Friedrich-Alexander-Universität
Technische Fakultät

Intraoperative Femur CCD-angle detection using segmentation

Team Dr. Tensor

Outline

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2. Technology
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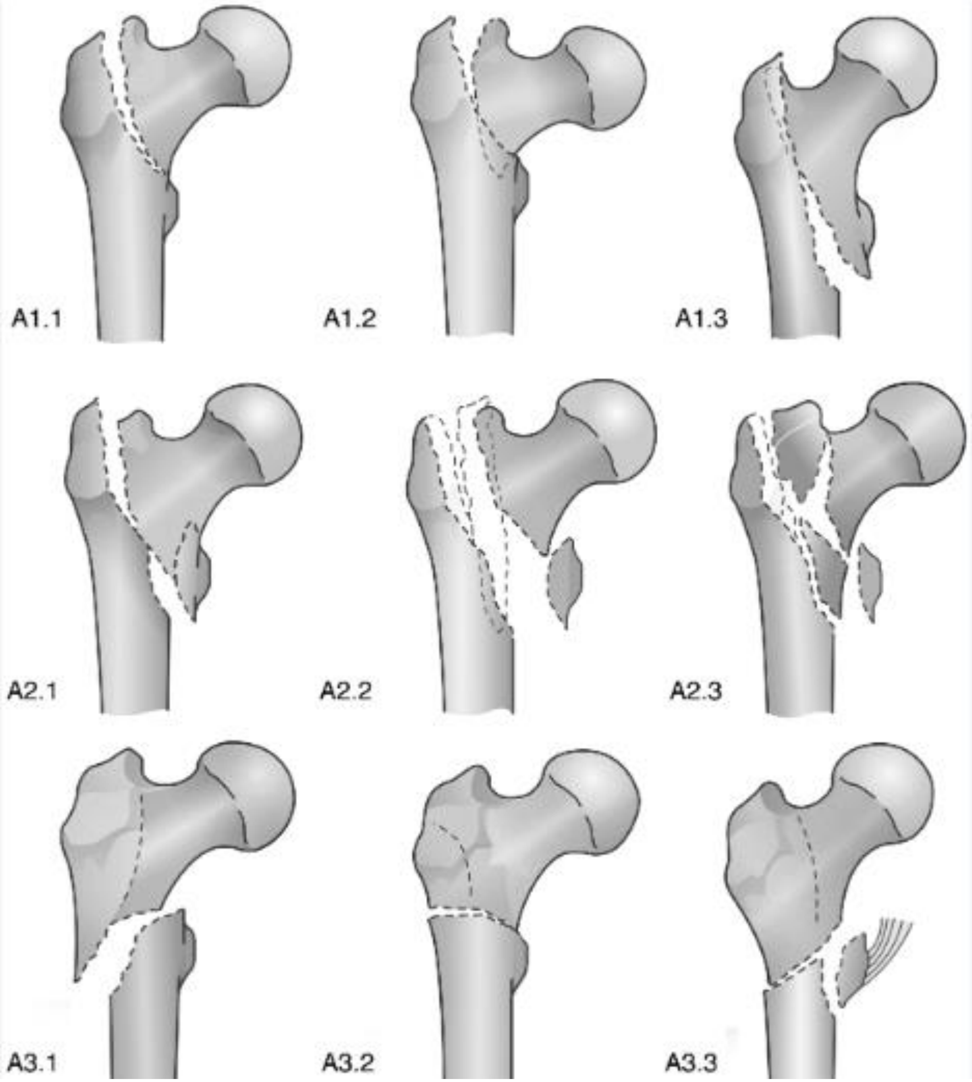
Problem Description

Caput-Collum-Diaphysis Angle Anatomy and measurement at present

Anatomy

- Femoral neck fractures **(FNFs**) are among the most common fractures in the elderly population, with a high mortality risk at one year, ranging up to 36%. Also, the management of such fractures entails a significant financial and societal burden.

- Femoral neck fractures typically ***require surgery*** to repair, and the treatment options may depend on various factors such as the type and severity of the fracture, the patient's overall health, and the ***surgeon's preference.*** Rehabilitation and physical therapy are also an essential part of the recovery process.



Source: @Dr. Holger Stadthalter

Problem Description

CCD Angle

The **CCD** angle, which stands for "center-center of the femoral head to the center of the femoral neck angle," is an important parameter that helps to determine the appropriate implant placement in femoral neck fractures (FNFs) surgery. However, **determining the correct CCD angle can be challenging for surgeons, and several difficulties may arise.**

To overcome these difficulties, the surgeon must carefully evaluate the patient's anatomy, fracture type, and other factors that may influence the CCD angle. Additionally, preoperative planning, including imaging studies, can help the surgeon to determine the optimal CCD angle for implant placement. Finally, the surgeon must have extensive knowledge and experience in FNFs surgery to make informed decisions regarding the CCD angle and implant placement.

And here we come in handy ...hopefully at least :)

We built up an interface that takes an X-ray image from the patient using the "open file" key in the UI design , and then view the segmented image with the CCD angles on the sides that can takes commands using voice control .

Problem Description

Problems with current method and Aim

Problems with current method

- Time-consuming process: The current procedure is time-consuming and can prolong the overall operation time.

- Difficulty in obtaining accurate measurements: The procedure involves multiple steps and manual calculations to determine the angle which are prone to errors and inconsistencies, leading to inaccurate measurements and potential complications in the treatment plan.

- High cost: The current measurement methods can be costly and may not be feasible for all patients and facilities.

