Investigation methods II.

Classification of examination methods

- Examination of live-dead tissues: SUBJECT TO APPROVAL
- Examinations according to the method:
  - In vitro examination (examination on dead tissues)
  - In vivo examination (examination on live bodies)
- Examinations according to types:
  - Static
  - Dinamic

Motion patterns

Motion analysis

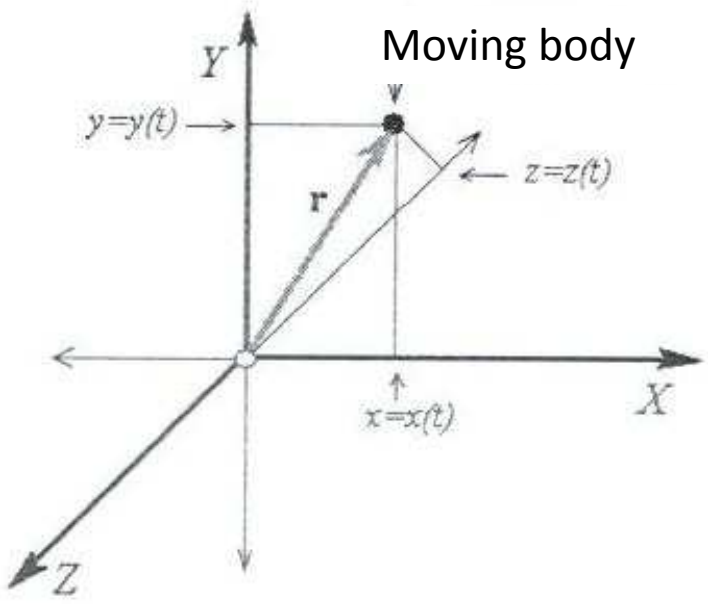
Investigation of different motion patterns

Goal:

- **Survey of motoric ability**
- **Learning of motion, checking the motoric memory.**
- **Analysis of special motion patterns**
- **Control the results of motion therapy and rehabilitation.**
- **Scientific research on motion analysis**

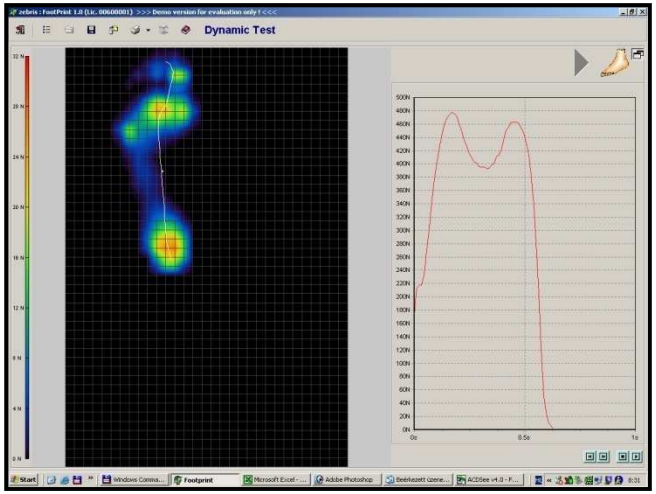
Types

- **Kinematics: determination of the position and the orientation in the space as the function of time (e.g. Cartesian coordinate system)**



Types

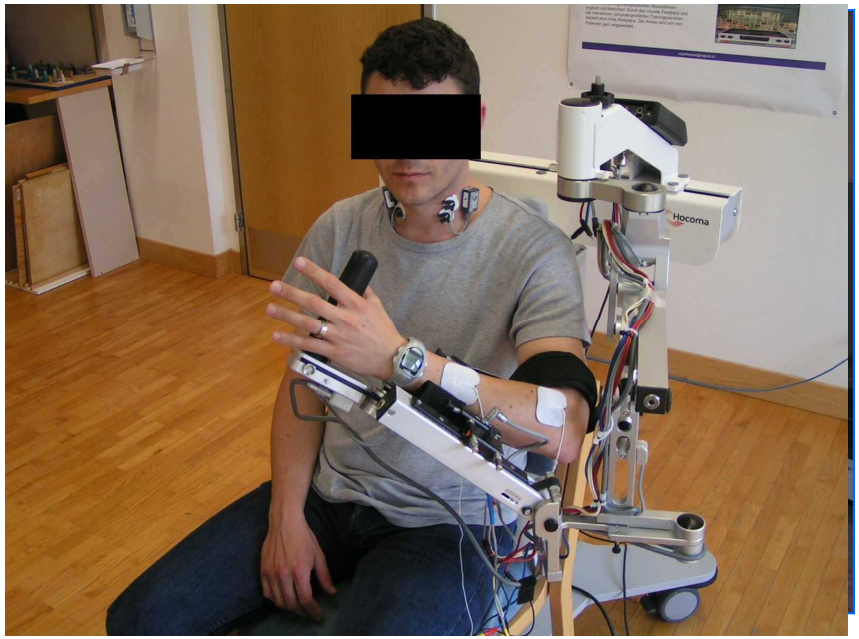
- Kinematics: description of different motion forms, respect to a given reference frame (e.g. Cartesian coordinate system) in the function of time
- **Kinetics: The investigation of forces which produce the motion**

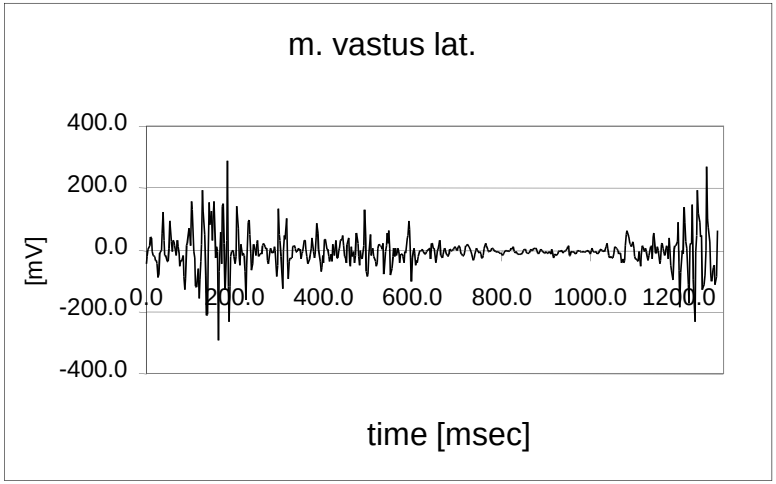


Reaction force and the measuring of the pressure distribution in the function of time

Types

- Kinematics: description of different motion forms, respect to a given reference frame (e.g. Cartesian coordinate system) in the function of time
- **Kinetics: The investigation of forces which produce the motion**
- **Else: Analysis of the activation of the muscles (elektromyography EMG), reaction time measuremt**





Summarizing the motion analysis

- **Goal;**
- **Type;**
- **Base;**
- **Equipment:**
- **Process of the measurement**
- **Measured quantities**

Kinematical investigations

Static Investigations

Goal **Analysis of the relative orientation of body segments respect to each other in a fixed position.**

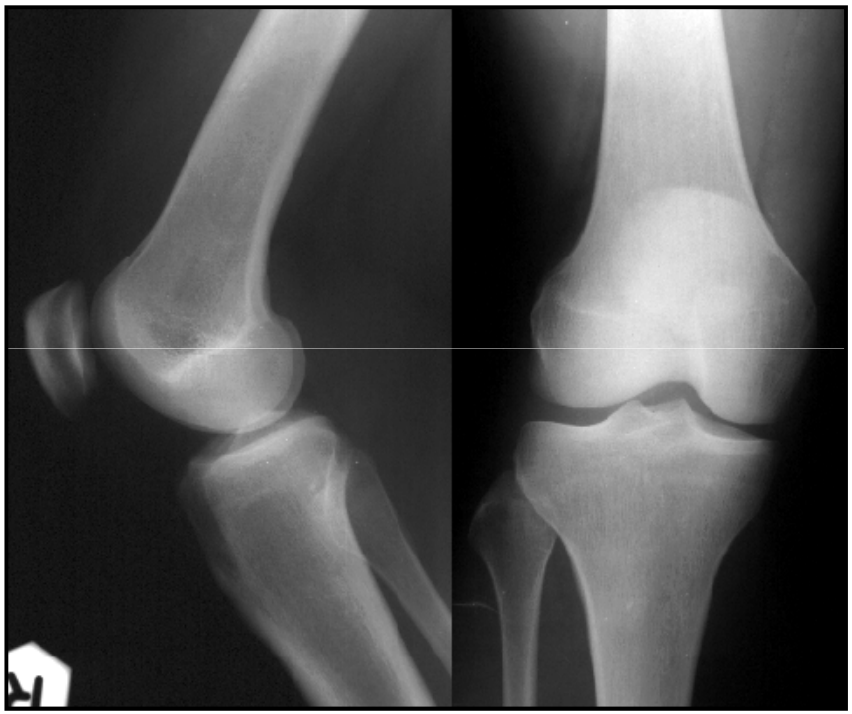
Types, equipments

- **Radiological investigations;**
- **Lengths measurements, axis measurements.**
- **Stability mesurements;**
- **Phots shoots.**

Radiological investigation

Goal:

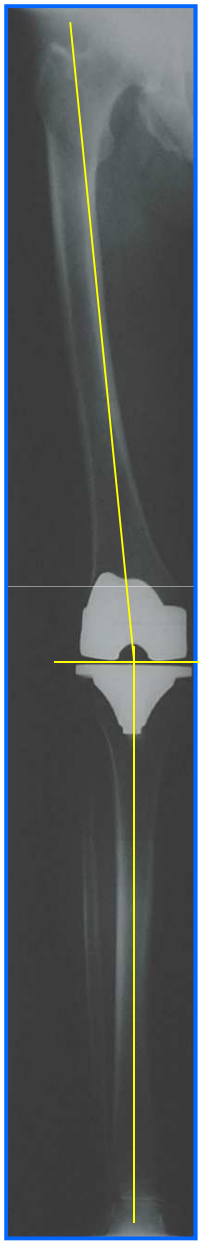
- **Detect of individual deviations (fractures, degree of arthrosis - Kellgren - Lawrence scale)**



Goal:

- Detect of individual deviations (fractures, degree of arthrosis - Kellgren - Lawrence scale)

