Introduction

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Conclusion
Perform 3D actions in a 3D space on a 3D Object: a human being

Therapeutic objects = Targets
Introduction
Basics
History
Frame based Stereotaxy: Clarke et Horsley - 1806

1990 1995 2000
Spine Surgery

Pedicular screwing
First generation: ROBODOC and CASPAR

- Femoral drilling
- Out of business
- Cost
- Invasiveness
- No added value
### Computer Assisted Orthopaedic Surgery

**PASSIVE SYSTEMS**

**Navigation systems**

- **Guiding systems**

  **3D localizers**
  
  Real-time feed back on the location of:
  - Therapeutic objects
  - Surgical instruments

**SEMI-ACTIVE SYSTEMS**

The surgeon is guided in a restricted volume

- **Guiding systems**

  **Padyc**

  **Synergistic robots**

  **Collaborative robots**

  **Impeachment robots**

[http://www-timc.imag.fr/]
ACTIVE SYSTEMS
Active robots which performs Part of the surgical procedure

Guiding systems

Active robots
Perform parts of the procedure
Based on per-op planning
Localization: non deformable Objects

- Bones or surgical tools
  - Location
  - Orientation

3D rotation matrix and the translation matrix to compute the transformation from $\text{Ref}_{\text{abs}}$ to $\text{Ref}_{\text{rb}}$
Non Deformable Objects

- Bony structures: therapeutic objects
- Surgical tools

Dynamic reference base (DRB)
Optical localizer with two 2 Dimensional sensors

Polaris:

**3D Localizers**

**Localizer = 1 Source + 1 Sensor**

- Optical localizer with two 2 Dimensional sensors

**Polaris**:

**Technical Specifications**

**Accuracy**: 0.15 mm/3D Rad

**Workstation Interface**: RS-232/422

Max. Data Rate: 115 kbps

**Position Sensor**:

- Weight: 2 kg
- Mounting: 5/16" thread tap oil mount
- Dimensions: 140 mm x 180 mm x 130 mm

**Enhanced Tool Interface Unit**:

- Weight: 8 kg
- Dimensions: 320 mm x 130 mm x 300 mm

**Power Requirements**:

- Hybrid: 106V/230V 50/60Hz, 2.5 A
- Portable: 100-200 V, 50/60 Hz, 8 A

Note: Weights and dimensions are approximate.
**Computer Assisted Orthopaedic Surgery**

### 3D Localizers

#### Optical systems
- Infra-red sensors
- **Basics**
  - Emitted by the DRB
  - Reflected by the DRB
  - Wave length **880 nm**
  - In the OR one can find
    - 70,000 Lux
    - 400 et 500 nm

#### Active systems
- **Drawbacks**
  - Cables on the operating field
  - Batteries
  - Weight
  - Sterilization issues

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Passive system

• Passive system

Sensitive to surrounding light

Pros
Cheap
Light
Can be set on any type of instrument

Surgical scene

Optical systems

3D Localizers

Drawbacks
Single use

Vision of the optical system
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40 000 TKA / Year / France
8 000 Uni / Year / France

- The challenges: two faces
  - Geometric challenge
    - Align the implants with respect to mechanical axes
  - Functional challenge
    - Perform a good ligament balance
    - Enough mobility
    - Enough stability
The challenges: two faces

Mechanical axes:

Geometric challenge:
- Align the implants with respect to mechanical axes

Functional challenge:
- Perform a good ligament balance

- Enough mobility
- Enough stability
• Functional challenge
• Ligament balancing

LK-off = wear

Instability
• Functional challenge
• Ligament balancing

Well align knee (HKA ~ 180°): Good cuts

Well align knee (HKA ~ 180°): Excessive cuts
- Functional challenge
- Ligament balancing

- Well align knee (HKA ~ 180°): Excessive cuts
  - Gap
  - Increase PE.
  - Laxity in extension

- Well align knee (HKA ~ 180°): Insufficient cuts
• Functional challenge
• Ligament balancing

- Well align knee (HKA ~ 180°): Insufficient cuts
- Excessive constraint

- Misalignment (Varus or Valgus):
- Distraction
- Retraction
- Constraint
- Laxity
• Functional challenge
• Ligament balancing

• Misalignment (Varus or Valgus):
  • Risks
    • Unbalance knee
    • Residual laxity / Excessive constraints
    • Overcorrection / Hypocorrection

• Retraction
• Release
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The solutions

Build a SPECIFIC model of the patient under surgery
• Build the specific GEOMETRY of this patient
• Align the prosthesis with respect to the patient axes

• Hip center
• Knee center
• Ankle center

• Localize in 3D the joint centers
• Build reference planes
Build a **SPECIFIC** model of the patient under surgery

- Build the specific **MORPHOLOGY** of this patient

Local adjustment to the bones
Ligament balance can only be made with local data

---

**Pros and Cons**

- **CT based approach**
  - Pre-operative planning
  - Cost – Radio protection issues
  - Archiving and communication of images : PACS
  - No increasing time for acquisition and planning

- **CT including Hip – Knee - Ankle**
- Setup time
- **Intra-operative registration (time consuming/accuracy issues**
**Pros and Cons**