Aim: computer-assisted automatic measurement process to reduce the potential for human error Hence improve efficiency and accuracy and minimizing the impact on the overall operation time and cost. This would help in improving patient care and treatment outcomes.

Problem Description

Input – output and shape of data for our problem

Explaining the proccess:

- Perform X-ray of the femur.

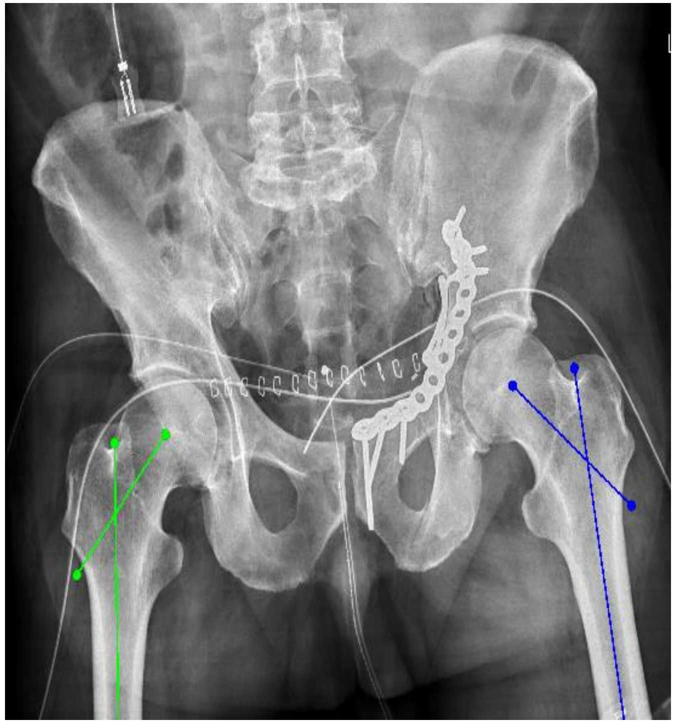
- Automatically measure angle by forming lines connecting the center of the femoral head to the center of the femoral neck and the line connecting the center of the femoral neck to the most distal point on the femoral shaft for both femurs

- Visualization

.

Input for the network :

Visualization required



Stressful Operation Theater

Key personnel involved in the operation
- Operating surgeon and assistant
- Anesthetist
- Scrub nurses
- Circulating staff
- Radiographer

Surgical risks involved during correction of Femoral Neck Fractures.
- Infection
- Bleeding
- Neurovascular injury
- Anesthetic risks
- Stroke/Death

During the surgery, The surgical team is under high pressure to perform the procedure effectively and efficiently while ensuring the patient's safety. The team must also communicate and coordinate effectively to ensure that the procedure goes smoothly.

Stressful Operation Theater

Imaging devices are **controlled manually** by the interventional radiologist or other medical professionals. However, this manual control can be physically demanding.

This was our motivation to implement speech recognition in our UI design in order to bring the AI system(**Dr. Tensor**)to be a part of the OT communication and avoid manual control.

Speech recognition technology could help to overcome these challenges by enabling the radiologist to control the imaging UI verbally, without having to physically manipulate the controls.

Dataset contains

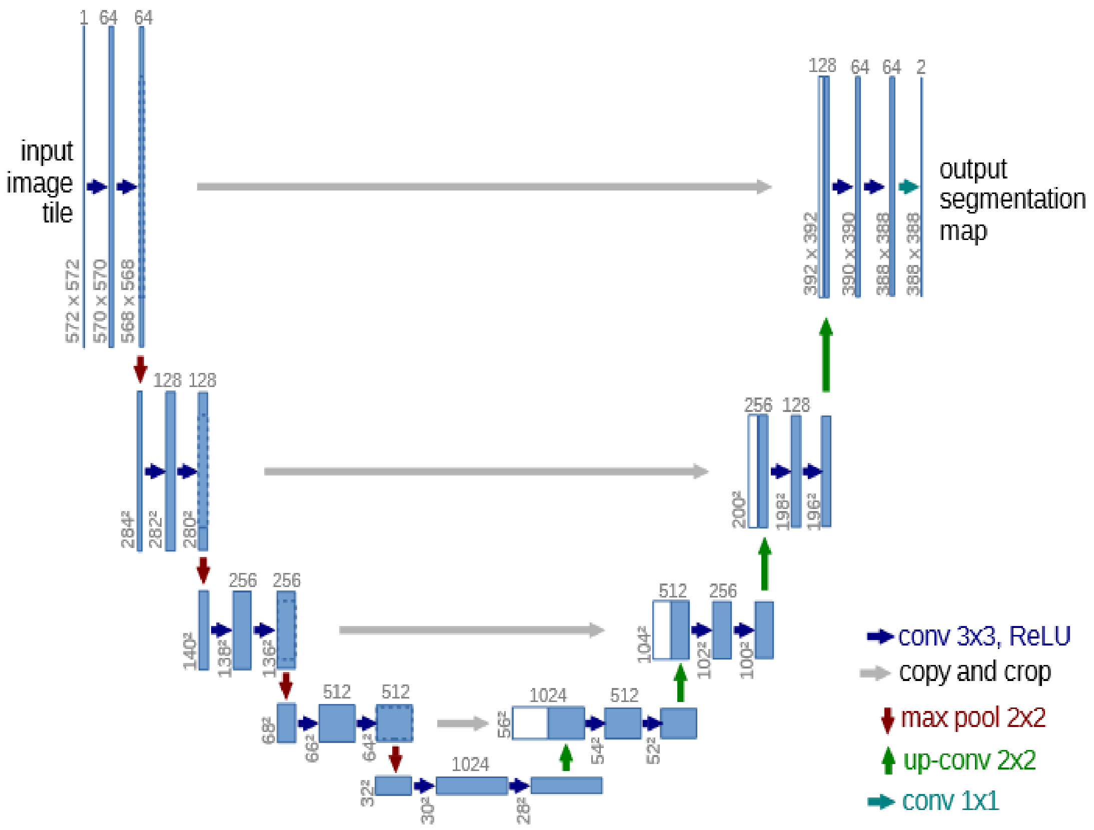
- 201 femur X-Rays of 166 patients.
- All images contain both left and right femurs.
- Data annotations by 8 members of current class.
- Neck lines annotations differ.
- They were re-annotated.

