Understanding the Impact of Laptop Power Saving Options on User Satisfaction Using Physiological Sensors

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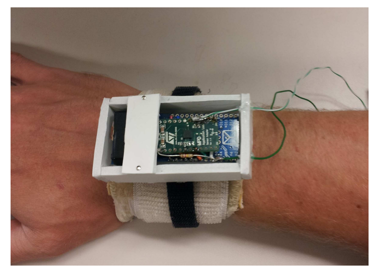
Introduction

- Many techniques can save power in laptops
- The effect on user satisfaction has not been well studied
- We analyze how power saving affects user satisfaction
- Using sensors, can predict user satisfaction with over 80% accuracy

Experimental Setup

User studies

- Users are attached to biometric sensors
- Play racing game for 45 minutes
- While playing game, 'annoyance events'
- Annoyance events reduces the computer's power usage by a specific Wattage
- **Goal**: detect if the user's biometric data changes due to performance changes



(a) Accelerometer + GSR

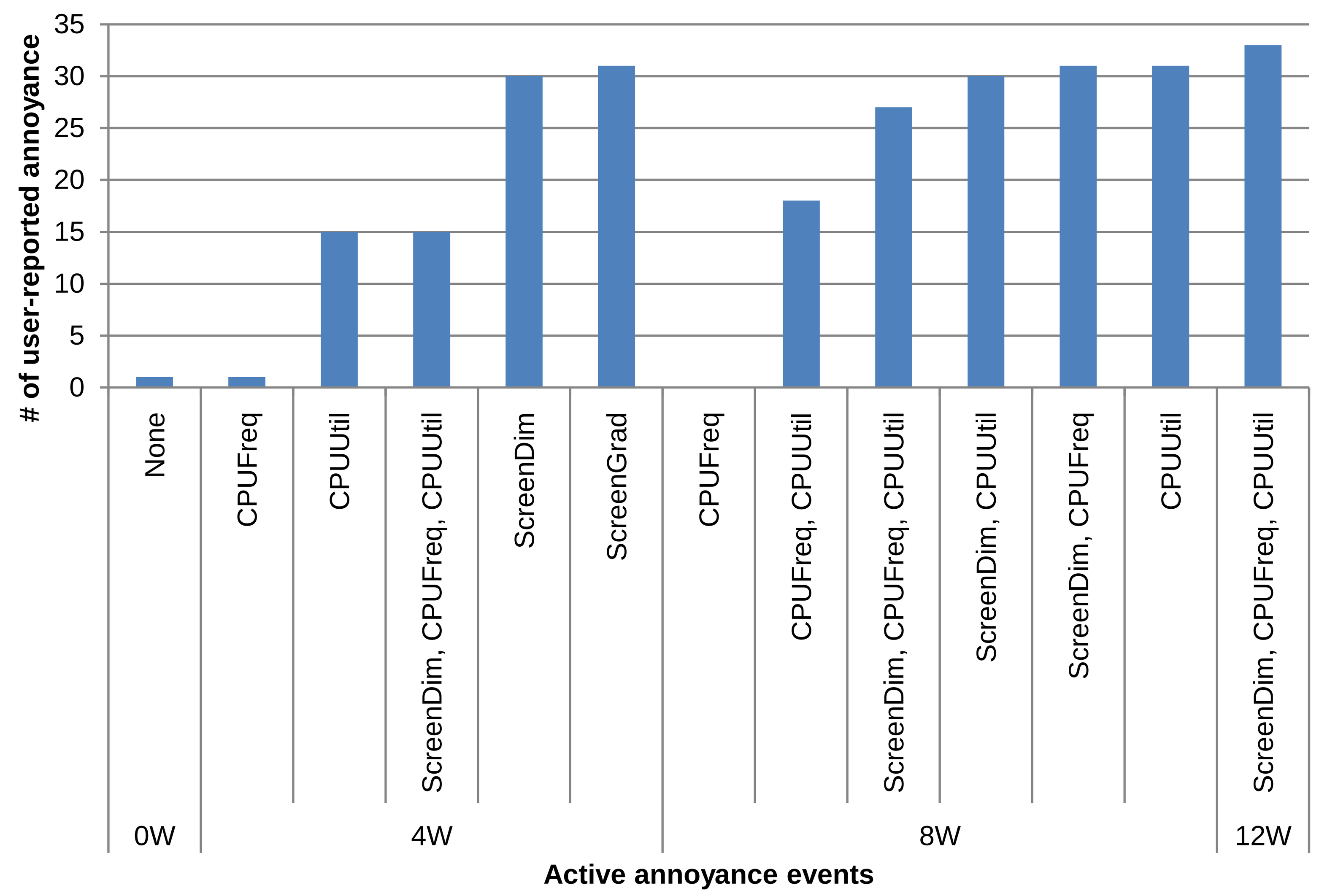
(b) Keyboard Force Sensors

(c) Head-mounted Eyetracker

Annoyance events

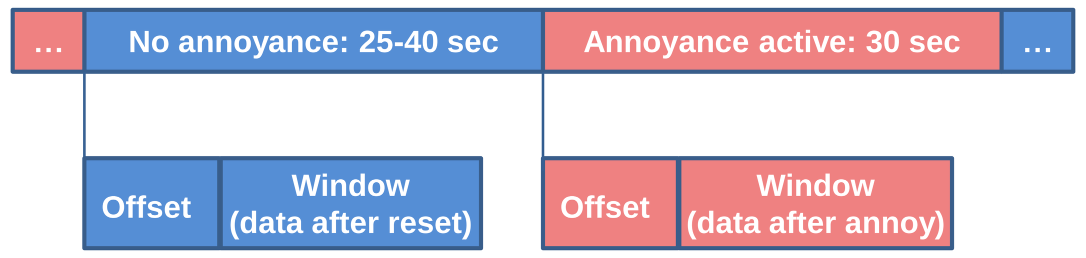
- CPUFreq - Processor frequency
- CPUUtil - Processor utilization
- ScreenDim - Screen brightness (instantaneous)
- ScreenGradual - Screen brightness (gradual)

Annoyance Events



