Confidence-based Data Management for Personal Area Sensor Nets

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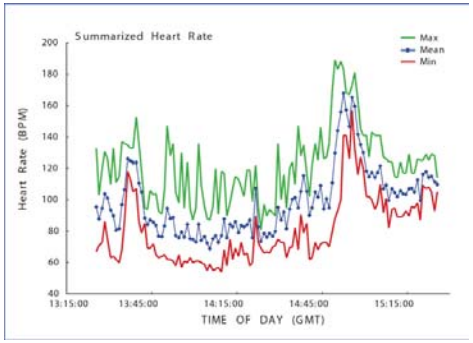
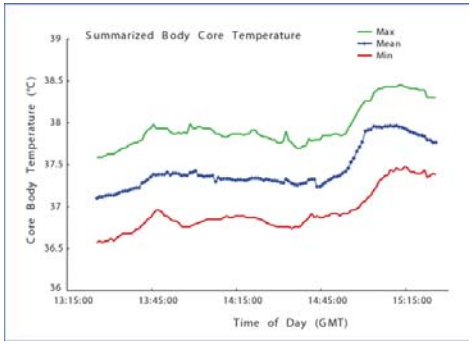
Talk Outline

- Warfighter Physiologic Status Monitoring (WPSM)
- Confidence-based Data Management for WPSM
- Related Work
- Future Directions

Warfighter Physiologic Status Monitoring (WPSM)

Soldier's life is hard.





Watch status remotely.

Prevent casualties.
Improve soldier's health.
Manage resources.

WPSM: The Wearable Sensor System

Medical Hub
Ambient Temperature
Worn on Belt

Core Temperature Pill
Ingested

Sleep Performance Watch
Worn on Wrist

GPS System
Worn on pack

Fluid Intake Monitor
Worn on Back

Life Sign Detection
Ballistic Impact Detection
Skin Temperature
Heart Rate
Respiration Rate
Actigraphy
Body Orientation
Worn on Chest

WPSM: Determining Physiologic Status

Physiologic Models

Area	State	Confidence
Thermal		90%
Hydration		60%
Cognitive		100%
Life Signs		90%
Wound Detection		80%

- Normal
- Attention
- Immediate Action
- System Fault

Uncertainty due to:
- models
- sensor data

WPSM: Estimating Thermal State

- Physiologic models and sensors required:

Model	*Skin Temp*	*HRate*	*Actigraphy*	*Geo-Loc*	*Resp Rate*	*Pill*	*# Sensors*
TSkin	✓						**1**
Threshold	✓	✓					**2**
Model1			✓				**1**
Model2			✓	✓			**2**
Model3		✓	✓	✓	✓		**4**
TCore						✓	**1**

WPSM: Confidence in State Estimation

- Confidence = F (Model, Latency, State, Environment)

Some models provide higher confidence.

Tskin	*Threshold*	*Model1*	*Model2*	*Model3*	*TCore*
50	70	80	90	95	100

Confidence decays due to latency (L) of a reading.

$$2^{-(\lceil L/15 \rceil - 1)}$$

Some states can be determined with higher certainty.

G	*Y*	*R*
50	47.5	45

Environmental conditions affect confidence of a model.

Env	*Work*	*TSkin*
cool	high	40
warm	high	20
hot	high	5

WPSM: Confidence Requirements

- Higher confidence is required for more important events:

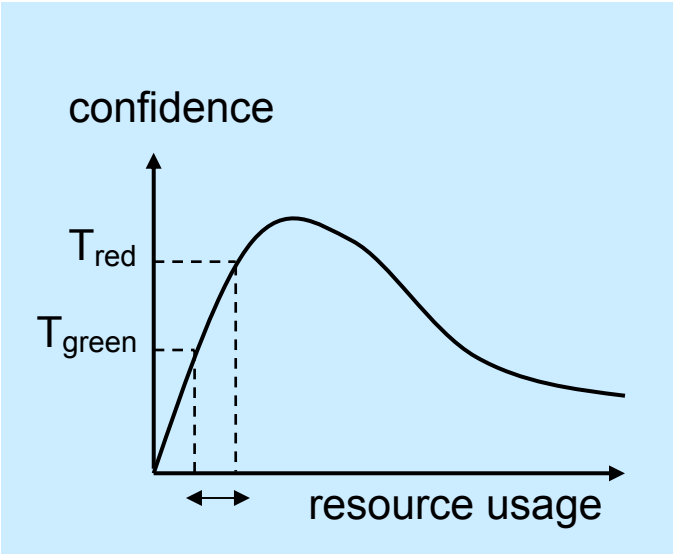
State	*Threshold*
Green	≥ 50
Yellow	≥ 70
Red	≥ 80

- Goal: to deliver state estimations with sufficient confidence at all times.