Algorithm

Segmentation using UNet

Semantic segmentation using UNet

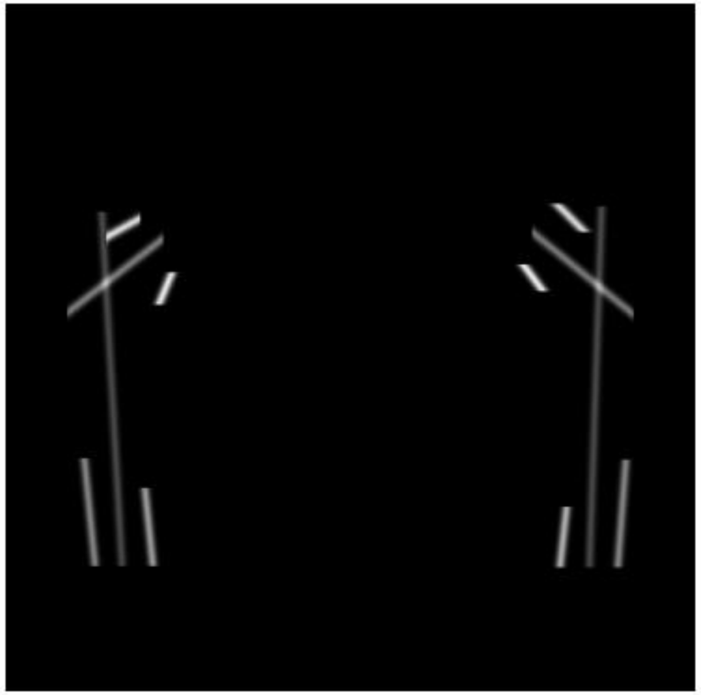
- Fully convolutional network
- Training with very few images.
- Contracting path for context learning and symmetric expanding path for precise localisation.
- Localisation is important in biomedical images.
- Deconvolution (2D transposed convolution for upsampling)



https://arxiv.org/pdf/1505.04597.pdf

Training

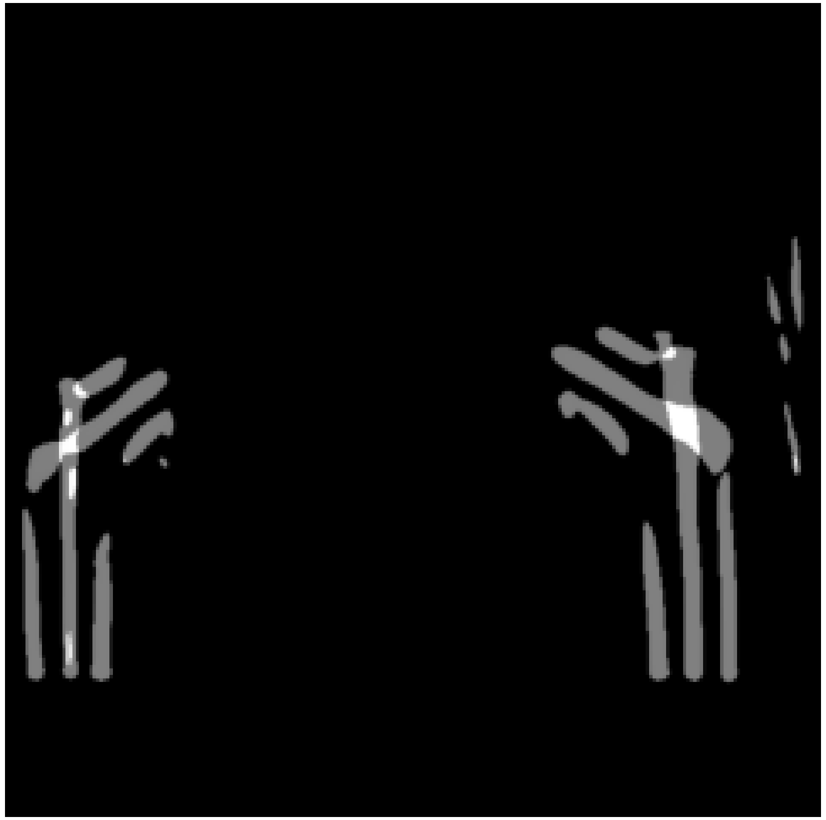
- Train, val, test split (8:1:1).
- All images of single patient go to same split.
- Augmentations: Linear contrast, scale, translate, rotate
- 512x512 input size
- 12 channels UNet output
- MSELoss with Adam optimizer.
- Z-score normalisation of input



12 channel input mask

Network predictions

- Sigmoid based cutoff applied on output
- Problems
  - Predicting line orientation
  - Outliers removal



