

Wearable Wireless Pulse Oximetry for Physiological Monitoring

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Presentation Outline

- Motivation
- Goal
- Background
- Development of a Wearable Pulse Oximeter
- Measurement Validations
- Future Development

Motivation

Telemedicine using wearable sensors can provide useful information for **emergency first responders** and facilitate **life saving rescues** of:

- *Soldiers*
- *Firefighters*
- *Mountain climbers*



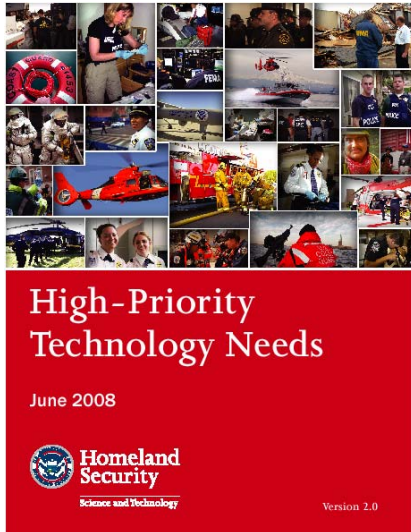
- **Operating in harsh and hazardous environments**
- **Operating over large geographical terrains**

Motivation

- Data derived from **sensors** can provide input information in models developed to assess and predict the health status of wounded soldiers.
- The reliability of the **wearable sensors** used and the data extracted is essential for the successful implementation of these predictive models.



Motivation



Representative Technology Needs for Improved Incident Management:

Personnel monitoring (*physiological monitoring of firefighters*) capability — In particular, **integrated body-worn sensor suite to provide real-time health analysis and issue alarms to both wearer and command staff.**

DHS Leads: Federal Emergency Management Agency and Office of Emergency Communications

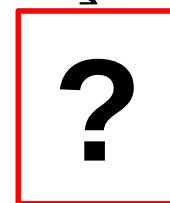
Motivation

- Firefighters experience tremendous CV demands with high-levels of short-term strenuous physical workloads and overexertion.
- Increased HR and core body temperature leads to increased physiological stress.
- Risks related to exhaustion, overheating and inhalation of combustion products can lead to work injuries and fatalities.



What are the Needs

Physiological Monitoring



Wearable

Our Goal

Development of a Robust Wearable Pulse Oximeter for Field Applications

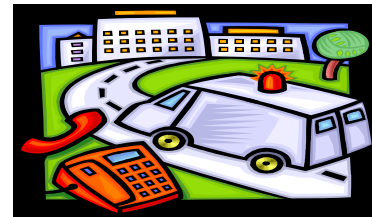


Background

Pulse oximeters are commonly employed in nearly all hospital areas where patients are at an increased risk of developing **hypoxemia**

- **OR (Anesthesia)**
- **ER**
- **ICU**
- **Ambulances**

⋮



Background

- Appeared in the early 1980's.
- Gained overnight popularity.
- By 1987, the standard of care for the administration of a general anesthetic in the USA included pulse oximetry.
- Transformed monitoring hypoxemia from a crude and imprecise visual color assessment into a reliable, quick, noninvasive and objective measurement.
- Now a mature technology in hospitals.

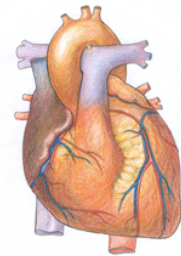
Background

- Life depends on uninterrupted O₂ supply.
- Different organs and tissues can survive lack of O₂ for different lengths of time: The brain is the most rapidly and irrevocably damaged organ.
- Because the brain regulates breathing and circulation, supplying O₂ to the whole body, deprivation of O₂ supply to the brain can be fatal.
- Mild cases of hypoxia can cause poor judgment and uncoordinated movement. Severe cases death is inevitable.
- After ~5 min, cutting off blood supply to the brain causes cells to die.
- Timing is everything!



Background

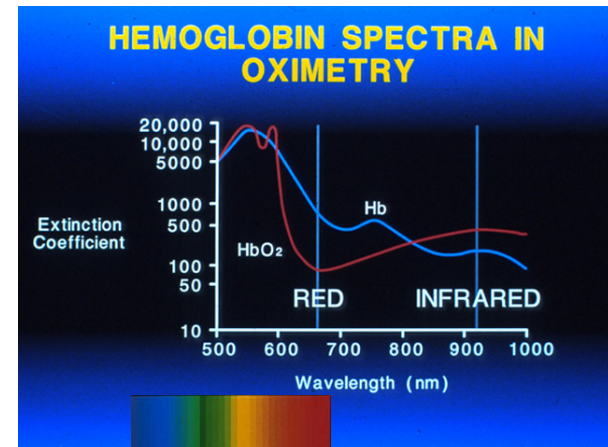
PULSE OXIMETERS RELY ON SPECTROPHOTOMETRIC PRINCIPLES TO DERIVE SpO_2 AND HR FROM A PULSATING VASCULAR TISSUE BED



