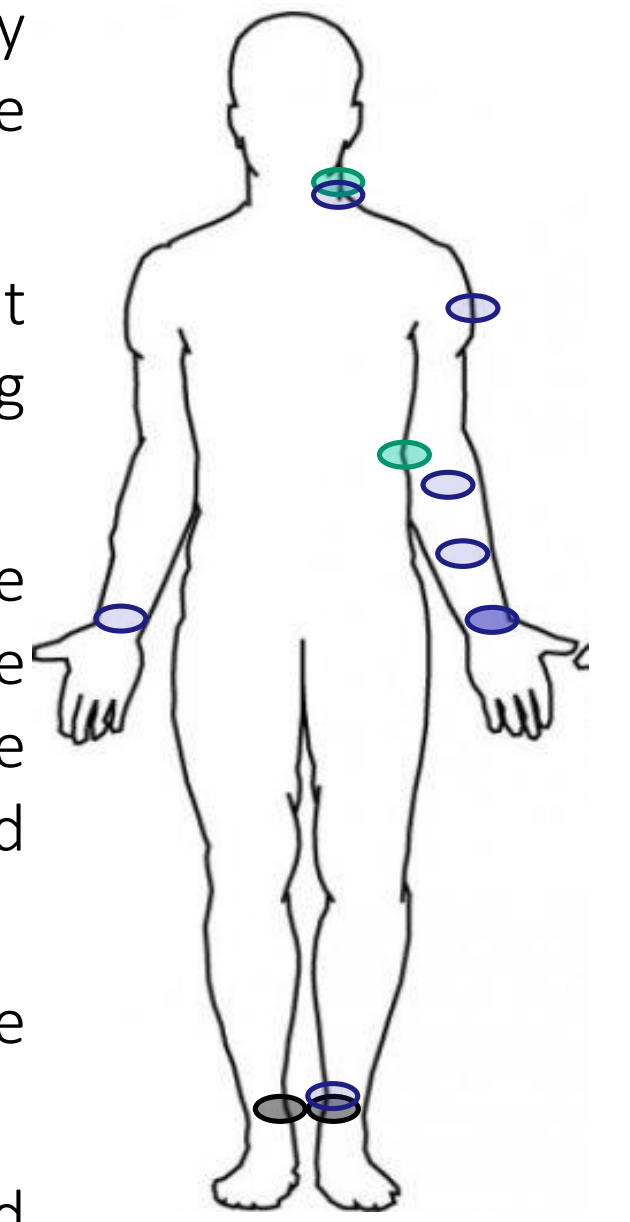
## Proposed algorithm

- Pan-Tompkins algorithm to detect the ECG QRS peaks.
- Characterization of the IPG signal locating both maxima and minima.
- Characterization of the impedance first derivative signal locating the three B, E and X points.
- Applying the SV approximated formula to obtain a first approximated value.
- Readjustment of the obtained data and calibration for each subject.



## Evaluation

- Fifteen healthy volunteers. Only eleven from them used to evaluate the model.
- One minute long measures in eight different spots. Breathing and holding breath measures.
- ECG and PPG signals as the reference signals. Evaluation of both the evolution of the propagation of the Pulse Wave and an approximated value of the Stroke Volume.
- Obtention of an average Wave Pulse form for each signal and subject.
- Readjustment of the SV value and calibration for each subject.



