ROBOTICS and AUTOMATIONS

Week 3

10/08/2023

Learning outcome: Week 3

Workshop:

Sensing and perception

Sensor characterisation

Lecture:

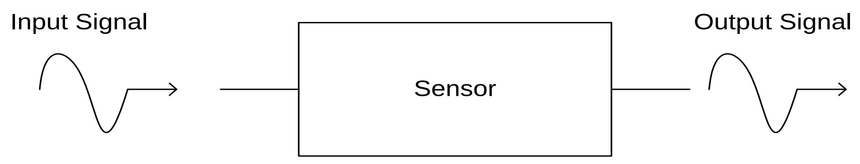
Translational Operation

Practical:

Design a robotic gripper

What are Sensors?

- American National Standards Institute (ANSI) Definition
  - A device which provides a usable output in response to a specified measurand



- A sensor acquires a physical parameter and converts it into a signal suitable for processing (e.g. optical, electrical, mechanical)

- A transducer
  - Microphone, Loud Speaker, Biological Senses (e.g. touch, sight,…ect)

Detectable Phenomenon

Stimulus	Quantity
Acoustic	Wave (amplitude, phase, polarization), Spectrum, Wave Velocity
Biological & Chemical	Fluid Concentrations (Gas or Liquid)
Electric	Charge, Voltage, Current, Electric Field (amplitude, phase, polarization), Conductivity, Permittivity
Magnetic	Magnetic Field (amplitude, phase, polarization), Flux, Permeability
Optical	Refractive Index, Reflectivity, Absorption
Thermal	Temperature, Flux, Specific Heat, Thermal Conductivity
Mechanical	Position, Velocity, Acceleration, Force, Strain, Stress, Pressure, Torque

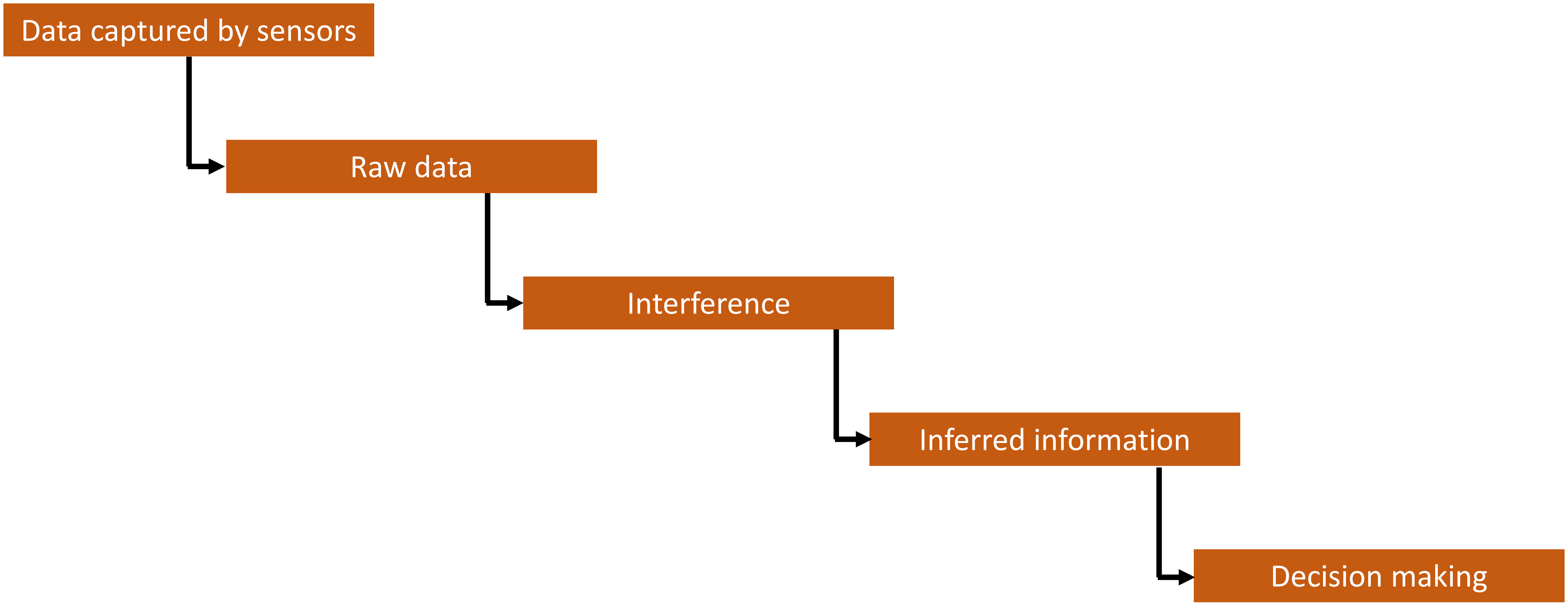
Physical Principles

- **Amperes's Law**
  - A current carrying conductor in a magnetic field experiences a force (e.g. galvanometer)
- **Curie-Weiss Law**
  - There is a transition temperature at which ferromagnetic materials exhibit paramagnetic behavior
- **Faraday's Law of Induction**
  - A coil resist a change in magnetic field by generating an opposing voltage/current (e.g. transformer)
- **Photoconductive Effect**
  - When light strikes certain semiconductor materials, the resistance of the material decreases (e.g. photoresistor)

Choosing a Sensor

Environmental Factors	Economic Factors	Sensor Characteristics
Temperature range	Cost	Sensitivity
Humidity effects	Availability	Range
Corrosion	Lifetime	Stability
Size		Repeatability
Overrange protection		Linearity
Susceptibility to EM interferences		Error
Ruggedness		Response time
Power consumption		Frequency response
Self-test capability		

Sensing and perception



Different ways to collect information

1) Filtering

The robot can aggregate information either over time or across sensors to make a more complete estimate

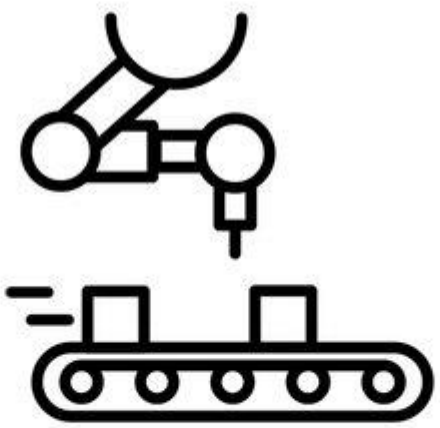
The complete shape of an object is constructed when all the frames are joined

2) Prior

The robot can use a model of its expectations of what to perceive to make better sense of the raw information it is capturing

A large data set of object shapes, which robot expects to see in its word, makes it possible to infer a reasonable completion of the shape.

