Cours de Bases de la Robotique

Mohamed Bouri, Hannes Bleuler

1. Introduction	MB: Intro Robots parallèles
2. Bases Théoriques	HB: Cinématique MB: Jacobien, Dynamique
3. Composants	HB: Capteurs, µ-actionneurs MB: Contrôle, Interfaces

1

Cours Bases de la Robotique

3.1 Capteurs pour la robotique
Sensors

Focus: General, industrial, medical robotics

Sensing for mobile, flying robotics & autonomous vehicles would be a lecture by itself

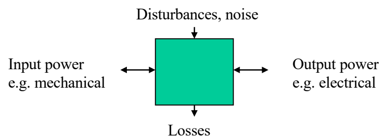
2

Today's program

- ***Definitions, Classifications (linear, absolute, incremental, …)***
- ***Position sensors:***
  - ***Inductive, Eddy Current***
  - ***Encoders (linear, rotary, opt., pot.-meter)***
  - ***Strain Gauges Jauge de déformation***
  - ***Position Sensitive Detector (PSD)***
  - ***Capacitive***
  - ***Linear-Variable-Differential-Transformer (LVDT)***
- ***Force sensors:***
  - ***Strain gauges Jauges de contraintes***
  - ***Displacement free force sensors***
  - ***Multi DOF sensors***

3

Just like an actuator,
a sensor is basically a
transducer
from one form of energy to another



4

Proprioception – Exteroception

- Proprioception: In order to know the robot's configuration; position, angle, velocity, acceleration or force.
  Reference within robot (or body) itself
- Exteroception: Vision from the task, taking external reference
  Position, orientation, mass, vision
  (vision is a huge topic of it own, not treated in this lecture)

5

Proprioception – Exteroception

- Notion importante en biomécanique

Exemple: Travail avec paraplégique: Problème d'absence de proprioception.

Le paraplégique ne perçoit ni la position ni la charge (force) de ses membres.

–> Nécessité de regarder ses membres, miroir, entendre les moteurs de l'exosquelette…

6

Sensors: Classification criteria

- ***what is the measurand?***
  - *Position (distance)*
  - *Velocity, acceleration*
  - *Angle, Rotational Speed, inclination*
  - *Force, Torque*
  - *Pressure, stress (normal, shear…)*
  - *Temperature, humidity,*
  - *Noise, vibrations*
  - *Electric/Magnetic field*

  etc.

Sensors: Classification criteria

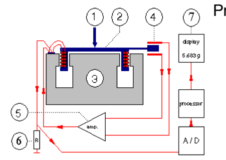
- ***what is the measurand?***
- ***What physical principle for the transducer from measurand to electronic signal?***

  Mechanical
  optical (interferometry, intensity, triangulation, t.o.f. etc.), infrared,
  acoustical,
  capacitive,
  inductive, eddy currents,
  hall effect
  piezoelectric, piezoresistive dilatation (thermal) …

Sensors: Classification criteria

- ***Measurand***
- ***Physical principle***
- ***Metrological principles:***
  - ***absolute vs. incremental (relative)***
  - ***differential***
  - ***averaging vs. local***
  - ***Indirect measurement: nulling.***

Example Nulling principle:
Precision scale Mettler Toledo



Zeegert van Huissteden, SARTORIUS, De

1. weighting platform
2. coil
3. permanent magnet
4. nulling sensor (capacitive, optical…)
5. servo amp
6. precision resistor

- Principle: Compensate weight with voice coil force
- zero position measrmt.only

Advantage: the sensor may be highly nonlinear!

It just must detect the sweep through zero with high repetitivity & sensitivity

Sensors: Classification criteria

- ***Measurand***
- ***Physical principle***
- ***Metrology principle***
- ***Technology***
  (Analog, discrete, integrated (MEMS), thick-film, Screen Printing, CMOS, CCD…)

  Compability (clean room, industrial conditions, explosive environment, bio compatibility, sterilizability…)

What is a sensor?

A sensor is a **transducer** …

It transforms a physical variable to be measured (the "**measurand**") into an electrical signal (the "**output**") to be treated by a data acquisition system.

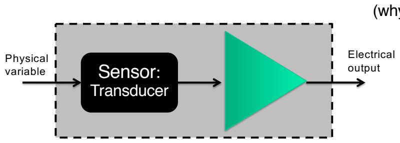
Ideally only one way, no noise, **no cross coupling** from other physical varialbles (such as e.g. temperature!)

Signal Conditionning

The first stage of signal conditioning is considered part of the sensor

The raw electrical signal is often very weak. Signal processing (ampl., signal extraction) as close as possible to measurand

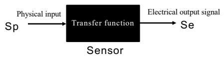
(why?)



13

Transfer Function

The functional relationship between physical input signal and electrical output signal.



- **Bandwidth**
- Time constant
- Static gain

e.g. assumed as first order sytem

$$Bandwidth = \frac{1}{\tau}$$

$$\frac{Se}{Sp} = \frac{G}{1+\tau s}$$

$$T_{5\%} = 3\tau$$

It is often determined by the pre-treatment electronics!