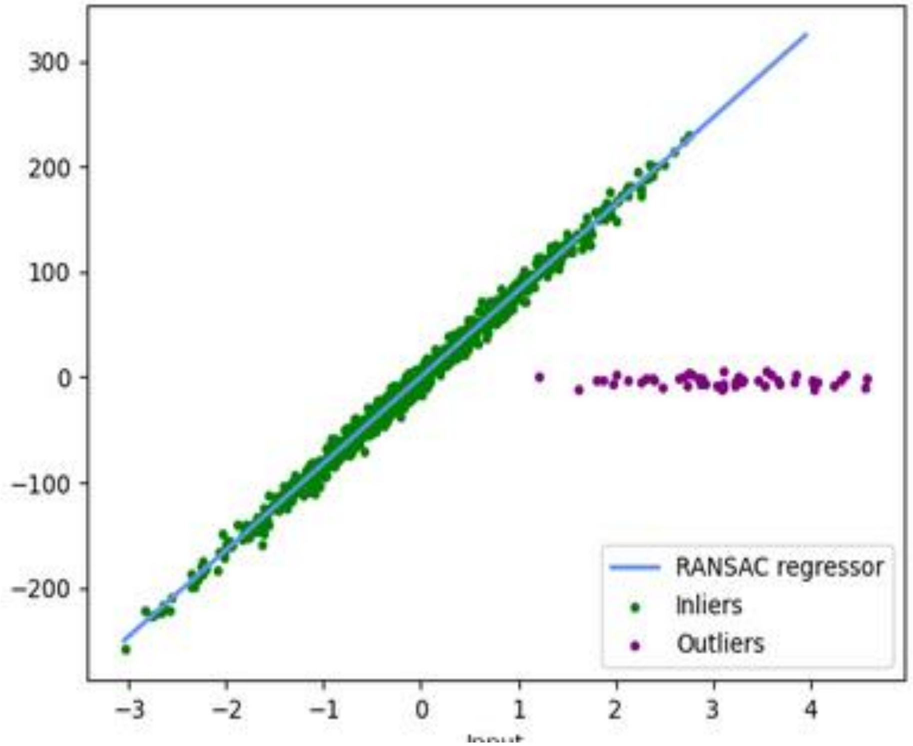
12 channel predicted mask

Postprocessing

Outliers removal using RANSAC (Random Sample Consensus)

RANSAC

- Separates data into inliers and outliers
- It randomly selects minimum data items (2 for line) and computes a fitting model.
- In second step, elements of entire dataset are checked with this model and classified as inliers or outliers based on some error threshold.
- This process is repeated until inliers are maximised.
- All points contribute equally.



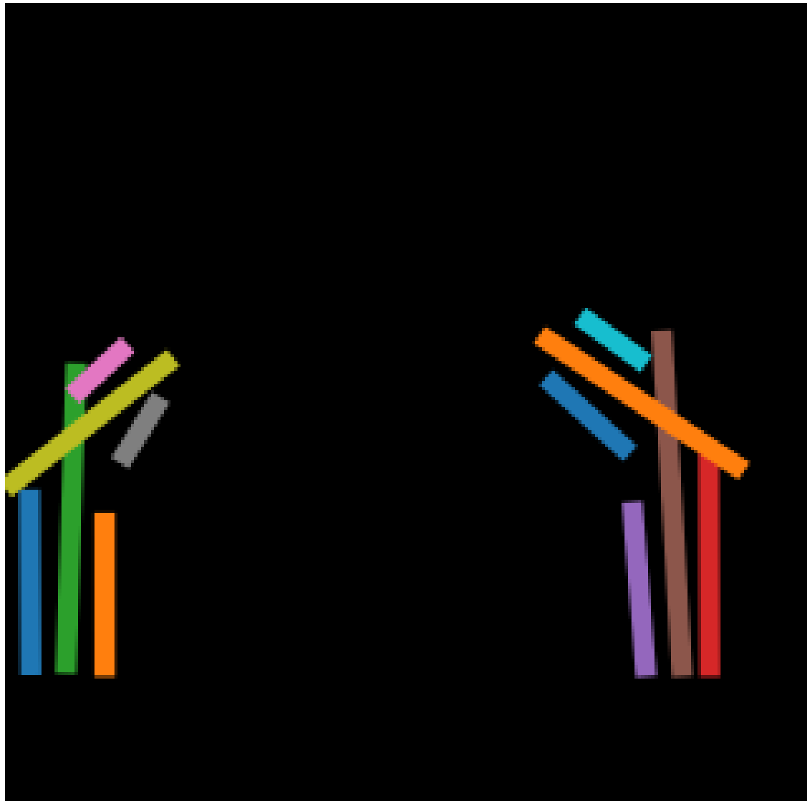
Source: https://www.baeldung.com/cs/ransac

Postprocessing

Outliers removal using RANSAC (Random Sample Consensus)

Network predictions

- Outliers are removed.
- Line orientations are predicted by best fit linear model provided by RANSAC