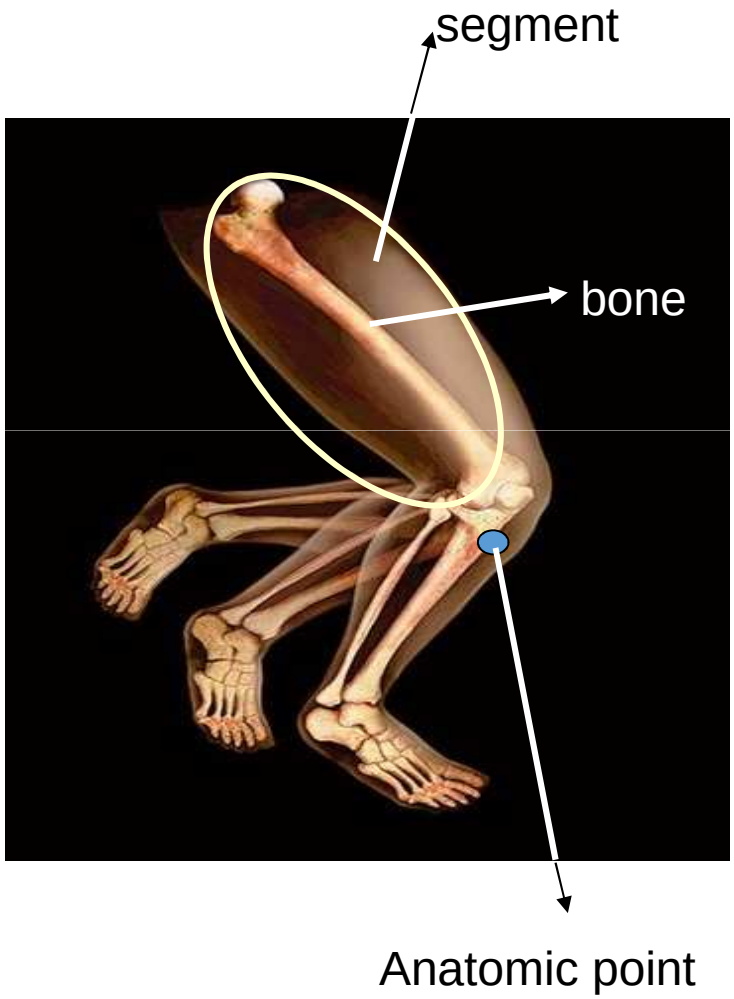
- **Determination of position of inbulid posthesises**



Goal:

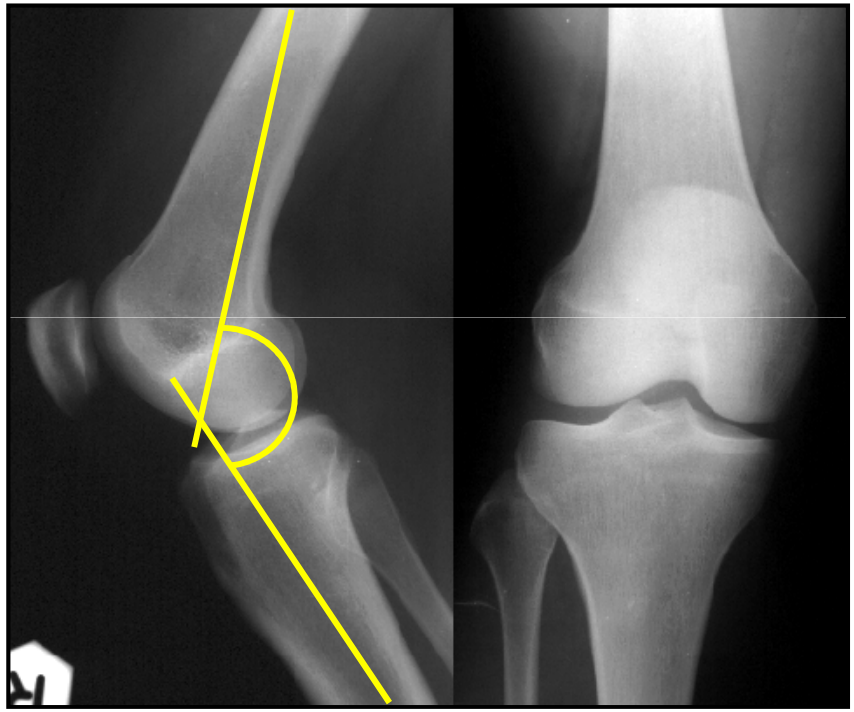
- Detect of individual deviations (fractures, degree of arthrosis - Kellgren - Lawrence scale)

- Determination of position of inbulid posthesises
- **Determination of spatial position of assigned bones using the charactheristic points of the bones (endpoints)**



Goal

- **Detect of individual deviations (fractures, degree of arthrosis - Kellgren - Lawrence scale)**
- **Determination of position of inbulid posthesises**
- **Determination of spatial position of assigned bones using the charactheristic points of the bones (endpoints)**
- Determination of relative angles in the joints (angle of the axis)



RSA – Radiostereo-metry analysis

RSA methods, process

Markerbased

- Placing of (tantalum balls with 1 mm diameter) markers
- Making X-ray images using a measurement frame or plate
- Identifying of markers and determination of coordinates based on the X-ray images.
- Calculation of the spatial coordinates of the markers.
- Calculation of the migration of the implants

Modelbased (without markers)

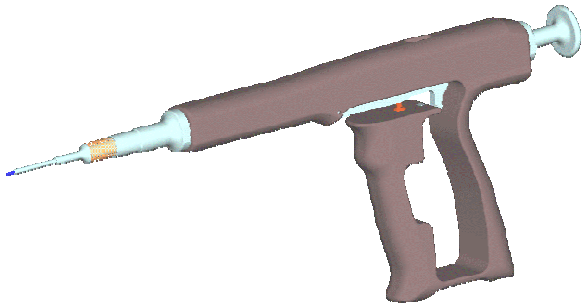
- Comparison of the models
- Determination of the integrated implant's contour using X-ray
- Calculation of the integrated implant's contour using digital technics
- Determination of the non-overlapping areas

Marker based

Placing the markers

Injection into the bone during surgery

- knee: femur and tibia
- Hip: pelvis and proximal



Builiding into the prosthesis during the manufacturing or during surgery

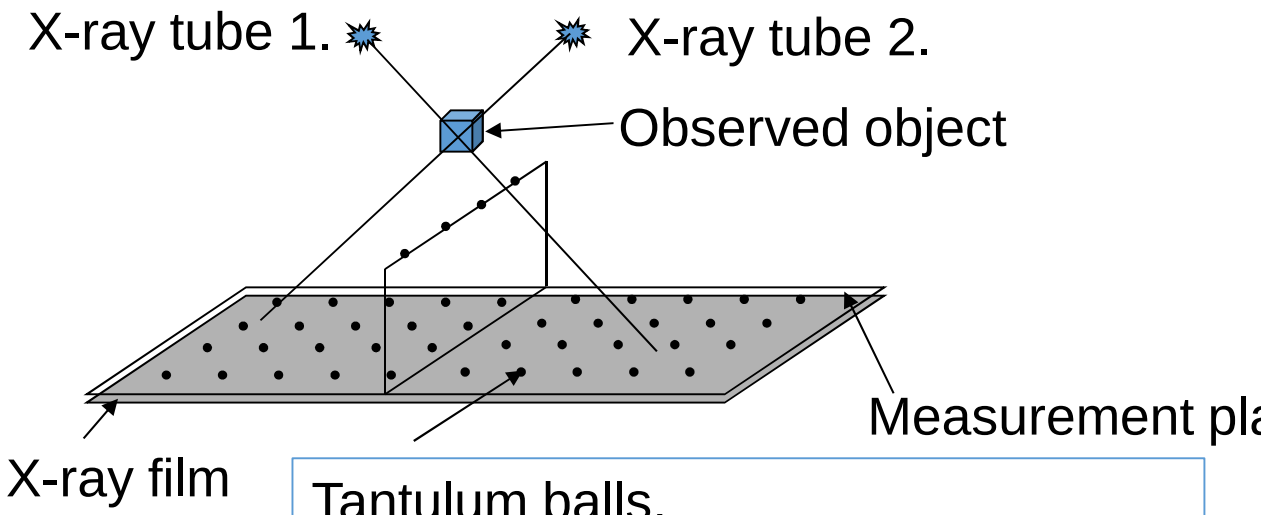
Markerbased RSA

Making X-ray images

- Under standard circumstances
- Nearly in the same time
- Using two X-ray tube
- Using measuring plate or measuring frame (global coordinate system)

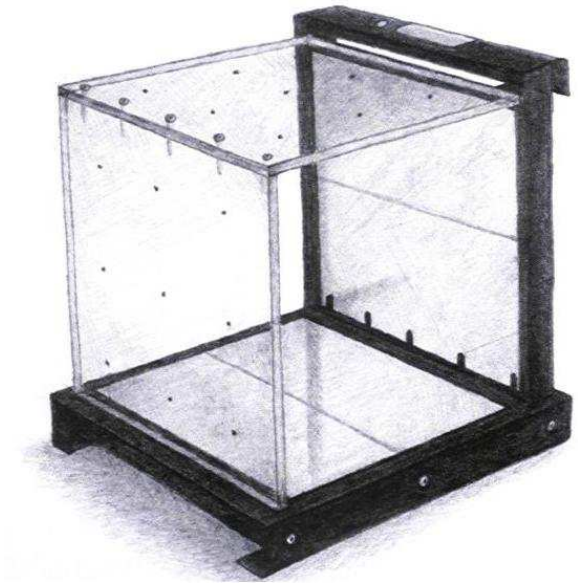
Markerbased RSA
Making X-ray images

Measurement plate (extrapolation)

