Needle tracking for ultrasound-guided biopsies with inside-out vision
Motivation and problem statement

- **Problem:**
  - Needle tip location uncertain in ultrasound image
  - Analyzing wrong cells might lead to wrong diagnoses

- **Motivation:**
  - Improve the healing process by less insertions
  - Analyze the right cells

- **Solution:**
  - Software framework for needle and ultrasound tracking
  - Visualization to assist the surgeons

- **Areas of application:**
  - Biopsy for cancer screening or
  - Applications in neurology

- **Partners:**
  - Klinikum rechts der Isar (IFL)
  - FRAMOS GmbH

References: Image from FRAMOS GmbH
Requirements and specification

- Reading project based papers
- Receive and display ultrasound image
- Receive needle pose in real-time
- Calibrate needle, needle vector, ultrasound plane, ... 
- Calculate intersection point and distances 
- Create Qt user interface 
- Implement 3D Vision 
- Implement Features

Gantt Chart

NeedleTrackingSystem Software
NeedleTrackingSystem Software

References: 3D Image generated with Blender
Ultrasound guided biopsy with inside out tracking

Reference: Image from „Interdisziplinäres Forschungslabor, Universitätsklinikum Rechts der Isar“
Software structure

Reference: Diagram generated by UMLet, 26.01.2016
Sequence Diagram

Optical Tracking System (OTS)

Ultrasound Transducer

T₁

T₂

T₃

T₄

Biopsy Needle

Needle Tracking System
Calibrations

- **Pivot Calibration**  
  (To get the transformation from needle to tip, fCal)  
  Move the needle with fixed tip

- **Plane Fit**  
  (To get the ultrasound plane, pcl)  
  Collect several points on ultrasound plane

- **Line Fit**  
  (To get the needle vector, pcl)  
  Guide needle through a tube

- **Ultrasound startpoints**  
  (Touch startpoints with needle tip)

Image references:

Calculations

\[ P_1(x_1, y_1, z_1) \quad P_2(x_2, y_2, z_2) \]
\[ P = P_1 + u(P_2 - P_1) \]
\[ E : Ax + By + Cz + D = 0 \]

- Intersection between needle vector and ultrasound plane
  Where would the needle go inside?
  \[ u = \frac{Ax_1 + By_1 + Cz_1 + D}{A(x_1 - x_2) + B(y_1 - y_2) + C(z_1 - z_2)} \]

- Distance between needle tip and ultrasound plane
  How far the needle has to get inserted?
  \[ d = \frac{(Ax_1 + By_1 + Cz_1 + D)}{\sqrt{A^2 + B^2 + C^2}} \]

- Distance between target and needle vector
  How should the needle be rotated?

References:
Project Outlook

- Improve the calibration process
  (Integrate calibration process into software, Achieve better accuracy)

- Add additional features
  (Target, Screencast, Config files, Select the target)

- Complete the 3D visualisation and settings
  (Add navigation, Meshes for ultrasound and needle, Add options)

- Verify the software
  (Guarantee that everything works correct)

- Improve the tracking device
  (Smaller tracking device, Mounted on ultrasound transducer)

- Solve the needle problem
  (Stiffer needle, Consider physical model for needle deflection)
Project Retrospective

- Proof of concept is provided
- Not yet usable for real biopsies
- Much more work than expected
- Too much focus on presentations
Thank you for your attention!

Do you have any questions?