14

Définitions de base

➢ Résolution	Resolution	
➢ Sensibilité	Sensitivity	
➢ Fidélité = répétabilité	Repeatability	(rel. accuracy)
➢ Justesse	Trueness	(abs. accuracy)
➢ Répétable et juste = précision	True and repeatable = precise	

15

Sensitivity

is the relationship indicating ***how much output you get per unit input*** *: Also called "gain"*

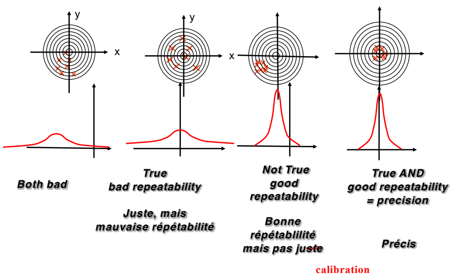
Slope *of the input-output curve*

Resolution

The resolution is defined as ***the minimum detectable measurand change****.*

16

Répétabilité vs. Justesse **Trueness – (rel.) Accuracy**



17

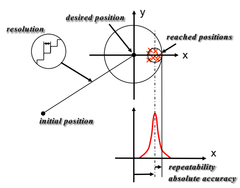
Resolution – Accuracy (applies to sensors & actuators)

the Resolution *is the smallest displacement achievable or measurable*

the Trueness "absolute accuracy" *is the deviation of the mean of the actual output from the true value*

Good repeatability "relative accuracy" *means small scatter when repeating a measurement*

Good repeatability AND good trueness result in good precision

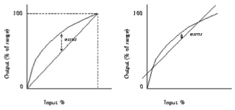


18

Linearity

When the sensitivity is constant,
i.e. independent from the measured value,
the input-output function will be linear

Nonlinearity: *Maximum deviation **of the slope** from a linear transfer function over the specified dynamic range.*



19

Plage de mesure

Dynamic Range

*The **limits within which the input (measurand) can vary while avoiding output saturation***

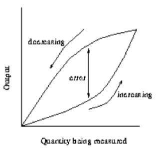
*If the dynamic range is exceeded, we reach **saturation**.*

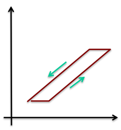
The output signal can either saturate or take meaningless values (wrap-arounds etc; beware, e.g. for angular measurements!) Ariane V crash: 8-bit, 16 bit problem !!!

20

Hysteresis

A sensor may give a different reading for the same quantity depending from the direction of approach





21

Dérive – Drift

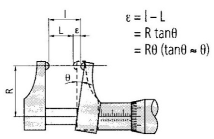
- Phénomène lent
- Le plus souvent due au changement de température
- Peut aussi être résulat du viellissement d'un capteur

22

Position Sensor Errors

Abbe error - is the linear positional error caused by the axis of measurement being offset from the axis of displacement

This error is avoide by measurement system **coaxial** with displacement to be measured.



23

Typical precisions in robotics

Conventional robotics (industrial):	*100 - 10 μm*
Precision robotics (micro-assembly): *(machine tools)*	*10 - 1 μm*
High precision robotics: *& Ultra-high precision* *(micro-robotics)*	*1- 0.001 μm* *(1 nm)*

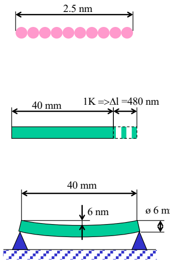
1/10

1/1000

24

One nanometer is very small!

- *1 nanometer = 10 Angstrom (Å)*
- *1 nanometer = ca. 4 atomic radii*
- *A 40 mm steel rod will expand 480 nm for a temperature change of 1 degree*
- *A 40 mm steel rod in length and 6 mm in diameter will bend 6 nm on its own weight*



25

Systematic and random errors

	Phenomenon	Influencing parameters	Improvement by
Systematic	Fabrication tolerances, misalignments, actuator backlash	Mechanical tolerances	Calibration, model identification control mode
	Sensors errors, miscalibration	Linearity, offset, quantization	Calibration, signal processing
	Electronics' and drivers resolution	D/A converters resolution	Higher resolution
Random	Mechanical deformation	Stiffness, maximum load force	High stiffness (compact, prestress), using elastic model
	Thermal drift	Temperature, thermal expansion coefficient	Material selection, temperature control, mechanical design (compact, compensation)
	Friction	Material selection, lubrication, velocity	Stiff mechanism, frictionless mechanisms (flexure, direct drive, ...)
	Mechanical backlash	Bearing tolerances, mechanical tolerances (gears)	Preloaded bearings, direct drive, flexure, control strategy...)
	Vibration, noise	Resonance frequency	Stiff mechanisms/low mass (high resonance frequency), elimination of sources' vibration, damping, vibration filtering (isolation table)

26

Récapitulation: Un bon capteur sera:

- Linéaire
- Faible bruit (Bon rapport Signal-Bruit)
- Réponse rapide
- Haute bande passante
- Grande plage de mesure combiné avec haute résolution ("High Dynamic Range")
- Haute sensibilité
- Haute précision
- Faibles dérives
- Faible hystérèse
- Découplé de paramètres autres que la grandeur mesurée

27

Position, velocity, acceleration, angle, rotational speed/accel.