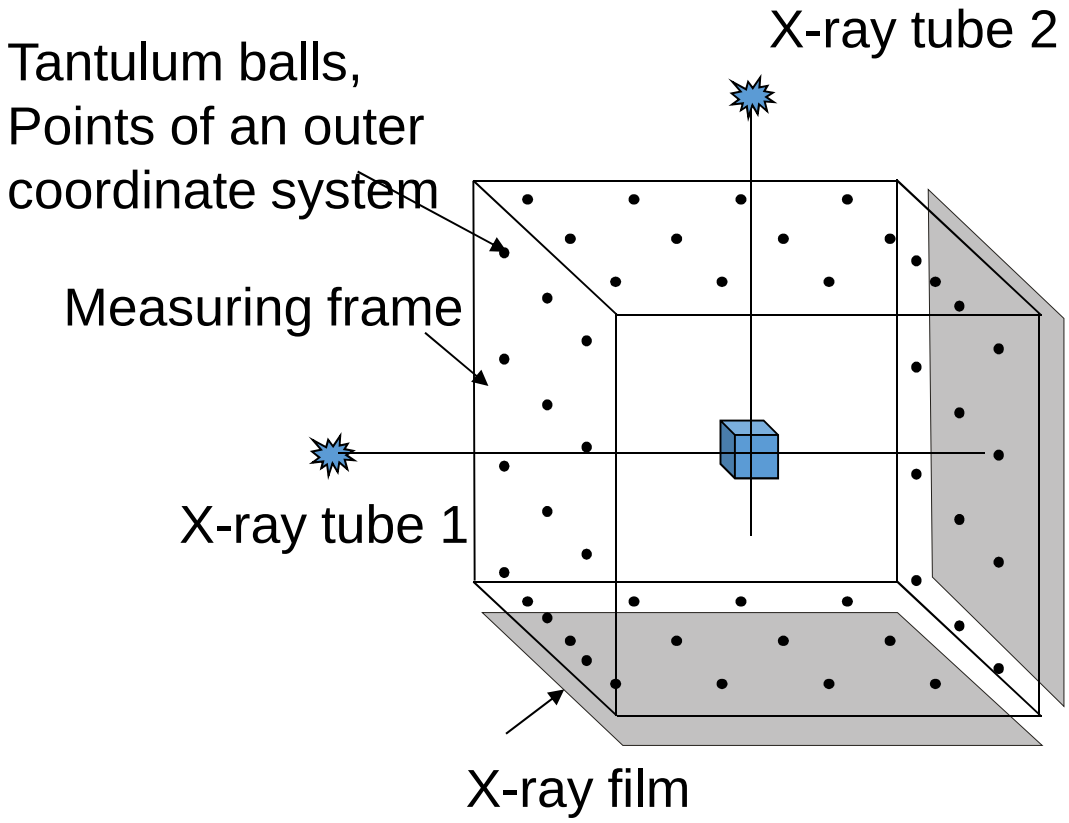


Tantulum balls,
Points of an outer coordinate system

Markerbased RSA
Making X-ray images



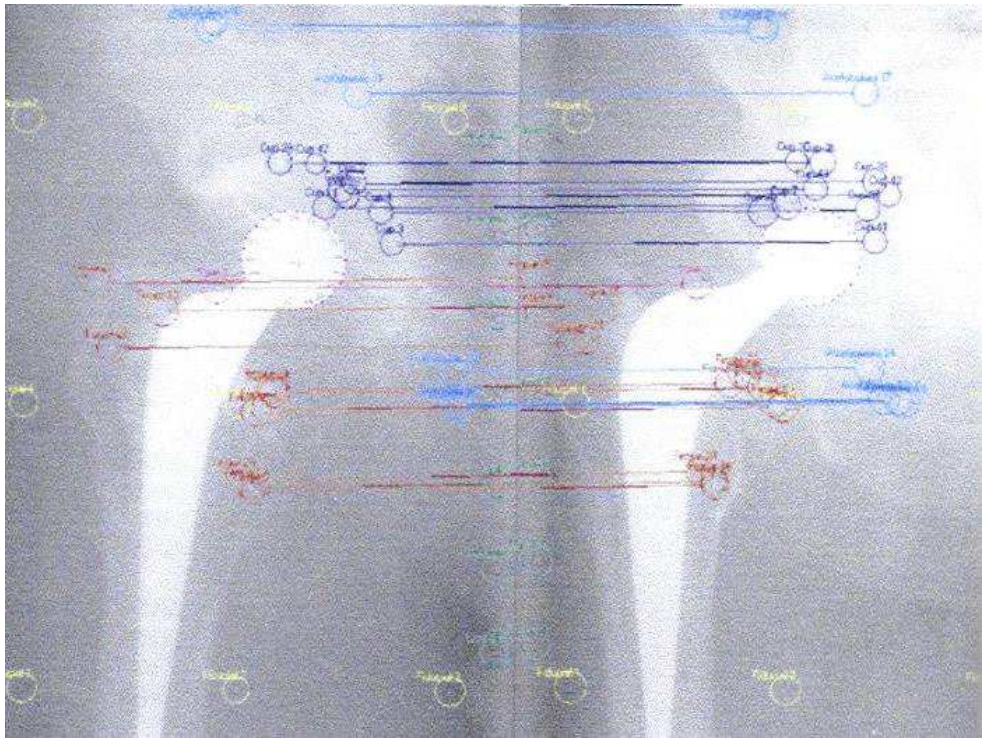
Measurement frame (interpolation)



Markerbased RSA

Determination of coordinates

- Identifying the markers
  - Digitalization
  - Distinguish, markers of the prosthesis and bones and the markers of the frame
- Determination of the planar coordinates of the markers.



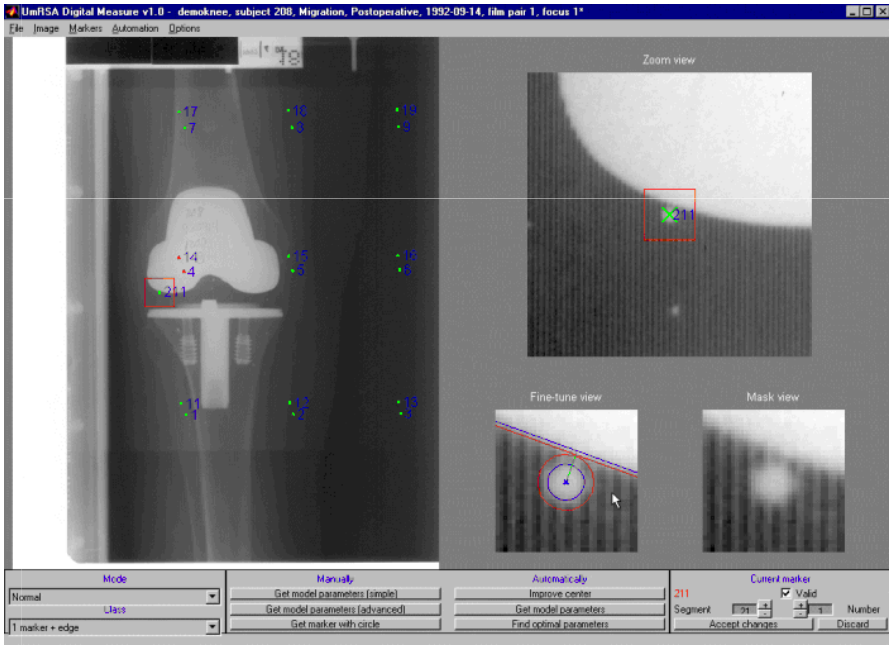
Markerbased RSA

Determination of coordinates

- Coordinate transformation

  The transformation of local coordinates (respect to the bone) into the global (measuring frame, measuring plate) coordinate system

- Determination of the spatial coordinate using mathematical methods
  - Newton-Gauss
  - FCP
  - DLT
  - DIRSA



Marker-based RSA

Computation of migration

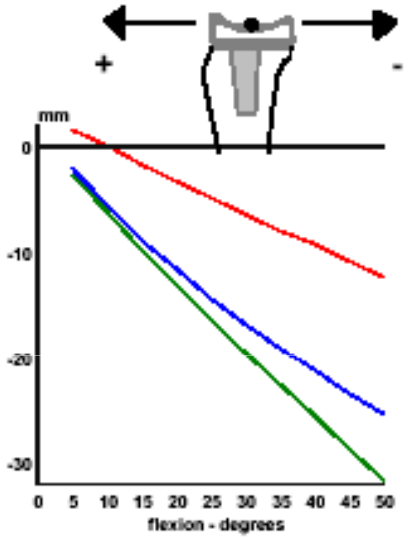
Migration:

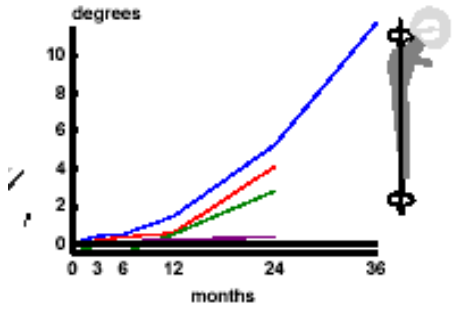
The displacement of the implanted implants, prosthesises respect to implated markers

Tracking in time

Short term(1-5 years)

Long term (>5 years)





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- Determination of the non-overlapping areas

Modell-based RSA

Compilation of the model

Types of modells:

- *CAD based*

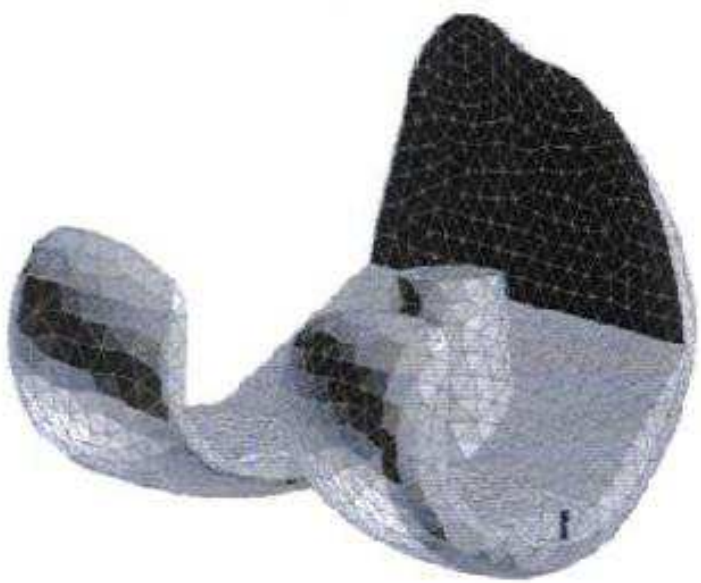
  Based on the plans of the prosthesis

  Triangle shaped elemts(hip: 12000, knee 5000)

