BIOMECHANICS:
Lecture #4 – Kinematics measurements

FACOLTÀ DI INGEGNERIA
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UNIVERSITÀ DI ROMA

1

REMIND:

If in the slide there this symbol the topic is not discussed in the textbook "Sensors and transducers for mechanical and thermal measurements"

The slide is available on the Moodle platform.

2

Introduction

Motion analysis has been used to study
- Gait,
- shoulder, arm, trunk, and head movements.

Motion can be measured in two ways:
- directly, by sensors attached to the human body
  - simple and inexpensive
  - less accurate
  - it is difficult to attach the sensors
- indirectly, by optical methods.
  - is accurate
  - can only be used in limited areas and
  - is expensive.

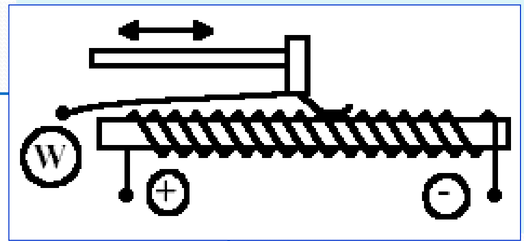
3

SENSORS ATTACHED TO THE HUMAN BODY

POTENZIOMETRI

4

Potentiometer



Divider resistors:

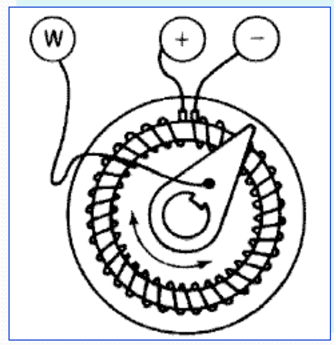
- voltage or
- current,

To detect movements:

- linear
- angular (up to 7,200°).

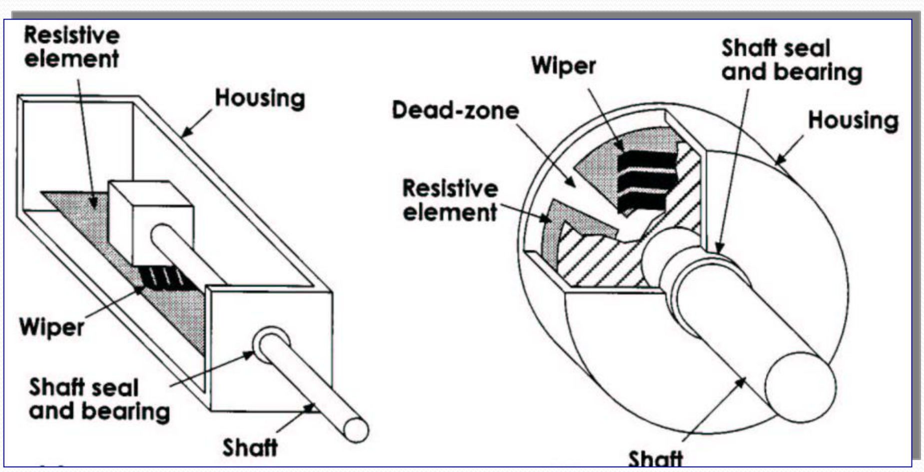
Making:

- conductive wire wrapped around a structure of sufficient mechanical stiffness support,
- using conductive plastic or metal-ceramic composites (cermets).



5

Potentiometer



6

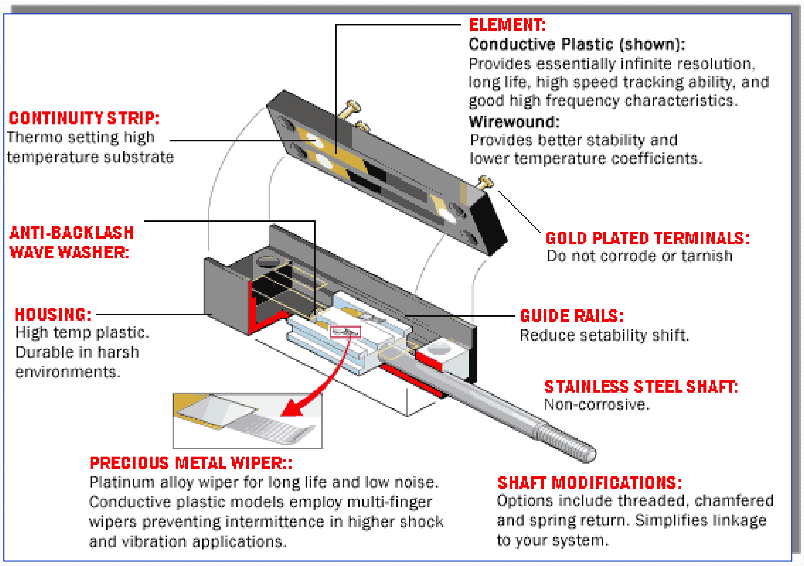
Potentiometer

	Conductive plastic	Wirewound	Hybrid
Resolution	Infinitesimal	Quantized	Infinitesimal
Power rating	Low	High	Low
Temperature stability	Poor	Excellent	Very good
Noise	Very low	Low, but degrades with time	Low
Life	10^6–10^8 cycles	10^5–10^6 cycles	10^6–10^7 cycles

HYBRID:

elements feature a wirewound core with a conductive plastic coating, combining wirewound and conductive plastic technologies to realize some of the more desirable attributes of both. The plastic limits power dissipation abilities in exchange for low noise, long life, and unlimited resolution. Like wirewounds, hybrids offer excellent temperature stability. They make an excellent choice for precision measurement.

Potentiometer



Potentiometer

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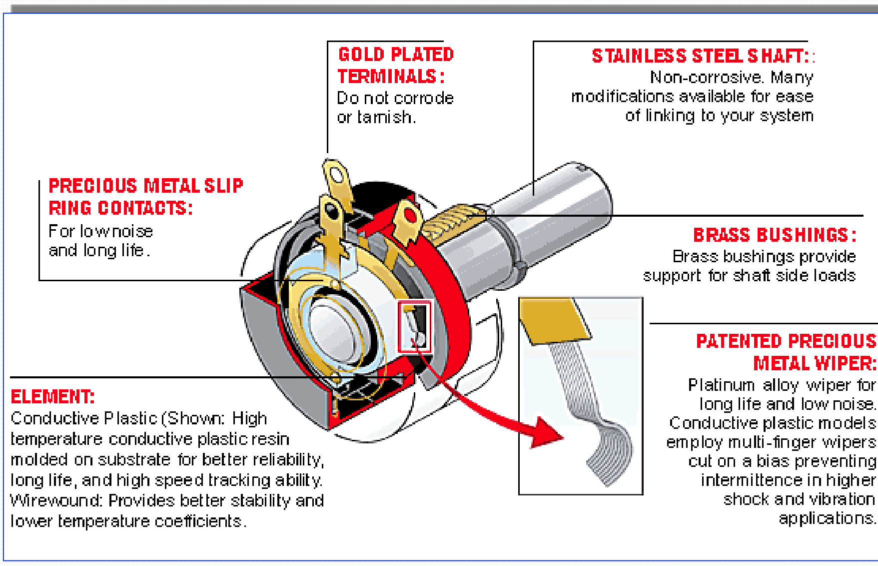

11

Potentiometer

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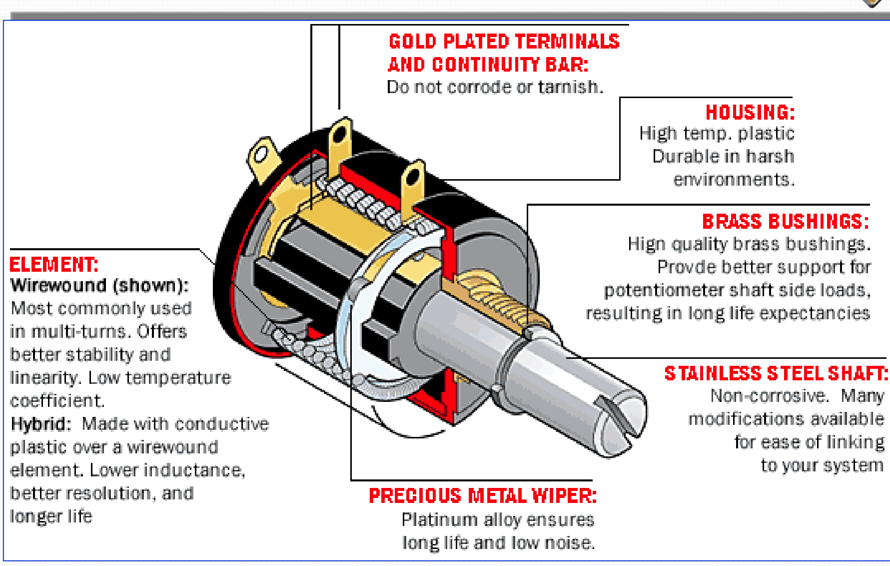
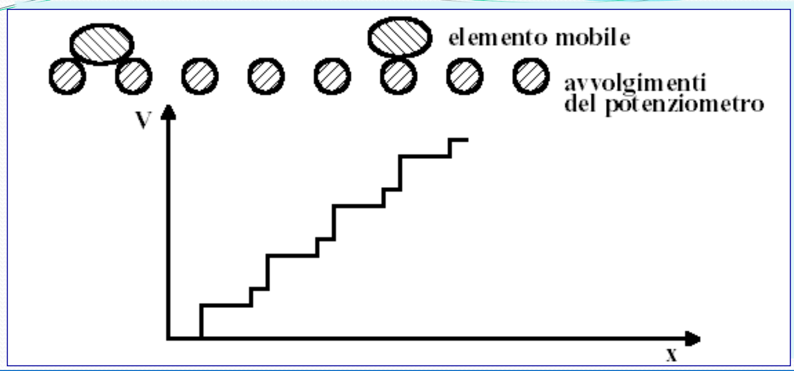


