Sistemas de Computação Móvel e Ubíqua 2018/2019

UBIQUITOUS COMPUTING – SENSORS

Ubiquitous Computing

The term *ubiquitous computing* (UbiComp), was devised by Xerox PARC Chief Scientist Mark Weiser (1991).

“This term is associated with the ubiquity of information technology and computer power, which in principle pervade all in everyday objects.”

First article http://s3.amazonaws.com/academia.edu.documents/31347638/weiser-orig.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1492686253&Signature=ZKm%2BZMEHIJvoeuiWOGQb1It7ve0%3D&response-content-disposition=inline%3B%20filename%3Dweire.pdf.pdf

Ubiquitous computing is a concept in software engineering and computer science where computing is made to appear anytime and everywhere.

Ubiquitous Computing

Ubiquitous computing can occur using any device, in any location, and in any format.

User interacts with the computer, with everyday objects such as a fridge or a pair of glasses.

Underlying technologies include for example: operating system, mobile code, sensors, microprocessors, new I/O devices and user interfaces, networks, mobile protocols, location and positioning and even new materials.

Ubiquitous Computing

Wide range of research areas such as:

- distributed computing,
- mobile computing,
- location computing,
- context-aware computing,
- sensor networks,
- human-computer interaction,
- artificial intelligence,
- …

Ubiquitous Computing

The main idea behind ubiquitous computing systems:

small, inexpensive, robust networked processing devices, distributed at all scales throughout everyday life objects.

Examples:

- Interconnection of a house lighting and heating systems with personal biometric monitors embedded in clothes so that the conditions for lighting and heating can be adjusted continuously and imperceptibly;
- Smart refrigerators that are aware of their contents, and could suggest possible menus or even notify users about the food out of date or missing;
- ...

Ubiquitous Computing

Human-computer interaction models based mainly on GUI-interface are not suitable for ubiquitous computing.

New human-computer interfaces more “natural” and embedded within our everyday life objects.

Multiple interaction environments.

Ubiquitous Computing

To build an ubiquitous system:

- Sensors/actuators,
- Autonomous power supply,
- Location and position systems,
- Communication infrastructure,
- Data management,
- Computing infrastructure,
- Human-computer interaction (new interfaces/technologies)
- …

Sensors

A **sensor** is a device that detects and responds to some type of input from the physical environment.

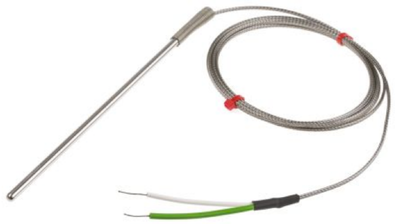
A **Sensor** is a type of transducer, that converts the physical parameter (for example: temperature, blood pressure, humidity, speed, etc.) into a signal which can be measured electrically or optically.

Example: the mercury in the glass thermometer expands and contracts the liquid to convert the measured temperature which can be read by a viewer on the calibrated glass tube.

Example: a thermocouple generates a known voltage (output) in response to a temperature (input from the environment).

Sensors (example)

Thermocouple: a thermoelectric device for measuring temperature, consisting of two wires of different metals connected at two points, a voltage being developed between the two junctions in proportion to the temperature difference.



Sensors (example)

Thermistor: is a type of resistor whose resistance changes with the change in temperature. In other words, it is a type of resistor in which the flow of electric current changes with change in temperature.

Sensors (example)

Thermocouple

- wide range of temperature sensing (Type T = -200-350°C; Type J = 95-760°C; Type K = 95-1260°C;
- can be very accurate;
- mostly linear;

Thermistor

- more narrow range of sensing (e.g. -55 to +150 C);
- usually very nonlinear;
- NTC thermistors have a roughly exponential decrease in resistance with increasing temperature;

Sensors

Sensors are used in everyday objects such as touch-sensitive elevator buttons (tactile), a lamp which dim or brighten by touching the base.

With advances in micro-machinery and easy-to-use microcontroller platforms, the uses of sensors have expanded beyond the most traditional fields.

However, analog sensors such as potentiometers and force-sensing resistors are still widely used.

Sensors, more and more integrated in our day-to-day life.

Sensors

Sensors need to be designed to have a small effect on what is measured.