Statistical Analysis

Goal: verify that we can detect a change in the sensor data before and after each annoyance event



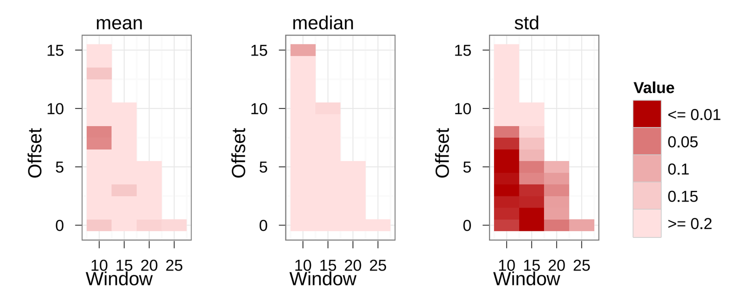
Method:

1. Post-process raw sensor data from 'annoying' events into sensor metrics
2. Group metric data around annoyance events for multiple windows/offsets
3. Take the standard deviation, mean, and median of above groups
4. Run a 2-tailed t-test comparing data from before/after annoyance
5. p-value <0.1: likely is a change in sensor data due to annoyance event

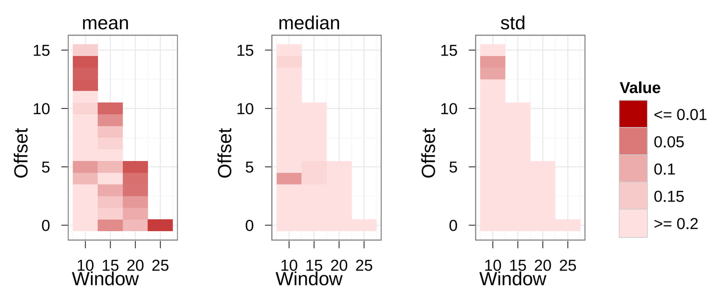
Metric	Sensor Location	Metric Description
AccelMag	Wristband	sum of squares of X, Y, and Z accelerometer axes
DeltaGSR	Wristband	change in GSR value since the last sensor reading
Keypress	Software	time since the last keyboard button press
MaxForce	Keyboard force sensors	largest current value from the force sensors
NormalMaxForce	Keyboard force sensors	same as MaxForce, but normalized to each key's highest force reading
PupilMovement	Head-mounted	change in position of the pupil since the last pupil reading
PupilRadius	Head-mounted	the radius of the pupil