12

Potentiometer



The resolution of the wire wound type potentiometers depends on: :

- The total number n of windings,
- the length L of the wire,

and it is equal to L / n;

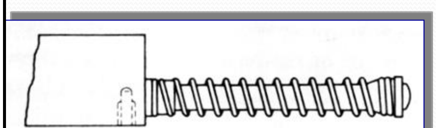
- Resolution: 0.05-1 percent.
- The sensitivity is a function of the supply voltage of the potentiometer (attention to the selfheating effect)

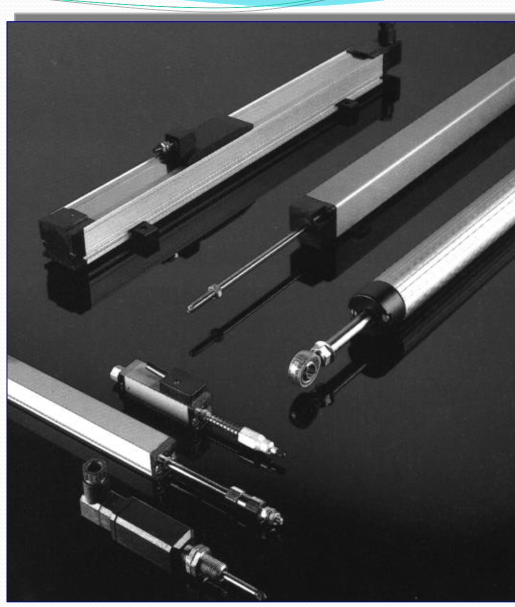
13

Potentiometer

Input-output relationship:

- Linear,
- logarithmic,
- exponential,
- etc.





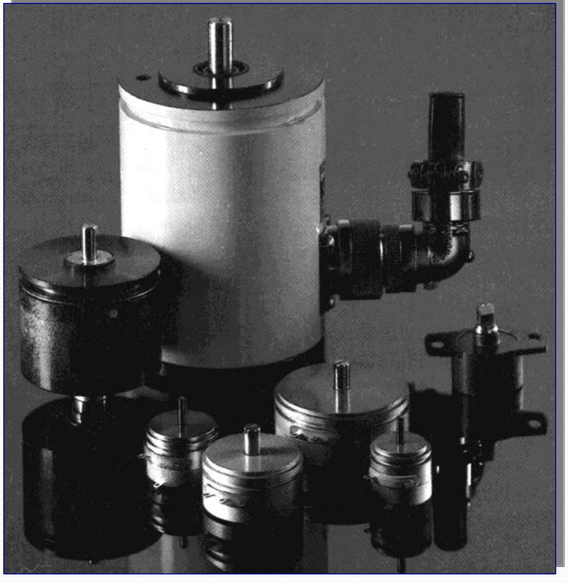
14

Potentiometer

MEASURING RANGE:
- About 10 mm,
- Around 20 degrees

PROS:
- cheap
- inherently accurate;
- simple measurement chain (constant-voltage power supply and voltmeter).

CONS:
- analog signal.



15

Potentiometer

The potentiometers in conductive plastic films or using cermets:
Resolution: 0.001 mm;

PROS:
- electrical noise lower than that of the wire-type potentiometers (oxide removal in those wire)
- a longer life period.

LIFE PERIOD
- wire potentiometers about 1 million cycles,
- Conductive plastic potentiometers about 10 million cycles.

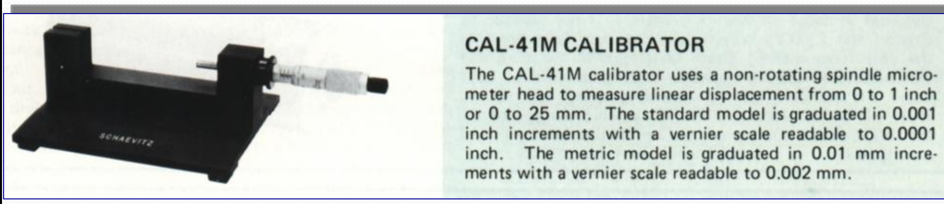
16

Potentiometer

an ideal displacement transducer, a zero-input mechanical impedance :

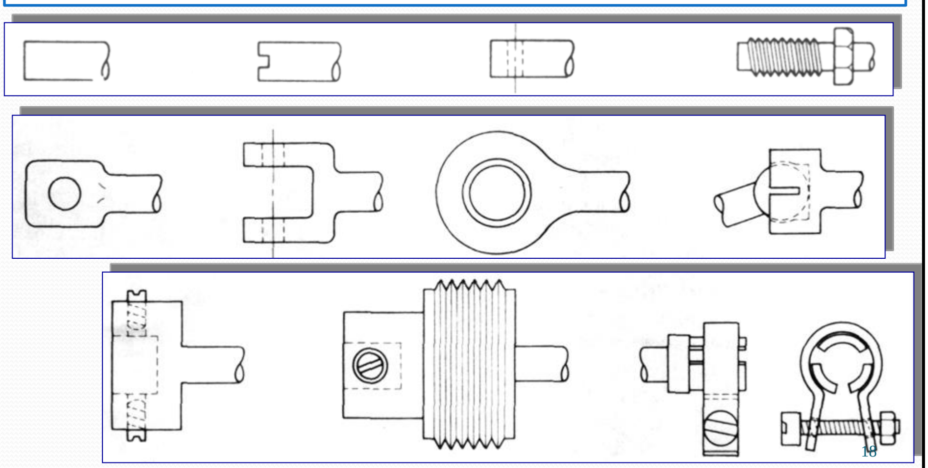
- about 200 g for potentiometers for measuring linear displacements
- about 0.3 g / cm to those for measuring angular displacements.

- Resolution: 0.025 mm,
- Sensitivity: 1 V / mm with potentiometers of 80 W / mm,
- dissipation capacity: 20 W / mm.

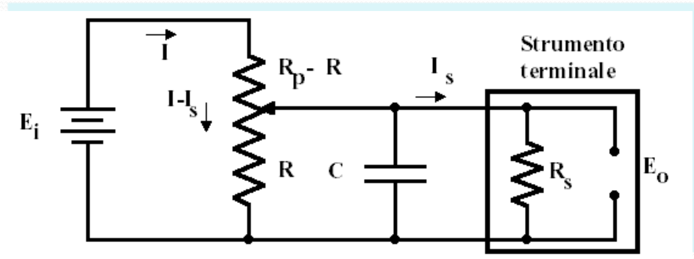


Potentiometer

CAUTION: mechanical connection made with a device placed between the object of measurement and the transducer.
This device should be examined by the experimenter with an attention identical to that given to all the other elements making up the measurement chain.



Potentiometer



$$E_o = I_s R_s = (I - I_s) R = E_i - I (R_p - R)$$

$$E_o = \left[\frac{R_s/R_p}{\left(R_s/R_p\right) + \left(R/R_p\right) - \left(R/R_p\right)^2} \right] \left(R/R_p\right) E_i$$

$$E_o = \left(1 - \eta\right)\left(R/R_p\right) E_i$$

19

Potentiometer

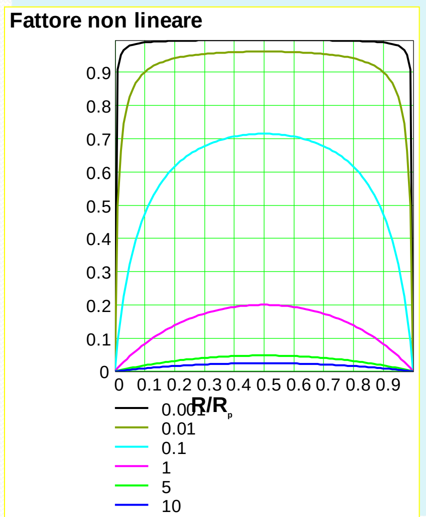
PLEASE NOTE:
the maximum deviation from linearity is reached for a value of x such that R / Rp = 0.5. For this position the mistake of not ERnl linearity is equal to:

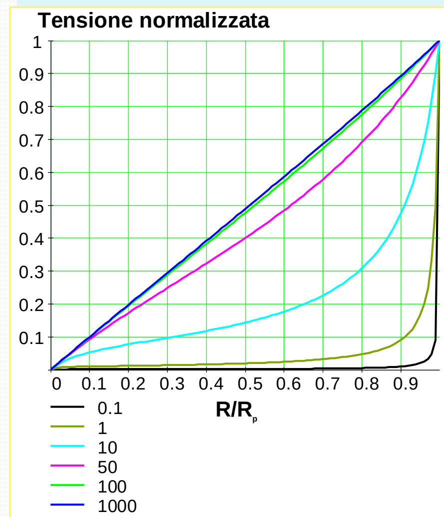
$$ER_{nl} = \frac{E_o - E_o'}{E_o} = \frac{1}{1 + 4\left(R_s/R_p\right)}$$

where E'o is the voltage that would occur without the presence of the output terminal instrument when R / Rp = 0.5.

20

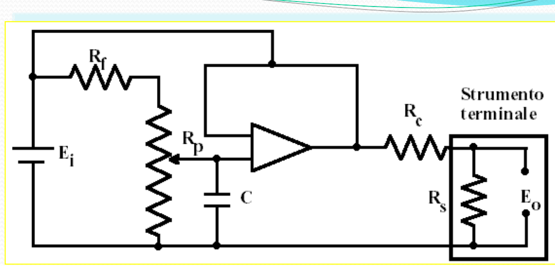
Potentiometer





21

Potentiometer



PROBLEM: measure the voltage output from a sensor with an high impedance in output connected to instruments having a value of a low input impedance content (e.g. paper recorders).
SOLUTION: the insertion between the transducer and the instrument an operational amplifier of the voltage-follower type.