Sensing different aspects of the Robot State

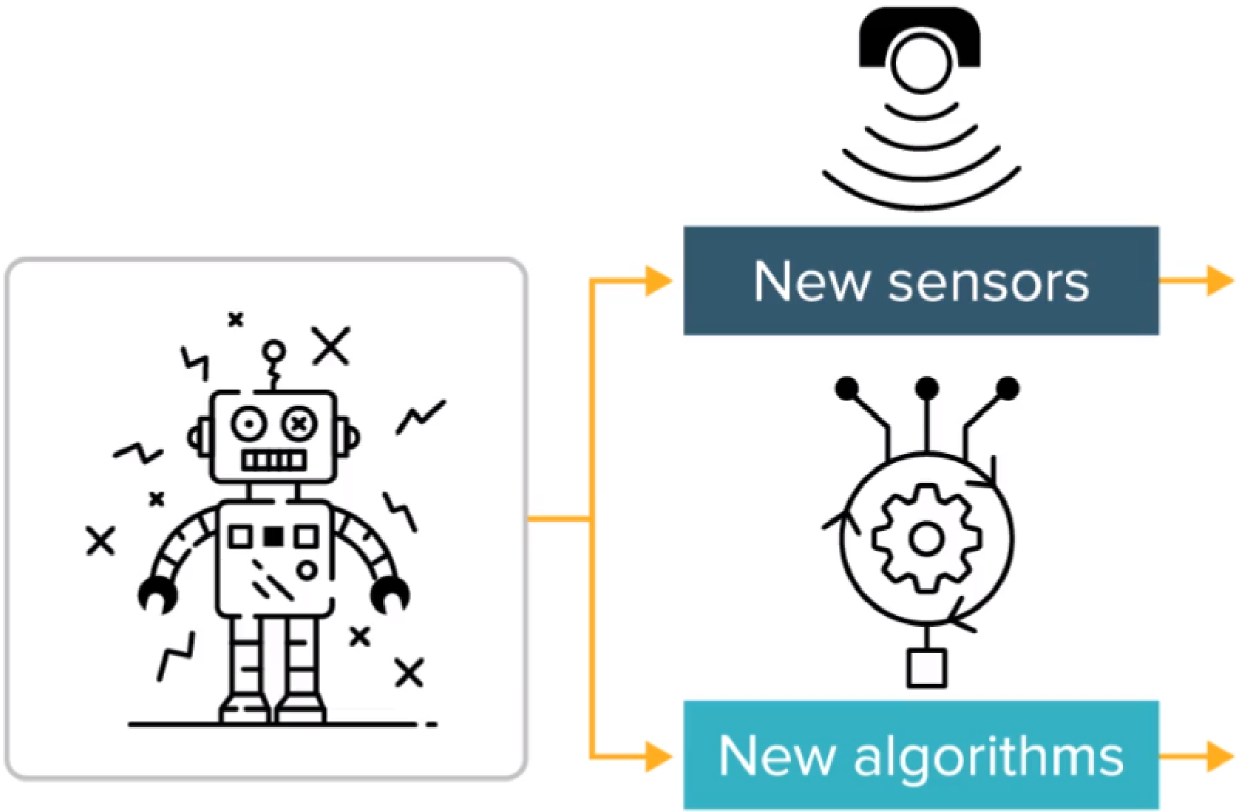


Sensing the robot’s internal state

In between robot and environment
Example: physical interaction, such as contact states and contact forces

Sensing the robot environment

Sensing in Robotic



Make information available at lower cost or with higher accuracy or with a more compact and lightweight footprint

Make the inference of more complex information possible within available computational limits

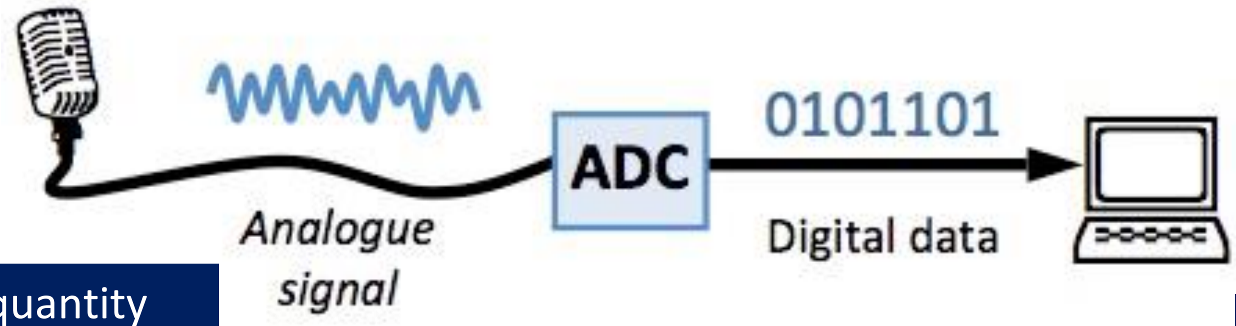
Examples:

- Probabilistic frameworks for accurate filtering
- Neural frameworks to learn complex priors from large data sets

in-class discussion 1

Will be discussed in class.

Transducer



Physical quantity

Digital signal

Transducer is defined as a device, which converts energy or information from one form to another. These are widely used in measurement work because not all quantities that need to be measured can be displayed as easily as others. A better measurement of a quantity can usually be made if it may be converted to another form, which is more conveniently or accurately displayed.

Transducer

https://www.youtube.com/watch?v=dfYQSRcdWOk&ab_channel=MagicMarks

Common transducers for sensing

Strain gauge	Hall effect sensor	Photo resistor
The strain gauge is one of the most important tools of the electrical measurement technique applied to the measurement of mechanical quantities.	A **Hall effect sensor** (or simply Hall sensor) is a type of sensor which detects the presence and magnitude of a magnetic field using the Hall effect.	Change its electrical resistance depending on the amount of ambient light
Used in force/torque sensors	Used in encoders	Used in force/torque sensors

