

# *Remote Photoplethysmography System for Vital Signs Estimation: Perceived Usability Evaluation by Elderly People*

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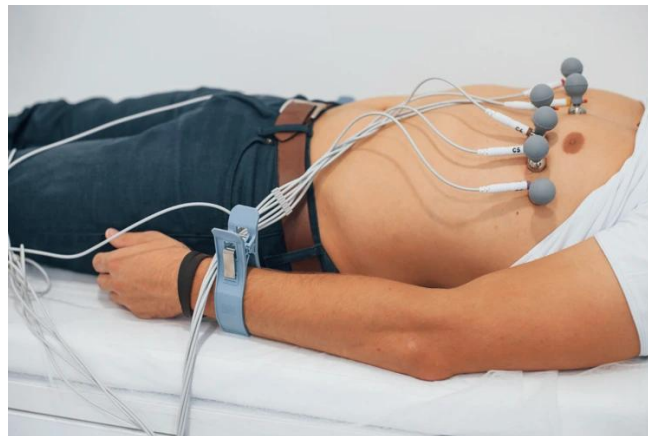


# Introduction – Vital Signs Monitoring

Continuous monitoring of vital signs plays a key role in preventing several heart and respiratory system diseases. Heart Rate (HR), Breathing Rate (BR) and blood oxygen saturation (SpO2) are important indicators for assessing the state of health

## Gold Standards Methods

- ✗ Contact-based
- ✗ Uncomfortable for the user
- ✗ Require trained manpower and specific equipment
- ✓ Accuracy > 99%

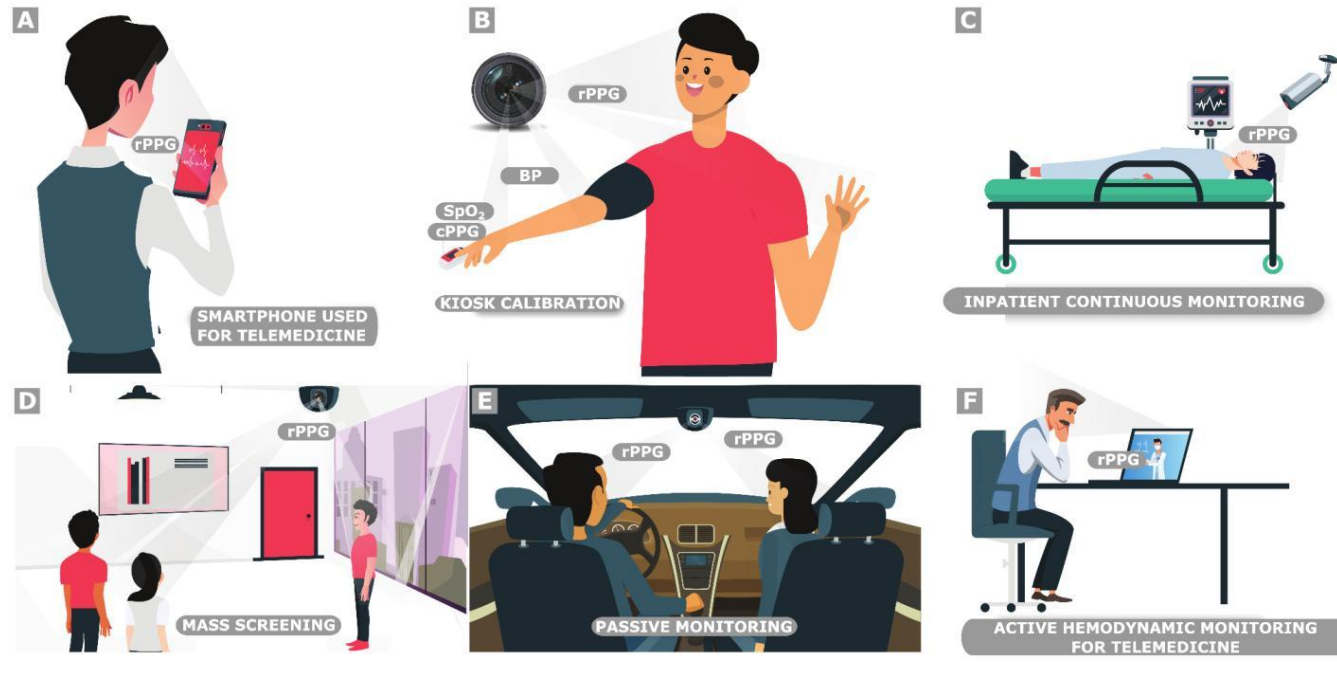
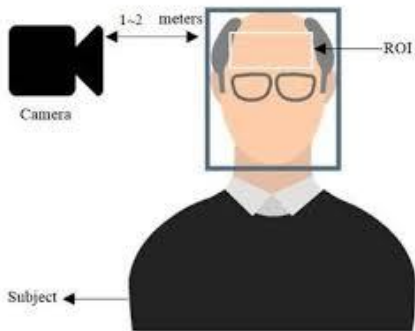