- *Reverse Engineering based*

  3 D scanning of the manufactured prosthesis

  Max.570000 triangle shaped elemets



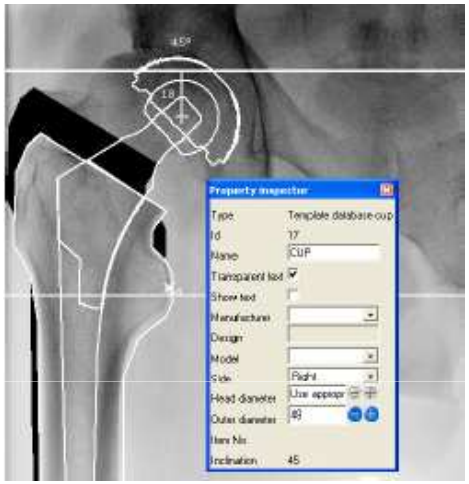
Modell-based RSA
Contour recording

- Standard circumstances
- Nearly the same time
- Using two X-Ray tube

Markerbased RSA

Imaging calculating the non-overlaped area

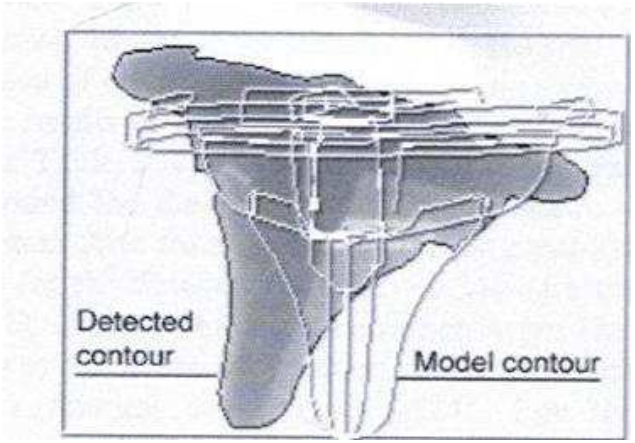
Reproduction of the spatial image



Determination of the spatial image using Canny edge detecting algorithm

Determination of the non-overlaping area

Determination the difference between the reproduced model and the originall model (FSQP algorithm)



Precision of RSA

Marker-based

Depend on:

- The stability of the marker placed in the bone
- Precision of the designation of the markers
- Precision and type of the scanner

Values:

- Translation: 0.1-0.5 mm
- Rotation: 0.15 ° - 1.15°

Model-based

Depend on:

- Precision and type of the model
- Number of the elements
- Type of the elements
- Precision and type of the scanner

Values:

- Translation: 0. 8-1.0 mm
- Rotation: 1.5 ° - 2.0°

Applications of RSA

- Following the migration of implants
  - Spatial movements of prosthesises early and late loosening
  - Polietilénbetétek kopásának ellenőrzése Check the wear of Polyethylene inserts
  - Determine the loosening tendency caused by geometric differences of the prosthesis
  - Cementing techniques, comparing different bone-cements
- Following the effeciency of Crucial ligament
  - Knee anterior-posterior stability
  - Check the knee rotation
- Checking the stability of the ankée
- Check spinal movement

Drawbacks of RSA

- Tantalum balls can be implanted just with surgery, it is not usable in case of conservative healing
- The signing of the implants with markers is endangerous on durability of the fixation (implanting during manufacturing)
- In case of model-based RSA the inaccuracy of the initial model is decreasing the precision of the model

Length measurements, Axis measurements

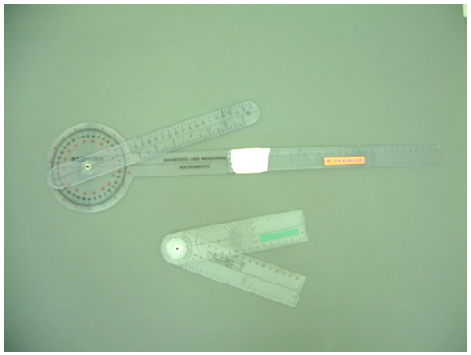
Goal:

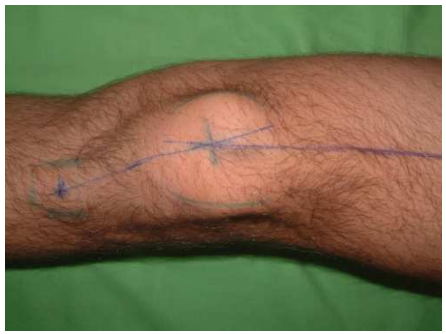
- **Determination of the lengths of limbs and it's segments (kalipers, measuring tapes)**;

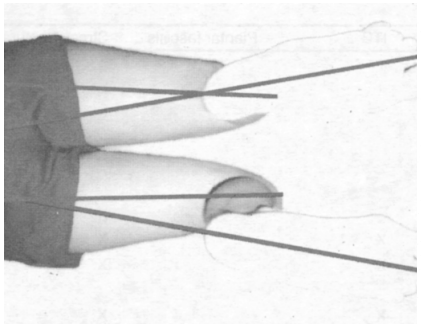
Axis measurements

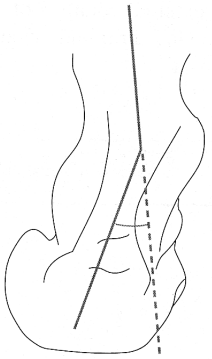
Goal:

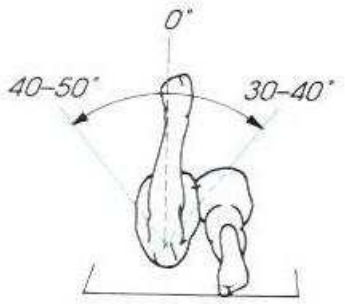
- **Determination of the lengths of limbs and it's segments (kalipers, measuring tapes);**
- **Angle of segments respect to each other (relative (goniometer):**
  - **Q-angle (thigh and leg angles)**
  - **Thigh-foot angle (rotation of the fibula)**
  - **Leg-heel angle**
  - **Ranges of joint movements.**











Stability measurements

Goal:

- **Mesurements the stability of the joints (generally forward and backward) direction arthrometer**

- **Types:**
  - **Investigated joint (knee-, elbow-, shoulder);**
  - **Loaded unloaded.**

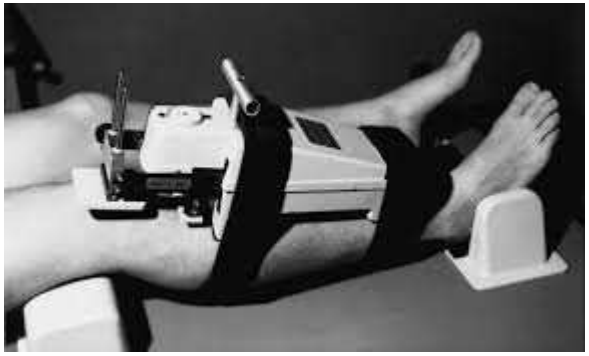
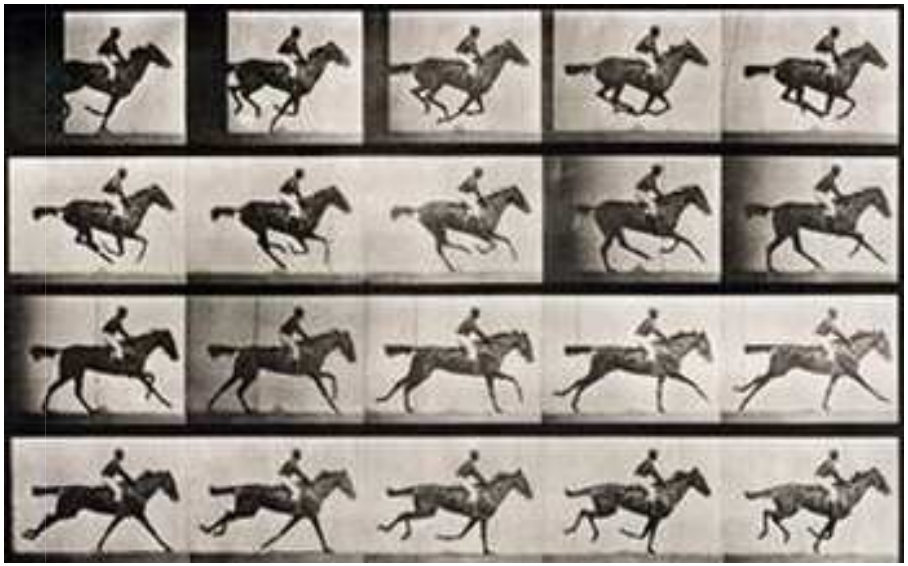


Photo shoots

Goal:

- **Studying postures study, definition and recording of tbe equilibrium state documenting,**



Muybridge: Locomation of Horses
(Stanford Egyetem)

Dynamical motion analysis (Motion capturing)

Goal: **measuring the kinematical properties during the motion, identify the forces which cause the motion**

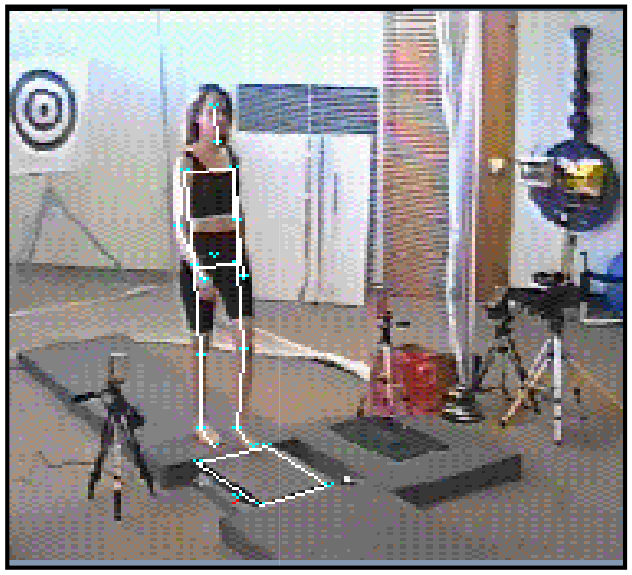
Systems:

- **Kinematical measurement**
  - **Optics-based systems**
  - **Electromagne-based system**
  - **Ultrasound-based systems**;
- **Kinetical measurements:**
  - **Force- and foot pressure distribution measuring units.**
- **Else:**
  - **Activity of muscles, electromyography Izmok aktivitását rögzítő elektromiográf (EMG)**;

Visual-Based Systems

Types:

- **Sensory-free (marker-free system): The points on the record can be manually designated afterd the measurement;**



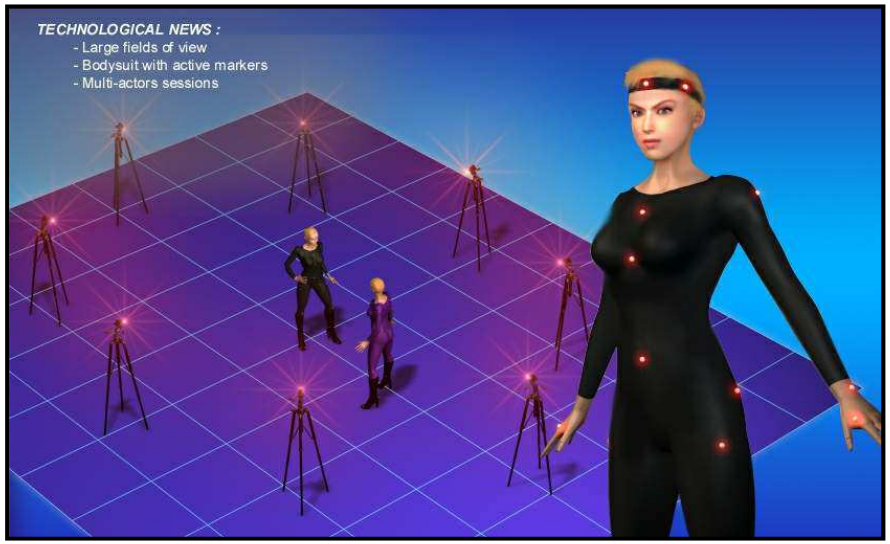
Types

- Sensory-free (marker-free system): The points on the record can be manually designated afterd the measurement;
- **Sensor-based (marker-based) sensors are placed in the test points, which allows the automatic processing;**
  - **Reflective sensors (passive markers)**
  - **Emitting sensors (active markers)**

Equipments - cameras

Recording the movement with at least two video recorder, which can be light-based (conventional video camera)

or IR-based cameras.



