Wearable Computing

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Sensors

Human Computer Interaction II

- Design Principles
- Theories
  - Levels-of-analysis
  - Stages-of-action
  - GOMS
  - Widget-level
  - Context-of-use
  - Object Action Interface models

Sensors and Wearables

- User
- Place
- Task
- Environment

Sensing the User

- Presence of a user
- Actions and Tasks
- Body and Mind

Simple example: Presence of the user

- Useful for the wearable computer: Save energy
- Useful for other systems: Communicate the presence of a user
- Useful for the user: No “on”-Switch...

Detecting User Presence

- Tactile: Design switches that detect

  Pro: Easy to implement (binary input)
  Con: Can be fooled.
- Temperature: Design sensors that detect body heat

  Pro: Harder to fool (but still possible), easier to integrate
  Con: harder to interface, computation needed
- Motion: Detect body motion

  Pro: Even harder to fool
  Con: even harder to interface, computation and signal analysis needed

The details . . .

- Task: Detecting users of a body-worn wearable computer
- Mechanics: User's Body presses switch when user is present
- Textile: pressure-sensitive textiles
- Electronics: Schmitt trigger circuit
- Computer I/O: Binary input
- System Software: event-driven, similar to ACPI switches
- Application Software: Event API

Sensors and signals

- A *sensor* is a transducer that is used for measurement
- (A *transducer* is a device that converts one form of energy to another)
- Sensors measure a property of the physical world . . .
- . . . and produce a corresponding signal that can be processed.
- Evaluating the signal at one fixed point in time is called a *measurement*
- A number of measurements taken at different times is called a *time series*
- Typically, these measurements are taken *sequencially at fixed equal time intervals*, i.e. once every second

Signals and Computers

- Typically, sensors produce electrical signals
- A property of the electrical signal (current, voltage, frequency, pulse width, phase) corresponds to the property measured by the sensor.
- In order to use the signal in a computer, the relevant property of the signal needs to be converted into a binary representation.
- This process is called A/D-conversion. It is performed by an A/D-converter.
- Typical A/D-converters convert the voltage of a signal into a binary representation.

Sampling

- Performing the digitalization of a signal at a fixed point in time is called sampling. Sampling is a form of measurement.
- Signals are continous, a binary representation produced by an A/D-Converter is discrete.
- Multiple signal values reproduce the same binary representation. This phenomenon is called *quanitzation*
- Through quantization, information is lost, resulting in the so-called *quantization error* for a single measurement and *quantization noise* for the whole signal.

How often do we need to sample

- Sampling in regular, fixed time intervals T produces a time series of binary values.
- The frequency $\frac{1}{T}$ is called sampling frequency.
- Question: How often do we have to sample? Answer: Depends on the signal
- The faster and the more often the signal changes, the more often we have to sample.
- Rule of thumb: Sample slightly more than twice as often as the period of the highest frequency component in the signal.
- Example: CD-Player Signals $\leq$ 20kHz, sample rate 44.1kHz

Classification of sensors

- Measured property
- Type of measurement (absolute vs. relative)
- Dimensionality
- limiting factors: precision, noise, frequency response,. . .

Measurable properties

- Distance and Position
- Motion
- Light
- Temperature

Distance and Position

- Signal Attenuation
  - Propagation of a signal in a medium
  - Assumption: propagation path attenuates signal
  - Original signal strength s_1, received signal strength s_2
  - Attenuation depends on signal properties and path properties
- Time-Of-Flight measurement
  - Propagation of a signal in a medium
  - Assumption: constant propagation speed v
  - Signal transmitted at time t_1, received at time t_2.
  - $d = (t_2 - t_1)v$

Position from distance and angle

- Triangulation
  - Known distances from three known points
  - Known distance differences from four points
  - Example: GPS
- Angle-of-arrival
  - Position from three angles to known points
  - Two angles sufficient for 2D positioning
  - Example: Ships

Motion

- Differential position
- Doppler
  - Frequency of received signal changes with relative motion
  - Self-transmitted or remote signal
- Inertial Measurement
  - Motion can be measured through accelleration
  - Accelleration can be measured
  - linear accelleration and rotation

Summary

- Sensors
  - Integration into wearables
  - Sensor Types
  - Details: position