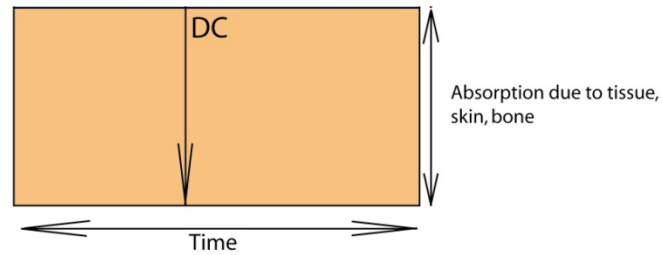
Blood depleted of O_2 appears purple



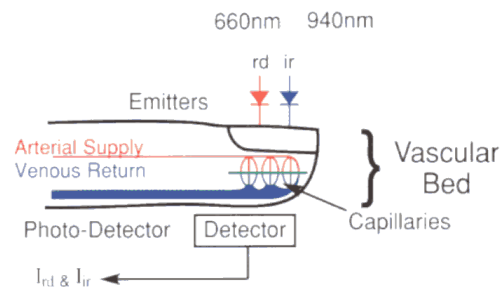
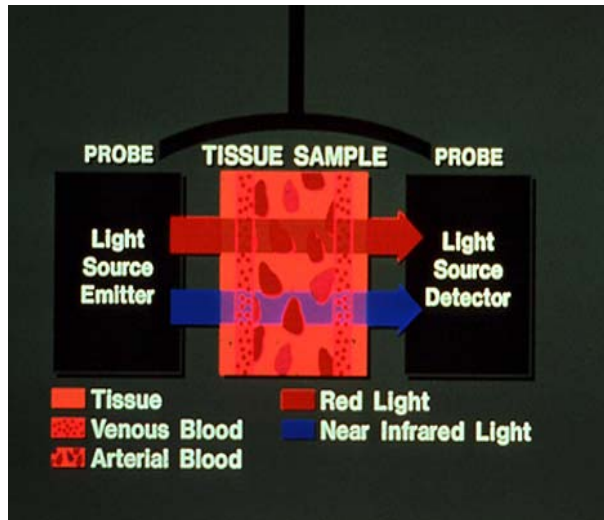
Blood rich in O_2 appears bright red



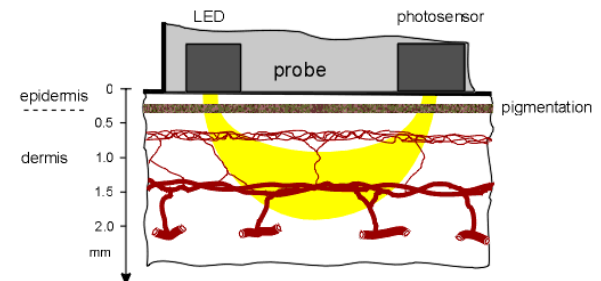
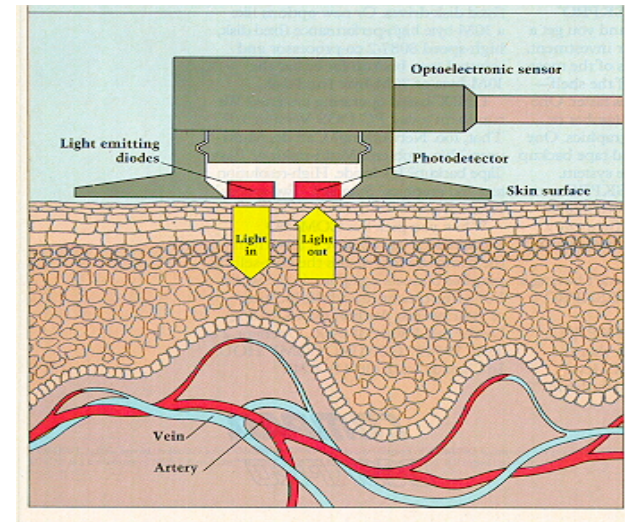
Background



Transmittance Mode

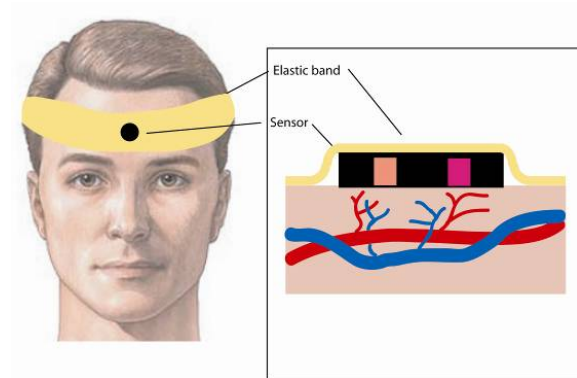


Reflectance Mode

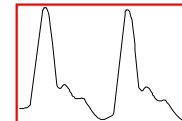


Advantage of Reflectance Mode

Why the Forehead ?



- Does not impede hand movements.
- Easy sensor attachment.
- More motion tolerant location (skull provides mechanical support).
- Provides strong and clean PPG signals.