CHARACTERISTICS:

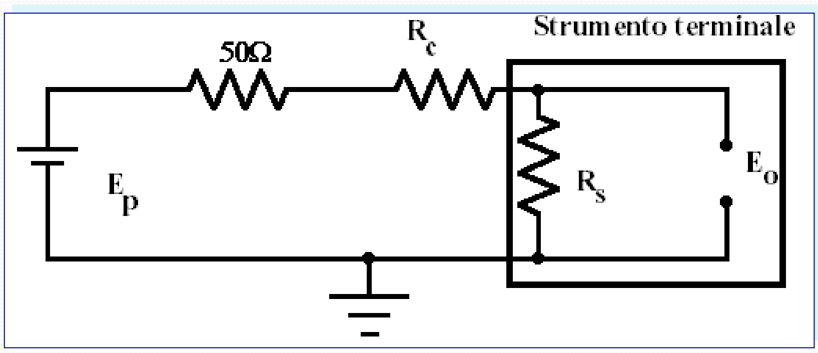
- a unitary amplification factor;
- high value of the input impedance (10^{11}-10^{12}W); and finally,
- low value of the output resistance (about 50W).

22

Potentiometer

The presence of a voltage-follower allows the conversion:

- of a voltage generator having a high electrical resistance in
- a system with low resistance value output and with a value of electric power that it can directly drive instrumentation also with low input resistance value.



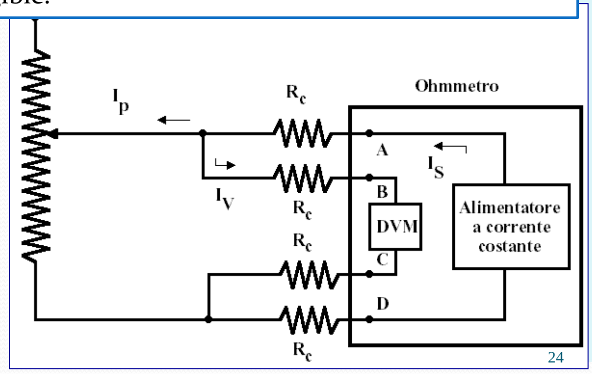
23

Potentiometer

- RC is the contact resistance between the connection cables and the instrument connectors.
- The fall of CEs potential which manifests itself to connectors A and D (EC = IPRC) has no effect in determining the potential drop across the potentiometer heads;
- Furthermore, since the impedance of the voltmeter is such that, the potential drop that has to B and C connectors determines an effect that can be considered negligible.

$$I_V \cong (1/100 \div 1/1000) \cdot I_s$$

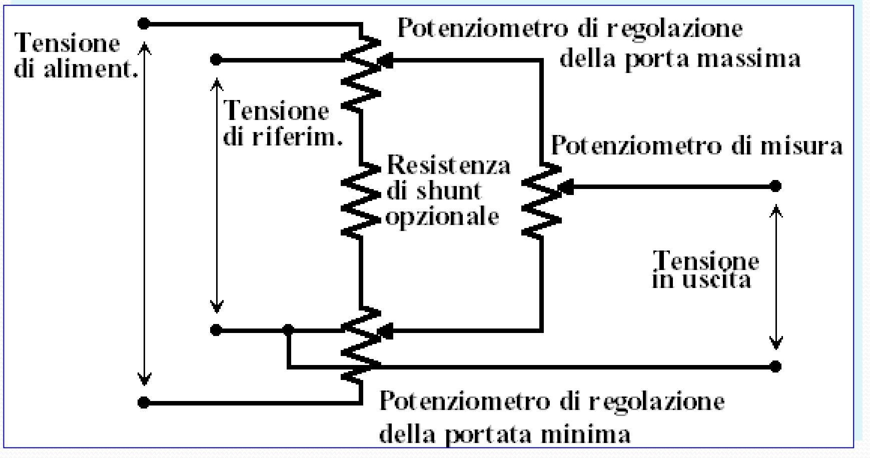
$$E_C^{'} = 2 I_V R_C$$



24

Potentiometer

You may need to adjust the output voltage range specified by the potentiometer within specified values: add two other potentiometers.



25

Potentiometer

CAUTION

GONIOMETERS

A goniometer is a special name given to the electrical potentiometer that can be attached to measure a joint angle.

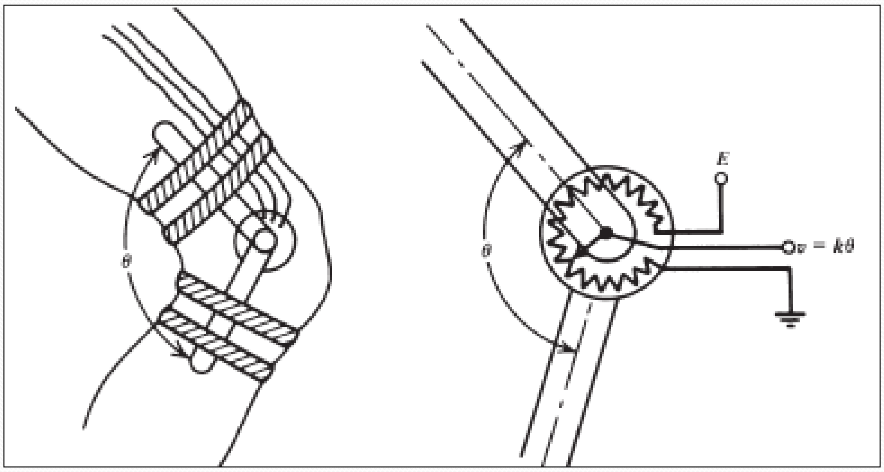
- One arm of the goniometer is attached to one limb segment,
- the other to the adjacent limb segment, and
- the axis of the goniometer is aligned to the joint axis.

A constant voltage E is applied across the outside terminals, and the wiper arm moves to pick off a fraction of the total voltage. The fraction of the voltage depends on the joint angle θ.

26

Potentiometer

CAUTION



27

Potentiometer

CAUTION

GONIOMETERS

PROS:

- A goniometer is generally inexpensive.
- The output signal is available immediately for recording or conversion into a computer.
- Planar rotation is recorded independently of the plane of movement of the joint.

28

Potentiometer

CAUTION

GONIOMETERS

CONS:

- Relative angular data are given, not absolute angles, thus severely limiting the data assessment value.
- It may require an excessive length of time to fit and align, and the alignment over fat and muscle tissue can vary over the time of the movement.
- If a large number are fitted, movement can be encumbered by the straps and cables.
- More complex goniometers are required for joints that do not move as hinge joints.

29

Potentiometer

CAUTION

GONIOMETERS

In general, goniometers are inexpensive and contain sufficient information for gait event detection. However, they have practical limitations.

- There is always a problem of attachment and the need for a range of devices to fit different-sized limbs and digits.
- Joint goniometers are vulnerable to breakage where they cross a joint.
- Other common issues are difficulties in alignment with, and determination of, joint centres of rotation, restriction of movement by the device, or incomplete decoupling of the measurement of motion in the two planes (cross-talk).
- The size, weight and physical location of the goniometer can be critical so that it does not interfere with function.
- Only relative angular data are produced, not absolute angles.
- Furthermore, it is unlikely that an older person preparing to embark on a period of exercise could successfully attach these devices without external assistance.

30

Potentiometer

Specification Summary:

GENERAL

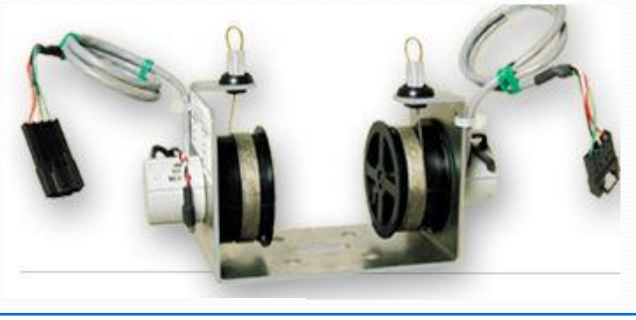
Full Stroke Ranges	0-3 and 0-5 inches, min.
Output Signal	voltage divider (potentiometer)
Accuracy	±0.15 % full stroke
Repeatability	±0.02% full stroke
Resolution	essentially infinite
Potentiometer Cycle Life	50 x 10^6 cycles*
Measuring Cable	0.024-in. dia. nylon-coated stainless steel
Enclosure Material	anodized aluminum
Sensor	conductive plastic potentiometer
Weight (maximum)	3-inch: 0.10 lbs., 5-inch: 0.26 lbs.

ELECTRICAL

Input Resistance	5K ohms (±10%)
Power Rating, Watts	1.0 at 40°C (derated to 0 @ 110°C)
Recommended Maximum Input Voltage	30V (AC or DC)
Temperature coefficient of voltage dividing ratio	< 2 ppm/°C
Temperature coefficient of resistance	
-50...+75°C	±200 ppm/°C
+75...+100°C	±300 ppm/°C
Output Signal Change Over Measurement Range	94% ±4% of input voltage

31

Potentiometer



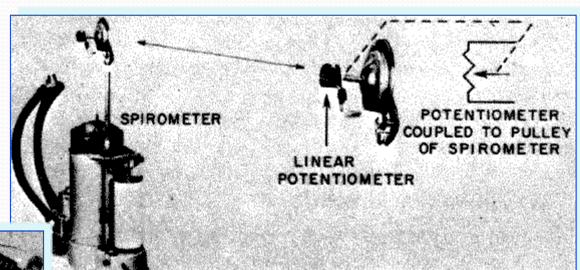
Linear cable extension position transducers are being used to provide measurement input for a revolutionary surgery system. Celesco Transducer Products, Inc., a world leader in cable extension transducers, and Intuitive Surgical, Inc., a minimally invasive telepresence surgery pioneer, collaborated to implement a measurement system for robots designed to perform surgery. The cable extension technology was chosen by high level engineers at Intuitive Surgical for its low cost and ease of use.