# Introduction – Vital Signs Estimation

While wearable devices such as smartwatches have gained widespread popularity, contactless systems have seen increased adoption, particularly following the COVID-19 pandemic

## Camera-based Methods

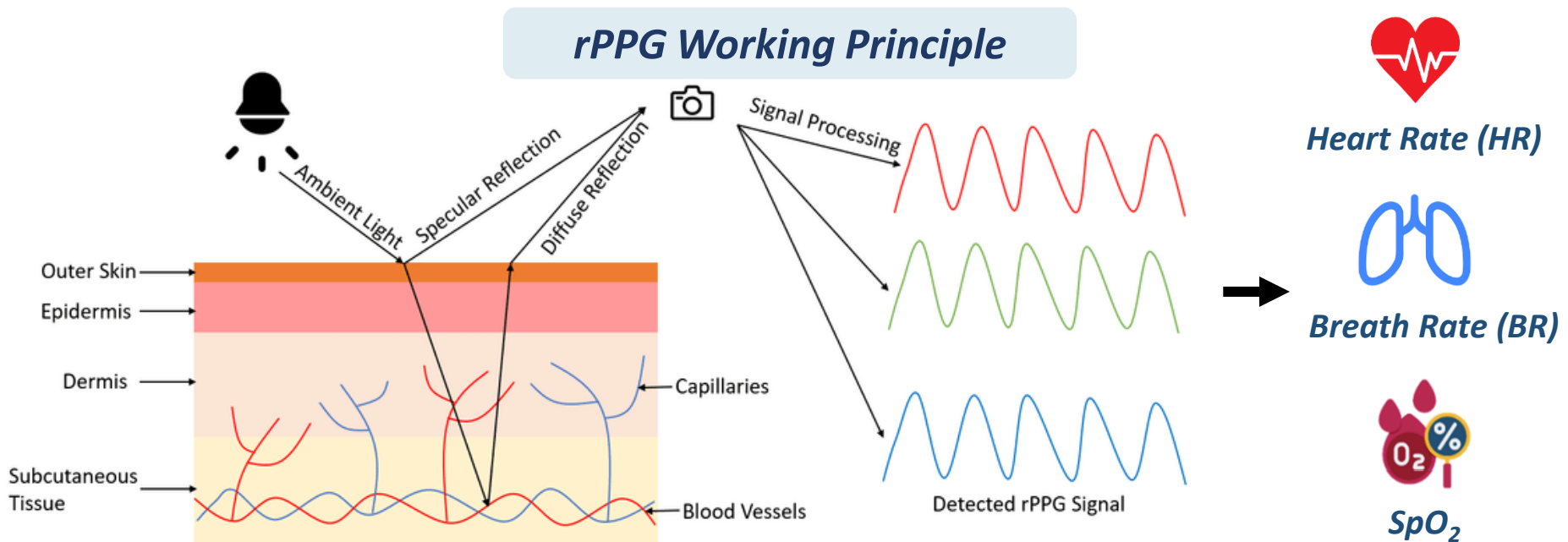
- ✓ Contact-less
- ✓ High acceptability
- ✓ Usability everywhere
- ✓ Low-cost devices
- ✗  $90\% < \text{Accuracy} < 97\%$