Accelerometer
Capacitive displacement sensor
Gravimeter
Gyroscope (Mechanical, opt., MEMS)
Inclinometer
Integrated circuit piezoelectric sensor
Laser rangefinder
Laser surface velocimeter
LIDAR
Linear encoder
Linear (rotational) variable differential transformer (LVDT, RVDT)

Odometer
Photoelectric sensor
Piezoelectric accelerometer
Position sensor
Rate sensor
Rotary encoder
Rotary variable differential transformer
Inductosyn
Tilt sensor
Tachometer
Ultrasonic thickness gauge
Variable reluctance sensor
Velocity

28

The most obvious position sensor:

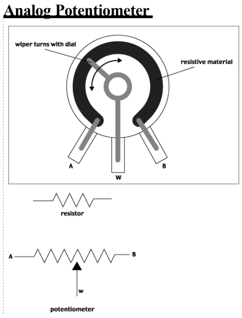
A simple potentiometer (rotational or linear)

Advantages:
- Low-cost
- No processing electronics
- Linear, instantaneous

Drawbacks:
- Not contact-free
- Output signal can be noisy
- Wear
- Thermal drift

29

Analog Potentiometer



Example

350° ±10 V

Assuming a 20 mV noise.

What is the expected maximal resolution?

20Volts / 20 mVolts = 1000 steps
[10 bits = 1024 steps]

ie. resolution of 350°/1000 = 0.35°

Not good and not sufficient

30

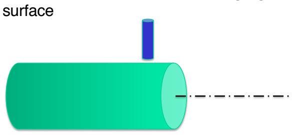
Main principles for position sensors

- Inductive (Electromagnetic)
  - "true" inductive
  - Eddy current
  - Resolvers, LVDT (Lin. var. diff. transformer)
  - Hall effect sensors
- Capacitive (Electrostatic)
- Optical (incl. infrared)
  - Interferometer
  - Incremental (relative)
  - Absolute encoder
  - PSD (Photo Sensitive Diode) Intensity, Triangulation
  - Time of flight

31

Inductive Sensor typ. ca 10-100 kHz

- Measures the inductance of a **ferromagnetic target**, which changes in function of the distance from sensor.
- Can be very accurate. Problem in case of tangential motion of target (typical: Rotating machinery)
  What is really measured, is the magnetic homegenity of the material. Accurate, if **averaging** over a large surface



32

Inductive Sensor

+ Large choice of commercial products, for every price, range, accuracy
+ Good averaging out of small target defects
+ Dirt-resistant

– Low measurement range (mm range)
– Target must be ferromagnetic and **homogenous** within the measurement volume

33

Eddy Current Sensor typ. ca 50 kHz – Mhz-range

Now we measure **not the imaginary part**, but the **real part of the impedance**

In practice, every sensor is a combination of both effects!

Now non-ferromagnetic, but **conducting target** possible! This is **much less restrictive** than the inductive principle.

+ Large choice of commercial products

– Now also sensitive to inhomogenities in conductivity
– Low range

34

Simple structure: Easy to adapt to harsh environements (hot, UHV, corrosive, liquid)

- Little effect of temperature:
  Has been made for T up to 500 °C
- UHV compatibility!
  In these cases not PCB, but screen printing on Alumine substrate, Ag–Pd conductors

35

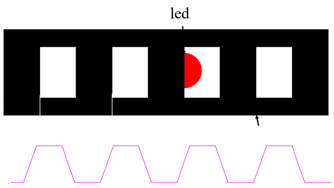
Incremental Encoders

- Measurement of angles or distance by increments
- Most common: Optical rules
- Increments on glass disc or rule: Typically 20 μ
- Electronic counter

- Relative sensor! Has to be calibrated (referenced) on power up

36

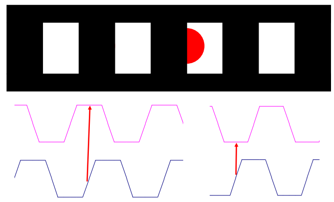
Optical Encoders (working principle)



How to discriminate the direction?

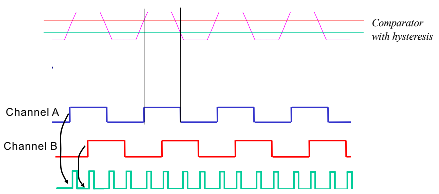
37

Direction detection: Signals in "quadrature" : 90° phase shift



38

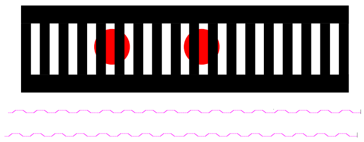
Encoders (signal conditioning)



The resolution is multiplied by 4!

