Sensing User Intention and Context for Energy Management

Angela Dalton
Carla Ellis

The Milly Watt Group
Duke University Department of Computer Science

Outline

- Motivation
- Case Study
  - FaceOff Architecture and Prototype
  - Evaluation
    - Best Case Feasibility Study
    - Responsiveness Study
- Future Work
- Conclusion

Motivation

- Current energy management techniques tied to process execution
- Can we use low power sensors to match I/O behavior more directly to user behavior and reduce system energy consumption?

Sensing User Intention and Context for Energy Management

Case Study: FaceOff

- Displays:
  - Typically responsible for large power drain
  - Power State can be controlled by software
  - State transition strategies naïve

A display is only necessary if someone is looking at it.

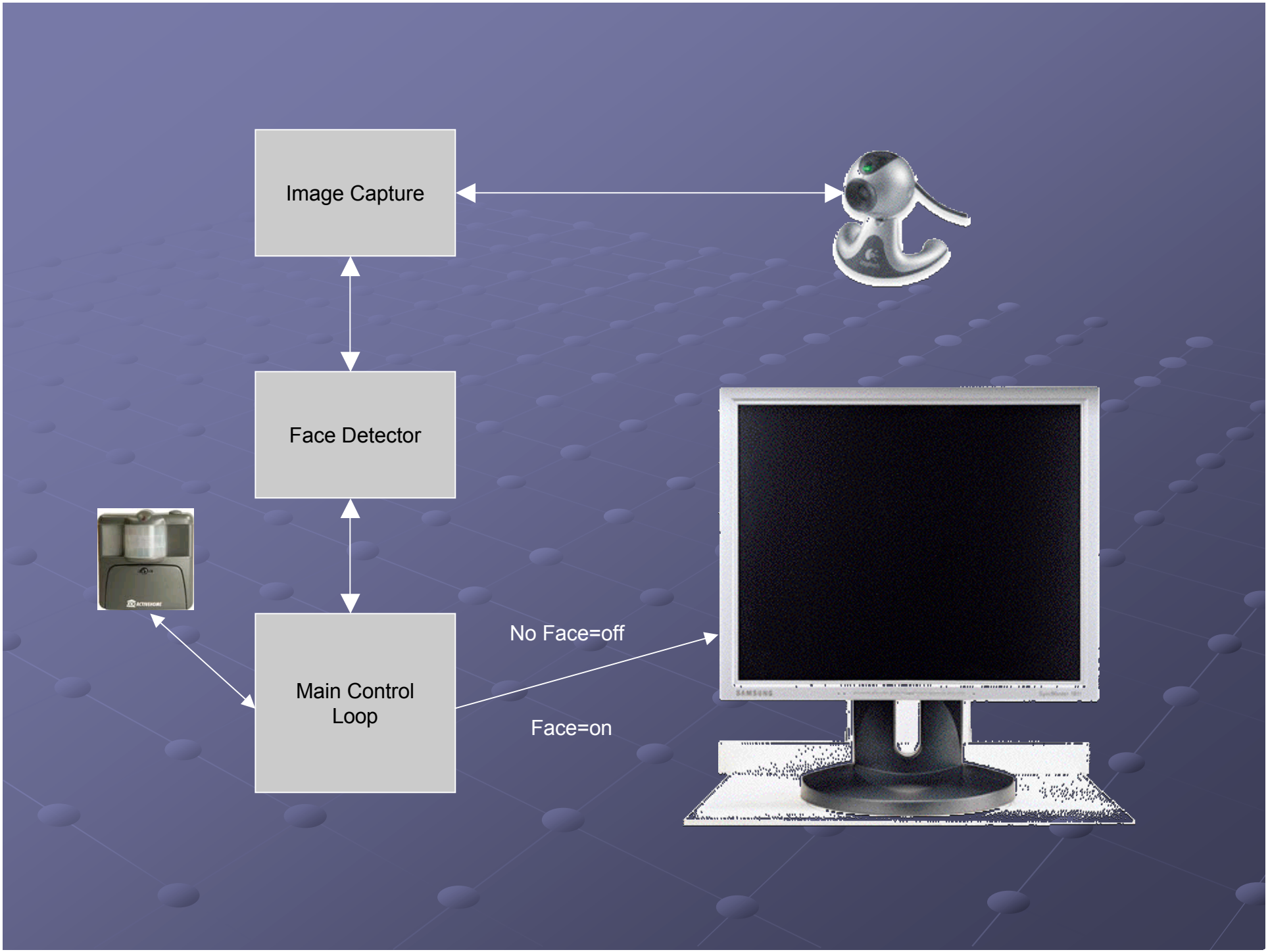


Image Capture
Face Detector
Main Control Loop
No Face=off
Face=on

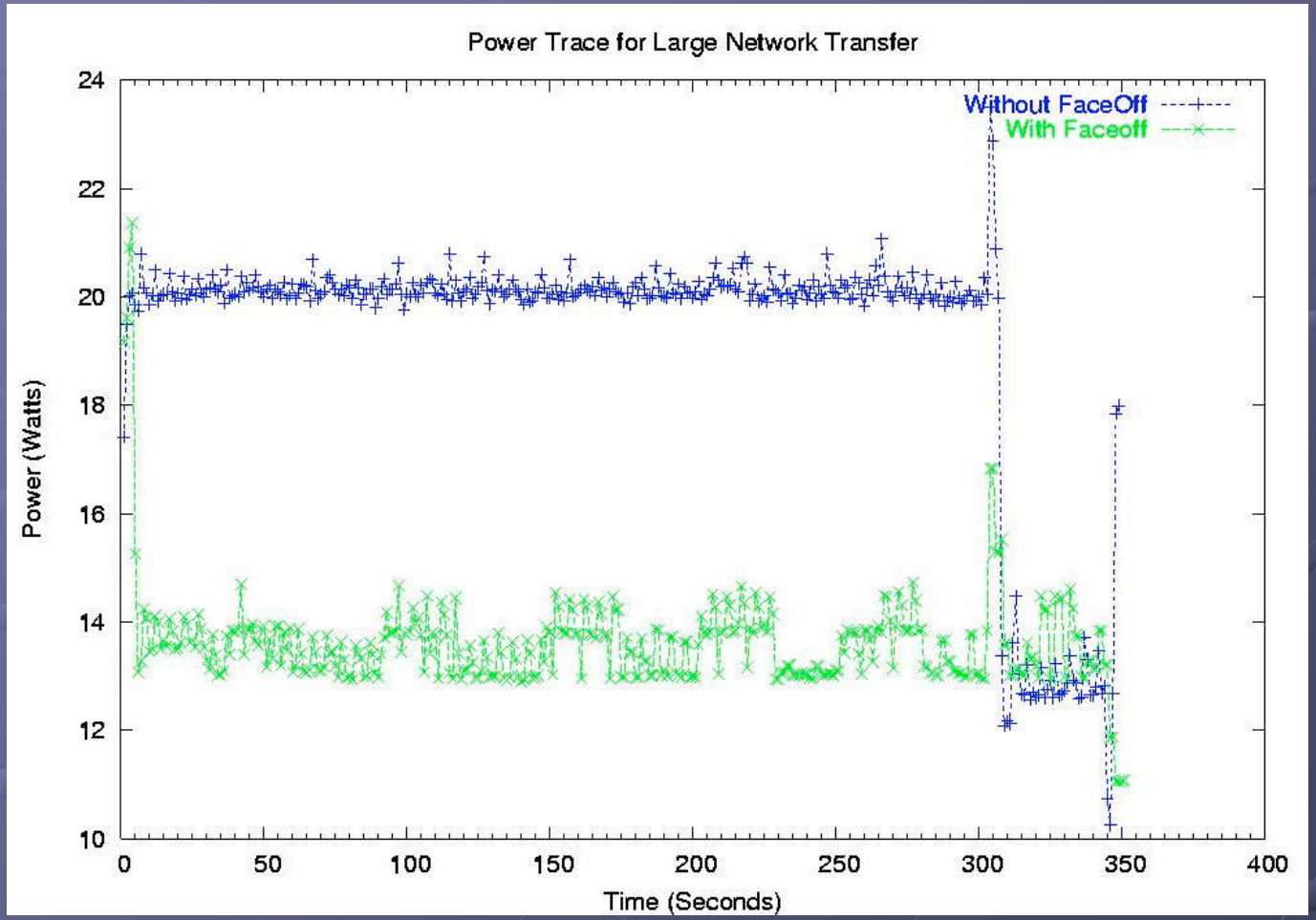
Prototype

- IBM ThinkPad running Linux
  - Base Power Consumption = 9.6 Watts
  - Max CPU = 8.5 Watts over Base
  - Display = 7.6 Watts
- Logitech QuickCam Web Cam
  - Power Consumption = 1.5 Watts
- Software components:
  - Image capture, skin detection, display power state control