# Remote Photoplethysmography (rPPG) for Vital Signs Estimation

Remote photoplethysmography (rPPG) is a contactless technique that estimates vital signs by analysing subtle variations in skin color caused by blood fluctuation in peripheral vessels

rPPG system analyses stream of user's face acquired using consumer low-cost devices, such as RGB or smartphone-integrated cameras



# *rPPG - Motivation and Outcome*

Ensuring usability is essential to make health monitoring solutions practical, efficient and accessible in real scenarios. Usability and acceptability are particularly critical for adopting systems, such as rPPG, especially among older adults as they strongly influence engagement and sustained use

## *Research Motivations*

- ✓ The need for non-invasive health monitoring solutions
- ✓ Importance of usability for elderly users and caregivers
- ✓ rPPG as a potential solution for telemedicine applications

## *Aim of the Study*

- ✓ ***Evaluate the perceived usability of the solution on both elderly and non-elderly people***
- ✓ ***Analyze feedback using standardized usability questionnaires***



# rPPG - System Overview

**Hardware:** NexiGo N960E webcam, Raspberry Pi 4

**Software:** Customized Signal processing pipeline for vital sign estimation

**User Interface:** Designed for accessibility and ease of use

## Algorithmic Pipeline

### Hardware



a)

≈ 69 €  
1920x1080p  
30 FPS



b)

≈ 90 €  
ARM-based  
8 Gb RAM



### PRE-PROCESSING

FACE DETECTION

ROI EXTRACTION

BRIGHTNESS  
ADJUSTMENT

### FEATURE EXTRACTION AND VITAL SIGN ESTIMATION

RGB DECOMPOSITION

AVERAGE, DETREND, NORMALIZATION

HR/BR

BAND-PASS FILTERING

CHROM METHOD

FAST FOURIER  
TRANSFORM

THRESHOLD FOR  
MAXIMUM HR/BR  
CHANGE



SpO<sub>2</sub>

PULSATILE  
ALTERNATE  
CURRENT (AC) &  
NON PULSATILE  
DIRECT  
CURRENT (DC)



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Vital signs estimation in elderly using camera-based photoplethysmography

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**Performances in controlled environment:**

HR: MAE = 2.20, RMSE = 3.96

BR: MAE = 1.80, RMSE = 2.15

SpO<sub>2</sub>: err% = 0.85%

# rPPG - Desktop Graphical User Interface

**Vital Signs Monitoring - CNR IMM**

*Live stream*

*Estimated Vital Signs*

**Vital Signs**

Heart Rate:	63 bpm
Breath Rate:	16 RR
SpO2:	98%

Ground truth vital signs (Optional)

Heart Rate:	<input type="text"/>
Breath Rate:	<input type="text"/>
SpO2:	<input type="text"/>

**Data sent successfully**

Stand still for: 29 seconds

*Messages for users*

*Countdown*

User Id: User\_2



# Usability - Definitions

**“Usability”** measures how easy and intuitive a software/website/application/interactive system is for users.

The most accepted definitions of usability come from **J. Nielsen** and **ISO 9241-11**

**J. Nielsen** describes usability as *“a quality attribute that evaluates ease of use and includes components such as learnability, efficiency, memorability, error reduction, and satisfaction”*

**ISO 9241-11** standard defines usability as *“the extent to which a system, product or service can be used by specific users to achieve specific goals with effectiveness, efficiency, and satisfaction in a defined context of use”*

# Usability - Evaluation

## Usability Assessment Tools

- ✓ **System Usability Scale (SUS)**: 10-items questionnaire where participants rate each item on a 5-points Likert scale. The resulting score, ranging from 0 to 100, offers a quick and reliable assessment of usability and is especially useful for benchmarking systems
- ✓ **Short Version of the User Experience Questionnaire (UEQ-S)**: 8-items, making it suitable for constrained circumstances. It evaluates two main dimensions: **Pragmatic Quality (PQ)**, focused on usability and efficiency, and **Hedonic Quality (HQ)**, related to attractiveness and emotional engagement, using a 7-point bipolar scale

# Usability - Evaluation

- ✓ **Odd-numbered items** reflect **positive aspects** of usability
- ✓ **Even-numbered items** highlight **negative aspects**