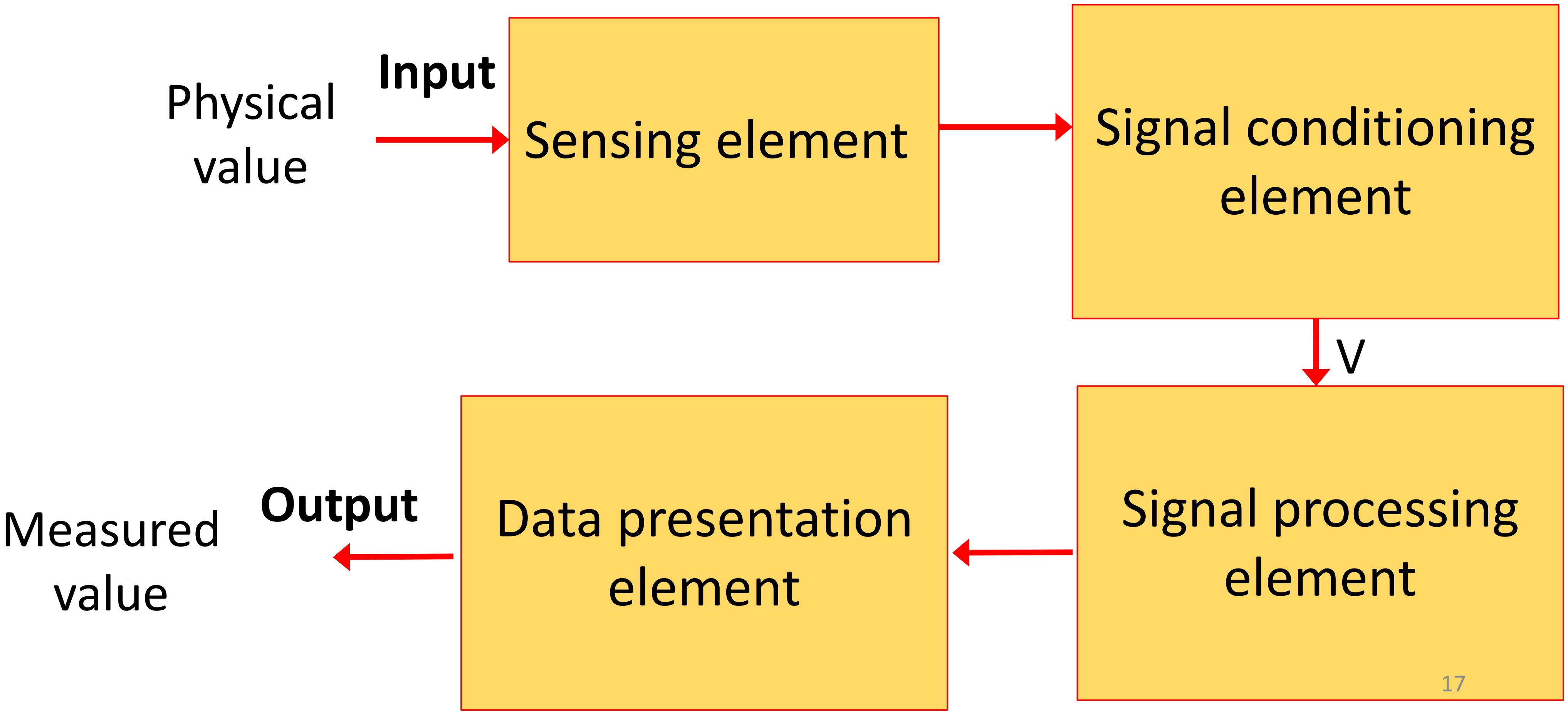
In class Assessment 2

Will be discussed in class.

Characterisation of sensing devices

Basic sensing elements

General structure of a measurement system

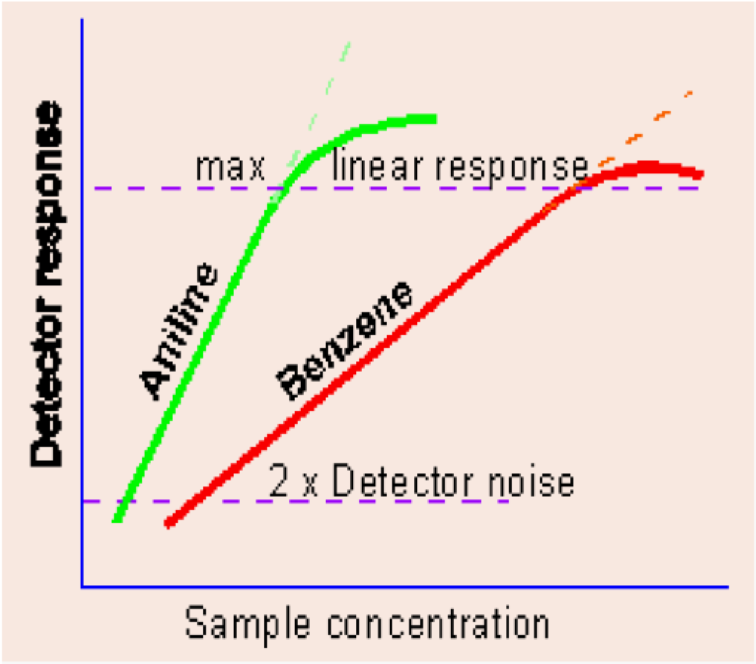


Span or Dynamic Range (bandwidth)

If in a measuring instrument the highest point of calibration is X_2 units and the lowest point is X_1 units.

- Instrument range is X_2 units
- Instrument span is $(X_{2-} X_1)$ units

- Span or range: The difference between the highest and lowest scale values of an instrument
- Bandwidth: The range of scale values over which the measurement system can operate within a specified error range (also used as another word for span)



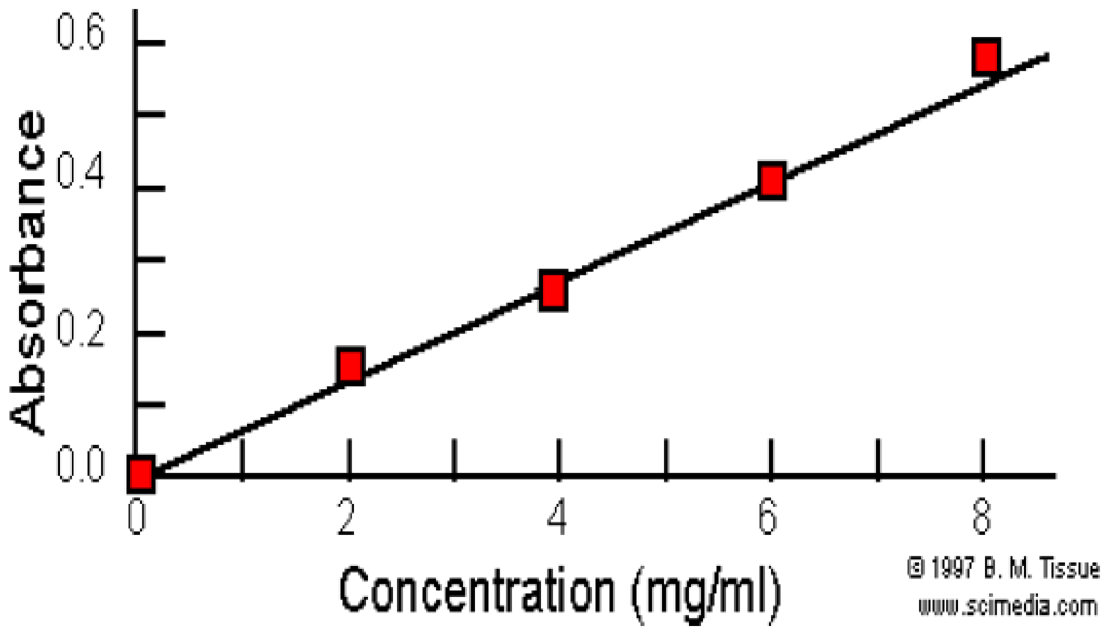
Accuracy

- Usually expressed as “accuracy to within x percent” of reading/spam
- The degree of correctness with which a measuring system yields the “true value” of measured quantity.
- Means that “true value within X percentage of instrument reading/span at all calibration points of the scale.
- When a temperature sensor with an error of 1% of reading indicates 100°C, the true temperature is between 99°C and 101°C.