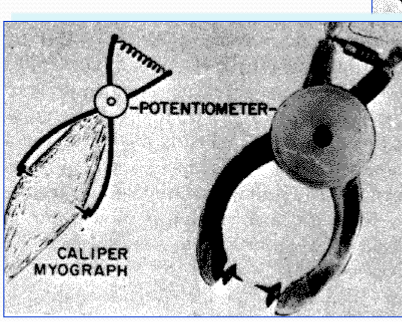
32

Potentiometer

33

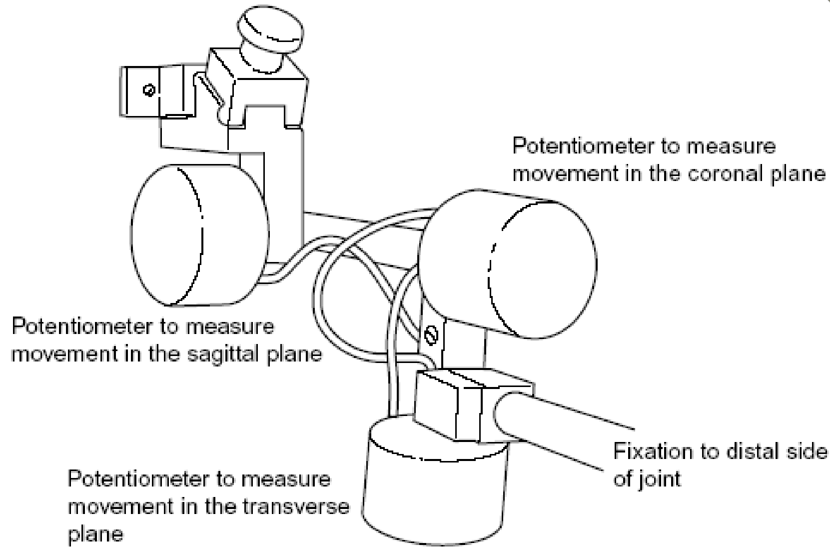
Potentiometer





34

Potentiometer



35

Potentiometer

The system consists of a unit with six potentiometers connected to seven metal rods that measures motion with 6 dof.

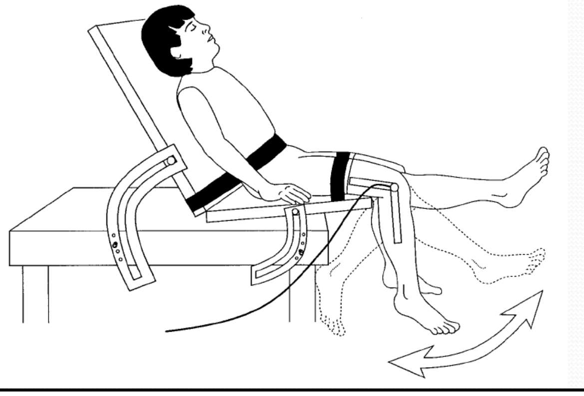
Each end of the potentiometer unit is attached to a post, one located on a helmet, the other located on a arness strapped to the upper thorax, providing measurements of head displacement relative to the thoracic post with virtually no restriction of motion.

36

Potentiometer

CAUTION

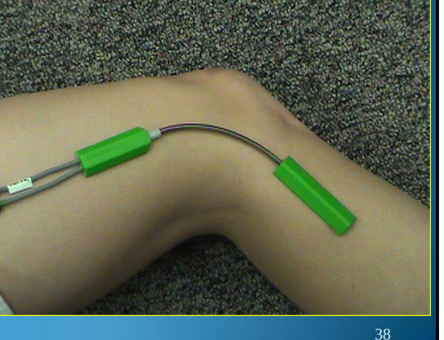
The data acquisition system consisted of an analogue-to-digital board and computer with customized software. The electrogoniometer consisted of a potentiometer attached to both a stationary and a moving arm. The moving arm slid within a precision-milled encasement that allowed the center of the potentiometer to maintain alignment with the center of the knee joint.



37

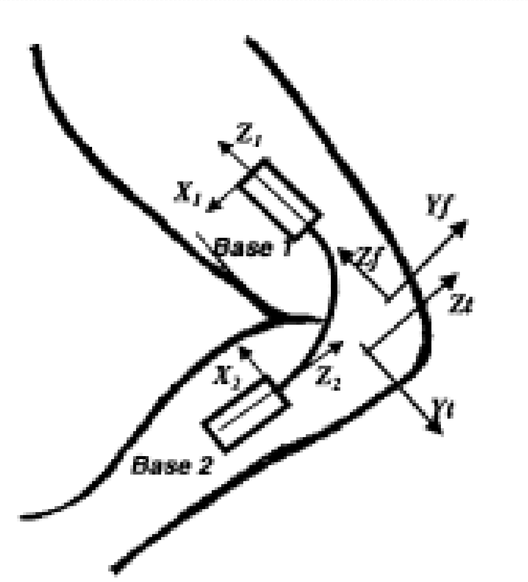
SENSORS ATTACHED TO THE HUMAN BODY

ELETTROGONIOMETER



38

Electrogoniometer



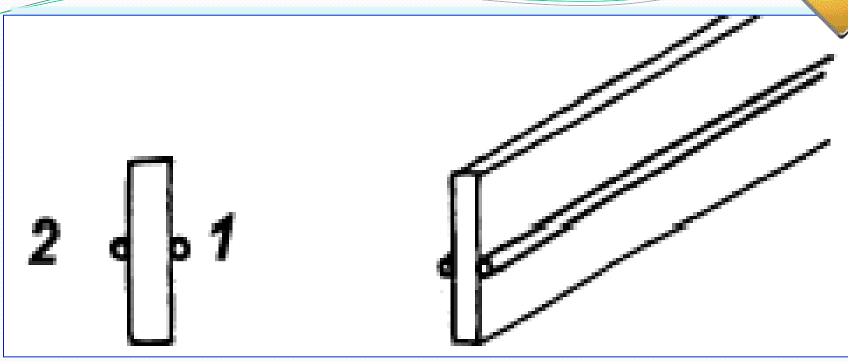
The flexible goniometer consists of :

- plastic endblocks that are connected at each end by
- a conductive piece of rubber.

The strain gauge housing inside the conductive rubber changes its electrical resistance in proportion to the change in the angle between the longitudinal axes of the endblocks.
The voltage output is proportional to the angle between the endblocks.

39

Electrogoniometer

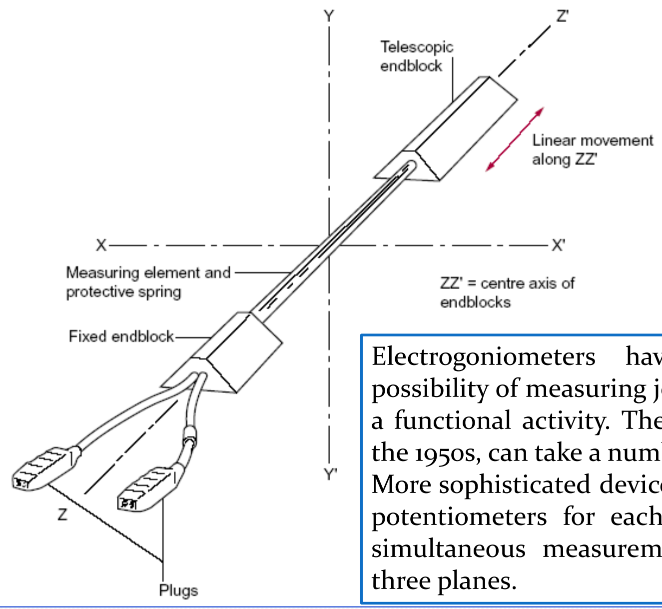


The strain gauge housing inside the conductive rubber changes its electrical resistance in proportion to the change in the angle between the longitudinal axes of the endblocks.
The voltage output is proportional to the angle between the endblocks.

- The axis of the goniometer does not need to be perfectly aligned with the axes of the joint.
- It is not easily damaged under large deformations.

40

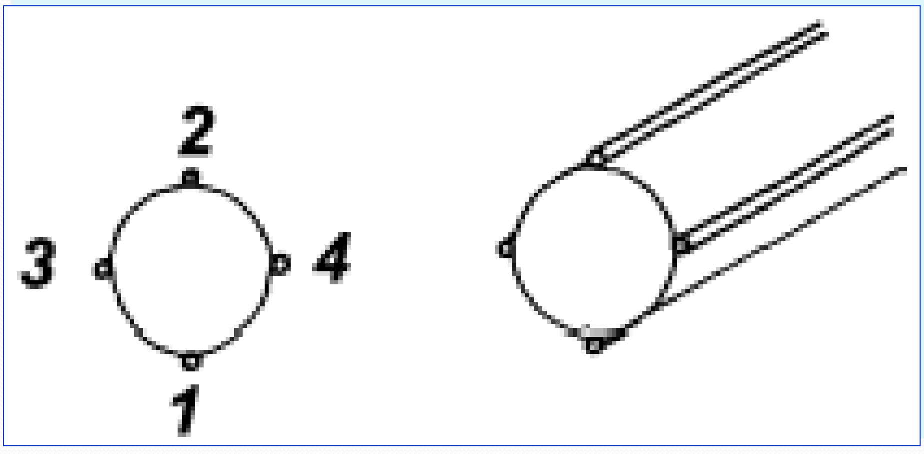
Electrogoniometer



Electrogoniometers have opened up the possibility of measuring joint movement during a functional activity. The electrogoniometer in the 1950s, can take a number of form.
More sophisticated devices may use up to three potentiometers for each joint, thus allowing simultaneous measurement of movement in three planes.