39

Enhancing the resolution of an optical encoder

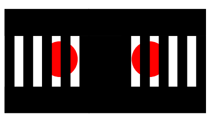


Problem: Light source (LEDS) too large with respect to the pitch

Solution: Use a fixed Mask with the same pitch!

40

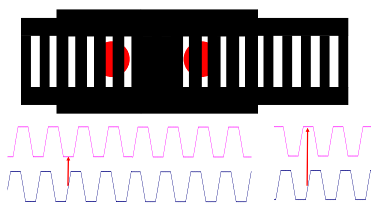
Encoders (working principle)



The masks are shifted by ¼ of pitch (direction detection)
The LEDS' relative position doesn't matter any more

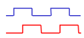
41

Encoders (working principle)

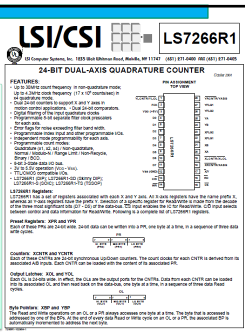


42

To count this



Use of a quadrature counter



Example of a quadrature counter
Size : 24 bits

If a 1000 pitch Incremental rotational encoder is used
Resolution
--- 360° / (1000 *4) = 0.08 °.

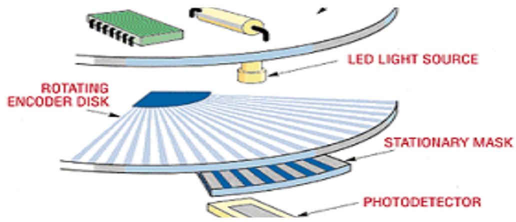
For a size of 24 bits
Size_maxi of counter = 2^24
Angle_max = 0.08 * 2^24 = 3728 turn

If the motor turns a screw with a step of 1 mm .....

Distance_max = 3.728 m

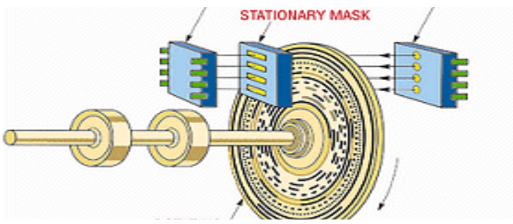
43

Incremental Encoder



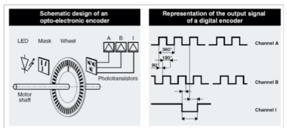
44

Absolute Encoder



45

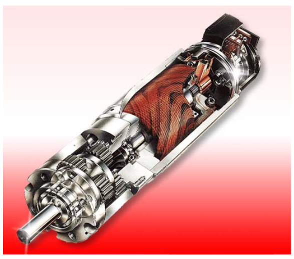
Rotary encoders



Robust
Compact
Moderate cost
Typically
200 – 1'000 lines/rev

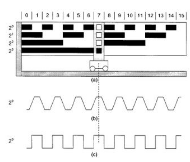
46

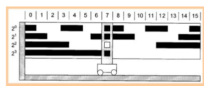
Rotary encoders (maxon motor)

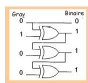


47

Absolute position



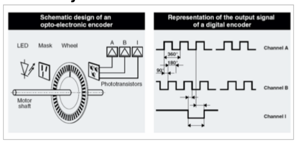


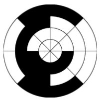


Only 1 bit changes between subsequent position with the Gray code.

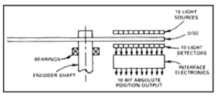
48

Rotary encoders





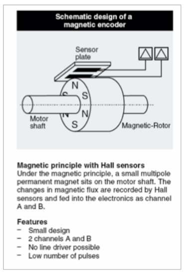
Absolute code wheel (3 bits)



Absolute code wheel (16 bits)

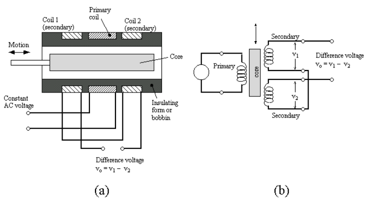
49

Rotary encoders (magnetic)



50

LVDT: Linear Variable Differential Transformer



Differential measurement principle:

Very robust to temperature change, supply voltage fluctuations etc.

No electronics at sensor itself
=> robust, large operating temp. Range

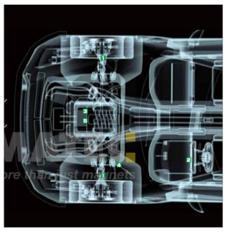
Used in industry & Airplanes
(control of flap position)

51

RVDT, a special type of the more general Resolver

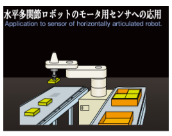
Basic resolvers are two-pole resolvers, meaning that the angular information is the mechanical angle of the ~~stator~~ **rotor**. They give the absolute angle position.