Sensors can also have an impact on what they measure.
Example: a thermometer inserted into a hot cup of liquid cools the liquid while the liquid heats the thermometer.

Making smaller sensors often reduces this effect and may introduce other advantages. Technological progress allows more and more sensors to be manufactured on a microscopic scale as micro-sensors.

Sensors

Sensing process

The form of the output signal will often be a voltage analogous to the input signal, though sometimes it may be a wave form whose frequency is proportional to the input or a pulse train containing the information in some other form.

Sensors

Sensor conversion phenomena are mainly physical phenomena such as thermoelectric, photoelectric, photo-magnetic, electromagnetic, magneto-electric, thermo-elastic, thermomagnetic, thermo-optic, photo-elastic …

Table 1: Stimulus

Stimulus	
Acoustic	Wave (amplitude, phase, polarization), Spectrum, Wave velocity
Electric	Charge, Current, Potential, Voltage, Electric field (amplitude, phase, polarization & spectrum), Conductivity, and Permitivity
Magnetic	Magnetic field (amplitude, phase, polarization, spectrum), Magnetic flux, Permeability
Optical	Wave (amplitude, phase, polarization, spectrum), Wave velocity, Refractive index, Emissivity, Reflectivity, Absorption
Thermal	Temperature, Flux, Specific heat, Thermal conductivity
Mechanical	Position (linear, angular), Acceleration, Force, Stress, Pressure, Strain, Mass, Density, Moment, Torque, Shape, Roughness, Orientation, Stiffness, Compliance, Crystallinity, Structural

Sensor - terminology

1. Sensitivity
2. Range
3. Precision
4. Resolution
5. Accuracy
6. Offset
7. Linearity
8. Response Time

Sensors - Sensitivity

A sensor's **sensitivity** indicates how much the sensor's output changes when the input quantity being measured changes.

Example: if the mercury in a thermometer moves 1 cm when the temperature changes by 1°C, the sensitivity is 1cm/°C (it is basically the slope Dy/Dx assuming a linear characteristic).

Example: a typical blood pressure transducer may have a sensitivity rating of 10mV/V/mm Hg; that is, there will be a 10-mV output voltage for each volt of excitation potential and each mm Hg of applied pressure.

Sensor - Range

The **range** of the sensor is the maximum and minimum values of applied parameter that can be measured.

The **dynamic range** is the total range of the sensor from minimum to maximum.

Example: a pressure sensor may have a range of -400 to +400 mm Hg. Alternatively, the positive and negative ranges often are unequal. For example, a certain medical blood pressure transducer is specified to have a minimum (vacuum) limit of -50 mm Hg (Ymin) and a maximum (pressure) limit of +450 mm Hg (Ymax).

Sensor - Precision

The **precision** refers to the degree of reproducibility of a measurement

If exactly the same value (steady state) were measured a number of times, an ideal sensor would output exactly the same value every time if the values are close together then it has a high degree of precision or repeatability.

Real sensors output a range of values distributed in some manner relative to the actual correct value.

Example: suppose a pressure of exactly 150 mm Hg is applied to a sensor. Even if the applied pressure never changes, the output values from the sensor will vary considerably. Some subtle problems arise in the matter of precision when the true value and the sensor's mean value are not within a certain distance of each other

Sensors – Resolution

The **resolution** is the smallest detectable incremental change of input parameter that can be detected in the output signal, it can be expressed either as a proportion of the reading (or the full-scale reading) or in absolute terms.

It is the ratio between the maximum signal measured to the smallest part that can be resolved - usually with an analog-to-digital (A/D) converter.

It is the degree to which a change can be theoretically detected, usually expressed as a number of bits. This relates the number of bits of resolution to the actual voltage measurements.

Sensors – Accuracy

"**Accuracy** can be defined as the amount of uncertainty in a measurement with respect to an absolute standard."

The **accuracy** of the sensor is the maximum difference that will exist between the actual value (which must be measured by a primary or good secondary standard) and the indicated value at the output of the sensor. The accuracy can be expressed either as a percentage of full scale or in absolute terms.

Sensors - Offset

The **offset** error of a transducer is defined as the output that will exist when it should be zero or, alternatively, the difference between the actual output value and the specified output value under some particular set of conditions.