41

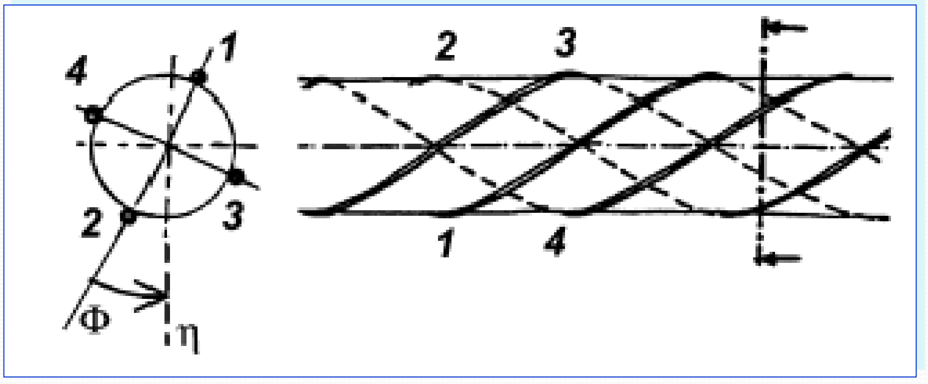
Electrogoniometer



The biaxial version of this device allows one to simultaneously measure movement in up to two planes, such as the sagittal and frontal planes.

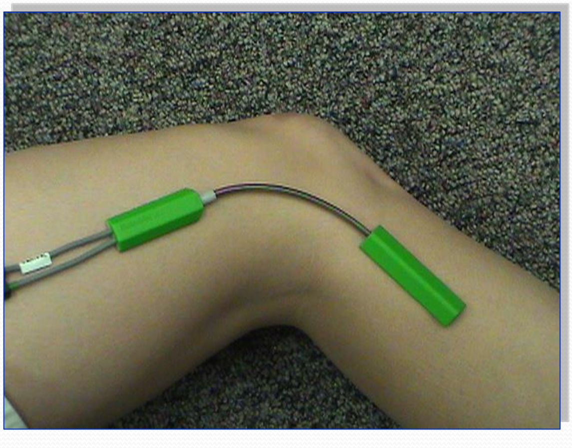
42

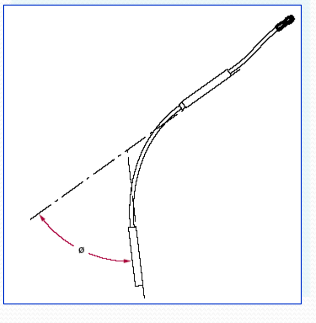
Electrogoniometer



43

Electrogoniometer





44

Electrogoniometer

45

Electrogoniometer

The "SG" series twin axis goniometers simultaneously measure angles in up to two planes of movement.

For example, to measure wrist movements, the endblocks of the SG65 goniometer are attached on the dorsal surface using double sided tape,(type. No. T10), one end over the third metacarpal, the other over the midline of the forearm, with the wrist in the neutral position.

The goniometer has two separate output connectors,

- one measures flexion/extension,
- the other radial/ulnar deviation.

When used to measure a single axis joint such as the knee or elbow, or when measuring a single plane of a twin axis joint, simply connect one channel, the other remains redundant. All twin axis SG series goniometers function the same way, the difference being physical size.

46

Electrogoniometer

47

Electrogoniometer

Fracture stiffness measurement in tibial shaft fractures: a non-invasive method

Summary—This paper presents a non-invasive method of assessing healing by measurement of fracture stiffness. The method works on the principle that if the load (F) applied at a certain known distance (Y) from the fracture is measured, then the moment (M = FY) at the fracture site can be calculated. By measuring the angle/deflection (θ) occurring at the fracture site using a suitable instrument (electrogoniometer), the necessary data to calculate fracture stiffness (FY/θ) would be available. The method was employed to assess the stiffness in a series of tibial shaft fractures treated conservatively, all of which healed uneventfully. This paper concentrates on a group of tibial shaft fractures in which the radiological criteria for fracture union were not satisfied even after a mean duration of 20 weeks treatment. The non-invasive method of measuring fracture stiffness supported the clinical impression of union in most cases at the first test, but was repeated on two more occasions to confirm the trend of progressive healing. The objective evaluation of fracture healing led to avoidance of surgical intervention in these patients, who went on to sound union.

48

Electrogoniometer

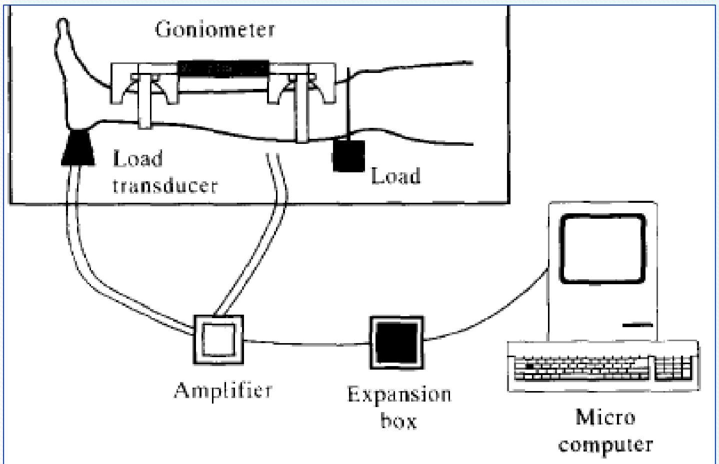


Figure 2. Diagrammatic representation of non-invasive measurement of fracture stiffness.

49

Electrogoniometer

Reliability and accuracy of different sensors of a flexible electrogoniometer

Abstract

Objective. To describe a gauging device for electrogoniometer sensors and to evaluate the reliability and accuracy of different sensors including two similar sensors.

Design. Repeated measurement design for reliability.

Background. Despite being considered reliable equipment, several aspects of electrogoniometer reliability and accuracy have not been reported so far.

Method. Five repeated measurements of each electrogoniometer sensor were perfomed in 1° increments, during the whole uniplanar amplitudes of flexion, extension, lateral deviations and rotational movements, totaling 6380 measurements.

Results. Values from the coefficient of variation and mean square error, respectively indicated that the reliability and accuracy of the sensors varied between sensors and movements, with goniometers being more reliable and accurate than torsiometers. A significant difference between identical sensors was identified.

Conclusions. No similar pattern of variation was found between the sensors evaluated, indicating that every sensor should be tested for its reliability and accuracy when highly precise measurements are needed, and particularly when bilateral limbs are being compared.

50

Electrogoniometer

CAUTION

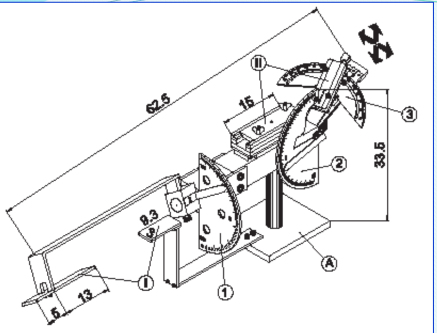


Fig. 1. Gauging device for flexible electrogoniometers (dimensions in cm).

Gauging device. As can be seen in Fig. 1, the device for gauging the flexible electrogoniometer included: a base and support (A); two compartments for placing the sensors (I and II) and three metal protractors for measuring the ranges of movement in three planes: vertical (about axis *Y–Y*) for flexion and extension (0–90°), horizontal (about axis *X–X*) for bilateral deviation (0–70°), and axial (along axis *Z–Z*) for rotational movements (0–90°).

51

Electrogoniometer

CAUTION

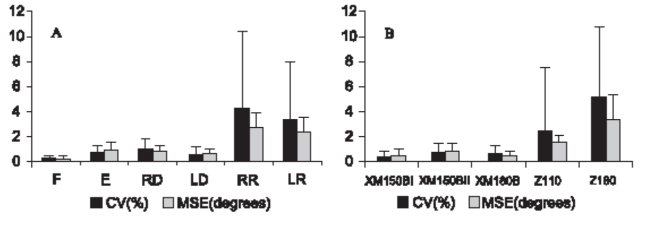


Fig. 2. Mean and standard deviation of the CV (in %) and of the MSE (in degree), for the movements (A) F—flexion; E—extension; RD—right deviation; LD—left deviation; RR—right rotation, and LR—left rotation, and for each sensor (B).

52

Electrogoniometer

Comparison of measurement accuracy between two wrist goniometer systems during pronation and supination

Abstract

Pronation and supination have been shown to affect wrist goniometer measurement accuracy. The purpose of this study was to compare differences in measurement accuracy between a commonly used biaxial, single transducer wrist goniometer (System A) and a biaxial, two-transducer wrist goniometer (System B) over a wide range of pronation and supination (P/S) positions. Eight subjects moved their wrist between −40 and 40° of flexion/extension (F/E) and −10 and 20° of radial/ulnar (R/U) deviation in four different P/S positions: 90° pronation; 45° pronation; 0° neutral and 45° supination. System A was prone to more R/U crosstalk than System B and the amount of crosstalk was dependent on the P/S position. F/E crosstalk was present with both goniometer systems and was also shown to be dependent on P/S. When moving from pronation to supination, both systems experienced a similar extension offset error; however R/U offset errors were roughly equal in magnitude but opposite in direction. The calibration position will affect wrist angle measurements and the magnitude and direction of measurement errors. To minimize offset errors, the goniometer systems should be calibrated in the P/S posture most likely to be encountered during measurement. Differences in goniometer design and application accounted for the performance differences.