From C.Ming Lee’s lecture notes, NTU

Calibration: standard curve

- A process of adapting a sensor output to a know physical or chemical quantity to improve sensor output accuracy i.e. remove bias
- A working or standard curve is obtained by measuring the signal from a series of standards of known concentration. The working curves are then used to determine the concentration of an unknown sample, or to calibrate the linearity of an analytical instrument-for relatively simple solutions



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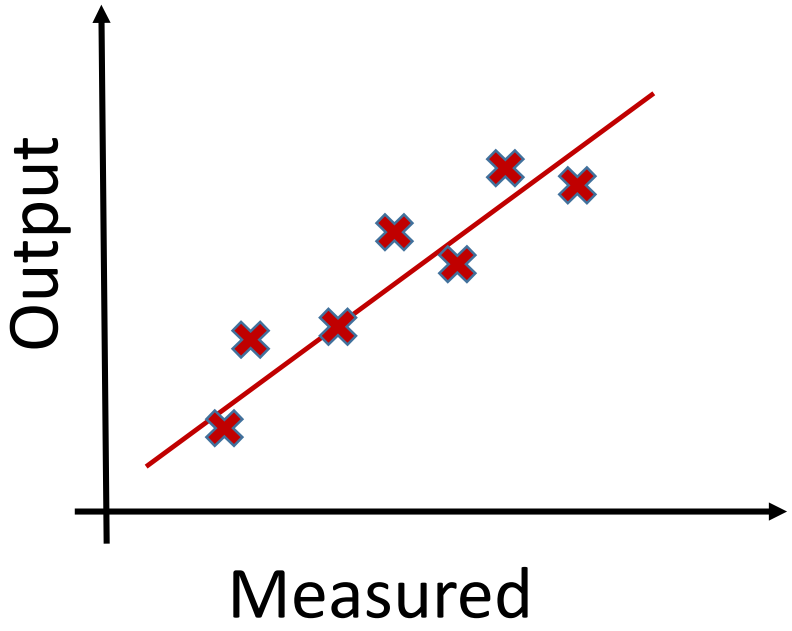
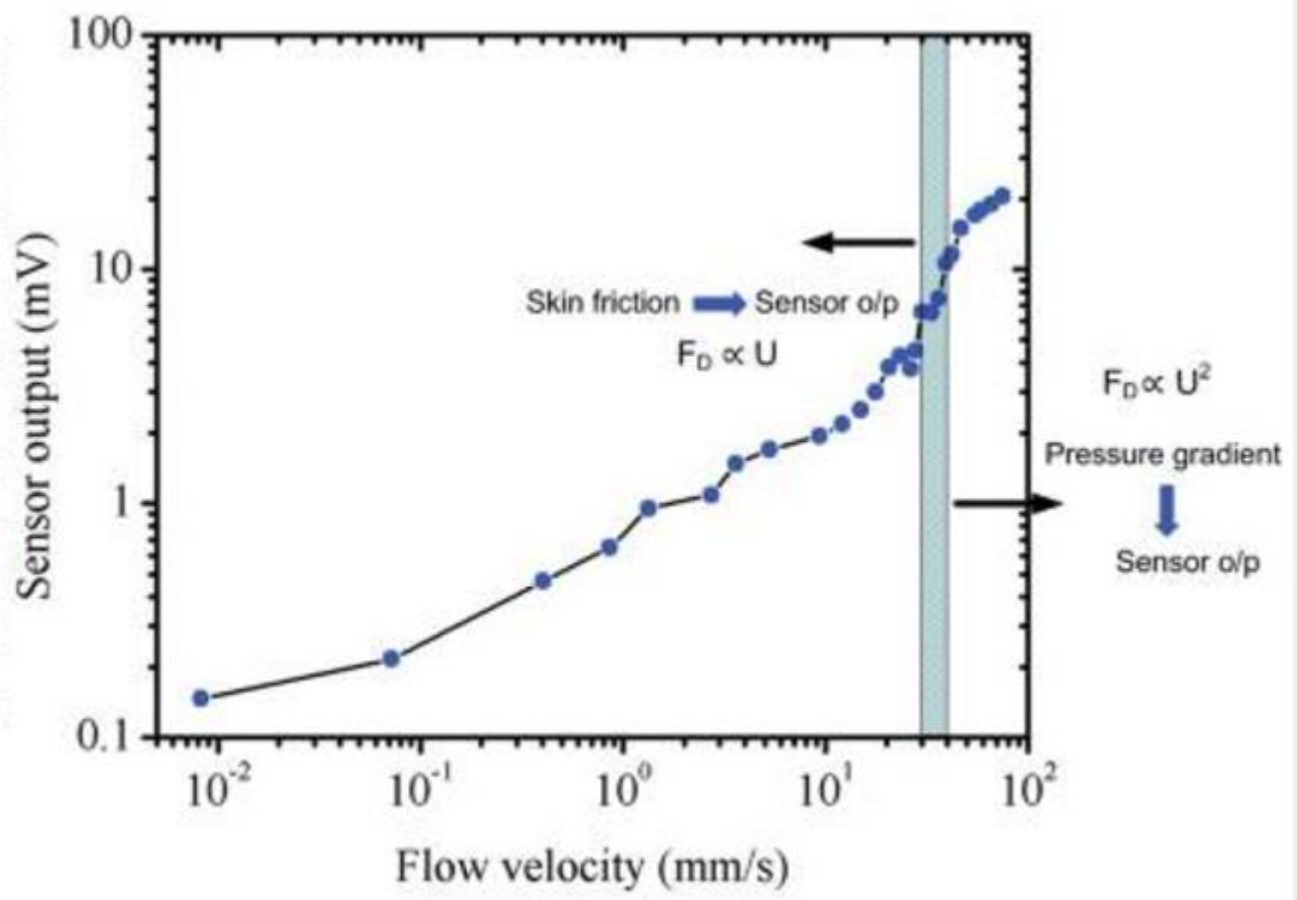
Linearity

- The calibration curve of a real instrument is typically, not a exact straight line

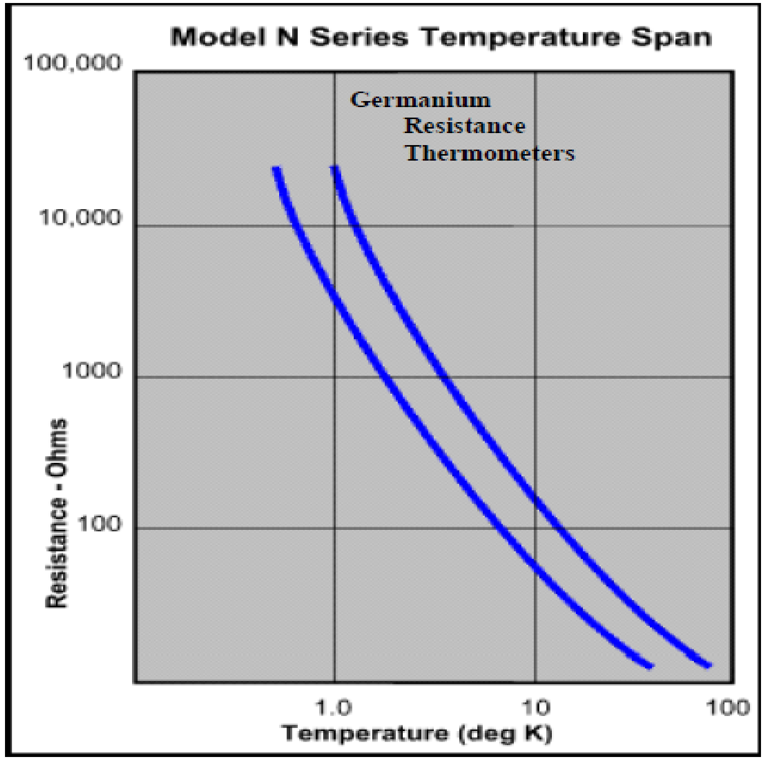
- The linearity explains the deviation of the calibration curve from a good fit straight line of it.