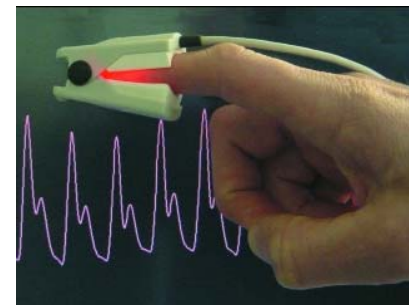
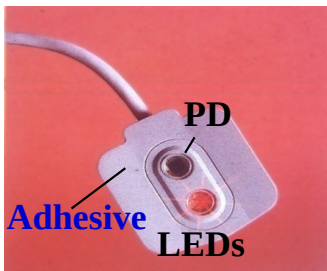


COTS Pulse Oximeters

Designed for Clinical Settings
(Patient movement relatively constrained)

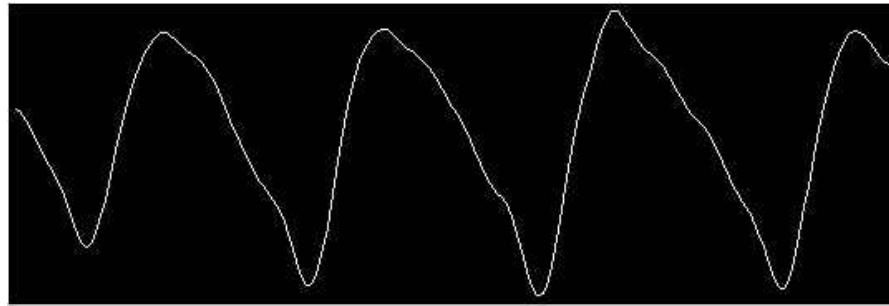


Commercial Sensors



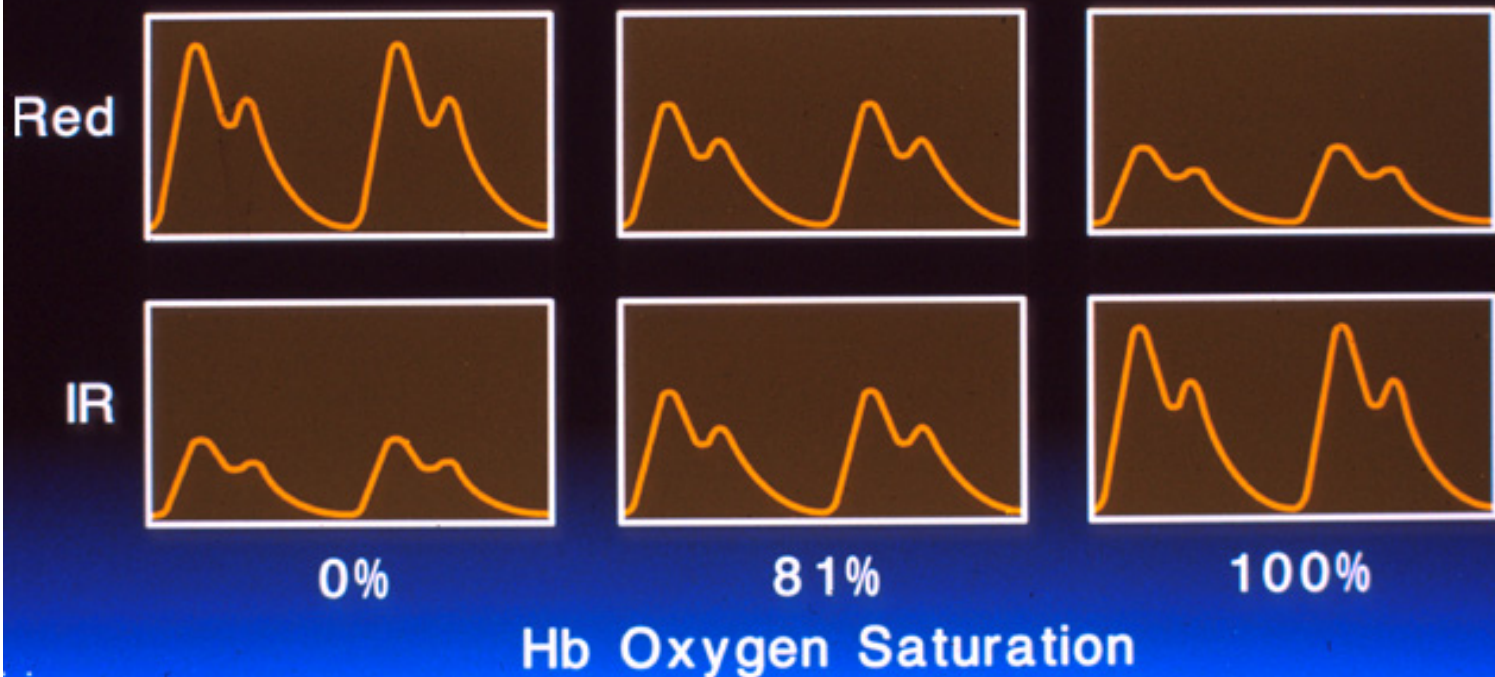
Principle

- Several prominent features can be extracted from the Photoplethysmogram (PPG).
- Monitoring multiple variables using a single sensor has distinct advantages.