12 predicted lines after postprocessing

Network Evaluation

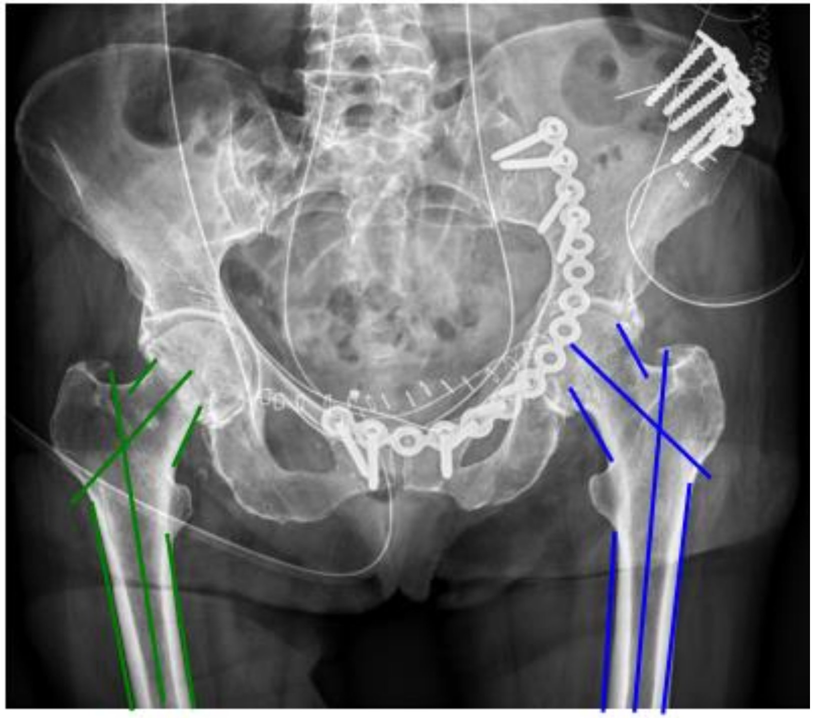
Angular error and Euclidean distance between centroids for individual lines

- Results on test dataset.
- MSELoss was used for training but it doesn't inform much about geometric details of individual lines.
- Angular error (angle between GT line and predicted line) calculated after applying RANSAC
- Euclidean distance between centroids of GT Mask and predicted mask of individual line.

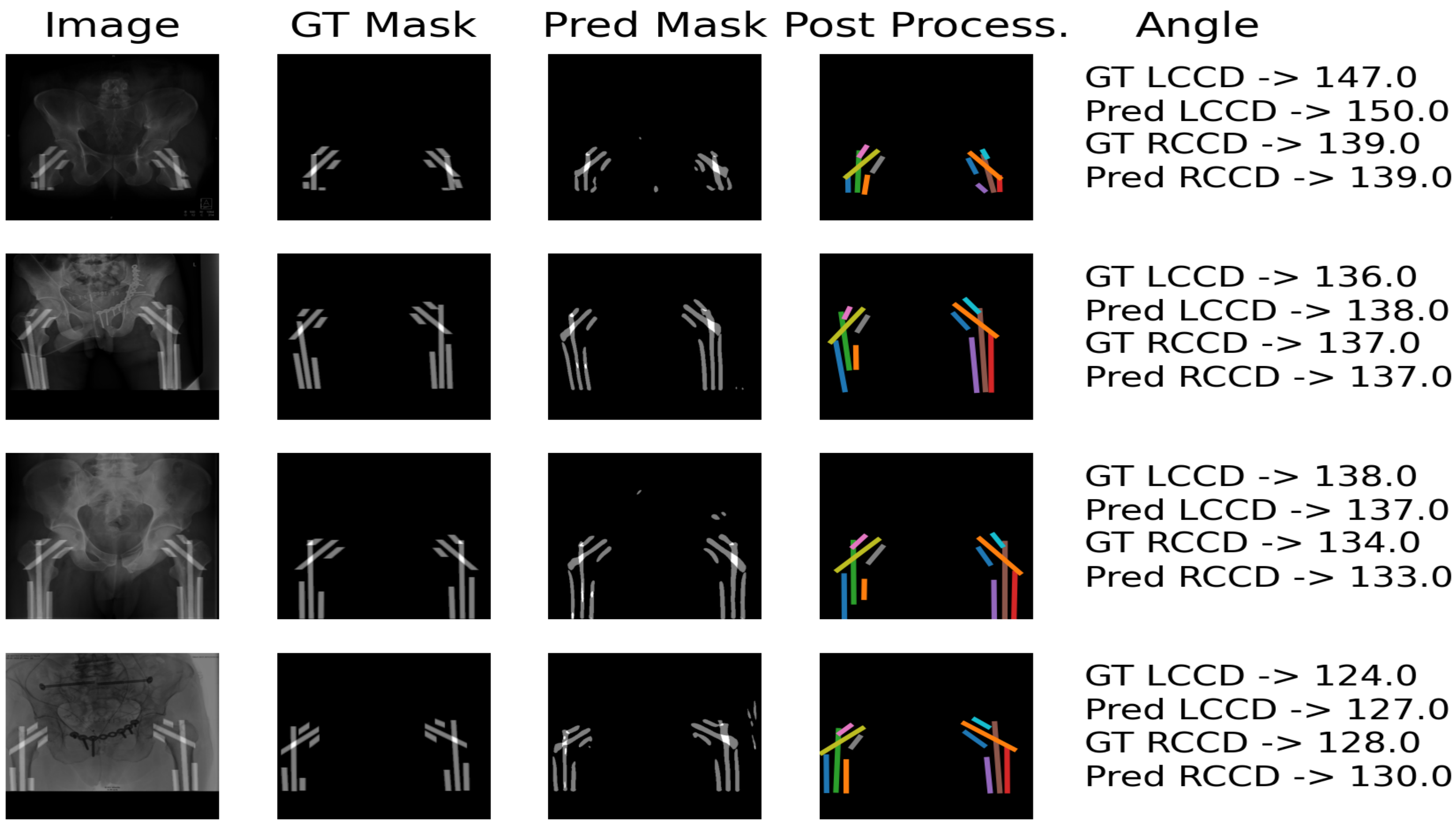
Line Segment	Mean Euclidean distance	Mean Angular Error (Deg)
Right Shaft Centreline	12.6	2.0
Right Neck Centreline	7	5.0
Left Shaft Centreline	9.6	1.9
Left Neck Centreline	14	2.7