Sensitivity

- A sensor detects information input, I_{in}, and then transduces or converts it to a more convenient form, I_{out} i.e $I_{out} = F(I_{in})$. So sensitivity is the amount of change in a sensor's output in response to a change at a sensor's input over the sensor's entire range.
- Very often sensitivity approximates a constant; that is, the output is a linear function of the input
- Sensitivity may mathematically be expressed as $\eta = \frac{dI_{out}}{dI_{in}}$

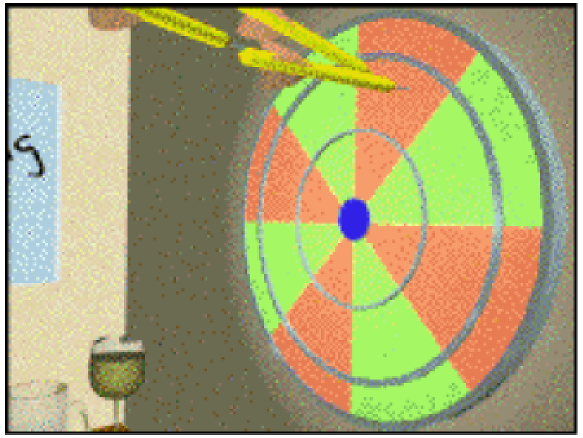


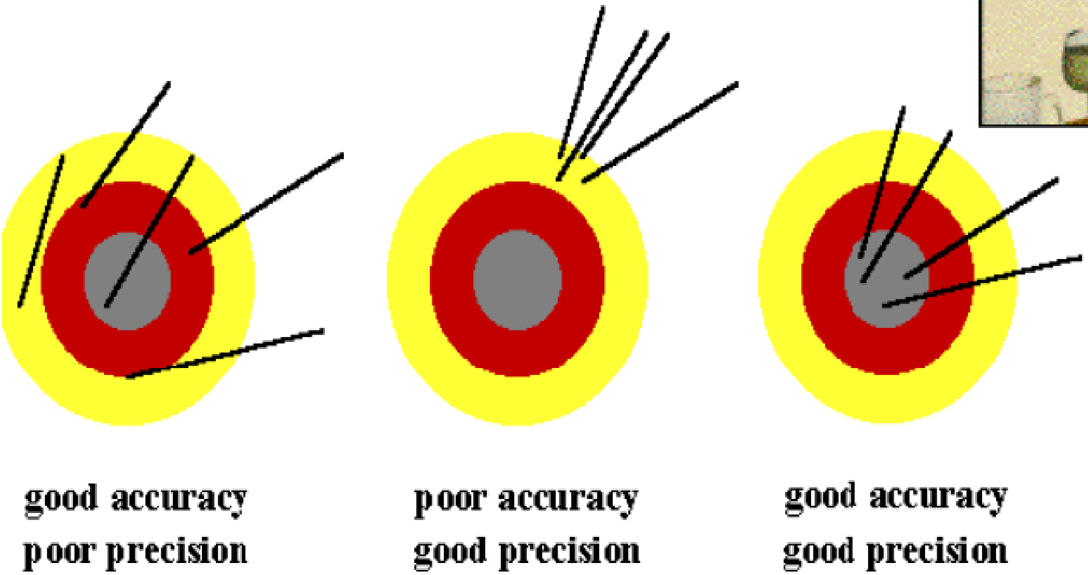
Sensitivity 35,000 Ohms/K @ 4.2 K
http://www.sci-inst.com/sensors/grt.htm

From C.Ming Lee's lecture notes, NTU

Precision or repeatability

- The difference between the instrument’s reported values during repeated measurements of the same quantity. Typically determined by statistical analysis of repeated measurements





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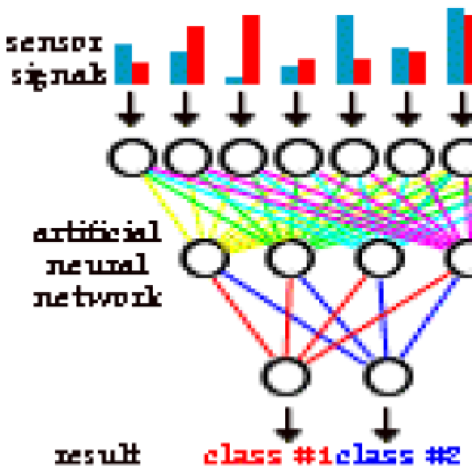
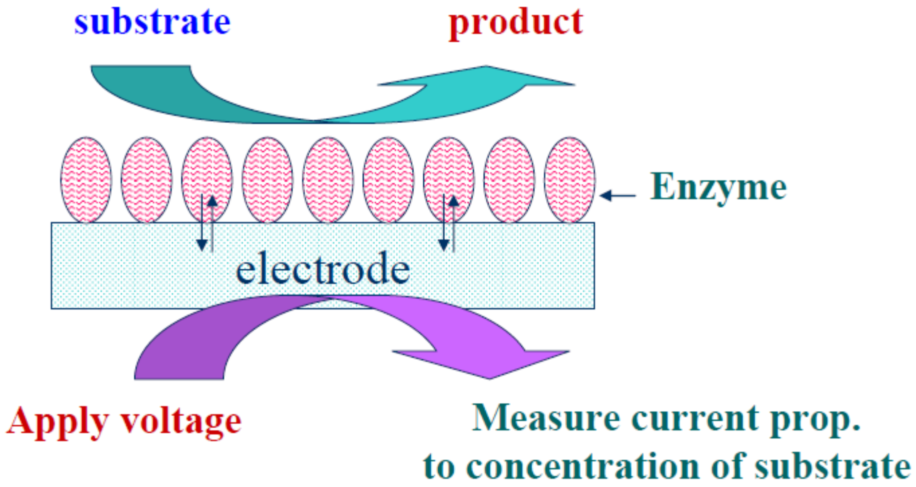
Selectivity

- Selectivity: The ability of a sensor to measure only one parameter, in the case of a chemical sensor, to measure only one chemical species
- Because of the lack of perfect selectivity arrays are often implemented (e.g., electronic nose and tongue)