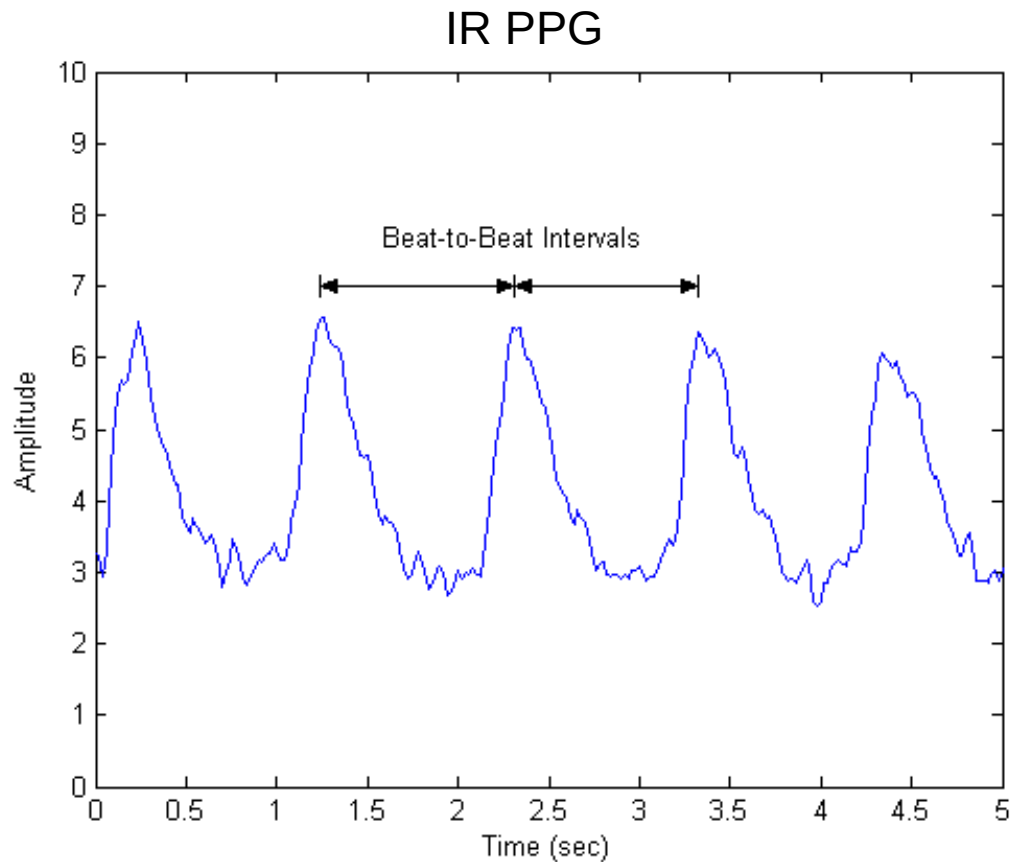


Principle (SpO₂)

