Prevention of Narcotics-Induced Respiratory Depression by Optical Early Detection and Capture

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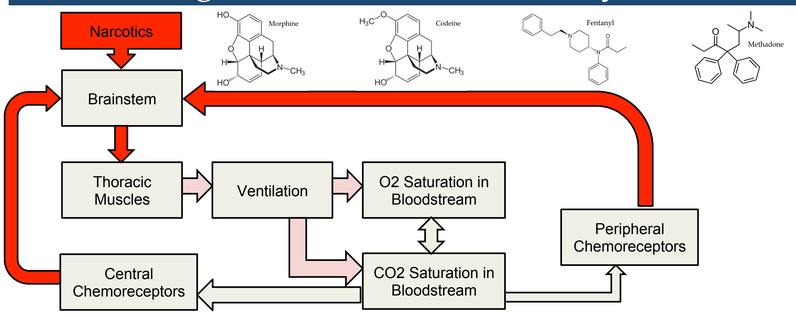
Background: "Dead in bed" syndrome



$$H_2O + CO_2 \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

- Narcotics, given for pain relief and sleep assistance after surgery, can inhibit the brainstem's control over breathing and lead to depressed ventilation, which can fatally deprive the patient of oxygen
- Current gas saturation and manual surveillance methods to detect this phenomenon do not provide timely and instructive information on patient respiratory activity.

Top Unmet Clinical Needs

Observation	Primary Need	Secondary Need
Fatal episodes of depression often happen when nobody is watching	The device is sensitive to changes in patient breathing	The device runs continuously. The device can detect when a person stops breathing. The device works regardless of positioning of the body.
Monitors and checking schedules irritate nurses and patients.	The device provides a comfortable experience to patient and staff.	The device is noninvasive. The device is precise and accurate. The device can simply be adjusted by medical staff.
Current NIRD detection senses patient respiratory symptoms.	The device detects important respiratory physiological trends.	The device eliminates the needs for human surveillance.

Our top unmet clinical need represents a significant roadblock of current methods to detect respiratory depression: measurement of specific indicators of narcotics-induced respiratory depression.

Benchmarking and Target Specifications

Metric	Unit	Gas Saturation	Human Surveillance	Marginal Value	Ideal Value
# of errors made per body position	Errors/ position	0	1-3	<3	<0
Time delay between respiratory arrest and alert	minutes	2	2-15	<5	<1
Accuracy in discriminating safe from critical values (for O_2 saturation under 80%)	Correct/ Total alerts	>95%	>99%	>95%	>99%
Distance from patient	Meters	0	>2	0	>2

To meet our top unmet clinical need and to outperform the current gold standards, our specifications for the top metrics serve as a standard that a sensitive, rapid, and specific solution must meet or surpass.