	<i>SUS items</i>
1	<i>I think that I would like to use this system frequently</i>
2	<i>I found the system unnecessarily complex</i>
3	<i>I thought the system was easy to use</i>
4	<i>I think that I would need the support of a technical person to be able to use this system</i>
5	<i>I found the various functions in the system were well integrated</i>
6	<i>I thought there was too much inconsistency in this system</i>
7	<i>I would imagine that most people would learn to use this system very quickly</i>
8	<i>I found the system very cumbersome to use</i>
9	<i>I felt very confident using the system</i>
10	<i>I needed to learn a lot of things before I could get going with this system</i>

$$\text{SUS Score:} = 2.5 \times \sum_{i=1}^{10} \left( \overbrace{(5 - r_i) |(i \bmod 2) - 1|}^{\text{Odd-numbered items contributions}} + \overbrace{(r_i - 1)(i \bmod 2)}^{\text{Even-numbered items contributions}} \right)$$

It's quick, reliable and widely benchmarked → SUS scores > 68 indicate 'good' usability.

# Usability - Evaluation

➤ **Pragmatic Quality (PQ): Functionality and ease of use**

**Daily utility**

		<i>UEQ-S items</i>							
<b>PQ</b>	<i>Obstructive</i>	-3	-2	-1	0	+1	+2	+3	<i>Supporting</i>
	<i>Complicated</i>	-3	-2	-1	0	+1	+2	+3	<i>Easy</i>
	<i>Inefficient</i>	-3	-2	-1	0	+1	+2	+3	<i>Efficient</i>
	<i>Confusing</i>	-3	-2	-1	0	+1	+2	+3	<i>Clear</i>
<b>HQ</b>	<i>Boring</i>	-3	-2	-1	0	+1	+2	+3	<i>Exiting</i>
	<i>Not Interesting</i>	-3	-2	-1	0	+1	+2	+3	<i>Interesting</i>
	<i>Conventional</i>	-3	-2	-1	0	+1	+2	+3	<i>Inventive</i>
	<i>Usual</i>	-3	-2	-1	0	+1	+2	+3	<i>Leading</i>

➤ **Hedonic Quality (HQ): Emotional engagement**

**Long-term adoption**

# Results

## Experimental Setting

Testing conducted in two elderly care facilities (middle of Italy)

### Participants:

- **20 elderly users: age 65-85 (mean age of 74.5)**
  - varying levels of education (mostly middle school education)
  - low-to-moderate familiarity with technology
- **7 caregivers: age 30-55**
  - nurses and care assistants with greater technological proficiency

## SUS Scores

Item	1	2	3	4	5	6	7	8	9	10	Average Scores
Users	5	1	5	5	5	1	4	4	5	1	80.0/100
Staff	5	1	5	1	5	1	4	1	5	1	97.5/100

## UEQ-S Scores

	PQ	HQ	Overall	Out of 100
Users	2.25	3.00	2.63/3.00	94.60/100
Staff	2.00	2.25	2.13/3.00	87.50/100

# Conclusions & Future Works

- ✓ High rates of rPPG system by staff (**SUS: 97.50**), reflecting professional suitability, while elderly users provided a strong but lower score (**SUS: 80.00**) → GUI must be modified to accommodate end-user feedbacks
- ✓ The UEQ-S results highlighted a trade off between functionality and emotional engagement, with scores of **2.13/3.00** (→ **87.5/100**) for Staff members and **2.63/3.00** (→ **94.6/100**) for elderly people

## Findings

- ✓ **The system is perceived as reliable and “friendly”, both by end-users and caregivers**
- ✓ Elderly users faced **minor usability challenges**
- ✓ Refinements such as larger fonts, high-contrast color schemes and more guided user experience could significantly **enhance accessibility and satisfaction**, encouraging broader adoption in diverse settings

## Future Works

- ✓ Long-term usability assessment
- ✓ **Larger and more heterogeneous** participant set to improve generalizability
- ✓ Stratifying participants based on their **digital literacy levels**
- ✓ Older adults living independently or in **different cultural and socio-economic contexts**

# THANK YOU

## for your attention

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