PLETHYSMOGRAPHIC COMPARISON OF LIGHT ABSORPTION

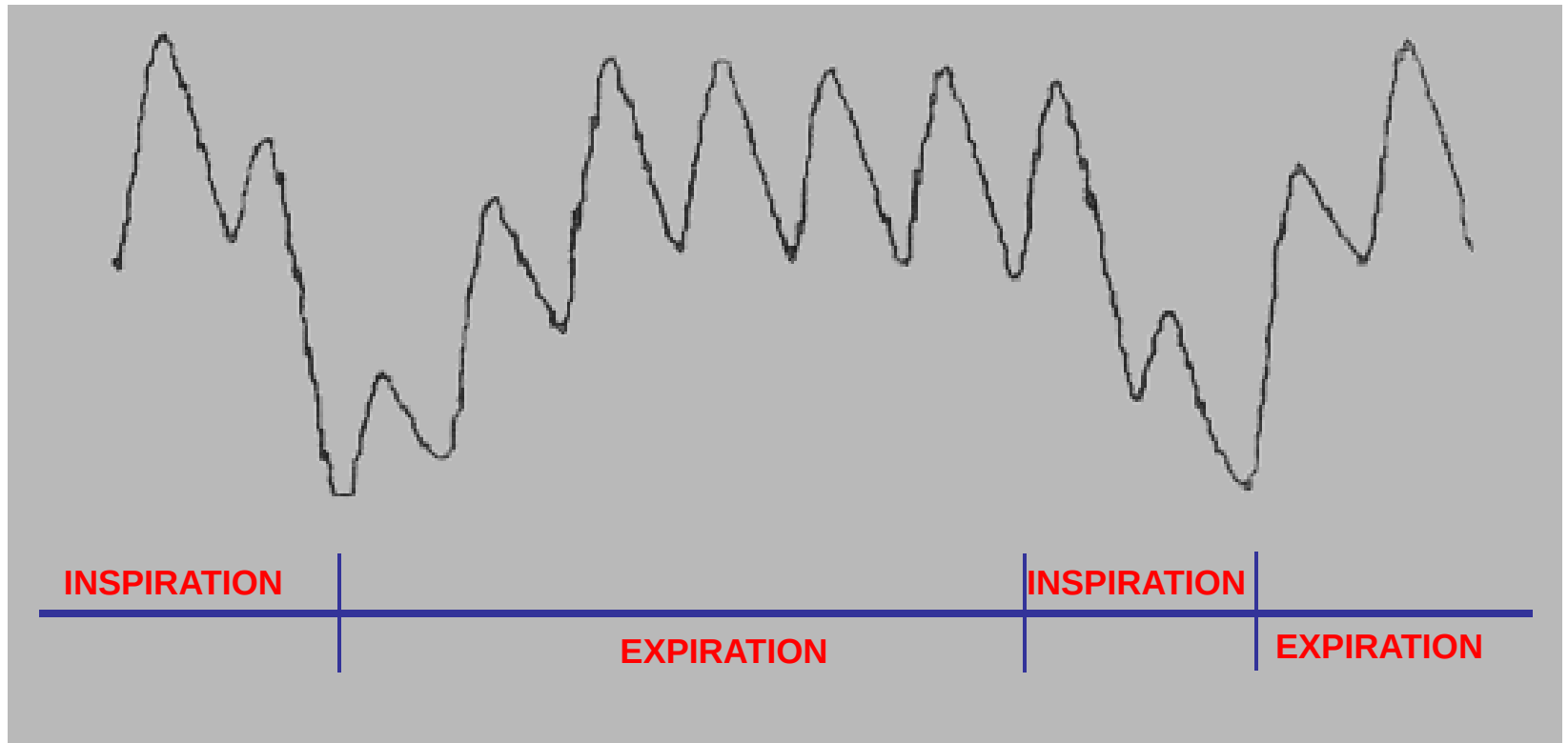


Principle (HR)



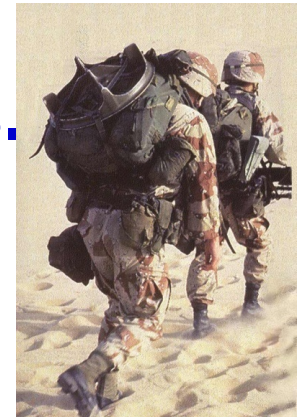
Principle (RR)

IR PPG



Use of Commercial Pulse Oximeters as a Wearable Device in the Field is Challenging

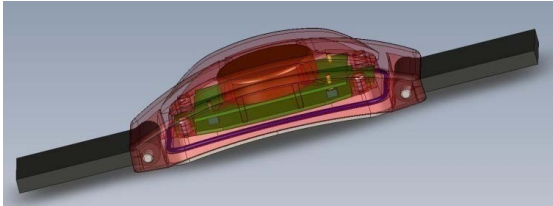
- Must operate reliably under adverse environmental conditions.
- Can not limit normal activities.



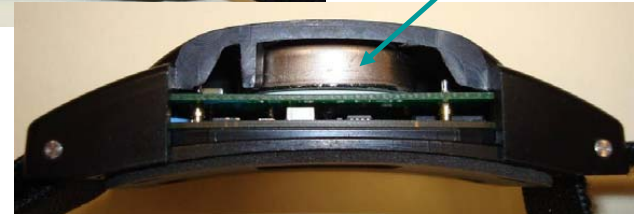
Design Criteria

- Multiple physiological variables
- Low power consumption
- Cost effective
- Small size
- Light weight
- Easy sensor attachment
- Transparent to user (“wear-and-forget”)
- Adequate computation power
- Wireless communication
- Improved immunity to motion artifacts