Equipments - markers

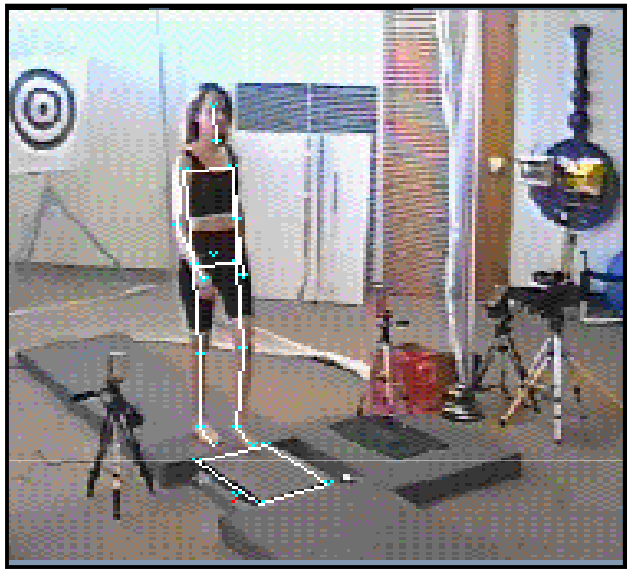
More sensor fixed at an
anatomical point for better visibility

for better visibility the sensor attached far from the body

Individual markers attached to the skin

Base

During the image processing, the spatial coordinates of the markers should be determined frame by frame (by hand or program) prior to the measurement theese markers should recorded also in the calibration phase



Conduction of the measurement

During the measurement the anatomical points should be touchable in caseof man half naked, bras women;

- **The markers should be glued or attached with a special element avoiding the relative motion.**

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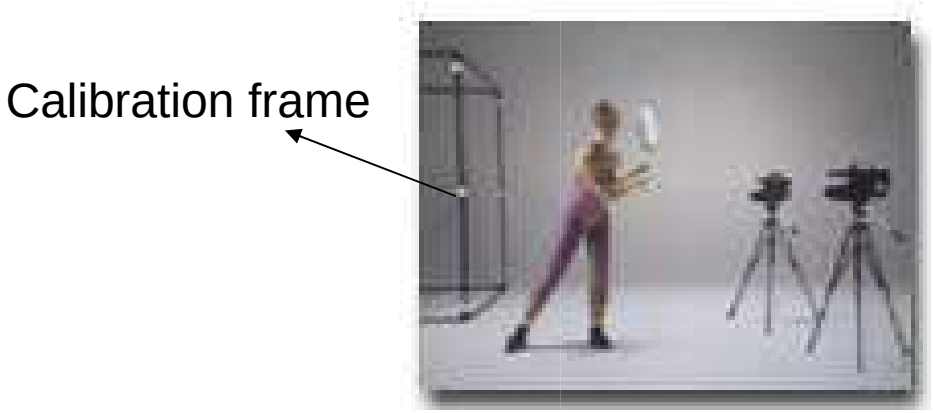
- **In the calibration phase a frame should assambled from known measurements rods to define the center of the coordinate system and directions;**



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- The markers should be glued or attached with a special element avoiding the relative motion.
- In the calibration phase a frame should assambled from known measurements rods to define the center of the coordinate system and directions;
- **During free or a predetermined motion (such as walking, elevation, etc), the motion is recorded by cameras.**

Sampling rate: **200-240 Hz**

Commercialy avaliable systems

- **APAS**
- **VICON**
- **Motus**
- **Primas**
- **Elite**

Measured quantities: **The spatial coordinates of the anatomical points or the attached markers**

Advantages and drawbacks

- **Any motion can be recorded;**
- **Complete freedom of movement;**
- **Requires enough experience in the application;**
- **Requires the use of multiple cameras;**
- **Large room required;**
- **Expensive purchase;**
- **Movements of the skin is also recorded;**
- **Point detecting, processing is slow, imprecise;**
- **Measurement error isin the order of centimeters**

Electromagnet-based

The basic assumption:

The human body's segments are rigid the motions are established in the joints.

Base:

The measuring system is recording the spatial position and orientation of in the frame of the transmitter. If the sensor is attached moving free thus motion of the sensor is same as the motion of the body segment

Equipments of the measurement

The different range transmitters are placed near to the measured person. During the motion the data aqusition box is collecting the position and the orientation of the attached sensors.

Data aqusition unit

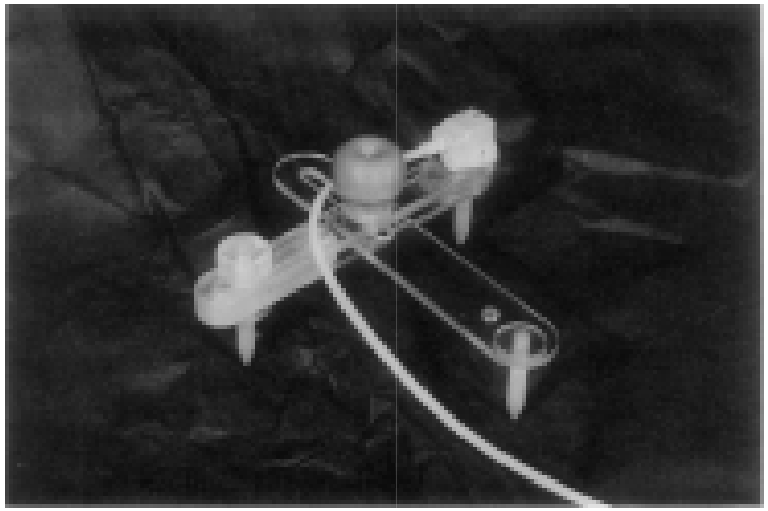
sensor

Large range transmitter

Medium range transmitter

Special elements

— **Frame of markers: If sensors can not attached to the body segments (scapula, foot) after stopping the motion using the frame the place of the segment is fixable**



Special element

- **Marking pencil: The translation and rotation of the body segments are measured in the global coordinate-system and these can be transformed a rotation into the local coordinate system of the segments. For this in the calibration phase the local coordinate system of the segments should be defined with a pencil**

Conduction of the measurement

During the measurement the anatomical points should be touchable in case of man half naked, bras women;

- **markers should be glued or attached with a special element avoiding the relative motion.**
- **In the calibration phase the local coordinate systems should be defined.**

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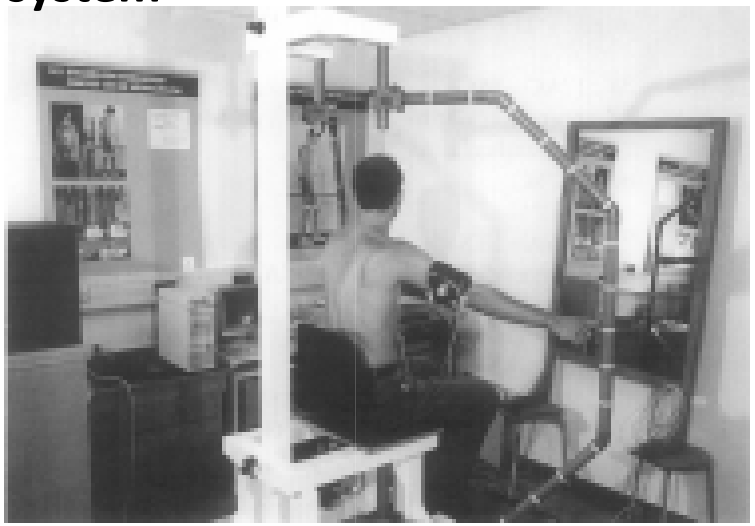

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- **During the predermined motion (walking, armlifting, e.g.) the spatial position and rotatio of the sensors are measured and recorded in the global coordinate system**
- **In case of the shoulder joint or foot motion after the stopping the measurements recording of the postion of three (anatomical) point.**

The sampling rate of the measurement: **20-120 Hz**

Commercially available systems

- **ISOTRACK**
- **Ascension**

Measured datas: **Sensor’s global position and orientation in the global coordinate system**

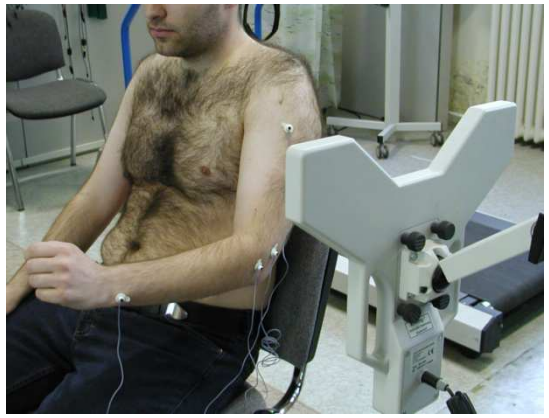
Advantages, disadvantages

- **It has greater accuracy than the Optical-based systems, max. 3.5 mm measurement error (authentication on the shoulder joints cadaver);**
- **The metal is changing the accuracy (reinforced concrete buildings)**
- **The measuring range of the system is limited (1-3 m);**
- **Closely spaced sensors are in interference;**
- **The body-mounted sensors can modify the movement (there is no difference after the 5-6 minute exercise);**
- **Recording movements of the skin;**
- **For the determination of the spatial position of some body-segments the movement must be stopped;**
- **Spatial position of anatomical points can not be determined;**
- **To connect, synchronize other additional elements is difficult.**