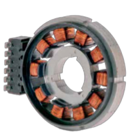
Multipole resolvers have 2*p* poles (*p* pole pairs), and thus can deliver *p* cycles in one rotation of the rotor: the electrical angle is *p* times the mechanical angle. Some types of resolvers include both types, with the 2-pole windings used for absolute position and the multipole windings for accurate position. Two-pole resolvers can usually reach angular accuracy up to about ±5′, whereas a multipole resolver can provide better accuracy, up to 10″ for 16-pole resolvers, to even 1″ for 128-pole resolvers.



52

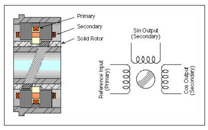
Resolvers: Example from Bomatec catalogue (Tamagawa)





53

Example Admotec Zurich



le Rotasyn utilise un entrefer constant qui le rend moins sensible à l'excentricité et aux champs magnétiques parasites. Il peut être directement connecté à des convertisseurs resolver-numérique (RDC en anglais) classiques.

Le Rotasyn ouvre la porte à une mesure rotative d'angle ou de vitesse sans joint tournant. Unemembrane métallique est introduite dans l'entrefer. Elle permet de confiner la partie électrique dans une zone hermétiquement étanche et ainsi de la soustraire aux influences extérieures.

54

High resolution over large range:

The dynamic range is limited by the signal to noise ratio

resolution	range	ratio	# bits
1 µm	1 mm	1'000	≅ 10
1 nm	1 µm	1'000	≅ 10
1 nm	1 mm	1'000'000	≅ 20
1 nm	1 m	1'000'000'000	≅ 30

When nm resolution has to be measured on several millimeters, incremental sensors and counters must be selected

Position Sensors

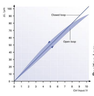
Low range sensors

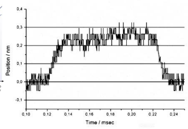
Strain gauges = Jauge de contrainte as position sensor

The strain $e = \Delta L/L$ *is defined as deformation* Δx

Strain gauges can be used as position sensors.

➡ *Stack piezo*

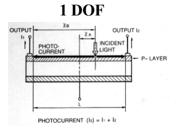


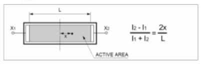


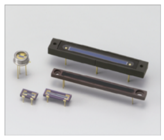
Position sensors (Position Sensitive Detector - PSD)

A incident light (e.g. laser beam) generates photocurrents in a PIN junction. The collected current provide the position information.

1 DOF

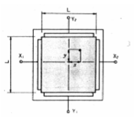






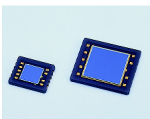
Position sensors (Position Sensitive Detector - PSD)

2 DOF



$$\frac{X_2 - X_1}{X_1 + X_2} = \frac{2x}{L}$$

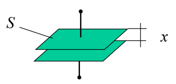
$$\frac{Y_2 - Y_1}{Y_1 + Y_2} = \frac{2y}{L}$$



Resolution (few µm)
Moderate range (a few mm)
Reduce size
Cost effective

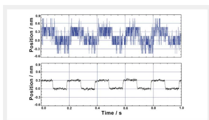
Position sensors (capacitive)

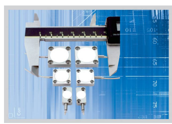
The capacity changes with electrode distances and/or surfaces



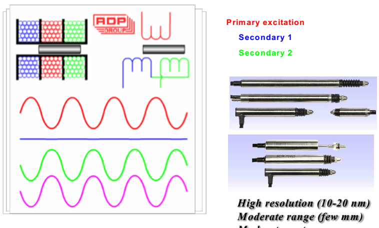
$C = \varepsilon_0 * \varepsilon_r * S / x$

Very high resolution (pm)
Short range (100-500 µm)
Bulky (cm³)
Expensive (sensor and electronics)





Sensors (Linear-Variable-Differential-Transformer, LVDT)



High resolution (10-20 nm)
Moderate range (few mm)
Moderate cost

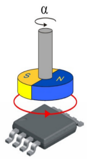
61

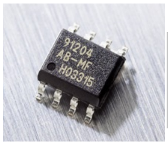
Sensors used in the « TWIICE » Exoskeleton

62

Hall effect angular position sensor

https://www.melexis.com/en/product/MLX91204/Integrated-2-Axis-Hall-Sensor





Nominal Supply Voltage	5 V
Height	1.7 mm
Size	6 mm x 5 mm
Overall Linearity	± 3.90 deg

6 Fr/pièce

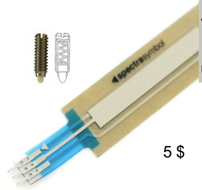
63

http://www.spectrasymbol.com/potentiometer/

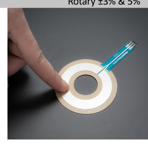
Soft pot

Pot

Life Cycle	>1 million
Height	≤0.5 mm
Actuation Force	-40°C 0.8 to 1.8 N +50°C 0.6 to 1.5 N
Linearity	Linear ±1% & 3% Rotary ±3% & 5%