Wearable Pulse Oximeter



Battery Module



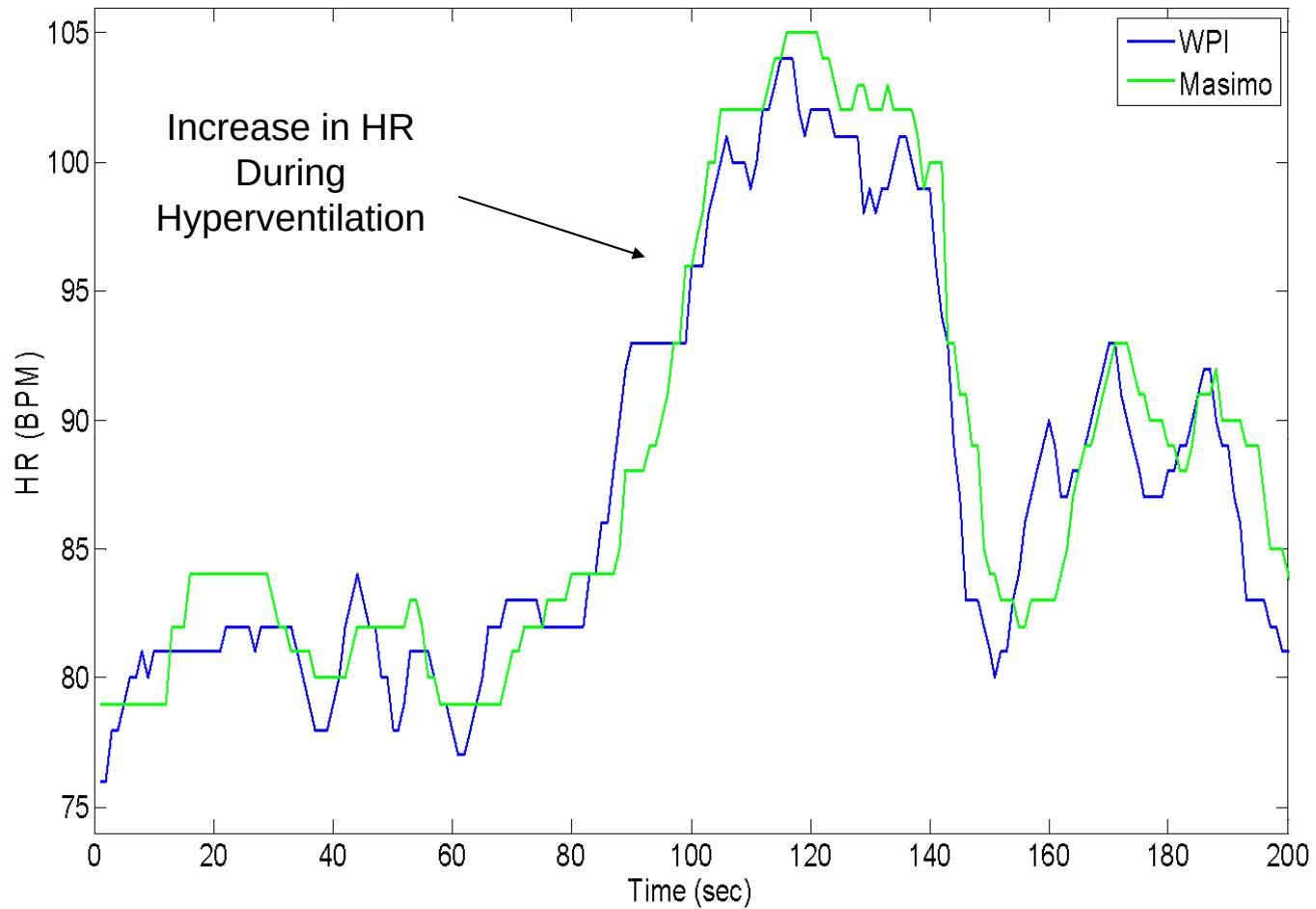
USB-Based Receiver



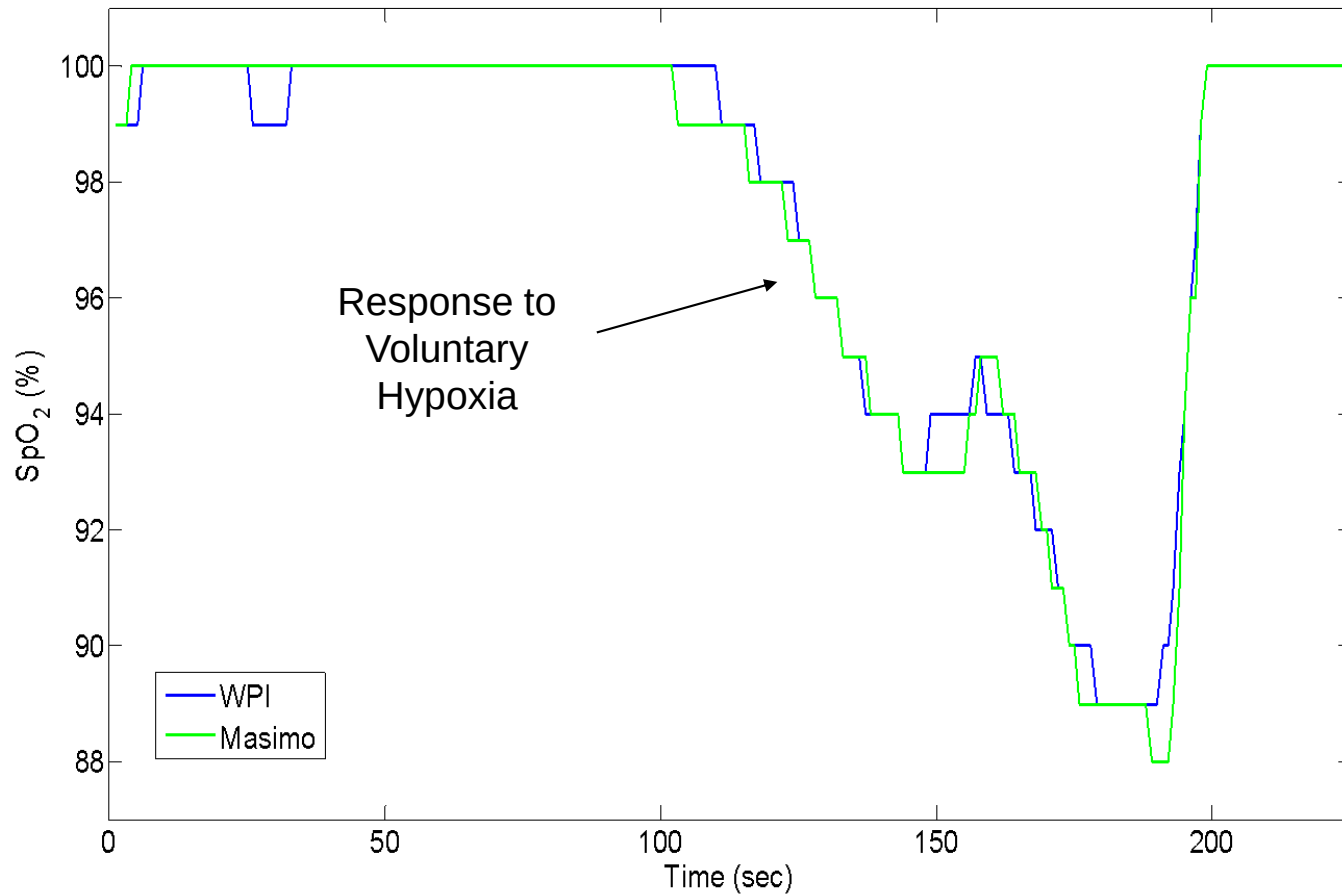
User Interface