- Fixed electrodes for Leg to Leg measure.
- Fixed electrodes for ICG measure.
- Wrist fixed pair of electrodes
- Moving pair of electrodes

$$SV = c \cdot (1 - t_{ejec} \cdot \Delta Z) \cdot V_C \cdot \sqrt{\frac{dZ}{dt_{max}}} \cdot \frac{1}{Z_0} \cdot t_{ejec}$$

Calibration Readjustment      Stroke Volume Approximation

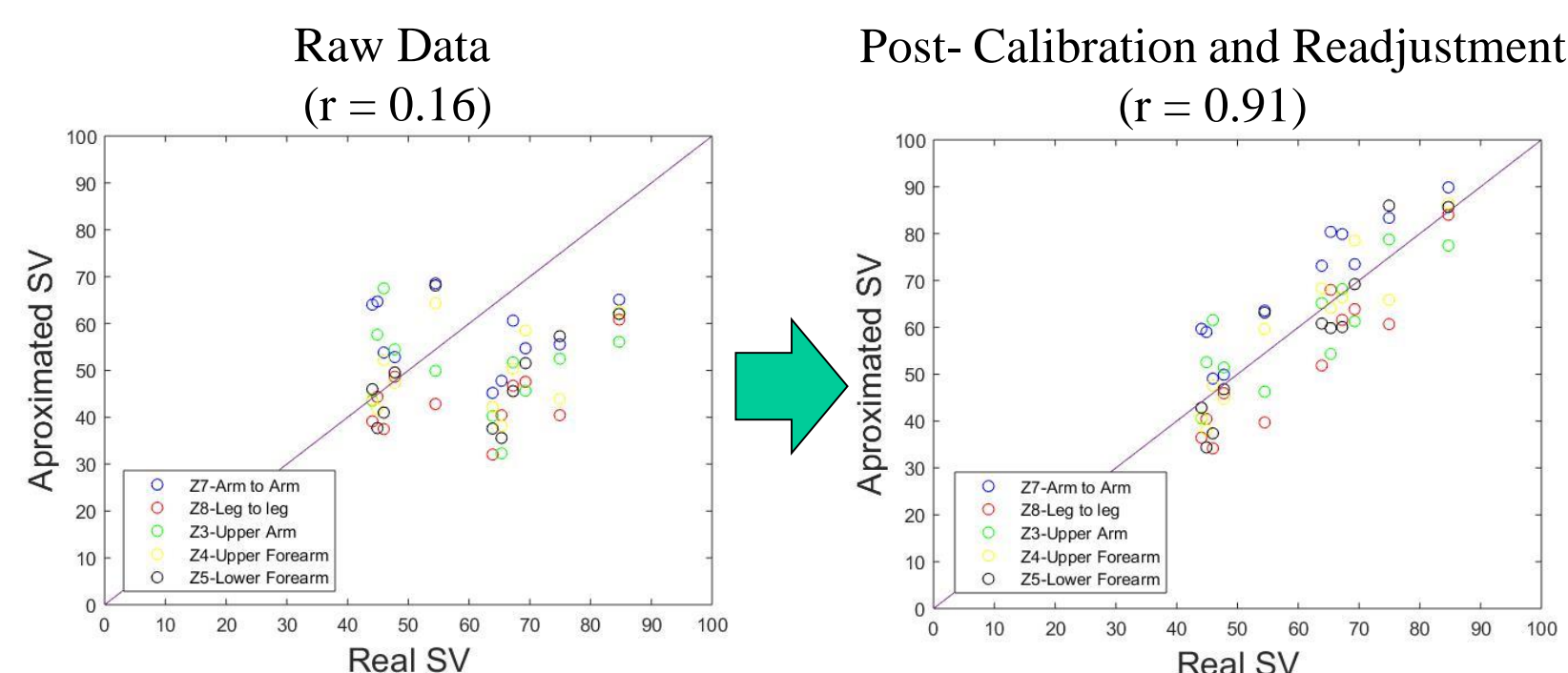
## HARDWARE

- BIOPAC MP36 device used to acquire the ECG, ICG, IPG and PPG signals.
- Development of a low-cost hardware able to acquire the same signals.