5 $



64

Load cell from CHF 20.- scale

Overall Linearity	0.03 %
Excitation voltage	<10 V
Input resistance	1 kΩ
Dim	35 x 32 mm
Height	6 mm

CHF 5.-

65

High-end sensors: Baumer, Kistler, LEM…

Baumer (Frauenfeld)

Détecteurs inductifs
Distance jusqu'à 16 mm
résolution ordre du nm

Ultrason, plages cm à m

résolution 0.3 mm
répétabilité 0.5 mm

Détecteurs Laser « time of flight »
Plage de mesure m à 10 m
résolution ordre du mm
répétabilité ± 5mm

Codeur absolus,
incrémenteaux
inclinometres
accéléromètres …

66

Encoders: Example

- Lenord + Bauer « Drehgeber »
  up to 100’000 rpm (200 kHz)

67

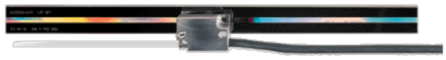
Linear encoders
Industrial products

Robust, reliable
Rather compact
Moderate cost
Resolution up to 5 nm

Numerik Jena

Renishaw

Heidenhain



Zerodur glass ceramic embedded in bolted-on Invar carrier

68

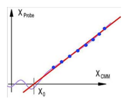
High-end sensors: Baumer, Kistler, LEM

- Kistler (Winterthur) force, torque, accelerometers, pressure
- Baumer (Frauenfeld) position, angle, acceleration, inductive, laser, ultrasonic etc.
- LEM (Geneva) electrical current

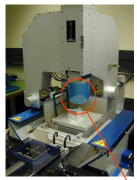
69

Metrology: Coordinate Measurement Machine (CMM)

Principle



“Zero force” contact probe



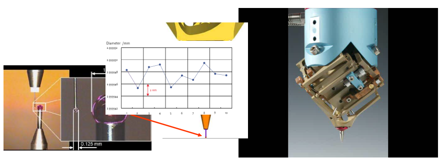
Housing for good temperature homogeneity

3D touch probe

courtesy METAS

70

Metrology: 3 D touch probe



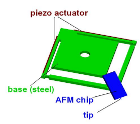
repeatability in one point: **5 nm**
accuracy within the volume: **< 30nm**
probe diameters: **1 mm down to 0.125 mm**

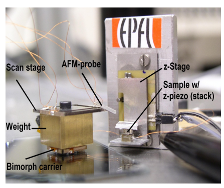
courtesy METAS

71

Un micro-robot équipé d’un AFM

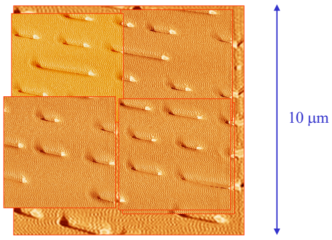
Scanner AFM





72

Mesure de position par AFM



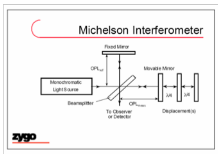
Optical Position Sensors

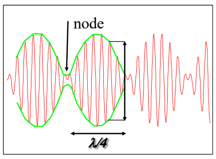
Exemple de Start-up EPFL

atracsys

Laser interferometer

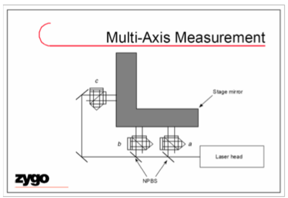
The reference scale is the wavelength of a laser beam. Interferences with a reference beam creates nodes every λ/4 (typically 160 nm).



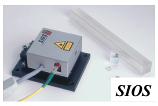


Fringe counter (nodes): typ. 160 nm
Interpolation (amplitude): typ. 0.16 nm (1'000)

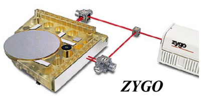
Multi axis configuration



Some examples of laser interferometers



SIOS

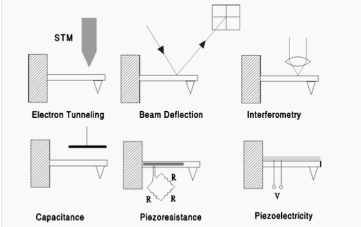


ZYGO

High resolution (0.1 - 5 nm)
large range (few m)
Rather expensive
Bulky

RENISHAW

Other example **Deflection sensors** for **Local** Measurements



Force Sensors

Multi-DoF sensor (6 dof wrist, Bejczy)

FSR Force Sensing Resistors

Semi-conductive paste (containing graphite particles) sandwiched between polymer layers, deposited by screen printing

Invented in the 1980ies by Mick Fleetwood looking for sensors for his drums…

Robust, low cost, good sensitivity, but limited precision (around 10%)
MΩ to kΩ @ 100 kN/cm²

Application in Biomedical Technology:

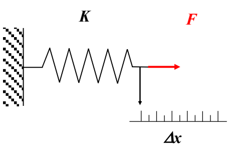
Foot sensor

Presence sensor in car seats

etc.