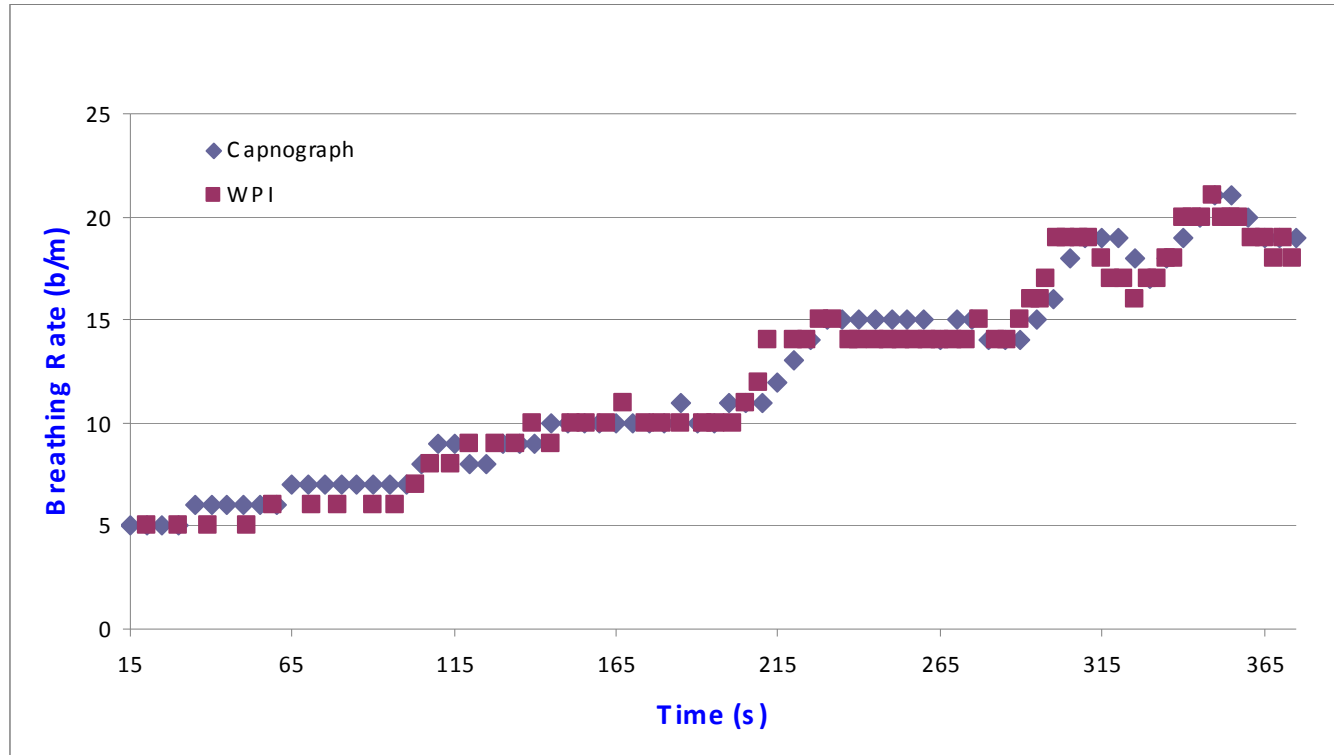
Measurement Validation (rest)



Measurement Validation (rest)

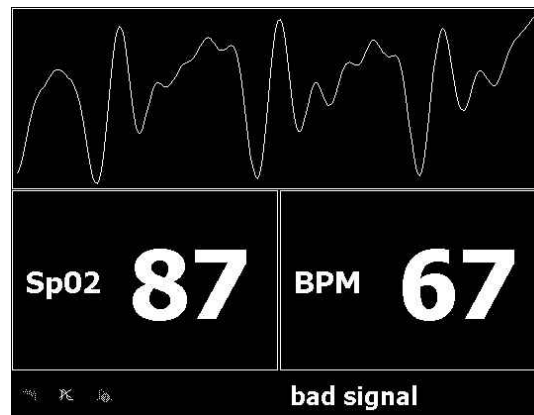


Measurement Validation (rest)