Ultrasound-based system

Methods:

- **Individual sensor based system**



- **Three sensor based (using triplets)**

Equipments of the measurement

- **individual, active (ultra-sound emitter) transducers**
- **Three sensors are inculded (reveiver) in the measuring-head**
- **Central unit**

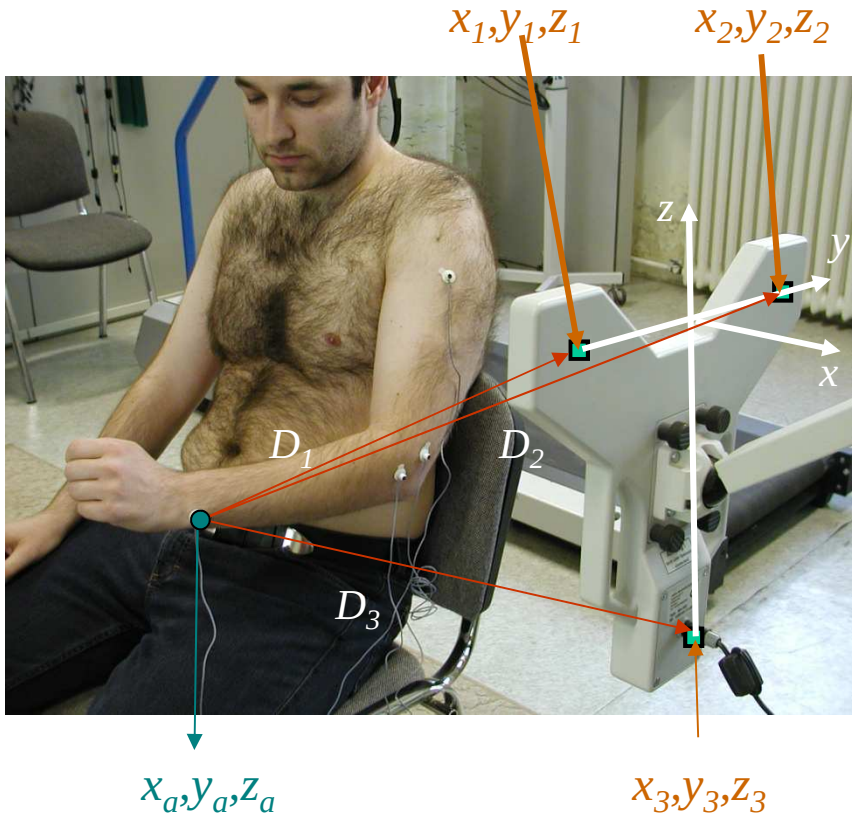
– **individual, active (ultra-sound receiver) transducers**

Measuring head
Three indiviudal receiver

Central unit

Determination of the spatial coordinates of the sensors

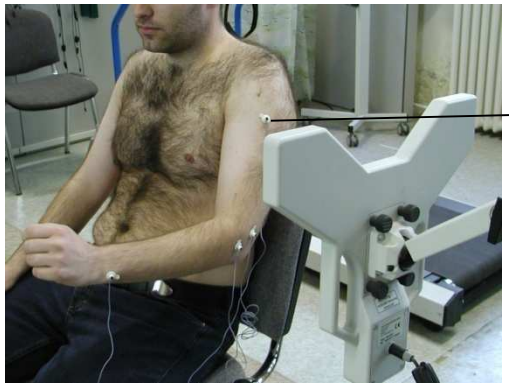
- **Measuring head is seeing the transducers;**
- **The distance between the receiver and the transducer can be determined from the propagation time of the ultra-sound;**
- **Three distance can be measurable;**
- **From the distances (D_i) and spatial coordinates from the receivers (x_i,y_i,z_i) the spatial coordinates of transducer (x_a,y_a,z_a) can be calculated with the method of triangularization**



Conduction of the measurement

During the measurement the anatomical points should be touchable in cas eof man half naked, bras women;

- **Transducers should be glued or attached with a special element avoiding the relative motion.**
- **During the predermined motion (walking, armlifting, e.g.) the spatial position and rotatio of the sensors are measured and recorded in the global coordinate system using the control software**



Frequency of the measurement: **20-100 Hz**

Commercially available systems:

- **ZEBRIS CMS 10**
- **ZEBRIS CMS 20**

Measured quantities: **Spatial position of the transducers**

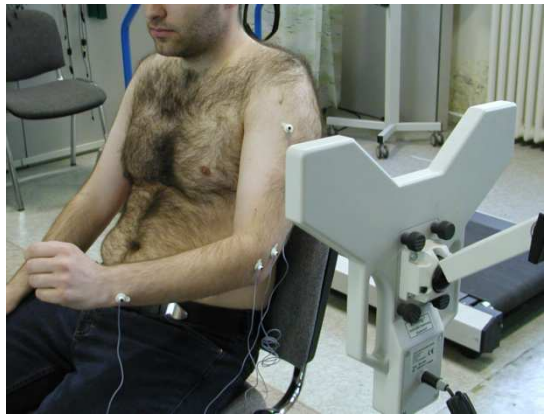
Advantages and disadvantages

- **It has more accuracy than the optical-based systems measurement error is 5.0 mm in size (authentication on case of several motion form);**
- **Movements of the skin is recorded;**
- **Just visible anatomical points can be involved into the measurement**
- **The measuring range of the system is limited (1-3 m);**
- **Closely spaced sensors are in interference;**
- **The body-mounted sensors can modify the movement (there is no difference after the 5-6 minute exercise).**

Ultrasound-based system

Methods:

- **Individual sensor based system**



- **Three sensor based (using triplets)**

Base

Assumption

The body segments of the human body are rigid all of the motions are established in the joints

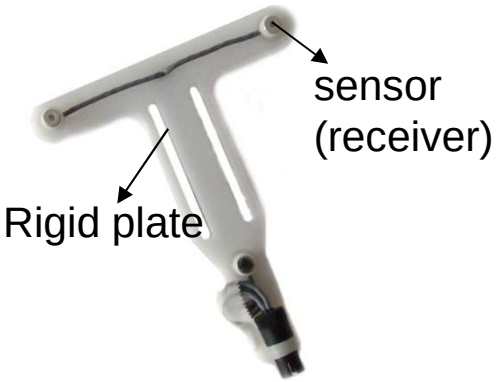
Base:

The motion of each rigid body can be described in the space, if the spatial coordinates of three different points (triplets) of the body is known in each time-moment. Any points of the investigated body can be calculated from the meadured coordinates of that three points. The relative of position of the three measured points should be determined in the calibration phase. [Kocsis, 2003].

Equipments of the measurement

- **Measuring head is emitting three ultra-sound signal**
- **The receiver triplets are mounted on the body segments**
- **Marking pencil for the definition of the anatomical points in the calibration phase**

Measuring head with three transducer



Triplet

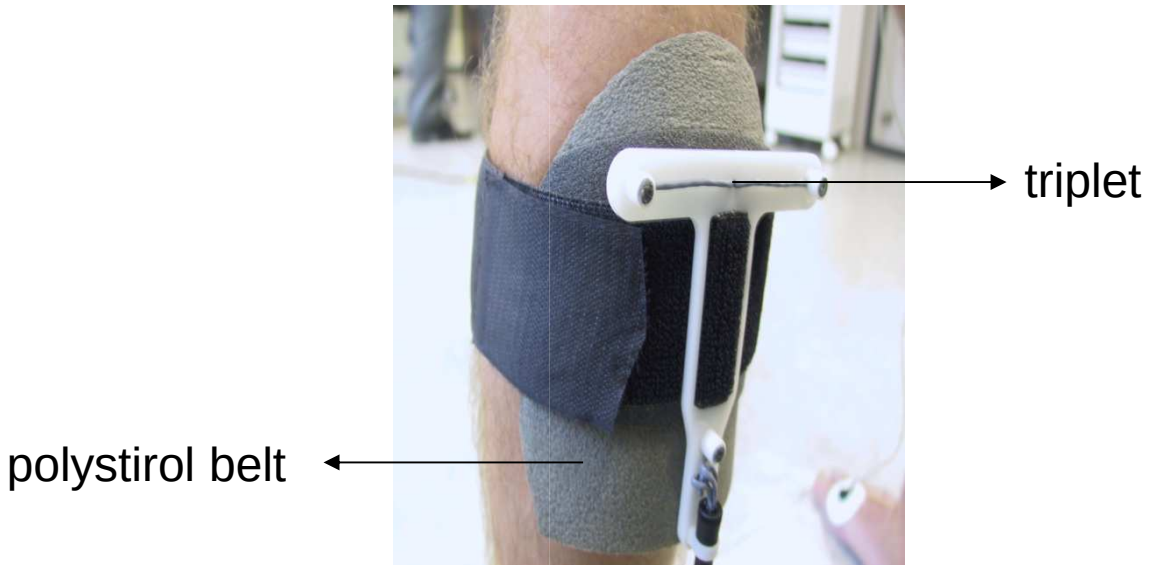
Marking pencil

Central unit

Data aqusition toolbox

Special elements

– **Polystirol belt-mounted triplet:** **The triplet is mounted on the body segment in motion free way because of the polystirol the movement of the muscle can be eliminated**



Special elements

– **Point mounted triplet: Because of the shape of some body-segments the mounting of measurement triplets can be solved only in special ways. For example, to record the movements of the scapula and to eliminate the skin movements, an ECG ball is needed for the mounting . The vacuum mounted tripled can be placed on the edge of the shoulder.**

Layout of the measurement

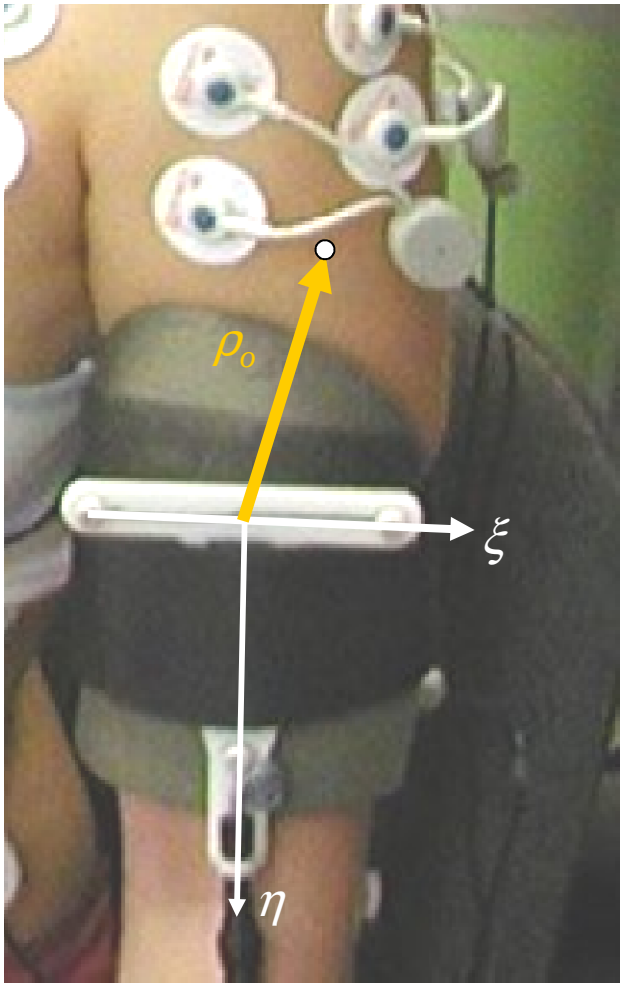
The measuring head is behind the examined person

- **Before the examined person (upper limb examinations) [Illyés]**
- **Behind the examined person (lower limbs) [Kocsis]**

The triplets are placed on the body segments.