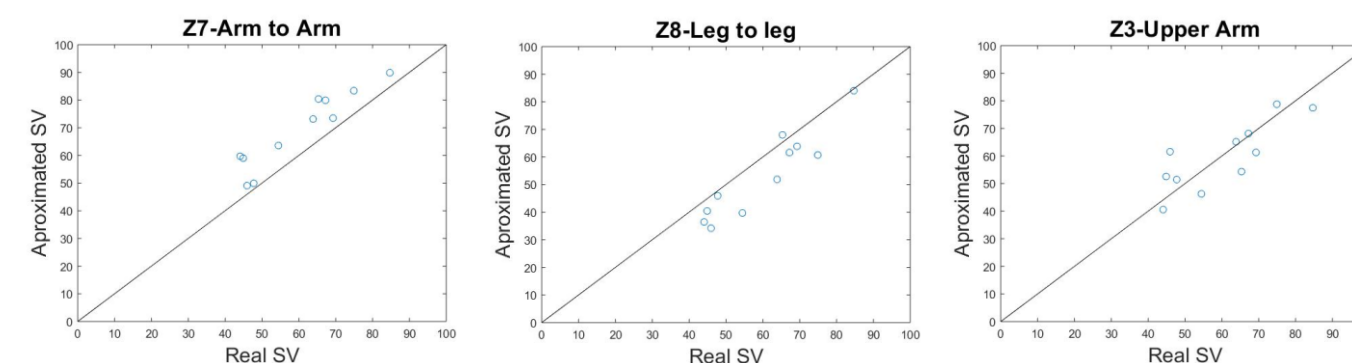
## Results

- A good approximation for the Stroke Volume could be obtained after the calibration and readjustment for each measure.
- The leg to leg signal tends to give smaller values than the real ones, while the arm to arm gives bigger ones.
- The evolution of the Wave Pulse amplitude was as expected, decreasing as the measure got further from the heart.