Predictions

Femur	MAE
Left	4.3
Right	4.9

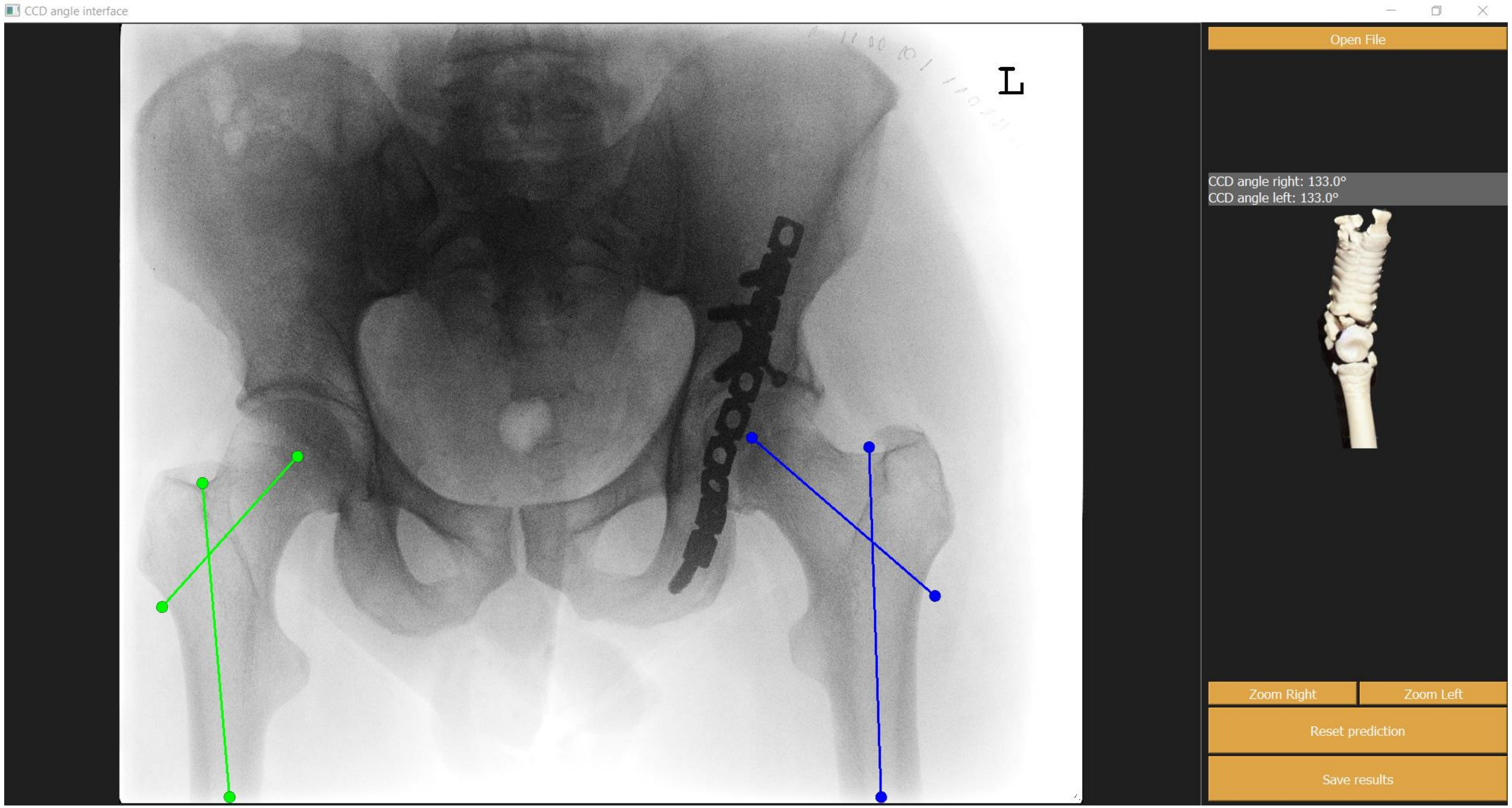


Predictions

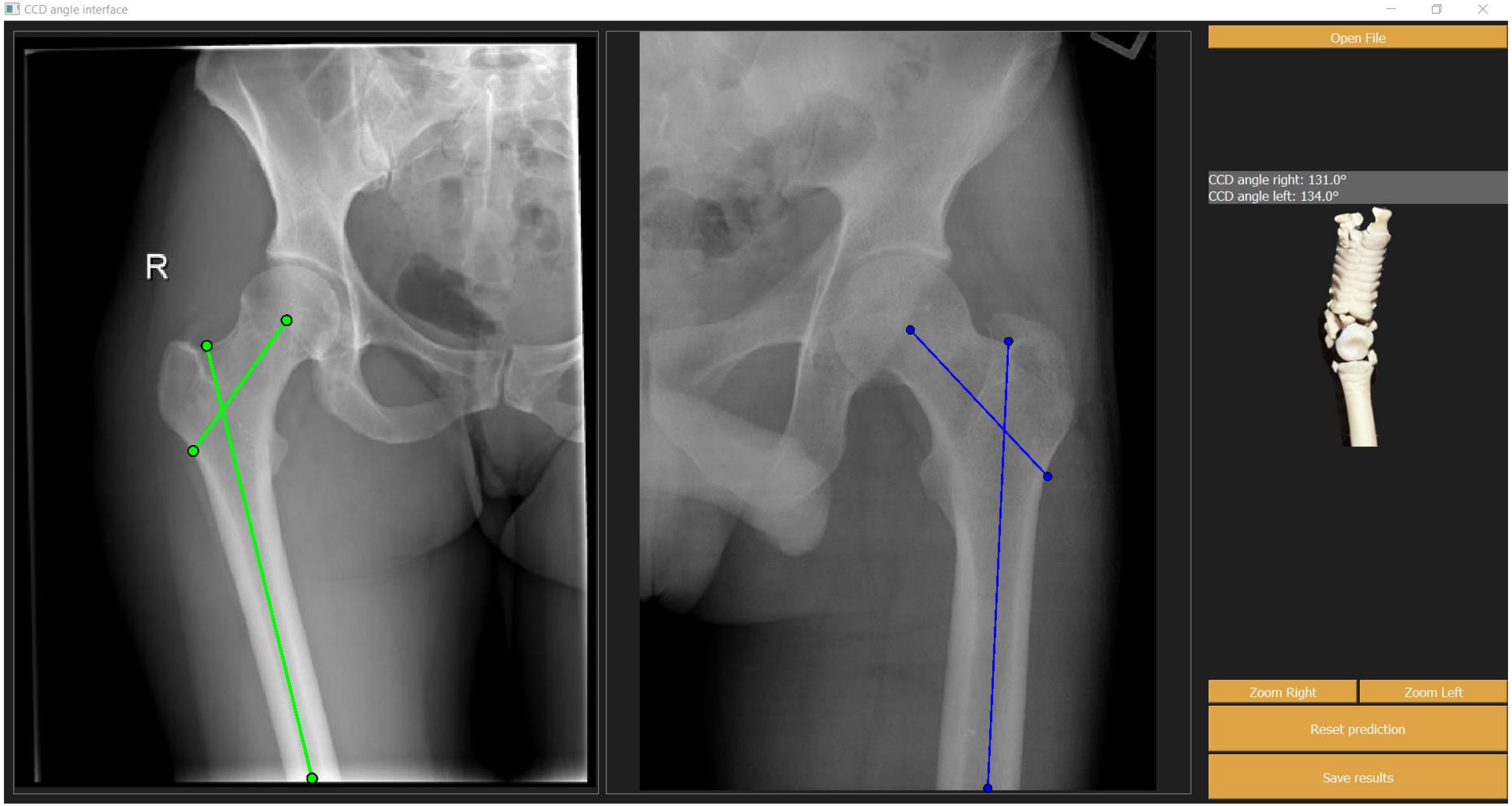


User Interface

- As minimalistic as possible