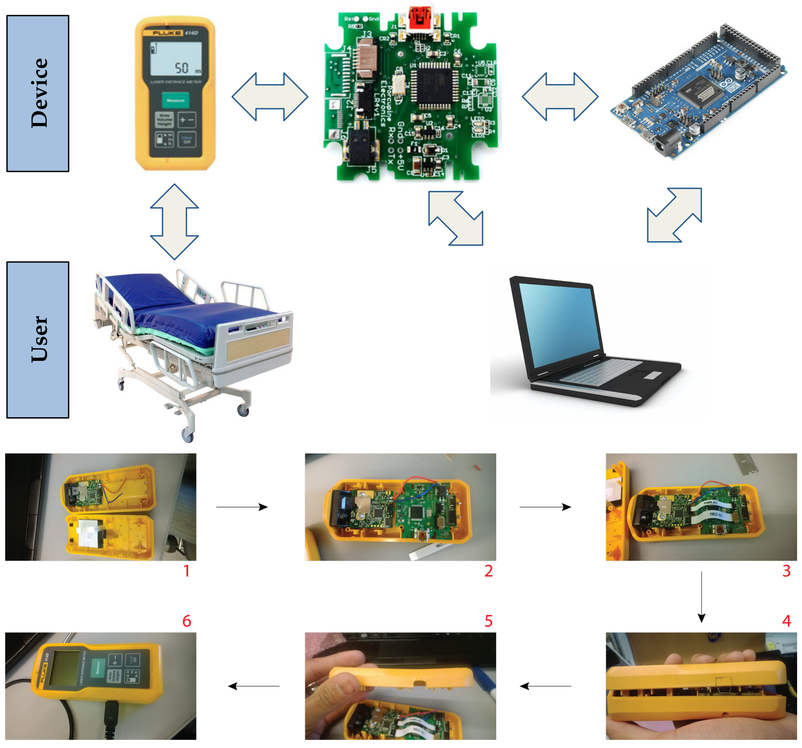
Concept Generation and Selection

Signal Detected	Alarm System	Patient Interface
Visual	Single Parameter	In Patient
Audio		On Patient (wired)
Electrical		On Patient (wireless)
Motion	Multi Parameter	Not On Patient
Chemical		
Thermal		

Sensing	Advantages	Tradeoffs
Thermal	• Live humans always emit heat	• Difficult to discern specific bodily events
Chemical	• Measurement of imperceptible moieties in human being	• Variable lag times between physiological change and signal manifestation
Optical	• High degree of precision	• Delicate, very power-consuming
Kinetic	• Human motion is ubiquitous	• Error-prone due to residual movements
Acoustic	• Data-rich readings from human body	• Data tends to be very noisy
Ultrasonic	• Low-cost detection of internal anatomy	• Lower resolution, prone to interference

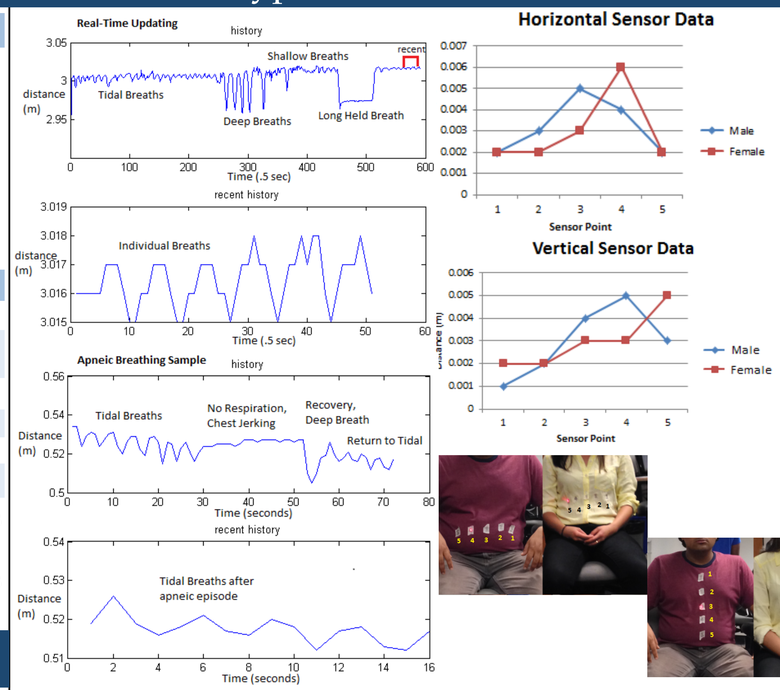
- Concepts were generated based on combinations of types of signals detected, alarm systems, and patient interfaces
- Of the sensing methods relevant to device design, pptical methods were chosen for their high resolution readings.

Top Concept : Laser Rangefinder (LRF)



Our top concept is a laser rangefinder that uses optical measurements of chest displacement to detect ventilatory status of patient. The laser rangefinder uses USB interface boards to communicate with a computer.

Prototype Results and Conclusions



- During a three-minute breathing time course, our LRF successfully detected four major types of physiologically normal breaths (tidal, deep, shallow, and held) and successfully resolved apneic episodes.
- Device was sensitive to displacements as small as 0.001 meters and within a second of activity.
- Maximum displacements reported when LRF is aimed at the patient's sternum (position 3).

Future Work

- Improvements to make laser emission safe for indefinite exposure
- Design of positional guidance system to make device compatible for all patient positions in hospital room
- Programming to discern specific respiratory events and trends

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