- **Non image based system**
  - Simple
  - Low cost – No radiation
  - Integration of intra-operative data
  - No registration issue
  - Increase the operative time
Computer Assisted Orthopaedic Surgery

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**No pre-operative images**

**Build a specific model of the patient: Acquisition**

- **Geometric data**
  - Axes
  - Hip center
  - Knee center
  - Ankle center

- **Morphologic data**
  - Bone surfaces

- **Digitization of points with a 3D probe**

**None image based approach**

- **Hip center**
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None image based approach
- Kinematics approach

Search of a point C of R_fem with the minimum trajectory during the acquisition motion

Hip Center

Rpolaris

R_femur

Ta0

Tb0

Tc0

Td0

Ta1

Tb1

Tc1

Td1

Hip Center

Rpolaris

None image based approach
- Morphologic approach

Knee Center

Hip Center
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None image based approach

Percutaneous digitization of points

Geometric approach

Error

Slope

Varus

Valgus
Computer Assisted Orthopaedic Surgery

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Geometric approach

What is really important to detect?

E. STINDEL, et Al. The center of the ankle in all-less based navigation system. What is really important to detect? CAOS Santa Fe 19-22 June 2002.

None image based approach

Patient
Computer Assisted Orthopaedic Surgery

- **Introduction**
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- **Conclusion**

**Perception**

- **Femoral and tibial shape: Bone morphing**
- **Use of statistical deformable models**

**Morphology**

- **Femoral shape: Bone morphing**
- **Acquisition – Deformation – Quality control**
**Femoral shape: Bone morphing**

- Quadtree (Lavallée): hierarchical division of the 3D volume to apply global and local deformation

---

**Non Image based**

Decision
**Computer Assisted Orthopaedic Surgery**

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**Level 1: based on morphologic data**

- **Planning Tibia**
- **Sensor**
- **Spacer**
- **Software**

**Alignment**

- Valgus 1.0
- **12.0mm**
- **10.0mm**
- Rotation tibia: 2°

Vérifier la proposition de planning, éventuellement ajuster la position et l’orientation de l’implant.
**Computer Assisted Orthopaedic Surgery**

**Decision**

- Level 2: based on dynamic per-operative data

- Test residual laxity
  - Varus Max.
  - Valgus Max.

- If the residual laxity is over a threshold

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**Conclusion**

- Loop until the threshold is reached

**Ligament balance**

<table>
<thead>
<tr>
<th>Int. laxity</th>
<th>MCA</th>
<th>Ext. laxity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 mm</td>
<td>179.1°</td>
<td>5.2 mm</td>
</tr>
</tbody>
</table>

Press on the blue pedal to:
- Continue the protocol and plan the femoral implant with these parameters.

Press on the yellow pedal to:
- Reperform laxity testing with the above spacer.
- Accept
Decision

- Level 2: based on dynamic per-operative data
  - Loop until the threshold is reached

- Level 3: Integration of quality control in the decision loop

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*Courtesy of Christophe Marmignon and Philippe Cenquin – TIMC - Grenoble*
Active system: robots

Passive system: navigation
- Freehand
- Tools are localized in the 3D space in real time with respect to the bones

Robotized cutting guides
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Basics

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Conclusion

7 000 cases / Year / France

Integration of bricks

- Hip center: Same brick

- Knee center: Specific solution

- Ankle center: Same brick

- 3D Planning

Computer Assisted Surgical Protocol - CASP
**Knee center**
- No access to the joint
- Mixed approach
- Man / Machine synergy


**TKA**  
**HTO**  
**THA**  
**ACL**

**Conclusion**
Anterior Cruciate Ligament Replacement

The challenges

- Isometry
- Avoid impingement

Planning

- Projection of the tibial point / Femoral notch projection
- Compute the anisometry map

For a specific tibial point choose the best location of the femoral point.
Anterior Cruciate Ligament Replacement

- Action
  - Take the usual guide
  - Attach a rigid body
  - Perform the calibration
  - Drill the tunnels with the help of the GUI

- Impingement
  - Digitized the anterior fiber of the graft
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100 000 cases / Year / France
# Computer Assisted Orthopaedic Surgery

## Total Hip Arthroplasty

### Introduction

- Basics
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- ACL
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### History

### TKA

### HTO

### THA

### ACL

### Conclusion
Total Hip Arthroplasty

- Reference plane

• Not an absolute reference
• Can be defined on an X-Ray
• Change in supine position
• Influence of anteversion values

TKA
HTO
THA
ACL

Conclusion
• Total Hip Arthroplasty

- Local bone morphing instead of global

• View of the acetabulum fossa before reaming

Fossa

Distance à la surface osseuse : 0.6 mm

Nombre de points acquis : 108

Corne Antérieure  Corne Postérieure
• Total Hip Arthroplasty

- Local bone morphing instead of global

- Fine tuning of the implants

- Final hip center location

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Total Hip Arthroplasty

- Fine tuning of the implants

CUPULE

<table>
<thead>
<tr>
<th>Inclinaison: 36°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longueur-Latéralisation</td>
</tr>
</tbody>
</table>

Antéversion: 32°

Conclusion

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