Sensors - Linearity

The **linearity** of the transducer is an expression of the extent to which the actual measured curve of a sensor departs from the ideal curve.

Note that in most cases, the static curve is used to determine linearity, and this may deviate somewhat from a dynamic linearity.

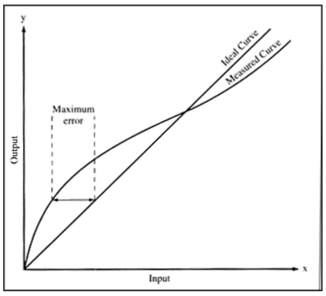


Figure 3. Ideal versus measured curve showing linearity error. Source: J J Carr, Sensors and Circuits Prentice Hall

Sensors - Linearity

Linearity is often specified in terms of percentage of nonlinearity, which is defined as:

$$\mathit{Nonlinearity}(\%) = D_{in(max)} / IN_{fs}$$

where

Nonlinearity (%) is the percentage of nonlinearity
$D_{in(max)}$ is the maximum input deviation
$IN_{f.s.}$ is the maximum, full-scale input

This static nonlinearity is often subject to environmental factors, including temperature, vibration, acoustic noise level, and humidity.

It is important to know under what conditions the specification is valid and departures from those conditions may not yield linear changes of linearity.

Sensors – Response Time

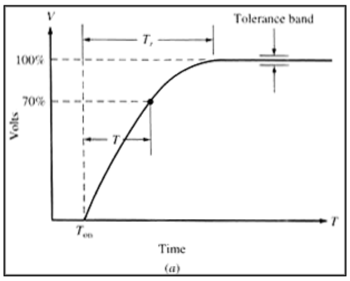
Sensors do not change output state immediately when an input parameter change occurs.

They will change to the new state over a period of time, called the **response time**.

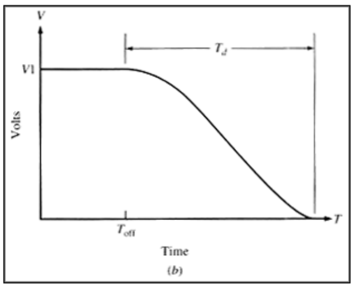
The **response time** can be defined as the time required for a sensor output to change from its previous state to a final settled value within a tolerance band of the correct new value.

Sensors – Response Time

Two types of response time



Response time following an abrupt positive going step-function change of the input parameter.



Decay time (Td) in response to a negative going step-function change of the input parameter.

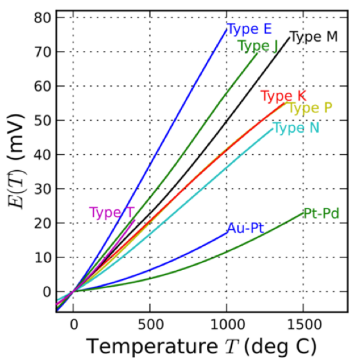
Sensors - Criteria to choose

There are certain features which have to be considered when choosing a sensor:

1. **Accuracy**
2. **Environmental condition**: Usually has limits for temperature/humidity
3. **Range**: Measurement limit of sensor
4. **Calibration**: Essential for most of the measuring devices as the readings changes with time
5. **Resolution**: Smallest increment detected by the sensor
6. **Cost**
7. **Repeatability**: The reading that varies is repeatedly measured under the same environment

Sensors - Calibration

Each sensor will have a "characteristic curve" that defines the sensor's response to an input.
The calibration process maps the sensor's response to an ideal linear response. How to best accomplish that depends on the nature of the characteristic curve.



Sensors - Calibration

Offset – easy to correct with a single-point calibration.

Sensitivity or Slope – A difference in slope means that the sensor output changes at a different rate than the ideal. The Two-point calibration process can correct differences in slope.

Linearity – Very few sensors have a completely linear characteristic curve. Some are linear enough over the measurement range that it is not a problem. But some sensors will require more complex calculations to linearize the output.

