A mixed reality application for needle targeting with trifocal stereo in real-time

Date: 31. Juli 2018
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Background information:
- Increasing number of surgical needle interventions
- Use Cases: Cancer Screening, Neurology, Sentinel Lymph Node Biopsy, ...
- Punch Biopsy with Ultrasound transducer

Problem:
- Needle tip location difficult to estimate
- Needle path and bending uncertain

Solution:
- Needle tracking with real-time visualization
- Estimation of the needle bending
- Result: ► increasing safety and efficiency
  ► faster healing by minimally invasive surgery

State of the art – Needle Targeting
State of the art – Needle Targeting

[1] Needle Targeting at IFL
Needle targeting operation

Needle [1]

Trifocal camera system

Ultrasound transducer [2]

Framos software

Needle targeting operation

Trifocal camera system

Ultrasound transducer

Framos software

Needle targeting operation

Needle\[1\]

Trifocal camera system

Ultrasound transducer\[2\]

Framos software

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Needle targeting operation

Trifocal camera system

Framos software

Needle targeting operation

Trifocal camera system

Needle [1]

Ultrasound transducer [2]

Framos software

Distance

Deviation

Software structure

- **Needle**
  - needleTrackerSender

- **Ultrasound**
  - ultrasoundTrackerSender

- **Trifocal**
  - pivotCalibration
  - calculateIntersection
  - needlePrediction
  - display
7 FRAMOS plugins

**NeedleTracker**
- is receiving needle poses via OpenIGTLink from Server
- Input: -
- Output: Needle Pose

**NeedleTrackerSender**
- is sending needle poses via OpenIGTLink to the NeedleTracker
- Input: -
- Output: -

**UltrasoundTracker**
- is receiving ultrasound pose and image via OpenIGTLink sender
- Input: -
- Output: Ultrasound Pose, Image

**UltrasoundTrackerSender**
- is sending poses and images to the UltrasoundTracker
- Input: -
- Output: -
7 FRAMOS plugins

AcquireImage
• is used by Framos to display images

UltasoundPlane
• is a static transformation to deal with the ultrasound plane

PivotCalibration
• is used to measure the needle tip from handle
  Linear equation system (SVD)
• Input: Pose Array
• Output: Pose

\[
\begin{bmatrix}
R_1 & -I \\
\vdots & \vdots \\
R_n & -I \\
\end{bmatrix}
\begin{bmatrix}
P_{TCS} \\
P_{WCS}
\end{bmatrix}
= 
\begin{bmatrix}
-t_1 \\
\vdots \\
-t_n
\end{bmatrix}
\]

7 FRAMOS plugins

NeedlePrediction
• is used for predicting the future needle path based on the needle vector
• Input: Pose Array
• Output: 5 indication points / ply cylinder

CalculateIntersection
• is used to calculate the intersection point between needle and plane and the distance between needle tip and plane
• Input: Plane Pose, Needle tip and direction
• Output: Intersection Point, Distance

[1] Cylinder ply file
FRAMOS Application Framework

Computer Aided Medical Procedures
Milestones and Project plan

- Familiarization with the topic and research - Alexandre Krupa: „3D ultrasound-guided robotic steering of a flexible needle via visual servoing“
- Designing the concept
- Implementation and integration
  - Framos software framework with C++
  - 3D representation with OpenGL and OpenCV
  - Stereo tracking poses via OpenIGTLink
  - Integrate image transfer with plugins
  - Calibrate cameras and needle  
    (intrinsic, extrinsic, needle, pivot, ultrasound)
  - Calculate and visualize additional information
- Build prototype
- Verification, validation and testing
- Documentation (GIT) and presentation
Time Line for the project – GANNT Chart

- Concept phase
- Research papers and state of the art
- Mockups
- Kick-Off presentation
- IDP Trifocal
- Implementation and Calibration
  - Stiff needle approach
  - Perform calibrations
- Software development and design
- Needle bending
- Testing
  - Surgery software testing
- Documentation and presentation
  - Creating documentation
  - Final presentation

Software Engineering

Project partners

FRAMOS GmbH
- Using the FRAMOS software framework
- Trifocal camera system

Klinikum Rechts der Isar
- Premises at the hospital: IFL
- Resources

CAMP chair:
- Interdisciplinary Project (IDP)
- Supervisors

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Additional considerations

Calibration with Optical Tracking System (OTS):
- Needle: handle, tip, vector
- Ultrasound: handle, plane
- Cameras: intrinsic, extrinsic

Needle bending aspects:
- Material stiffness
- Needle length
- Tissue to investigate
- Model of deviation error

Software development problems
- Utilizing dependencies and libraries
- Dealing with input and output values
- OpenIGTLink sending process
Project summary and outlook

Suggestions for improvement
- Better visualization of needle bending
- More accuracy and insert real data
- Improving task workflow
- Change software framework
- Missing functionality: Select the target, insertion point
- Rather Proof of concept than usable for real biopsies

Future work:
- Using additional preoperative MRT
- Verify and improve functionality
- Additional software features
- Video recordings of surgery for teaching
- Robotic surgery
Thank you for your attention!

Interdisciplinary Project (IDP)
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