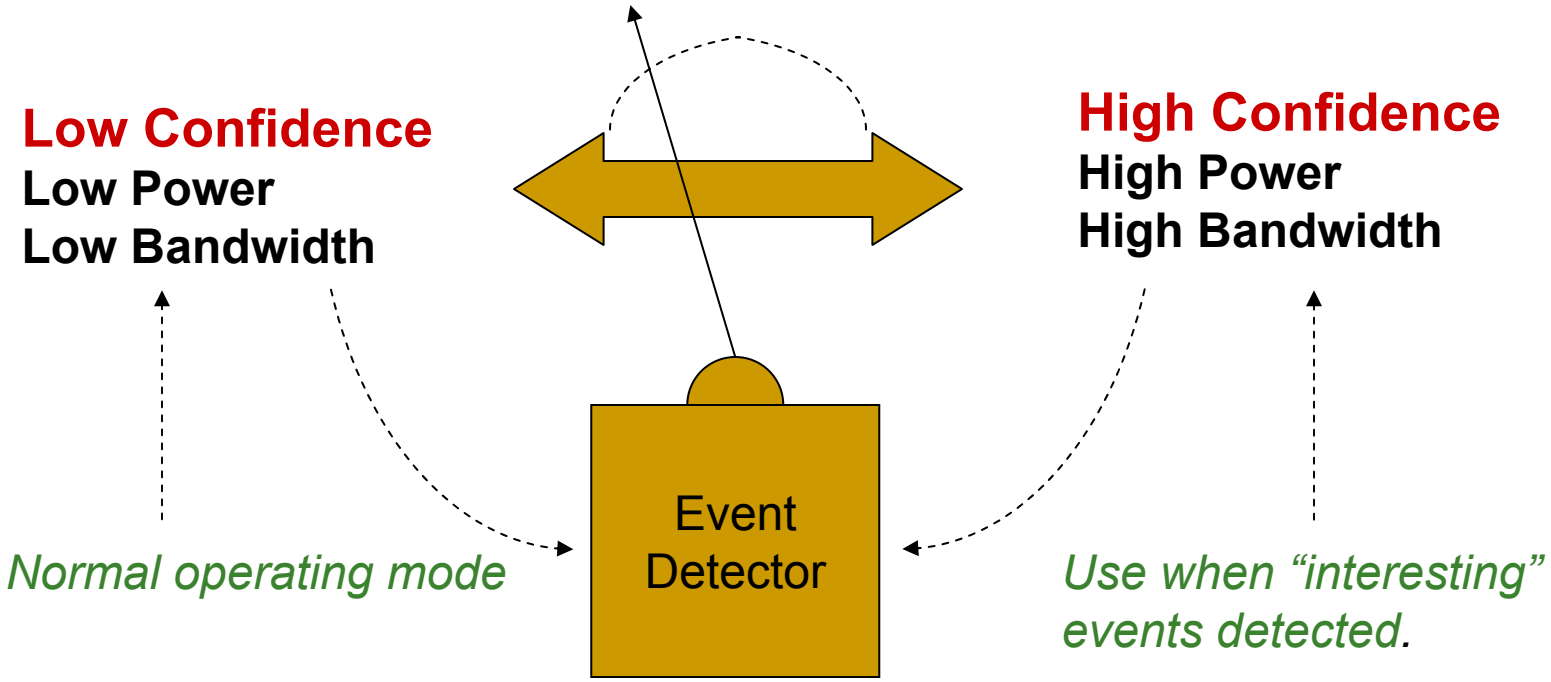
The Confidence Paradox

- Higher confidence requires higher network traffic
  - use more sensors
  - sample more
- Higher network traffic may cause
  - shorter battery lifetime
  - collisions and drops
  - higher latency

  .. and therefore, lower confidence



Confidence-based Data Management (CDM)



Only consume more resources when you need to increase confidence.

CDM: Exploiting Redundancy

- Sensors push at factory-set sampling rates
- Run models concurrently and pick the highest confidence estimation

Model	***Avg. Confidence***	***% Drop***
Model 1	64.92	0
Model 2	72.73	1.98
Model 3	77.75	5.79
All	79.22	5.71

- Responds to dynamic changes in confidence factors, *but not resource-efficient*

CDM: Adjusting Sampling Rates

- Sensors push at adjustable sampling rates
- Sensors sampled at different rates based on
  - Model sharing
  - Physiologic area importance
  - Latency decay functions
- *Readjustment required when confidence factors change*

CDM: Two-way Data Communication

- Sensors push at dynamically adjustable sampling rates
- Dynamic switch between estimation models
- Improved battery lifetime:

Model3	***Model1 → Model2 → Model3***
9 hours	14 hours

Related Work

- Query Processing in Sensor Networks
  - e.g., TinyDB, Cougar
- Quality- and Model-driven approaches
  - e.g., TiNA, QUASAR, BBQ
- Data Management for Personal Area Sensor Nets
  - e.g., T2, CodeBlue
- Wireless Sensor Networks
  - MAC protocols like S-MAC

Future Directions

- The big picture: remote triage beyond the warfighter
- Pushing model computation into the sensor network
- Confidence modeling for unreliable devices
- More robust statistical models (e.g., Bayesian Networks)
- Failure handling

More Information

- WPSM web page:
  - http://www.usariem.army.mil/wpsm/
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