Statistical Analysis Results

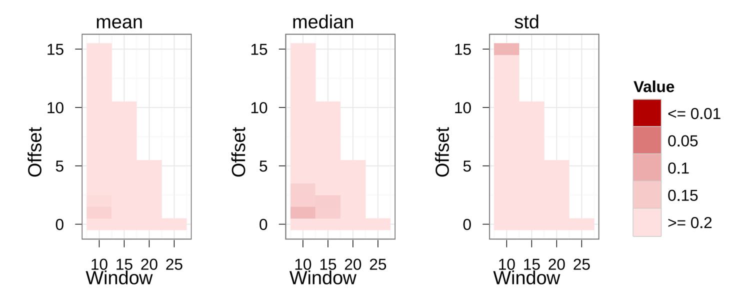
- T-test graphs compare data around 'annoying' events
- Sensors have varying 'lag time' (offset)
- Smaller windows are generally more effective than larger ones
- Additional analysis in paper



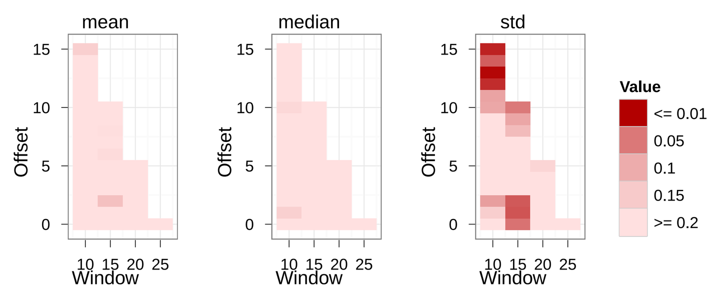
(a) DeltaGSR



(b) KeyPress



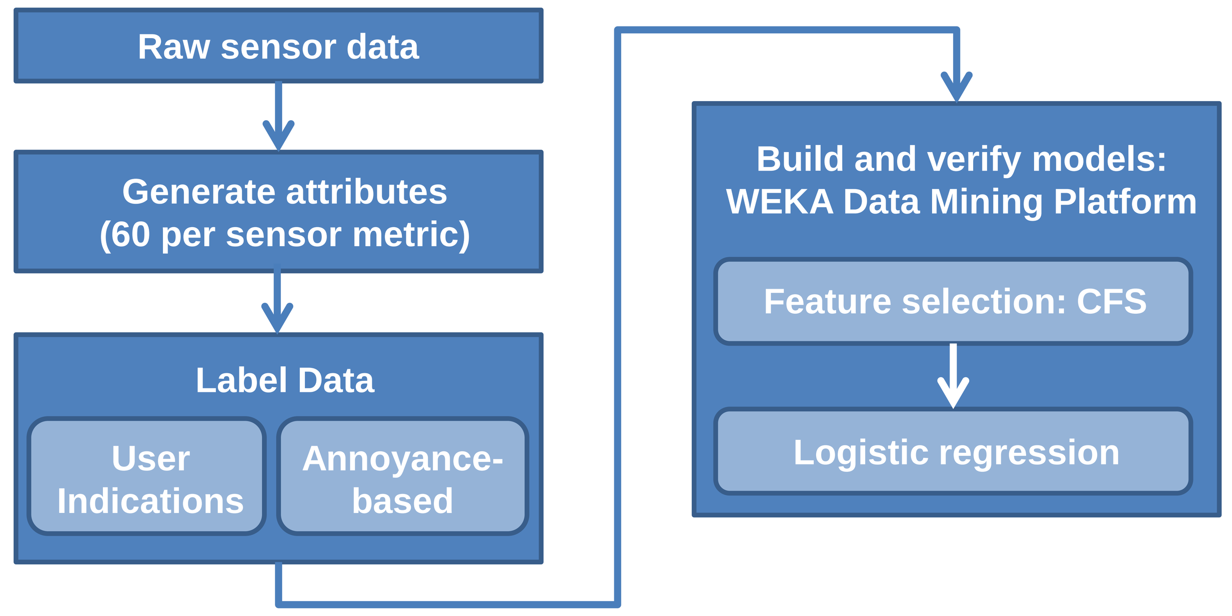
(c) NormalMaxForce



(d) PupilMove

Prediction System

Goal: Predict when the user is (and isn't) annoyed



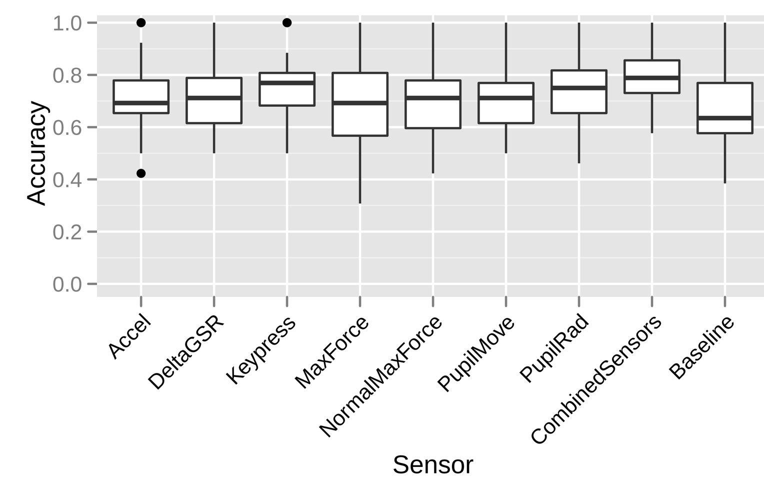
Prediction Results

User Study 1

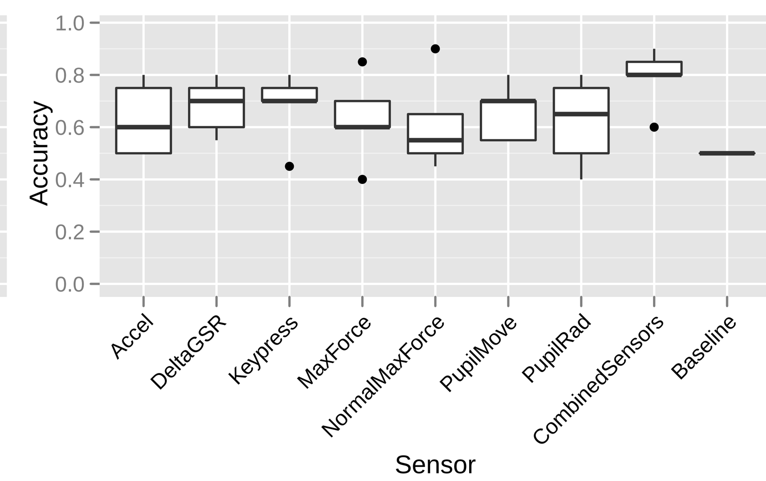
- 20 users
- Users verbally indicate when performance worsens
- 520 total annoyance events
- User indicating annoyance labels data 'true'

User Study 2

- **Purpose**: Indicating annoyance may affect sensor data
- 5 users
- Users don't indicate when performance worsens
- 100 total annoyance events
- Use subset of annoyance events
- Label data w/ Study 1 annoyance frequencies



(a) Prediction Accuracy (Users Indicate Annoyance)



(b) Prediction Accuracy (Users Don't Indicate Annoyance)

Conclusions

- Power saving generally less noticeable w/ multiple simultaneous techniques
- We can statistically differentiate between when user is and isn't annoyed
- Can predict user annoyance with up to 80% accuracy w/ no user indication
- Provides new routes for power optimization