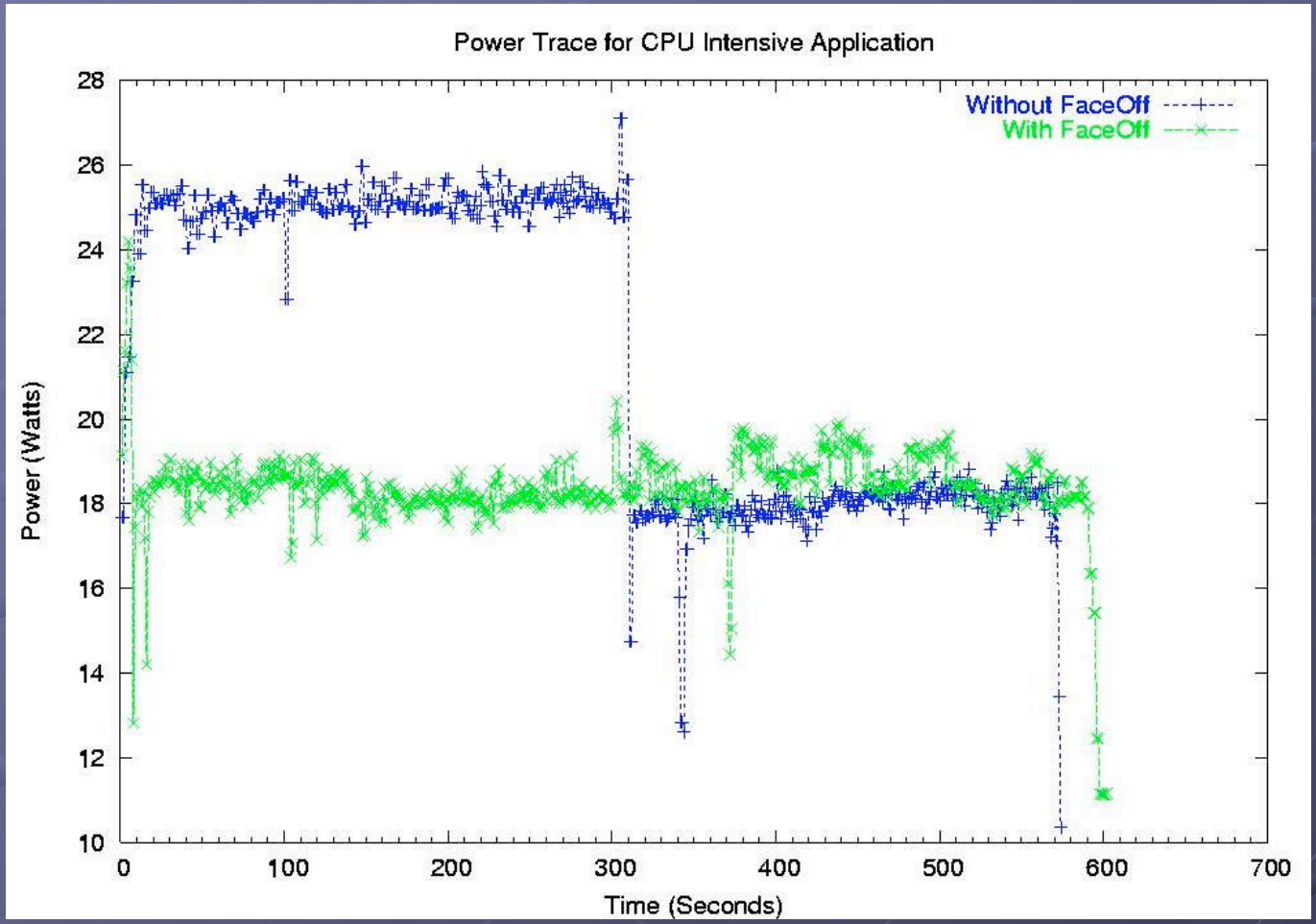
Best Case Feasibility Study

- What is the potential for energy savings?
  - Assume Zero Overhead and Perfect Accuracy
- Tradeoff of energy costs:
  - CPU/Camera vs. Display
- Effect on System Performance
  - Network file transfer (113 MB)
  - CPU intensive process (Linux kernel compile)
  - MP3 Song (no display necessary)