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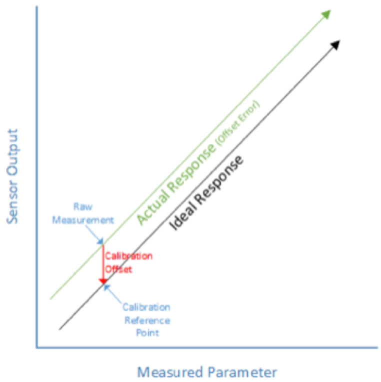
Sensors - Calibration

One point calibration is the simplest type of calibration, it can be used to correct for sensor offset error.

One point calibration can also be used as a "drift check" to detect changes in response and/or deterioration in sensor performance.



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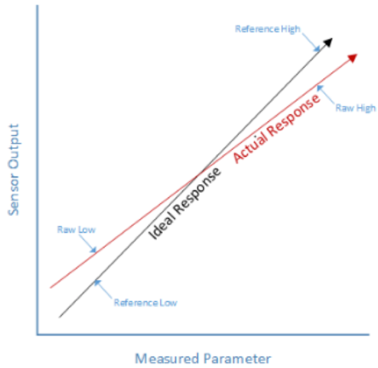
Sensors - Calibration

Two point calibration can be used in cases where the sensor output is known to be reasonably linear over the measurement range.

To perform a two point calibration:

1. Take two measurements with your sensor: one near the low end (RawLow) of the measurement range and one near the high end (RawHigh) of the measurement range.
2. Repeat these measurements with your reference instrument.
3. Calculate "RawRange" (RawHigh – RawLow).
4. Calculate "ReferenceRange”.
5. CorrectedValue = (((RawValue – RawLow) * ReferenceRange) / RawRange) + ReferenceLow



Sensors - Classification

The sensors are classified into the following criteria:

1. Primary Input quantity (Measured)
2. Transduction principles (Using physical and chemical effects)
3. Material and Technology
4. Property
5. Application

Sensors - property

Classification based on property, examples:

Temperature: Thermistors, thermocouples, RTD's, IC and many more.

Pressure: Optic fiber, vacuum, elastic liquid based manometers, LVDT, electronic.

Flow: Electromagnetic, differential pressure, positional displacement, thermal mass, etc.

Level Sensors: Differential pressure, ultrasonic radio frequency, radar, etc.

Proximity and displacement: LVDT, photoelectric, capacitive, magnetic, ultrasonic.

Biosensors: Resonant mirror, electrochemical, surface Plasmon resonance, Light addressable potentiometric.

Image: Charge coupled devices, CMOS.

Gas and chemical: Semiconductor, Infrared, Conductance, Electrochemical.

Acceleration: Gyroscopes, Accelerometers.

Others - Moisture, humidity sensor, Speed sensor, mass, Tilt sensor, force, viscosity.

Physical sensors categories

Passive sensors: The sensor receives energy already in the environment. These sensors consume less energy, but often have signal and noise problems.

Example: a camera, uses the energy (light) in the environment to capture a snapshot; Radiometer.

Active sensors: The sensor emits some form of energy and then measures the impact as a way of understanding the environment, they require power supply (*excitation signal)*. Active sensors are self-generating devices because their own properties change in response to an external effect.

Example: ultrasonic, laser, and IR sensors.

Active Sensors - Example

A radar used by police to measure the speed of traveling vehicles is a use of **active remote sensing**.

The radar device is pointed at a vehicle, pulses of radiation are emitted, and the reflection of that radiation from the vehicle is detected and timed.

The speed of the vehicle is determined by calculating time delays between the repeated emissions and reception of the pulses.

This can be calculated very accurately because the speed of the radiation is moving much, much faster than most vehicles.

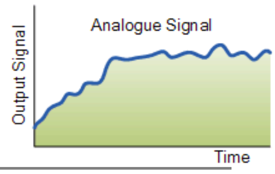
Analog Sensors

Analogue Sensors produce a continuous output signal or voltage which is generally proportional to the quantity being measured.

Examples: Physical quantities such as temperature, speed, pressure, displacement, strain, etc.

The temperature of a liquid can be measured using a thermometer or thermocouple which continuously responds to temperature changes as the liquid is heated up or cooled down.

Analogue sensors



Analogue sensors tend to produce output signals that are changing smoothly and continuously over time. These signals tend to be very small in value from a few micro-volts to several millivolts, so usually some form of amplification is required.

Then circuits which measure analogue signals usually have a slow response and/or low accuracy.