53

Electrogoniometer

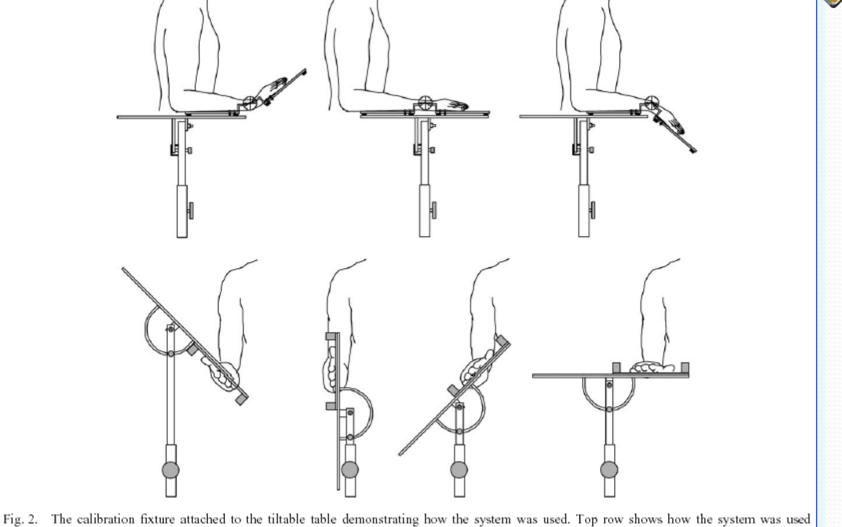


Fig. 2. The calibration fixture attached to the tiltable table demonstrating how the system was used. Top row shows how the system was used to position in flexion and extension, R/U movements were performed in the neutral (middle) position. Bottom row from left to right shows how the system was used to position the wrist and forearm in 45° supination, 0° neutral, 45° pronation and 90° pronation, respectively.

54

Electrogoniometer

Measurements of wrist and forearm positions and movements: effect of, and compensation for, goniometer crosstalk

Abstract

Flexible biaxial goniometers are extensively used for measuring wrist positions and movements. However, they display an inherent crosstalk error. The aim was to evaluate the effect, of this error, on summary measures used for characterizing manual work. A goniometer and a torsiometer were combined into one device. An algorithm that effectively compensated for crosstalk was developed. Recordings from 25 women, performing five worktasks, were analyzed, both with and without compensation for crosstalk. The errors in the 10th, 50th and 90th percentiles of the flexion/extension distributions were small, on average $<1^{\circ}$. The ulnar/radial deviation distributions were weakly dependent on forearm position. The flexion/extension velocity measures were, for the 50th and 90th percentiles, as well as the mean velocity, consistently underestimated by, on average, 3.9%. For ulnar/radial deviation, the velocity errors were less consistent. Mean power frequency, which is a measure of repetitiveness, was insensitive (error $<1\%$) to crosstalk. The forearm supination/pronation angular distributions were wider, and the velocities higher, than for the wrists. Considering wrist/hand exposure in epidemiologic studies, as well as for establishing and surveillance of exposure limits for prevention of work-related upper extremity musculoskeletal disorders, the crosstalk error can, when considering other errors and sources to variation, be disregarded.

Electrogoniometer

Fig. 1. A flexible biaxial goniometer (equipped with two cables and with its flat surface facing downwards) and a torsiometer (equipped with one cable and with its flat surface facing upwards) joint together using shrinking tubing.

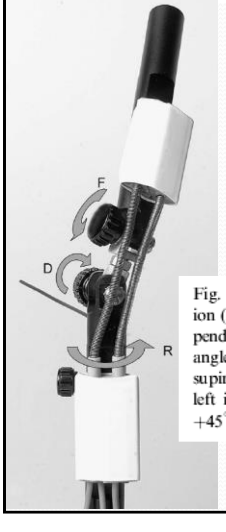
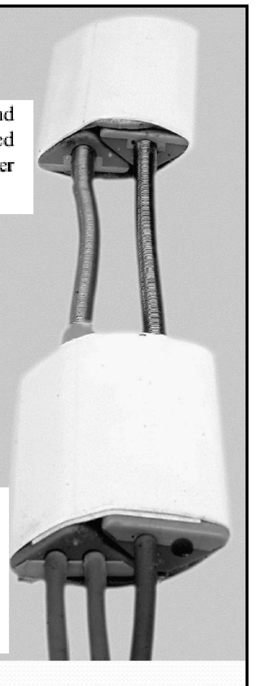


Fig. 2. Test jig with a combined goniometer and torsiometer. Flexion (F), deviation (D) and rotation (R) angles could be adjusted independent of each other. The arrows indicate positive directions for the angles, which correspond to palmar flexion, ulnar deviation and supination of the right wrist and forearm. The pin (pointing to the left in the figure) indicates the rotation angle. The jig is shown in $+45^{\circ}$ of flexion, $+10^{\circ}$ of deviation and $+30^{\circ}$ of rotation.



Electrogoniometer

CAUTION

A new instrumentation system for training rowers

A dry-land rowing system was developed to provide the coach and/or athlete with quantitative information about the athlete's kinetics and kinematics while the athlete trains. This system consists of a Concept II rowing ergometer instrumented with a force transducer and potentiometer, four electrogoniometers attached to the athlete's ankle, knee, hip, and elbow, and a data acquisition computer. The force transducer is used to quantify the athlete's pulling force. The potentiometer signal is used to locate the position of the handle. The electrogoniometers provide signals proportional to joint angles. A link segment model of the human body is used to locate joint centers based on limb lengths and joint angles. The computer is used to collect and process all the transducer signals, perform the link segment calculations and provide feedback to the coach or athlete in the form of a stick figure animation overlaid with kinematic and kinetic information. This system allows the coach and athlete to quickly study a rower's mechanics, to evaluate the effects that technique changes have on the power produced by the athlete, and to identify technique differences between athletes.

57

Electrogoniometer

CAUTION

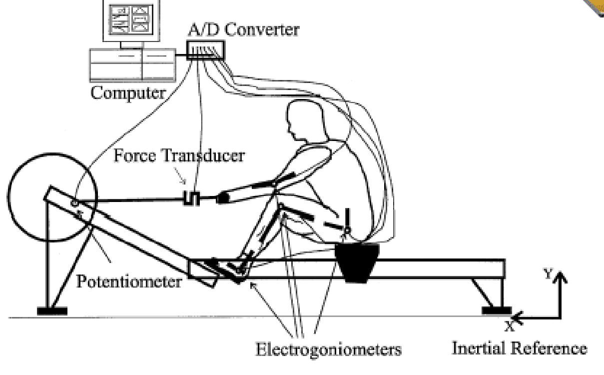


Fig. 1. Schematic diagram of the data acquisition equipment and setup used in the biofeedback rowing system. A force transducer generates a signal proportional to the athlete's pulling force. A potentiometer is used to locate the position of the rowing handle relative to the chain gear. Four electrogoniometers are used to quantify ankle, knee, hip and elbow joint angles. A data acquisition computer records and processes all signals and then displays a stick figure animation of the rowing motion overlaid with kinematic and kinetic data.

58

Electrogoniometer

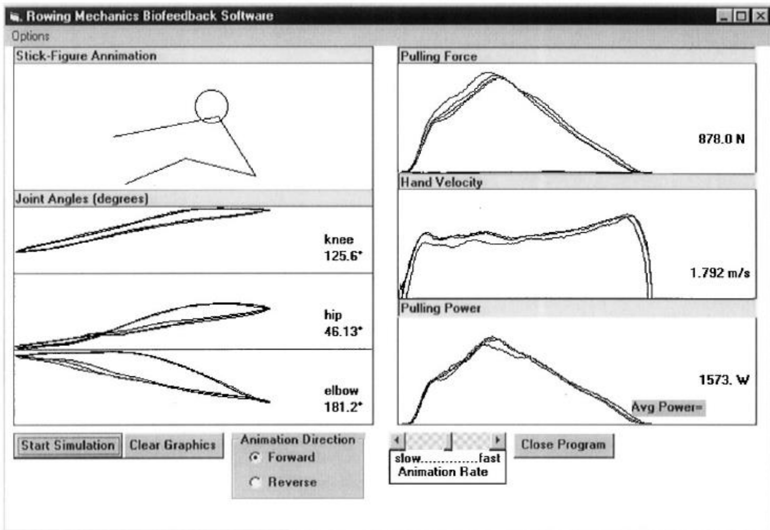


Fig. 3. An illustration of the feedback display given to the coach and/or athlete. A stick figure animation of the athlete is provided along with knee, hip, and elbow angles expressed as a function of the handle position. Pulling force, velocity and power are also displayed as a function of handle position.

59

Electrogoniometer

An optical fiber goniometer can also be used to measure angles in fingers and hands .

This device is mainly used as a virtual-reality interface. The CyberGlove is a fully instrumented glove that accurately measures up to 22 joint angles from the bending of the fibers.

The ratio of light intensity between the ascending and descending fibers is proportional to the angle of the joint.