File Transfer Traces



Kernel Compile Traces



Energy and Time Comparisons

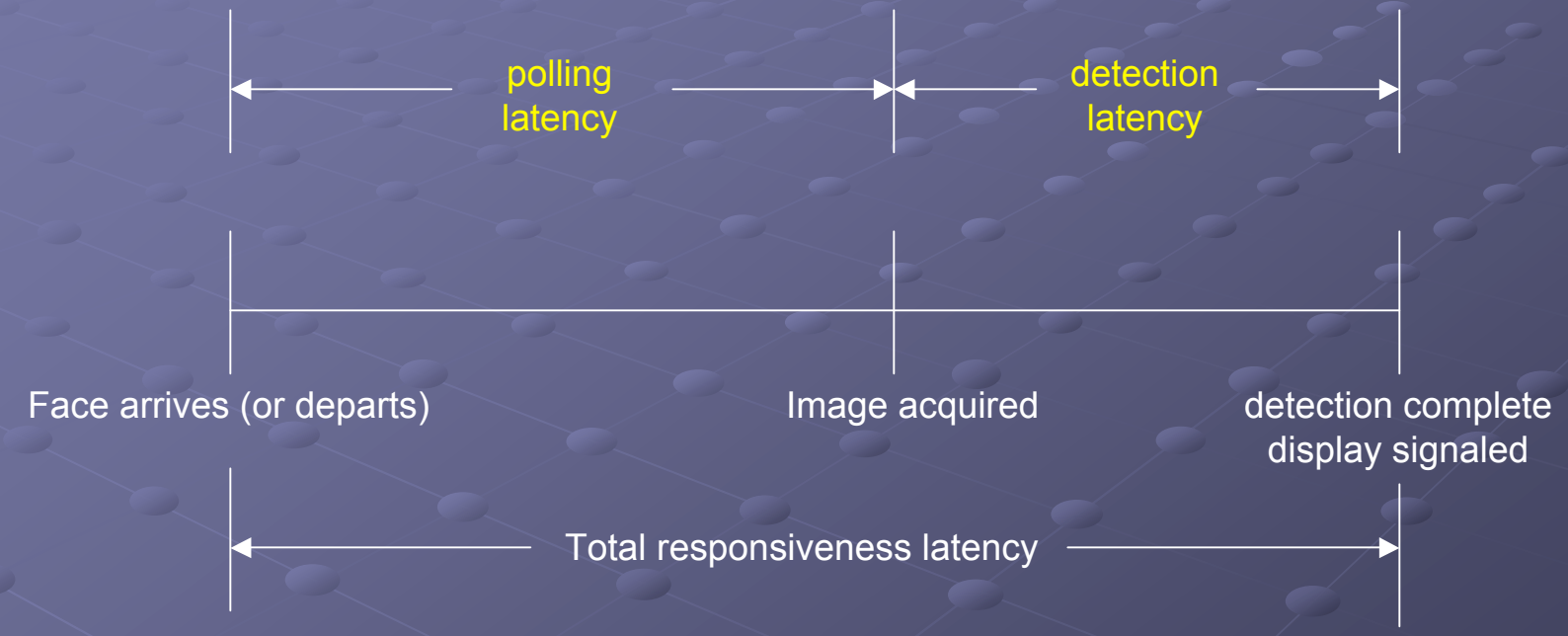
Energy(J)	Default	With FaceOff	% Savings
Compile	12506.85	11023.07	11.86
Transfer	6795.42	4791.19	29.49
MP3 Song	4,714	3,403	27.81

Time(s)	Default	With FaceOff	% Overhead
Compile	575	603.5	4.96
Transfer	348.6	351.3	0.77
MP3 Song	251	251	No noticeable effect on playback

Responsiveness Study

- Use full prototype including skin detection
- Establish baseline timing
- Examine Responsiveness
  - varying system load
  - varying polling rate

Responsiveness Timing



Baseline Timing

- Prototype Polling Latency
  - On average _ image polling rate
  - 500 ms on average for 1 s polling rate
- Baseline Detection Latency
  - ~135 ms
  - Ran system for a period of one hour
  - No load on system

Detection Latency Under Load

Workload	Average (99% Confidence)	Maximum	Minimum
Network Transfer	175±7ms	305ms	116ms
Kernel Compile	230±5ms	669ms	51ms
MP3 Song	154±3ms	229ms	84ms

Varying Polling Rate

- Reduce overhead by reducing polling rate
  - Increases responsiveness latency
- Adaptive polling rate
  - Eliminate polling in presence of UI events
  - Begin polling as duration without UI events increases and face is detected
  - Reduce polling when no face present
    - Similar problem with latency increase upon return

Optimization with Motion Sensor

- Combine adaptive polling & motion sensing
- Meet responsiveness requirements with minimal FaceOff system overhead
- Eliminate image polling when no motion
- Switch display state on immediately when motion detected and restart image polling

Implementation

- Prototype using X10 ActiveHome Wireless Motion Sensor and Receiver
  - Receiver connects to serial port
  - Reading port blocks until sensor triggers
  - Takes up to 10 seconds to recharge
- Promising addition to FaceOff system

More Roles for Sensors

- Touch Sensor
  - Detect picking up of a PDA
- Light, Sound sensors
  - Adjust display brightness (iPAQ)
  - Adjust speaker volume
- 802.11 Signal Strength sensor
  - Determine possibility of offloading computation

Enhanced Sensors

- “Active Camera”
  - Perform some or all of the face detection
- Color filtering
  - Preprocessing skin color segmentation
- Low Power microcontroller for external sensor control, computation

Future Work

- Continue work on optimizing responsiveness
- Comprehensive user study
  - Survey of usability
  - Characterization of usage patterns
    - End-to-end experiment

Conclusions

- Context information offers promising method of energy management
- FaceOff illustrates feasibility of approach
- Available very low power sensors as well as optimization techniques would improve upon the FaceOff energy savings

Questions?

The Milly Watt Group

http://www.cs.duke.edu/ari/millywatt

Duke University Department of Computer Science