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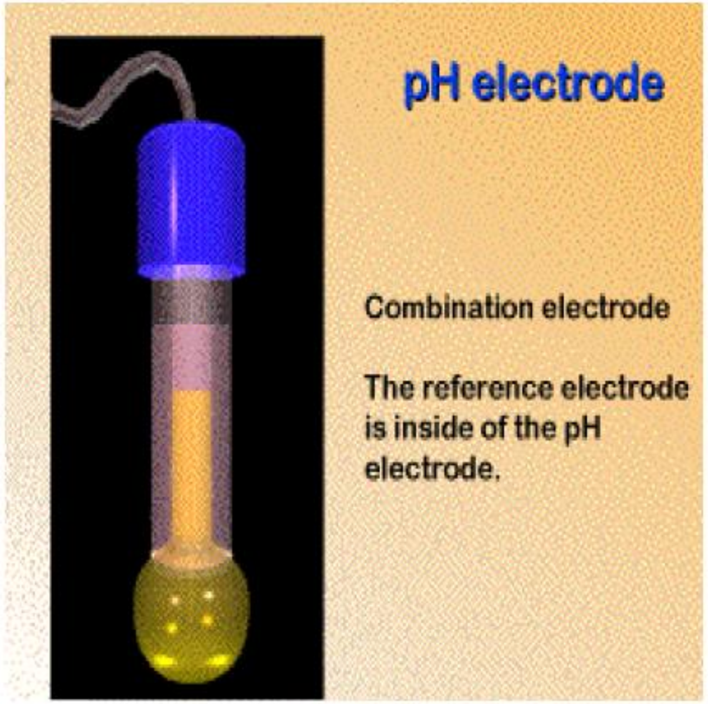
Resolution

- The smallest increment of change in the measured value that can be determined from the instrument's readout scale.



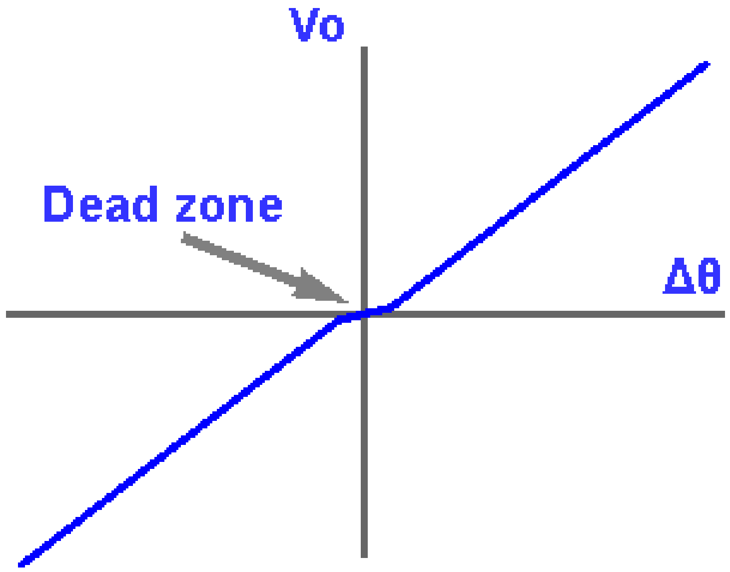
For example: in a temperature transducer if 0.2°C is the smallest temperature change that observed, then the measurement resolution is 0.2°C.

From C.Ming Lee's lecture notes, NTU

Dead zone

Dead zone is the largest value of a measured variable for which the measurement output stays zero.

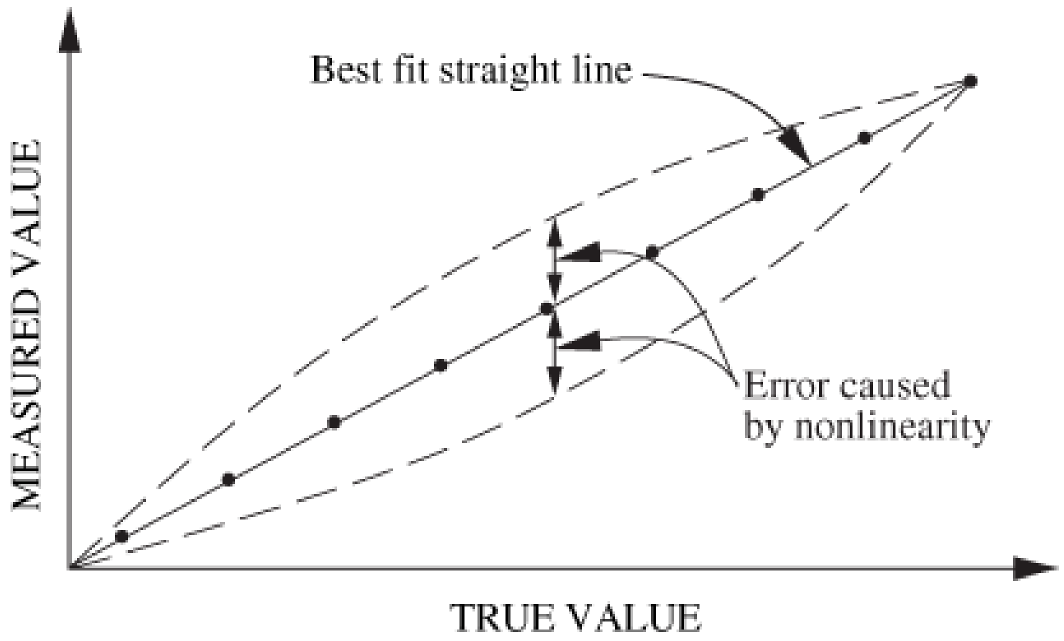
Dead zone occurs due to factors such as static friction in a mechanical measurement system.



Dead zone

- The **hysteresis error** of a pressure sensor is the maximum difference in output at any measurement value within the sensor's specified range when approaching the point first with increasing and then with decreasing pressure.

- It can occur due to various factor such as gear backlash in mechanisms, magnetic hysteresis, piezoelectric hysteresis or due to elastic hysteresis.



Week 3: In-class assignment-Group Discussion

Will be discussed in class.