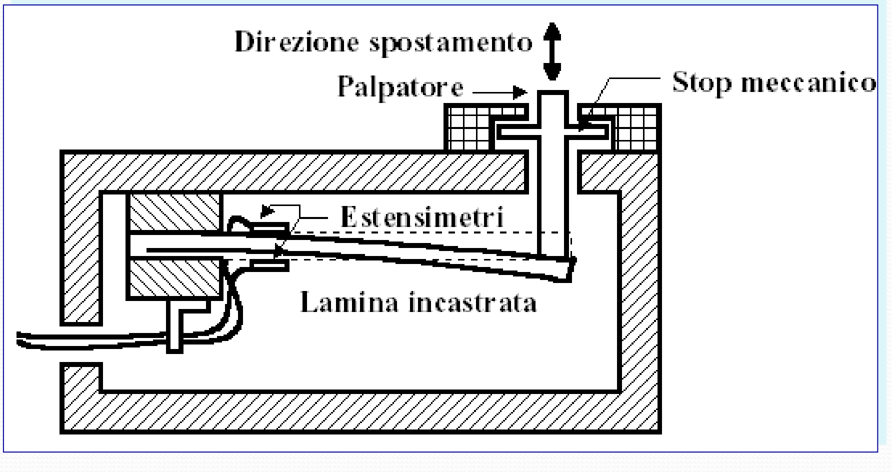
60

SENSORS ATTACHED TO THE HUMAN BODY

ELECTRICAL RESISTANCE STRAIN GAGES

61

Electrical resistance strain gages



62

Electrical resistance strain gages

LIQUID STRAIN GAGE:

The mechanical behavior of ligaments and tendons in situ and in particular the tension generated by a muscle or the elongation undergone by a tendon and ligament during motion is of particular concern in biomechanics.

The force or strain that is developed within these structures can be measured directly via a compliant transducer attached to the tendon or ligament, or

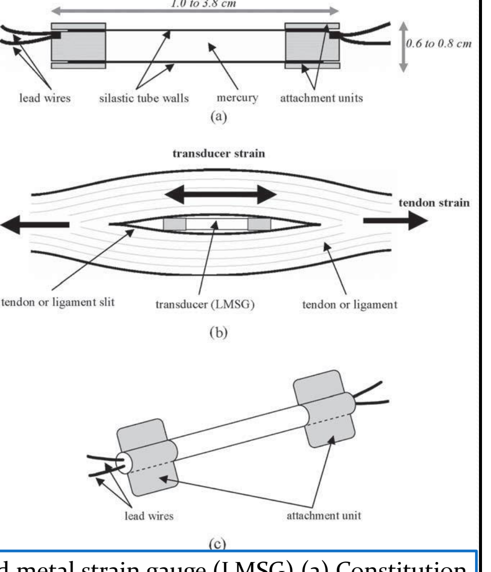
indirectly using inverse dynamic calculations (noninvasive method).

For the direct approach only invasive devices are applicable. This means that the transducer must be implanted within the tendon or ligament and it must be compliant enough to measure the tissue tension without interfering with its normal use during movement.

Electrical resistance strain gages

LIQUID STRAIN GAGE:

- a deformable rubber tube, of reduced diameter,
- inside which it is placed the conductive fluid;
- the ends of the tube are hermetically sealed by electrodes by which is measured the value of the electrical resistance of the transducer.

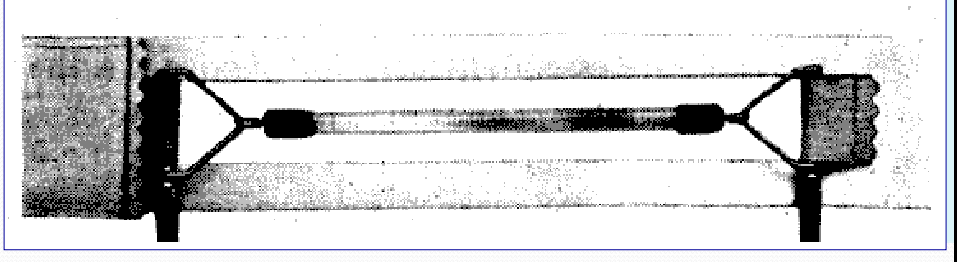


$$\frac{\Delta R}{R_0} = 2 \cdot \frac{\Delta L}{L} + \left(\frac{\Delta L}{L}\right)^2 \qquad \frac{\Delta R}{R_0} \cong 2 \cdot \frac{\Delta L}{L}$$

Schematic diagram of the liquid metal strain gauge (LMSG) (a) Constitution and dimensions of the LMSG. (b) Position of the transducer within the tendon or the ligament. (c) General schematic view of the LMSG.

Electrical resistance strain gages

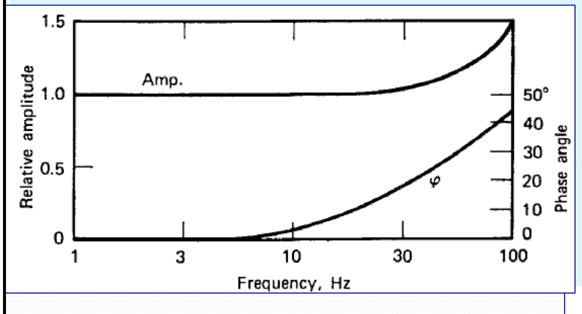
LIQUID STRAIN GAGE:
an embodiment of the transducer which uses mercury as a conductive fluid, a tube inside diameter equal to 0.5 mm, outer diameter of 2mm and a length of 30 mm.

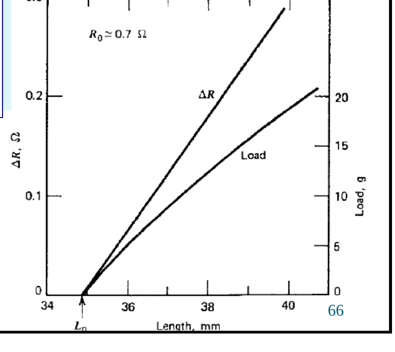


65

Electrical resistance strain gages

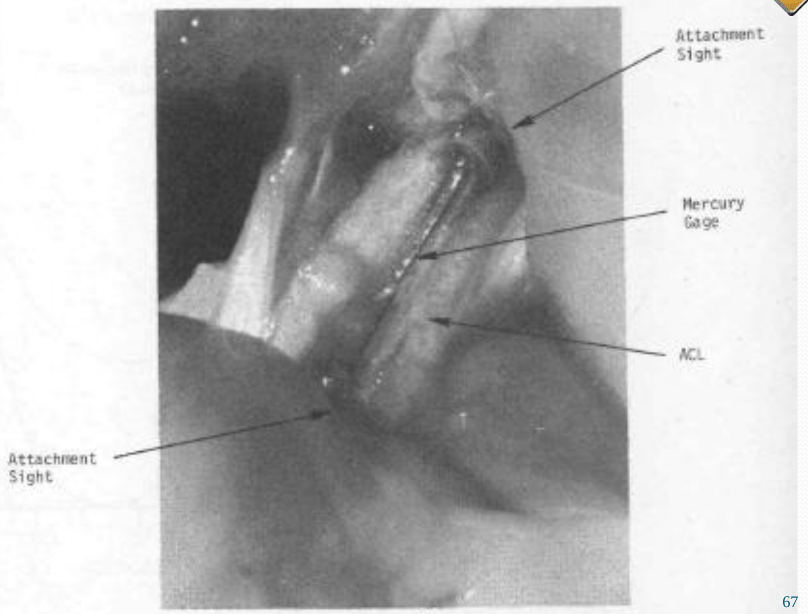
attention to the deterioration of the electrodes: drift phenomena caused significantly to the corrosive nature of the mercury (mercury obtained by three successive distillations).





66

Electrical resistance strain gages



67

Electrical resistance strain gages

LIQUID STRAIN GAGE:

- The liquid metal column is enclosed in the tube under a slight overpressure. This slight overpressure prevents subpressure during straining, which might predispose to water penetration through the slightly permeable silicone tube wall;
- The more the gauge is stretched, the more the liquid metal column's length increases and its cross-sectional area decreases, and the more its electrical resistance increases.

68

Electrical resistance strain gages

CAUTION

LIQUID STRAIN GAGE:

Several parameters can influence the relation obtained between the transducer signal and the tendon load during the calibration test: the tendon temperature, the course of the tendon different in the calibration test compared with the experiment.

The signal amplitude of the LMSG is temperature dependent because the resistance of the gauge increases with temperature rise. In experiments performed to calibrate the LMSG, an increase in temperature of 1 °C produced a mean increase in the signal amplitude corresponding to a strain of 0.051% to 0.185%.

Significant differences in temperature (15–20°C) may be expected between in in vitro and in vivo circumstances which require exact determination of these changes. Ignoring the influence of temperature difference may induce an artefact of approximately 1% of strain.

69

Electrical resistance strain gages

CAUTION

LIQUID STRAIN GAGE:

Also, since the tendon cannot be fixed in vitro in exactly the same way as it is in vivo, the fibres to which the transducer is attached can be strained differently and the load distribution within a tendon can differ between the in vivo experiment and the in vitro calibration.

The fibres to which the transducer is attached may be strained differently in vitro than they are in situ under the same tendon load. The mutual position of the tendon or ligament fibres may change because of the lack of deviation around joints and a change in the positions of origin and insertion.

70

Electrical resistance strain gages

CAUTION

LIQUID STRAIN GAGE:

The life is theoretically limited (about 6 months) because the silastic tubing around the liquid metal column is porous and its integrity can be affected by passage of liquid and dissolved gas.

A slow oxidation of the mercury due to oxygen diffusion through the silastic tubing can take place.

In in vivo experiments, small differences in the signal are observed between measurements made 48 h after surgical implantation of the mercury-in-silastic strain gauge in the tendons and those carried out 2 weeks after the surgery.

The service life of these transducers is also short because of a possible break of connection wires or a contact loss between the connection wire and the liquid metal column following movements of tendon or ligament against the surrounding tissues.

71

Electrical resistance strain gages

CAUTION

LIQUID STRAIN GAGE:

There are also local changes of tendon mechanical properties (changes of stress–strain relationships) because of an acute inflammatory reaction (fibrin, serosity and scar tissue) in the transducer implantation.

With the LMSG, there is also a risk of release of toxic substance (mercury or other liquid metal) into the body following a rupture of the silastic tubing containing the liquid metal column.