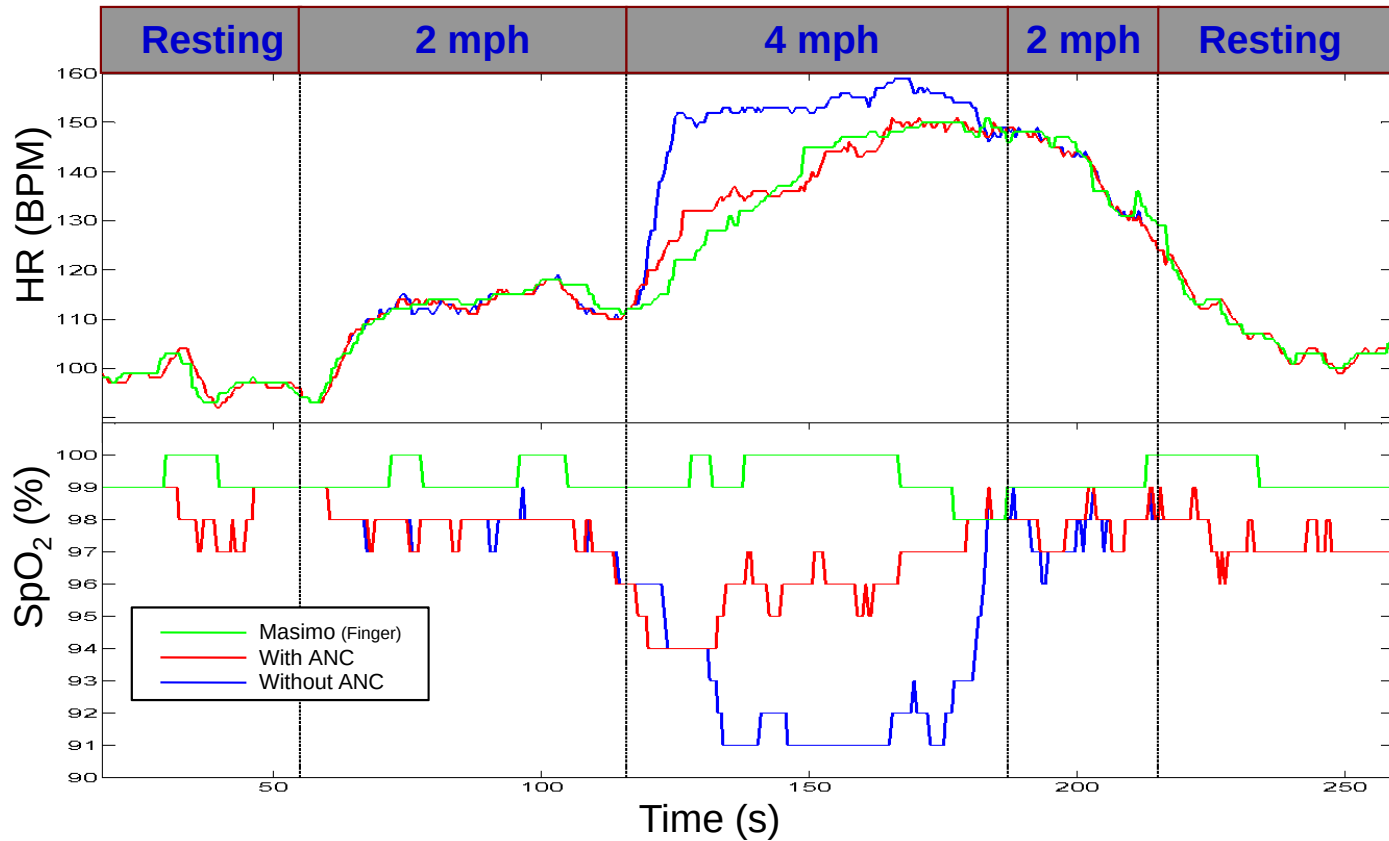


Limitations of Pulse Oximetry

- Highly reliable when used on motionless subjects.
- Motion artifacts can obscure the true PPG signal with noise, leading to inaccurate readings, false alarms, dropouts, and missed true alarms.



Adaptive Noise Cancellation in Pulse Oximetry



Future Developments

- Firefighters can experience inhalation of CO (e.g. malfunctioning furnaces) and Cyanide (e.g. burning plastic products).
- Acute CO and HCN poisoning renders the blood unable to carry sufficient amount of O₂.
- Symptoms of acute exposure include general weakness, headache, confusion, anxiety, nausea and vomiting.
- If exposure is severe, unconsciousness and death.

Future Developments

- Traditional testing of HbCO and MetHb involves blood sampling and waiting for lab results.
- Conventional pulse oximeters use only two wavelengths of light.
 - They cannot distinguish between HbO₂, HbCO and MetHb.
 - Provide false readings when CO and MetHb levels are elevated.
- Multi-wavelengths to measure SpO₂, HR, HbCO and MetHb, simultaneously.

ACKNOWLEDGEMENTS

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Thank You!

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