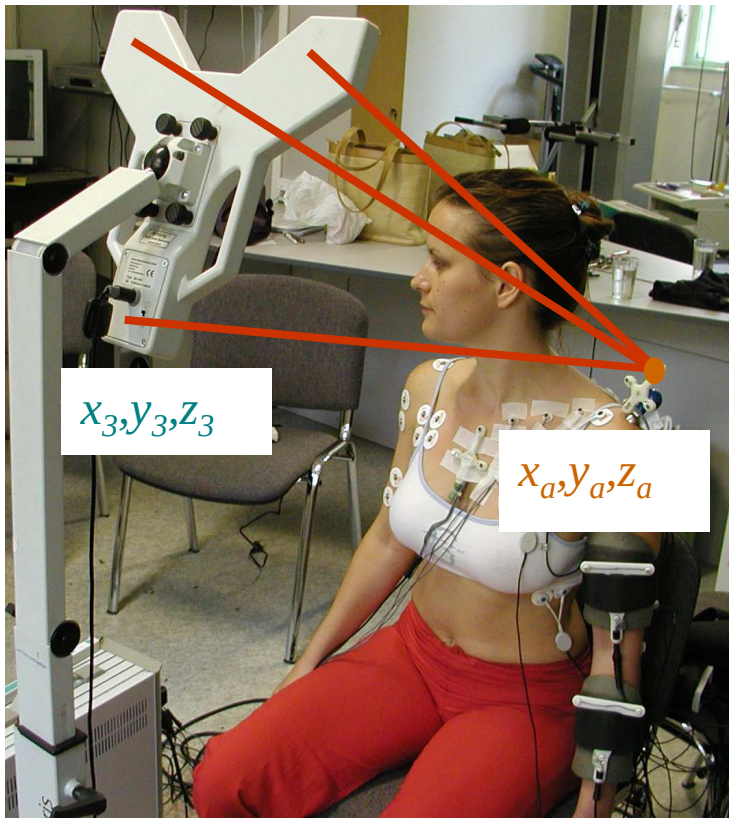
Calibration

Determination of the local coordinates of the body segments in the reference frame of three basic reference point (triplets mounted on the body segments) .



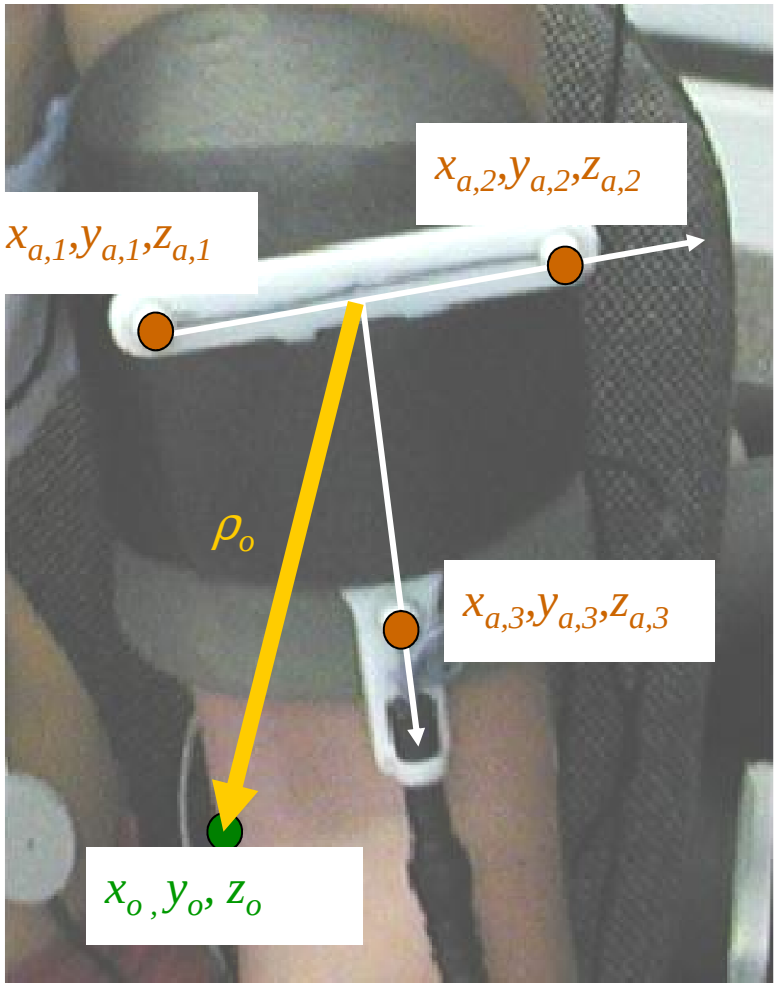
Measuremnt

From distance between the markers and three sensors of the measuring head and the knowing the position of the transducers the global position of the markers are computable with the method of triangularization. [Kocsis]



Measurement

During the motion the position of the examined anatomical point is computable from the global position of the triplets and from the local position of theese anatomical points respect to triplets. With theese method any number of the anatomical point is measurable.



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Mérés menete

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- **During the predermined motion (walking, armlifting, e.g.) the spatial position and rotatio of the sensors are measured and recorded in the global coordinate system using the control software**

Ultra-sound based measurement system

Frequency of the measurement: **20-100 Hz**

Commercially available systems:

- **ZEBRIS CMS-HS**

Measured quantities: **Spatial coordinate of the anatomical point**

Advantages disadvantages

- **High accuracy of 1mm for an experienced person, for an untrained person the measurement error is under 3 mm measurement error, measurement error (authentication in case of several motion);**
- **Fast processing of the results;**
- **Movement of the skin should be prevented;**
- **Synchronization of various additional switching elements, is solved;**
- **The measuring range of the system is limited (1-3 m);**
- **The body-mounted sensors can modify the movement (there is no difference after the 5-6 minute exercise**

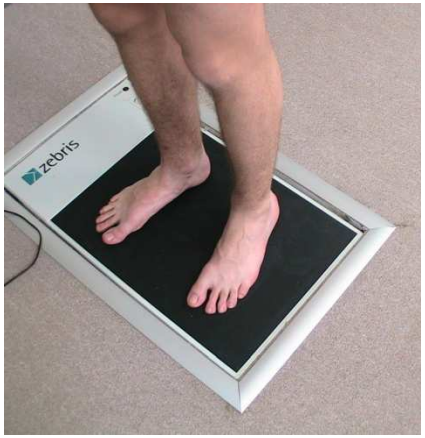
Measurement of ground- reaction force and distribution

Base: **The measurement of the ground-reaction force bases on the Newton's 3rd law (action-reaction principle). The body is pushing the ground with the weight of the body, and the force which acting on the body with same magnitude in opposite direction is called reaction force.**

Equipments: **Separated or built-in to a treadmill force plates, which measures only the magnitude of ground-reaction force, and or foot force distribution (pedograph).**

Conduction of the measurement

- **In case of the keeping of static equilibrium the examined person should stand on the plate for a determined time. (usually 30-60 seconds)**
- **In case of walking analysis, the examinad the person is walking through the built-i n platforms /pedograph with a chosen velocity (natural, slow fast)**



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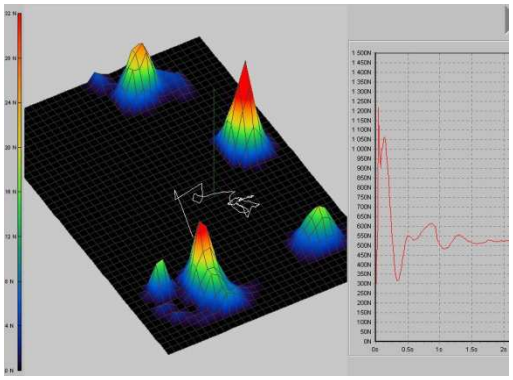
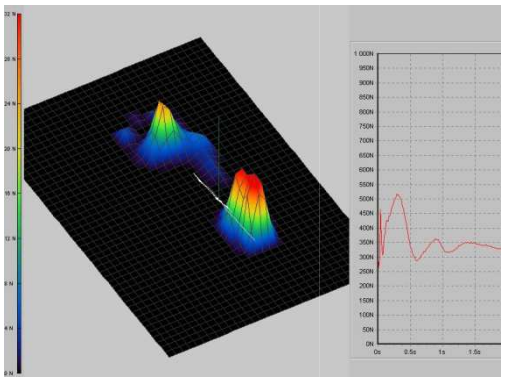
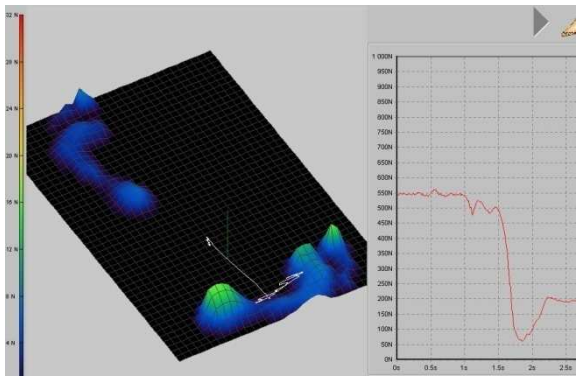
- **Special movement on th plane (fencing)**