Interlink Electronics IEE, Luxenbourg

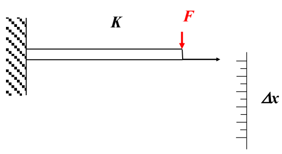
Force sensor, principle



$F = K * \Delta x$

A force sensor (load cell) is basically an elastic body and a position sensor.

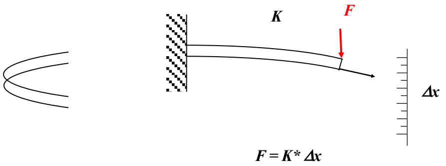
Force sensor, principle



$F = K * \Delta x$

A force sensor (load cell) is basically an elastic body and a position sensor.

Force sensor, principle

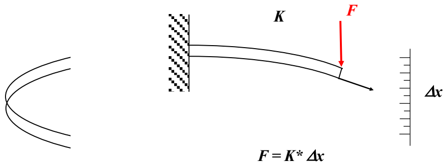


$F = K^* \Delta x$

A force sensor (load cell) is basically an elastic body and a position sensor.

85

Force sensor, principle

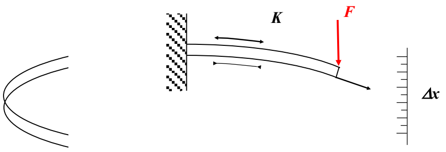


$F = K^* \Delta x$

A force sensor (load cell) is basically an elastic body and a position sensor.

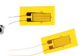
86

Force sensor, principle



$F = K^* \Delta x$

The deformation can be measured with strain gauges



87

Position sensor (strain gauges)

The strain e is proportional to the deformation Δx

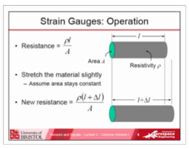
Strain gauges are often used as position sensors.

Stack piezo

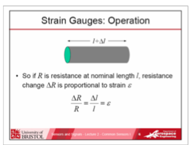
Piezo cantilevers: flexure

88

Strain gauges


Strain Gauges: Operation

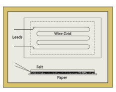
- Resistance = $\frac{\rho l}{A}$
- Stretch the material slightly
  - Assume area stays constant
- New resistance = $\frac{\rho(l+\Delta l)}{A}$

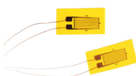

Strain Gauges: Operation

- So if R is resistance at nominal length l, resistance change ΔR is proportional to strain ε

$$\frac{\Delta R}{R} = \frac{\Delta l}{l} = \varepsilon$$

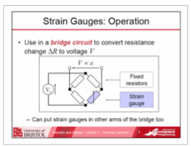
Source: http://seis.bris.ac.uk/~aeagr/sensors/lecture2.pdf



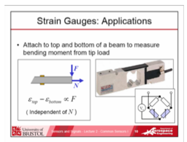


89

Strain gauges


Strain Gauges: Operation

- Use in a ***bridge circuit*** to convert resistance change ΔR to voltage V
  - Can put strain gauges in other arms of the bridge too


Strain Gauges: Applications

- Attach to top and bottom of a beam to measure bending moment from tip load

$\varepsilon_{top} - \varepsilon_{bottom} \propto F$

(Independent of N)

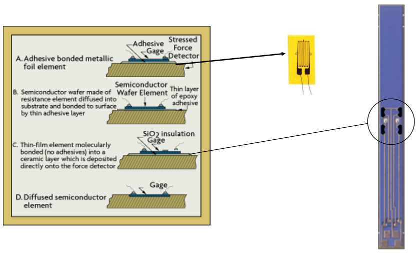
Source: http://seis.bris.ac.uk/~aeagr/sensors/lecture2.pdf

$F = K^* \Delta x$ ⟶ Sensitivity: $K = F / \Delta x$

High sensitivity means low stiffness (small K).
It is generally a problem for high accuracy manipulation

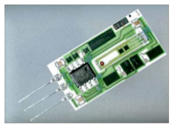
90

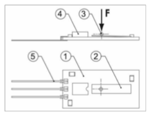
Different types of strain gauge technology



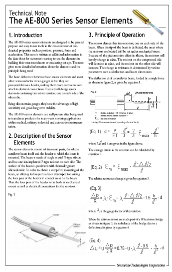
91

Commercial products: Millinewton (Sensile), SensorOne





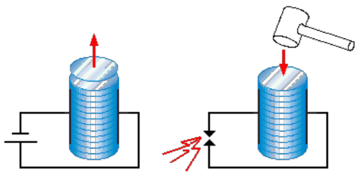
1 Base
2 Cantilever Beam
3 Force Centering Ball
4 Amplification Circuit
5 Lead Frame SIL



Technical Note
The AE-800 Series Sensor Elements

92

Piezoelectric transducers:



Piezo as an **actuator**:
charge -> strain -> stress

Piezo as a **sensor**:
stress -> strain -> charge

93

Piezoelectric materials

- quartz (weak)
- salt (very weak)

polycrystaline ferroelectric ceramics:

- BaTiO3,
- Lead Zirconate Titanate (PZT)

94

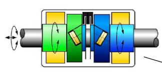
Basic mechanism:
Stress -> strain -> charge

- Also charge -> strain (actuator)
- complex geometry
  (polarisation direction, strain tensor, shear…)
- small displacements, high forces, high voltages
  (µm to tens of µm for cm size PZT, 100s of Volt)
- nonlinearity, hysteresis
- Ceramics -> brittle -> prestress

95

mechatronics technology

2-dof friction drive « LINROT »
for translation and rotation



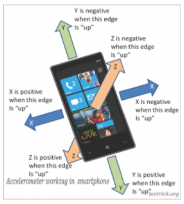
6-dof force sensor

- for extended bandwidth
- compensation of friction and inertia
- signal conditioning electronics already integrated

xitact
medical simulation

96

Accelerometers, Gyroscopes
IMU for Inertial Mearsurement Unit



- MEMS-fabricated
- Detection of motion of proof-mass
- Detection:
  - capacitive
  - optic (laser)
  - piezoelectric or piezoresistive
  - others

- Applications:
  - crash detection
  - motion analysis
  - smarrtphone
  - games etc.

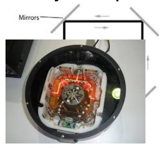
97

Gyroscopes

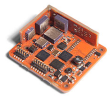
Detection of orientation

- gyrocompass
- magnetic compass)
- Optical gyroscopes (precise, expensive)
- MEMS: Out-of-plane oscillation

Together with accelerometers:
"IMU" Inertial Measurement Units



Applications: Mobile robotics, Biomedical, Drones etc.



xsens

98

Problème des mesures inertielles:

Position & Orientation s'obtiennent après une double intégration

Repère zéro?

Compléter avec GPS, SLAM*), utilisation de la gravitation et de repères pour l'initialisation & la recalibration

*) SLAM: Simultaneous Localisation And Mapping

99

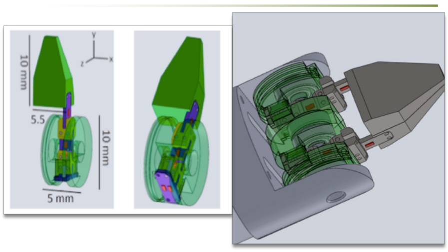
Exemple d'une start-up EPFL qui exploite les capteurs IMU MEMS:

Gaitup

100

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

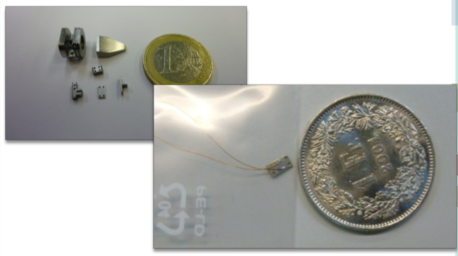
Force sensing in surgical telemanipulators



101

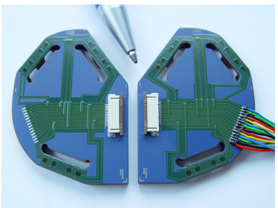
EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Pièces d'horlogerie...



102

Force Sensor for Knee Surgery:

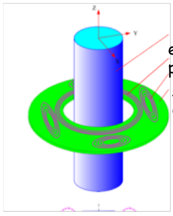


103

Deux « spécialités »

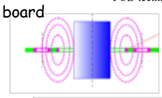
104

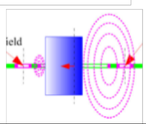
Example: Technology choice (PCB) leads to new sensor:
Transverse Flux Sensor



excitation coil
pickup coil
standard Printed
Circuit board

- Analog
- RF Electromagnetic
- Distance, conductivity
- PCB technology





Philippe Bühler,
Mecos Traxler AG Winterthur

105

Transverse Flux Sensor

Excitation frequ.
20 kHz to 3 MHz

depending on electr.
& magnetic properties
of target material

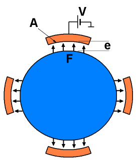
Potential for high precision since there is **averaging over large target** area.
Unaffected by low frequ. & static fields.

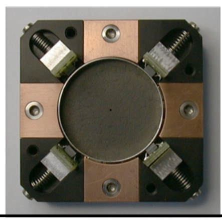
106

MOVIC 2008

2-D diamagnetic vibration sensor

Electrostatic actuators
for nulling

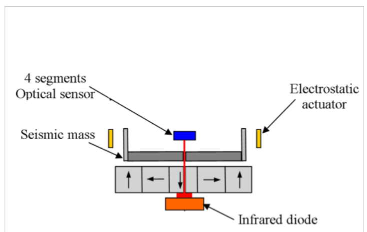




107

MOVIC 2008

2D accelerometer with a
4-segment photodiode



108