Continue on Spatial Description and Transformation

OPERATORS: TRANSLATIONS, ROTATIONS, AND TRANSFORMATIONS

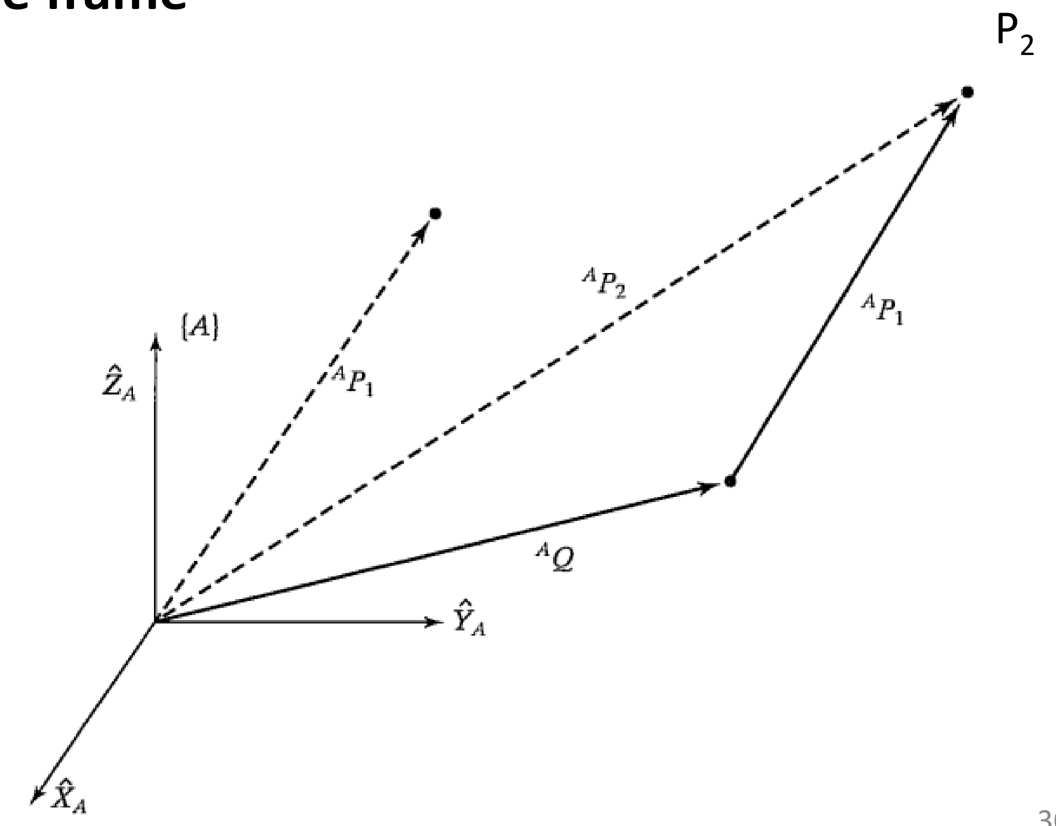
The same mathematical forms used to map points between frames can also be interpreted as operators that translate points, rotate vectors, or do both. This section illustrates this interpretation of the mathematics we have already developed.

Operators translate and rotate vectors on the same frame

Translational operators

$$^{A}P_2 = {}^{A}P_1 + {}^{A}Q.$$

Where Q is the translation vector



Example 1:

Vector A_{P1} is translated 10 unit in X and 5 unit in Y directions. Find the new resulting vector ${}^{A}P_2$ if the original vector ${}^{A}P_1$=[3 7 0]^T

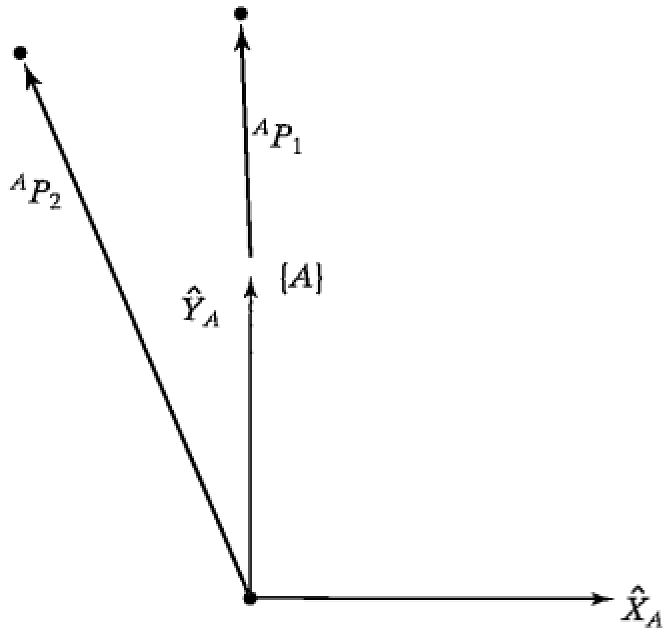
Example 2:

Vector A_{P1} is translated -9 unit in X and 12 unit in Y and -4 units in Z direction. Find the new resulting vector ${}^{A}P_2$ if the original vector ${}^{A}P_1$=[3 7 0]^T

Rotational operators

The rotation matrix that rotates vectors through some rotation, R, is the same as the rotation matrix that describes a frame rotated by R relative to the reference frame.

Although a rotation matrix is easily viewed as an operator, we will also define another notation for a rotational operator that clearly indicates which axis is being rotated about:



$$^{A}P_2 = R_K(\theta)\,^{A}P_1.$$

Example 3:

Vector A_{P1} is rotated 30 degrees about Z axis. Find the new resulting vector A_{P2} if the original vector $A_{P1}=[0\ 2\ 0]^T$

Transformation operators

As with vectors and rotation matrices, a frame has another interpretation as a transformation operator. In this interpretation, only one coordinate system is involved, and so the symbol T is used without sub- or superscripts. The operator *T* rotates and translates a vector A P1 to compute a new vector,

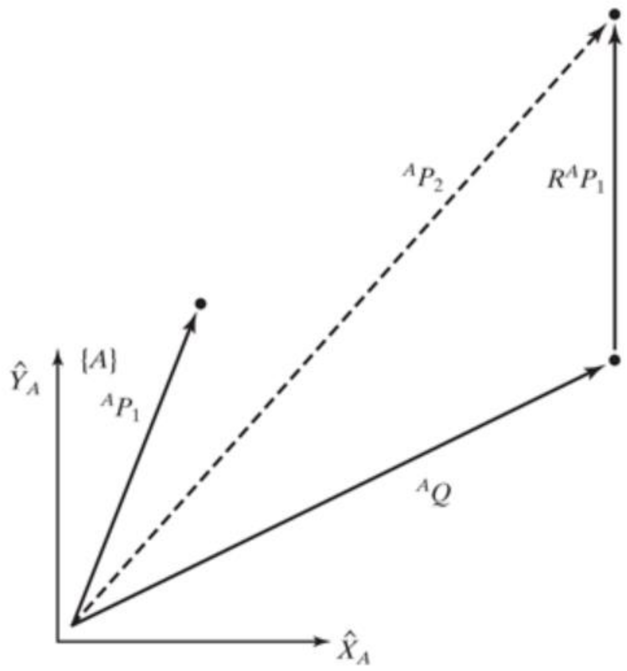
$$^{A}P_2 = T\ ^{A}P_1.$$

- The transform that rotates by R and translates by Q is the same as the transform that describes a frame rotated by Rand translated by Q relative to the reference frame.

- A transform is usually thought of as being in the form of a homogeneous transform with general rotation-matrix and position-vector parts.

Example 4:

Figure 2.11 shows a vector ${}^{A}P_1$. We wish to rotate it about $\hat{Z}_A$ by 30 degrees and translate it 10 units in $\hat{X}_A$ and 5 units in $\hat{Y}_A$. Find ${}^{A}P_2$, where ${}^{A}P_1 = [3.0 \quad 7.0 \quad 0.0]^T$.