72

Electrical resistance strain gages

LIQUID STRAIN GAGE:

LOWER BODY NEGATIVE PRESSURE THIRD MANNED SKYLAB MISSION

Additional measurements carried out during preflight and postflight tests included respiratory excursions from a mercury strain gage across the lower thorax,

Mercury Strain Gage Adaptor:

for Interfacing Mercury and other Single Element Low Resistance Transducers with Grass Polygraph and EEG DC Amplifiers

73

INDIRECT MEASURES

MARKERLESS OPTICAL METHODS

74

Markerless optical methods

CAUTION

Currently, one of the primary technical factors limiting the advancement of the study of human movement is the measurement of skeletal movement from markers or sensors placed on the skin. The movement of the markers is typically used to infer the underlying relative movement between two adjacent segments (e.g. knee joint) with the goal of precisely defining the movement of the joint. Skin movement relative to the underlying bone is a primary factor limiting the resolution of detailed joint movement using skin-based systems.

Ideally, the measurement system/protocol should be neither invasive nor harmful and only minimally encumber the subject.

Furthermore, it should allow measuring subjects in their natural environment such as their work place, home, or on sport fields and be capable of measuring natural activities/motion over a sufficiently large field of view.

75

Markerless optical methods

CAUTION

The development of markerless motion capture methods is motivated by the need to address contemporary needs to understand normal and pathological human movement without the encumbrance of markers or fixtures placed on the subject, while achieving the quantitative accuracy of marker based systems.

Systems are typically divided into two categories:

- Active vision systems
- and passive vision systems.

76

Markerless optical methods

CAUTION

Active systems :
emit light information in the visible or infrared light spectrum in the form of laser light, light patterns or modulated light pulses

PROS

- provide very accurate 3D measurements,

CONS

- require a controlled laboratory environment and often are limited to static
- Measurements (a full body laser scan typically takes several seconds to capture the surface of a human body).

Passive systems:
rely purely on capturing images.

The main focus on the development of vision systems for markerless motion capture currently lies on employing passive systems.

77

Markerless optical methods

CAUTION

There has been some work done on markerless optical methods. By placing a number of video cameras around a subject and tracing the silhouette of the walking subject on each it is possible to generate a 3-dimentional silhouette of that subject.

This has already been achieved but the next step of using such a silhouette to determine the coordinate systems associated with the moving body segments has not yet been satisfactorily achieved.

78

Markerless optical methods

Clinical applications require knowledge of detailed and accurate representation of 3D joint mechanics. Some of the most challenging issues in whole-body movement capture are due to:

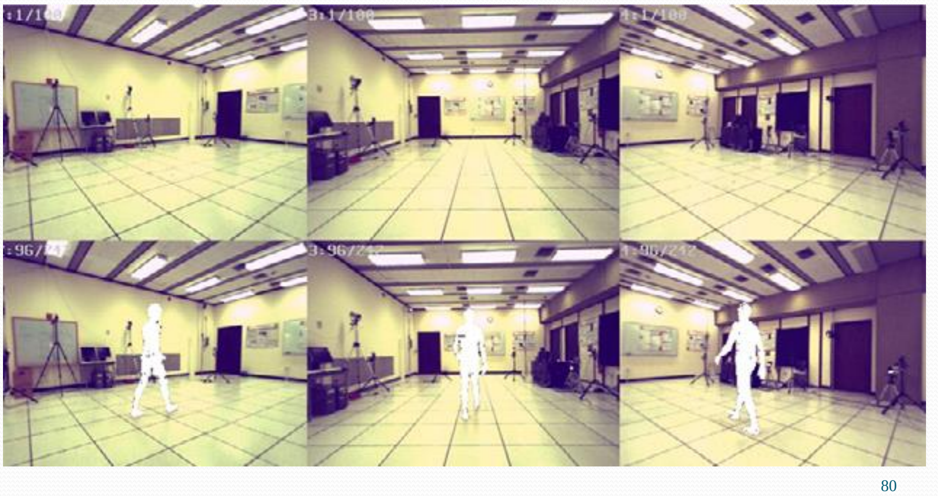
- the complexity and variability of the appearance of the human body,
- the nonlinear and nonrigid nature of human motion,
- a lack of sufficient image cues about 3D body pose, including self-occlusion as well as the presence of other occluding objects, and exploitation of multiple image streams.

The self-occlusion problem is addressed when multiple cameras are used, since the appearance of a human body from multiple viewpoints is available.

79

Markerless optical methods

The subject was separated from the background in the image sequence of all cameras using intensity and color thresholding compared to background images.

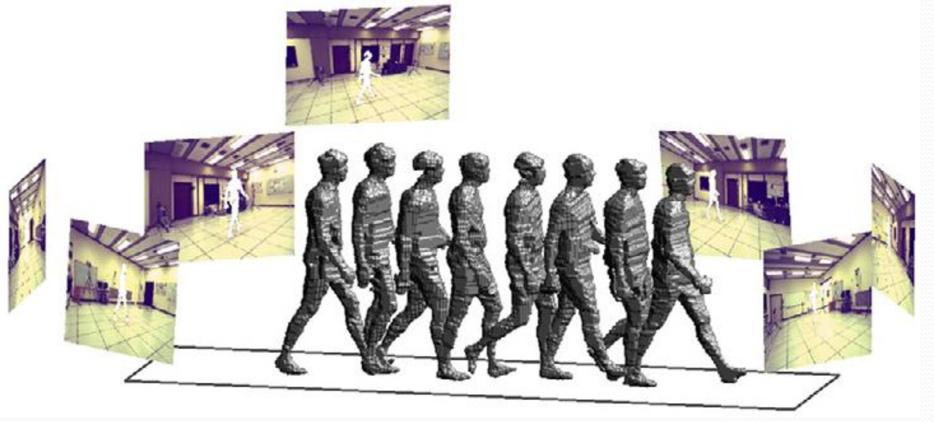


80

Markerless optical methods

CAUTION

The 3D representation was achieved through visual hull construction from multiple 2D camera views. Increasing the number of cameras leads to decreased variations across the viewing volume.



81

Markerless optical methods

CAUTION

The errors affecting the accuracy of a markerless motion capture system can be classified into

- errors due to limitations of the technical equipment and
- errors due to the shape and/or size of the object or body under investigation.

Configurations with fewer than 8 cameras resulted in volume estimations greatly deviating from original values and fluctuating enormously for different poses and positions across the viewing volume.

Visual hulls were not able to capture surface depressions such as eye sockets and lacked in accuracy in narrow spaces such as the arm pit and groin regions. Configurations with 8 and more cameras provided good volume estimations and consistent results for different poses and positions across the viewing volume.

82

Markerless optical methods

Markerless motion capture systems offer the promise of

- expanding the applicability of human movement capture,
- minimizing patient preparation time, and
- reducing experimental errors caused by, for instance, inter-observer variability.

Gait patterns can not only be visualized

- using traces of joint angles
- but sequences of snapshots that allow the researcher or clinician to combine the qualitative and quantitative evaluation of a patient's gait pattern.

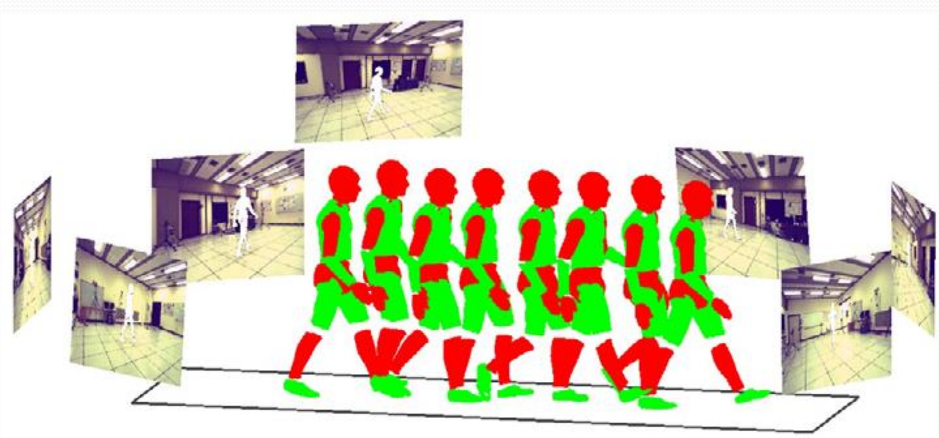
Thus, the implementation of this new technology will allow for:

- simple,
- time-efficient,
- and potentially more meaningful assessments of gait in research and clinical practice.

83

Markerless optical methods

Articulated body matched to visual hulls: human body segments

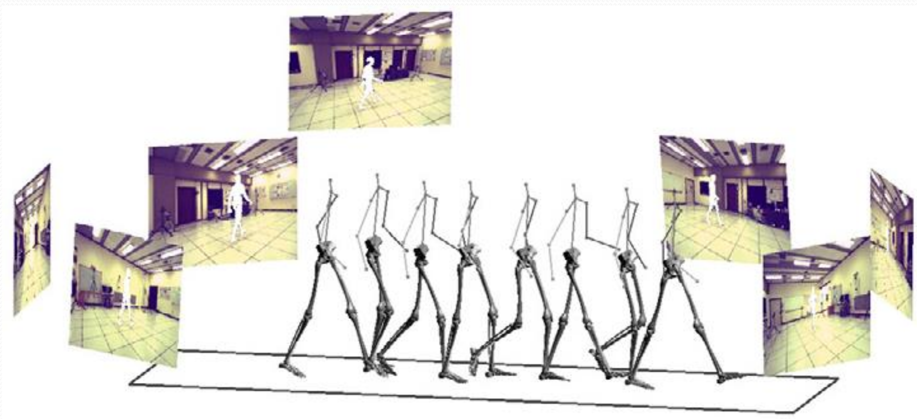


84

Markerless optical methods

CAUTION

Articulated body matched to visual hulls: kinematic chain.



85

BIOMECHANICS:
Lecture #4 – Kinematics measurements

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88