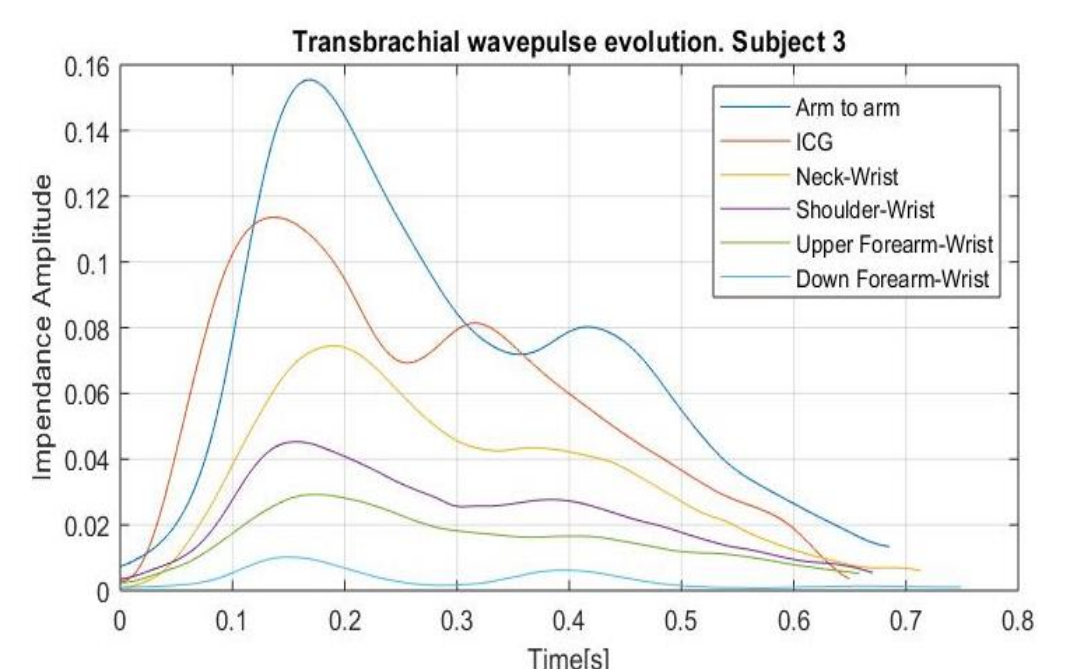
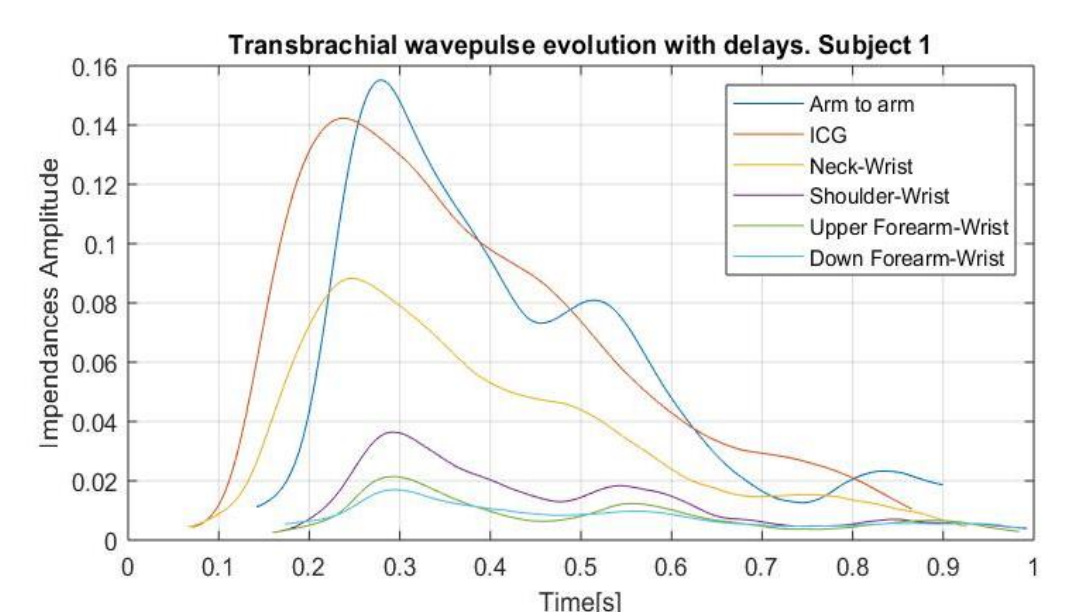


APPROXIMATION VALUE OF THE STROKE VOLUME

	Real SV [mL]	Arm to Arm [mL]	Leg to Leg [mL]	Upper Arm [mL]	Mid Arm [mL]	Low Arm [mL]	Calibrate Coeff.
S1	69.28	73.50	63.87	61.28	78.53	69.22	0.74
S2	65.33	80.41	68.01	54.31	64.10	59.82	0.54
S3	44.89	59.09	40.43	52.53	38.04	34.36	0.83
S4	54.46	63.65	39.69	46.24	59.60	63.11	1.25
S5	47.75	49.91	45.94	51.44	44.68	46.79	1.03
S6	74.92	83.41	60.68	78.74	65.84	85.95	0.76
S7	63.86	73.23	51.85	65.13	68.31	60.78	0.58
S8	44.07	59.72	36.44	40.57	40.78	42.83	1.04
S9	67.22	79.96	61.58	68.13	66.41	60.04	0.67
S10	84.69	89.94	84.09	77.40	86.42	85.61	0.73
S11	45.95	49.06	34.18	61.55	47.57	37.37	0.89



EVOLUTION OF THE WAVE PULSE FORM WHEN PROPAGATING THROUGH THE ARM



## Conclusions

- IPG signals can be used to monitor the cardiovascular system instead of the commonly used ICG signal.
- The propagation factor for each subject remains almost the same, making it possible to approximate the SV value from any spot of the body.
- A versatile device can be developed to allow both patients and doctors to monitor the cardiovascular system using easier measure spots such as the leg to leg in a weighing scales.