Solution:

The vector ${}^{A}P_1$ rotated and translated to form ${}^{A}P_2$.

The operator *T*, which performs the translation and rotation, is

$$T = \begin{bmatrix} 0.866 & -0.500 & 0.000 & 10.0 \\ 0.500 & 0.866 & 0.000 & 5.0 \\ 0.000 & 0.000 & 1.000 & 0.0 \\ 0 & 0 & 0 & 1 \end{bmatrix}. \tag{2.34}$$

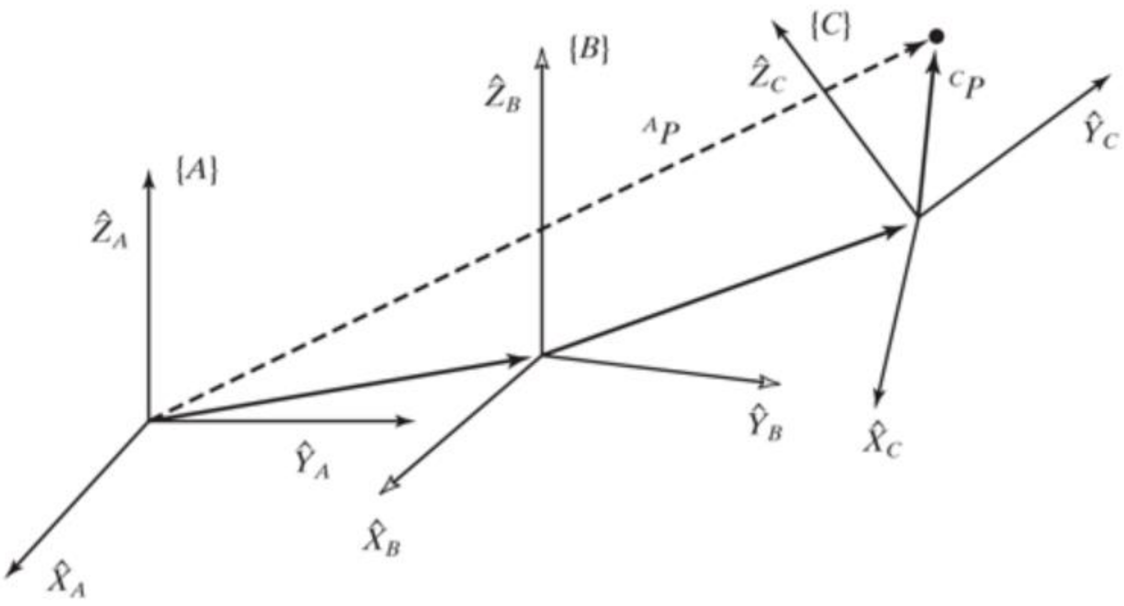
Given

$${}^{A}P_1 = \begin{bmatrix} 3.0 \\ 7.0 \\ 0.0 \end{bmatrix}, \tag{2.35}$$

we use *T* as an operator:

$${}^{A}P_2 = T\ {}^{A}P_1 = \begin{bmatrix} 9.098 \\ 12.562 \\ 0.000 \end{bmatrix}.$$

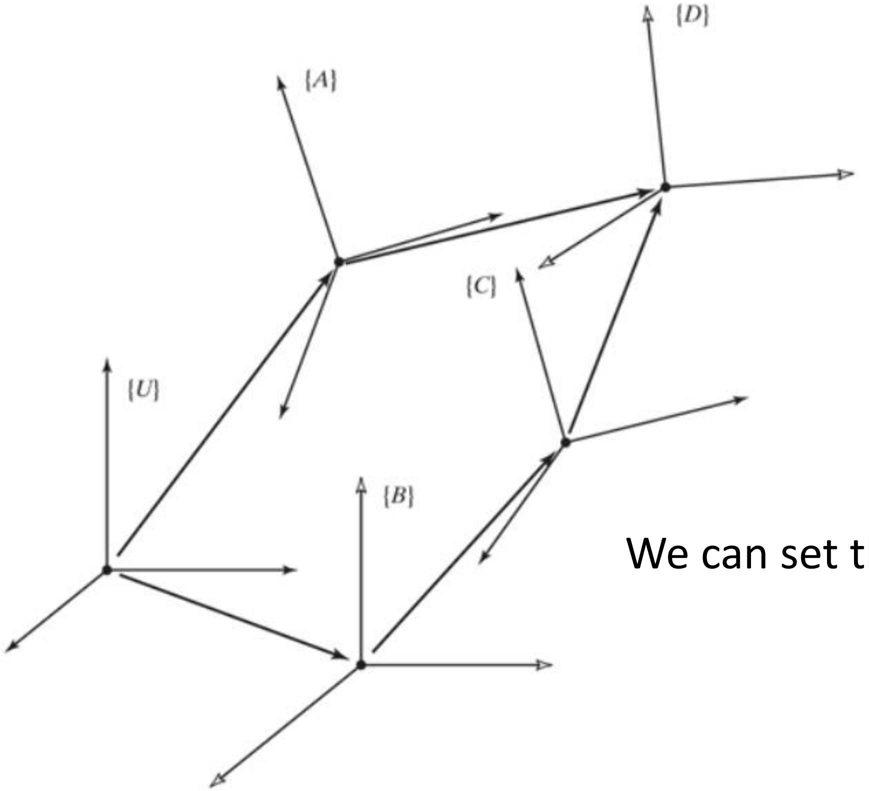
Transformation Arithmetic



$$^AP = {}^A_BT\ {}^B_CT\ {}^CP$$

we have ^CP and wish to find ^AP

Transform Equations



Set of transforms forming a loop.

$$ {}^{U}_{D}T = {}^{U}_{A}T \; {}^{A}_{D}T; $$

second;

$$ {}^{U}_{D}T = {}^{U}_{B}T \; {}^{B}_{C}T \; {}^{C}_{D}T. $$

We can set these two descriptions of ${}^{U}_{D}T$ equal to construct a transform equation:

$$ {}^{U}_{A}T \; {}^{A}_{D}T = {}^{U}_{B}T \; {}^{B}_{C}T \; {}^{C}_{D}T. $$

Transform equations can be used to solve for transforms in the case of n unknown transforms and *n* transform equations.

Example 6:

Vector A_{P1} is rotated relative to frame {A} about x-axis by 45 degrees and translated -12, 3, 10 units in X_A, Y_A, and Z_A, respectively. Define transformation matrix (T), then the new resulting vector A_{P2} if the original vector $A_{P1}=[-2\ 6\ -5]^T$

Example 7:

frame {B} is rotated relative to frame {A} about z-axis by 30 degrees and translated 4 units in x-axis and 3 units in y-axis. Frame {C} is rotated relative to frame {B} about x-axis by 60 degrees and translated 6 units in x-axis and 5 units in z-axis. Find the position of point "P" relative to frame {A} if C_p =[8 7 9]^T

End of week 3