- All functions on main screen



User Interface



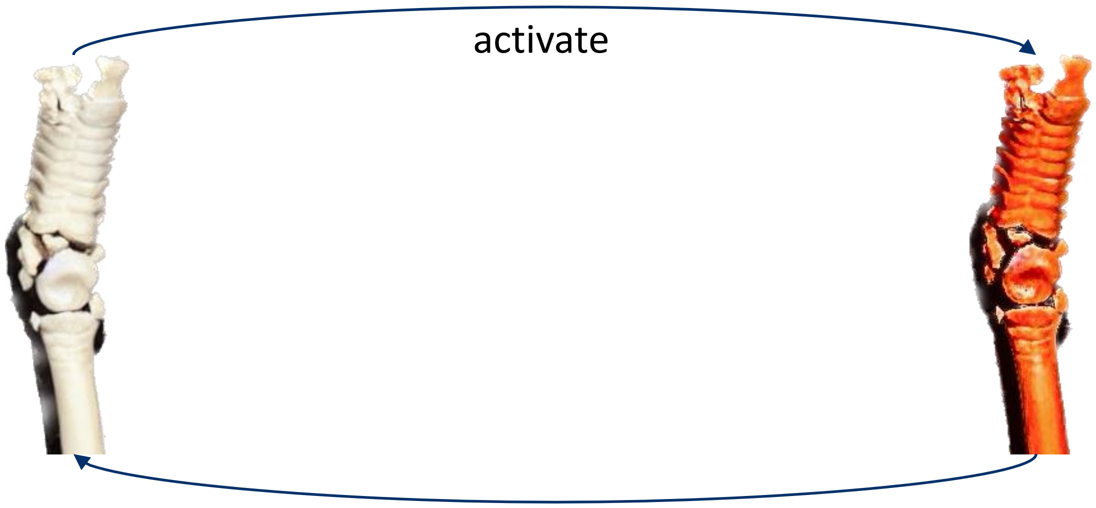
User Interface

System state

- System activation by keyword
  - ”activate”
- Show system state using icon of different colour