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- Special movement on th plane (fencing)
- **In case of treadmill built-in force plate/pedograph, the examined person is walking with constant velocity for 3-5 minutes on the treadmill**

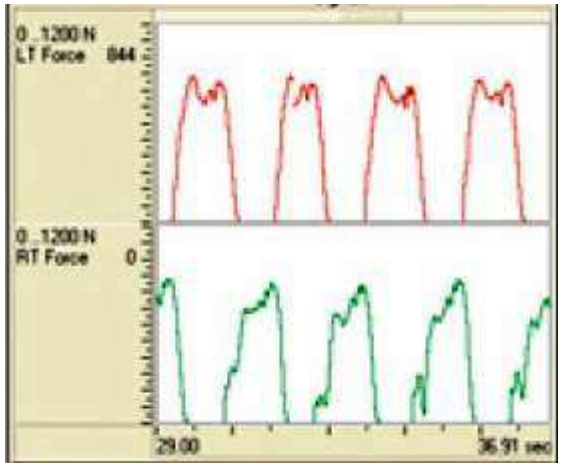
Frequency of the measurement: 100-240 Hz

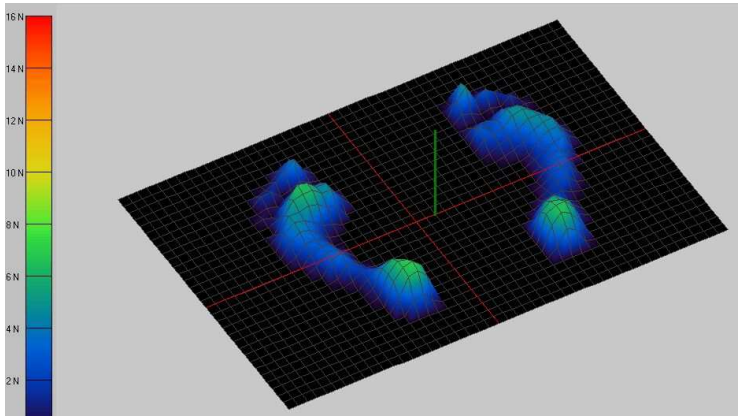
Commercially availabe system

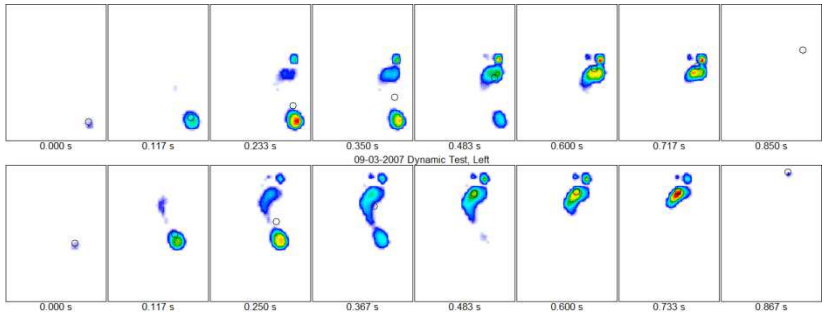
- **ZEBRIS**
- **KISTLER, e.g.**

Measured quantities

- **Magnitude of the reaction force and the changing it in time**
- **Figure of the force distribution**







Advantages, drawbacks

- **The following of the changing of the kinematical parameters are enough fast and precious**
- **With the knowing of the velocity the distance-time parameters can be determined.**
- **In case of some pedographs the value of the pressure can be readable just from a colourscale**

Measurement of muscle activity

Base: **In case of the contraction of the muscle the changing of the electrode-potential is measurable.**

Equipments: **Electromyograph, which measures the electrode potential between two sensors Types:**

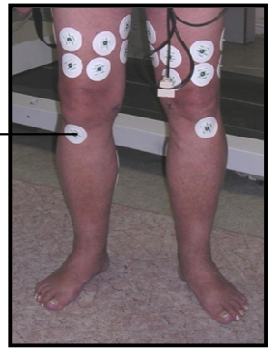
- **Needle (individual muscles, deep muscles, painful, sterilization, hard-hitting);**
- **On surface**
  - **Method of wireing: monopolar or bipolar;**
  - **Sensor shape: round, oval, square shape.**

monopolar circular contact sensor

Conduction of the measurement

- **Finding the muscle belly generally with Ultrasound**
- **Fixing the reference- or groundpoint which is neutral in electric sense**
- **Decreasing the resistance of the skin (hair removal, removing of epithelial tissue with a special sandpaper)**
- **Mounting the electrodes. The distance between the electrodes is arbitrary, usually 10 mm .**

referencepoint



Sensorpair on the muslce belly

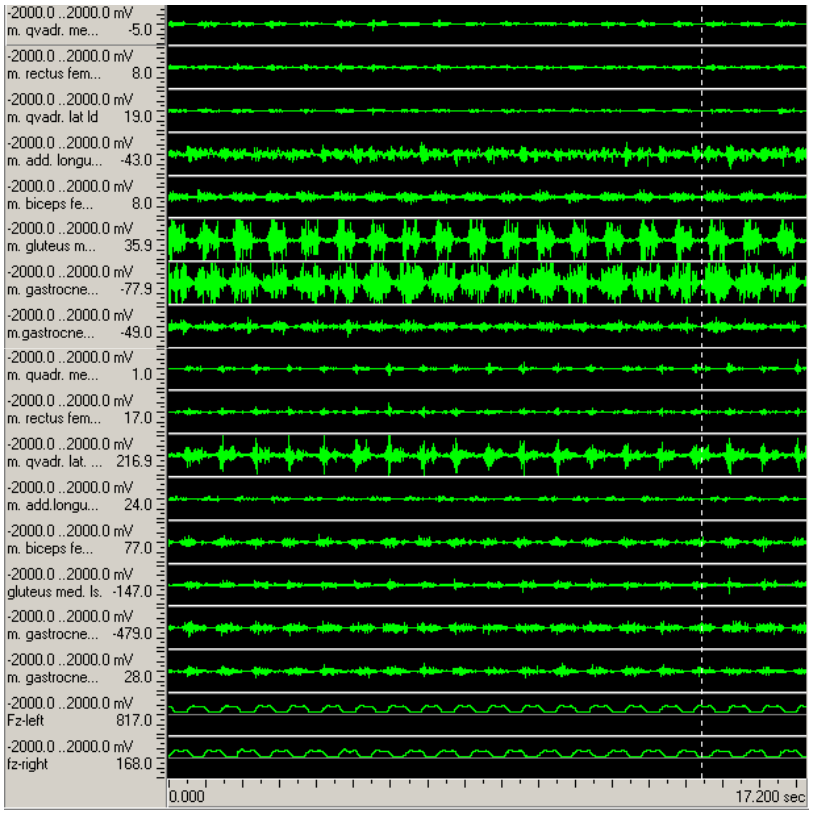
Conduction of the measurement

- Finding the muscle belly generally with Ultrasound
- Fixing the reference- or groundpoint which is neutral in electric sense
- Decreasing the resistance of the skin (hair removal, removing of epithelial tissue with a special sandpaper)
- Mounting the electrodes. The distance between the electrodes is arbitrary, usually 10 mm .
- **Trackig the changing of the electrode potential of the examined muscle**

Freqency of the measuremt **500-2000 Hz**

Measured quantities:

Electromyogram which is the potential-change between two electric detector, in the function of time

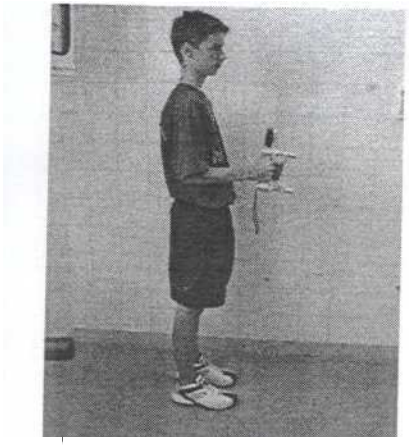


Advantages, drawbacks

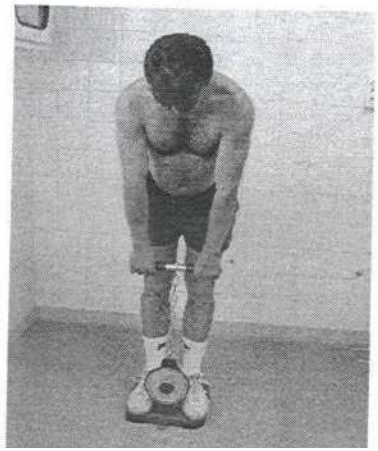
- **If you are using a needle electrode movement will be difficult to implement, but muscles can be measured individually;**
- **When using surface electrodes only superficial muscles, muscle groups can be tested, the cross-check is especially important;**
- **The process is difficult, but complex analysis can be made.**

Force measurements

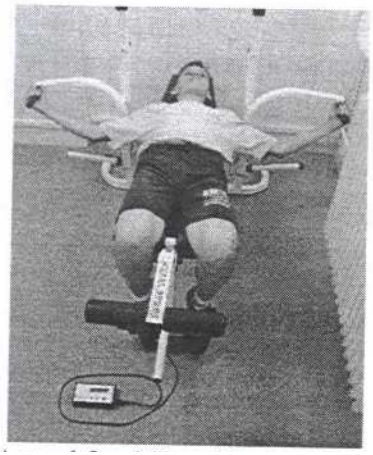
- Static investigation



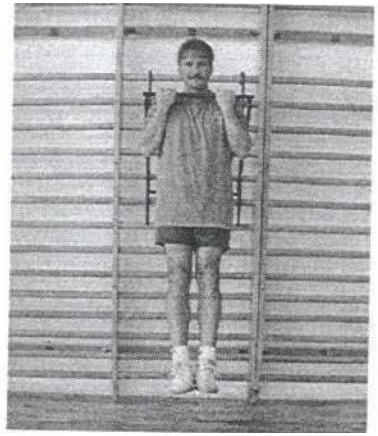
Grasping Force



Force of the latissimus dorsi



Tension force of the shunk thigh



Static force measurement with hanging

Reaction-time measurement

- Reaction-time: the time between the stimulus and the answer (ability of concentration)
- Stimulus:
  - Voice
  - Light stimulus
  - E.g
- Válasz:
  - Pushing buttion
- Field:
  - Sports medicine (anaerob átmenet)
  - Diseases of nervous system

Ángyán: Az emberi test mozgástana