Analogue signals can be easily converted into digital signals by the use of analogue-to-digital converters (ADC).

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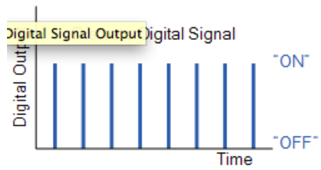
Digital sensors



Digital sensors produce a discrete digital output signals or voltages that are a digital representation of the quantity being measured.

Compared to analogue signals, digital signals have very high accuracies and can be both measured and sampled at a very high clock speed.

The accuracy of the digital signal is proportional to the number of bits used to represent the measured quantity.

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Sensors

examples

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Sensors - context awareness

The combination of simple sensors is very interesting

Each simple sensor capture just a small aspect of an environment, but the combination may result in a good characterization of the context.

Awareness of context can not be inferred only from location

Table 1. Real world situations related to sensor data (adapted from [29]).

Situation	**Sensor Data**
User sleeps	It is dark, room temperature, silent, type of location is indoors, time is "night-time", user is horizontal, specific motion pattern, absolute position is stable
User is watching TV	Light level/color is changing, certain audio level (not silent), room temperature, type of location is indoors, user is mainly stationary
User is cycling	Location type is outdoors, user is sitting, specific motion pattern of legs, absolute position is changing.

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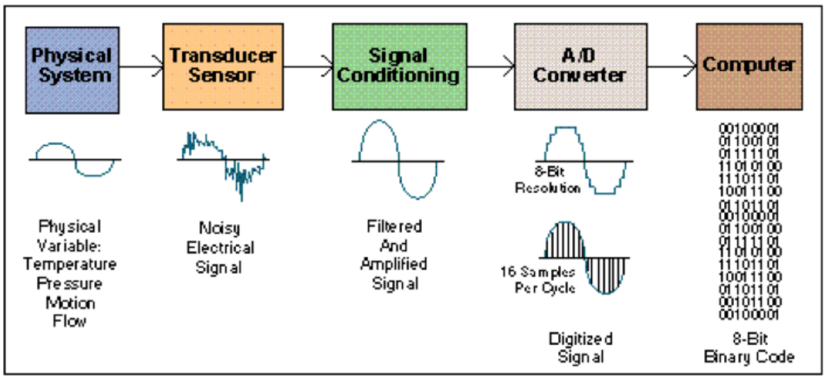
Sensors / Actuators

Quantity being Measured	Input Device (Sensor)	Output Device (Actuator)
Light Level	Light Dependant Resistor (LDR) Photodiode Photo-transistor Solar Cell	Lights & Lamps LED's & Displays Fibre Optics
Temperature	Thermocouple Thermistor Thermostat Resistive Temperature Detectors	Heater Fan
Force/Pressure	Strain Gauge Pressure Switch Load Cells	Lifts & Jacks Electromagnet Vibration
Position	Potentiometer Encoders Reflective/Slotted Opto-switch LVDT	Motor Solenoid Panel Meters
Speed	Tacho-generator Reflective/Slotted Opto-coupler Doppler Effect Sensors	AC and DC Motors Stepper Motor Brake
Sound	Carbon Microphone Piezo-electric Crystal	Bell Buzzer Loudspeaker

Data Acquisition System



Smart sensors

What is a smart sensor?

A smart sensor is a device that can compute, communicate and sense the environment.

Each one interacts with the physical space to sense some properties, such as: temperature, pressure, light, vibration, speed.

Interact with each other to propagate information (sensed data).

Interact with each other to coordinate.

Smart sensors

What makes sensors smart?

- Self Identification and Self Diagnostic
- Time Awareness
- Digital Output
- Provide software functions like Signal processing, Data logging
- Conforms to a standard data and control protocol

Smart sensors

Takes input from the physical environment and processes data by performing predefined operations and functions and then process data before passing it on.

Enable more accurate and automated collection of environmental data with less erroneous noise among the accurately recorded information.

Allow the detection of data and key performance metrics that can be examined to improve the efficiency.

Smart sensors

Examples:

Industrial - equipment is monitored and controlled for analyzing compression, temperature, moisture, and vibrations.

Healthcare - continually analyze individual patient activity and for example, automatically predict a heart attack before the patient feels sick.

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