Not listening

Listening, waiting for command



After execution of command
or 5 seconds

User Interface

Voice Model OpenAI Whisper

Model: Whisper Base

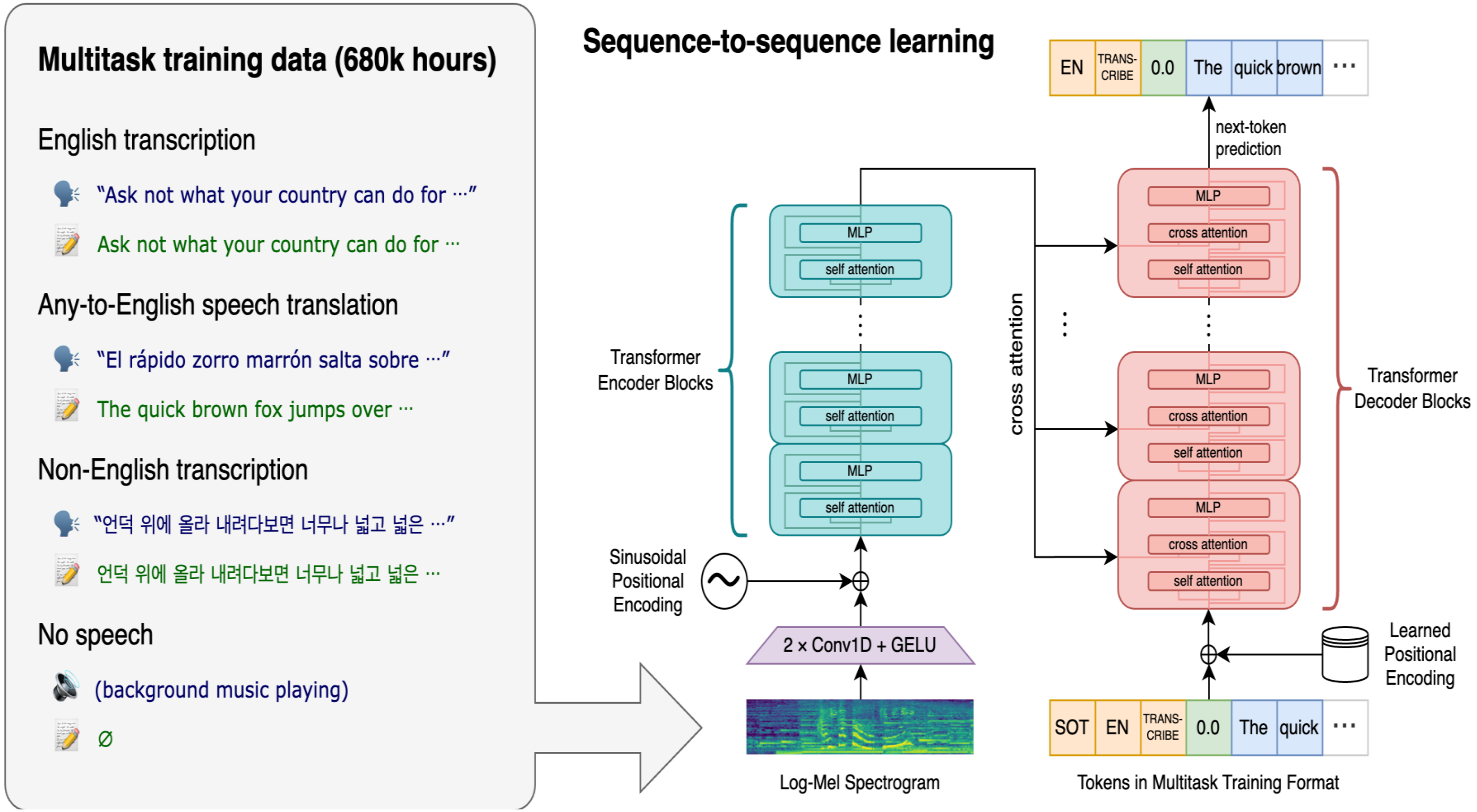
Type: HuggingFace Transformers

Parameters: 74 M

Library used for recording audio: SpeechRecognition

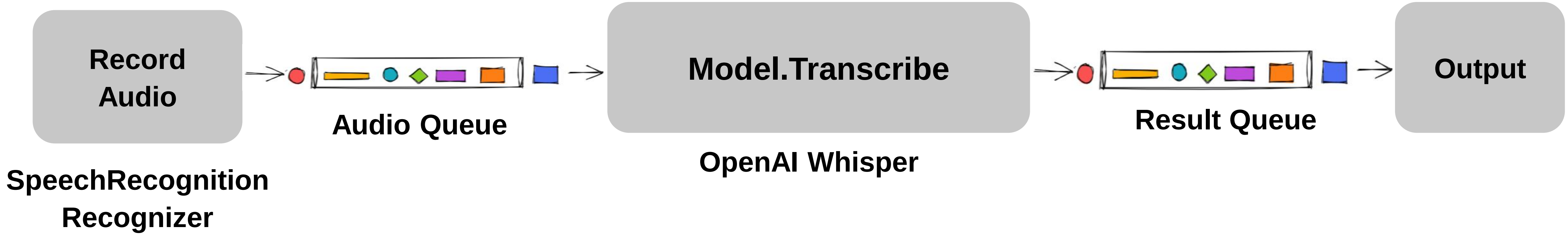
The Library supports OpenAI whisper model which works offline.

Size	Parameters
tiny	39 M
base	74 M
small	244 M
medium	769 M
large	1550 M



User Interface

Working of speech model



User Interface

Voice Control commands

After **Activate** when the red mic shows in the UI:

Left: Zoom on the left femur CCD angle and when said again the system zooms out

Right: Zoom on the Right femur CCD angle and when said again the system zooms out

Save: Saves the screenshot with date and time along with the information said after save command and **Okay** command is used to limit the information to be saved.

Open: Opens the most recent image in the previously most recent opened folder.

These commands doesn’t work with the white mic image that means the system is not activated and needs to be activated again by **Activate** command.

User Interface

Evaluation

- Small user study
- within-subject
- Questionnaire on usability, design and functionality
  - Answer once for using mouse, and voice control

User Interface

Demonstration

Further discussions

Missing parts , things could have gone better

Editing the CCD angle using voice activation:

- We wanted to integrate more for the option to edit the CCD angle by voice control in case the Surgeon wants to add some degrees there for his conventional reason, but we couldn’t manage to start with this idea , ...maybe later :)

- We wanted to go more deeper in options in the interface using the "open folder" , for example: say **next** to view next image in the folder , and **previous** for the one before that , which is doable but we ran out of time :(.

- Leave notes

Thank You

for your attention!