Automated Spinal Segmentation and Remote Monitor Calibration for Surgical Assessment

Members: Damiano Marsilli, Arijit Nukala, Jonathan Young

Project # 8

Mentors: Antony Fuleihan, Evan Haas

Summary

- **Data**
  - 1.62 million instrumented spinal fusion procedures annually [1]
  - Complication Rate 50% [2]
  - Revision Rates 36% [2]
- Expert assessments can wildly change for a given patient over the course of multiple days
- Information is only available about static positions of the patients

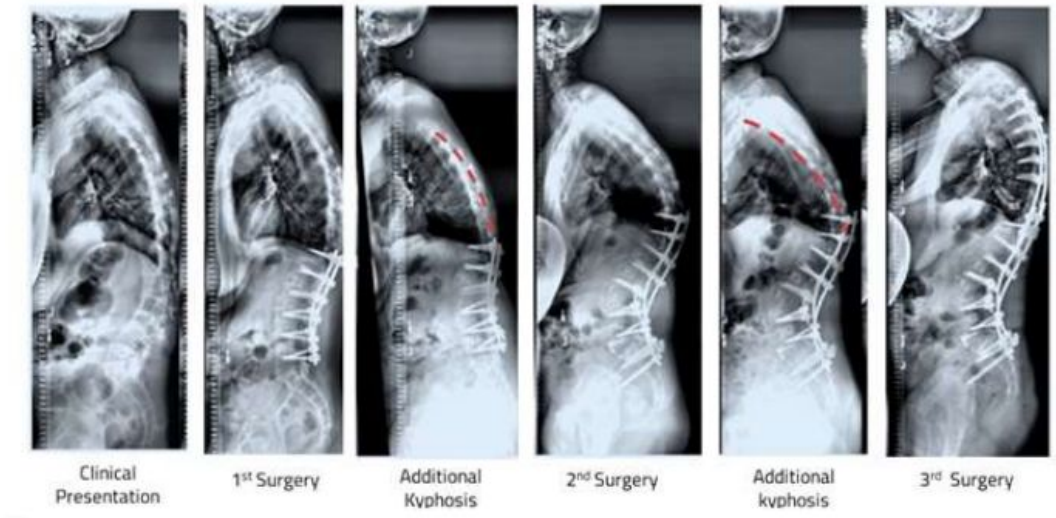
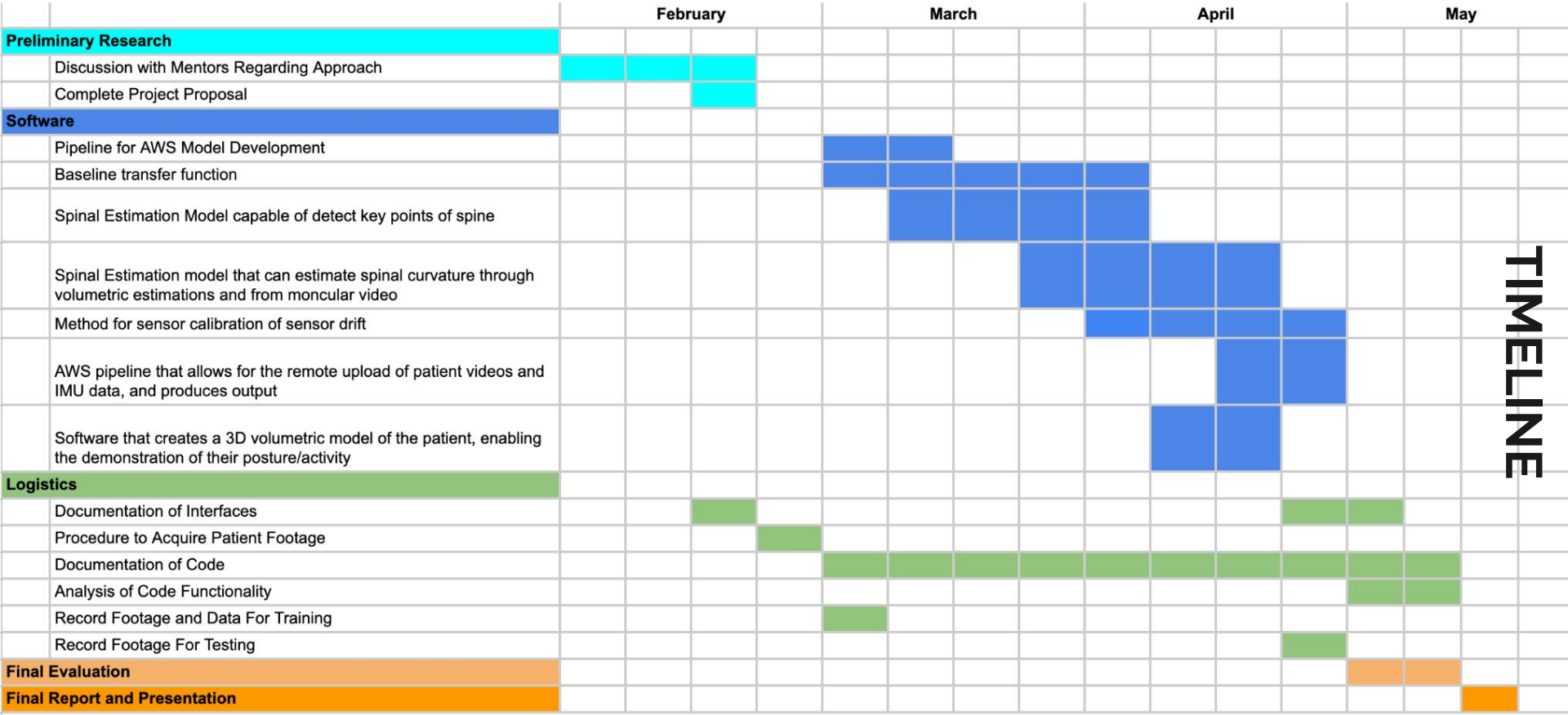
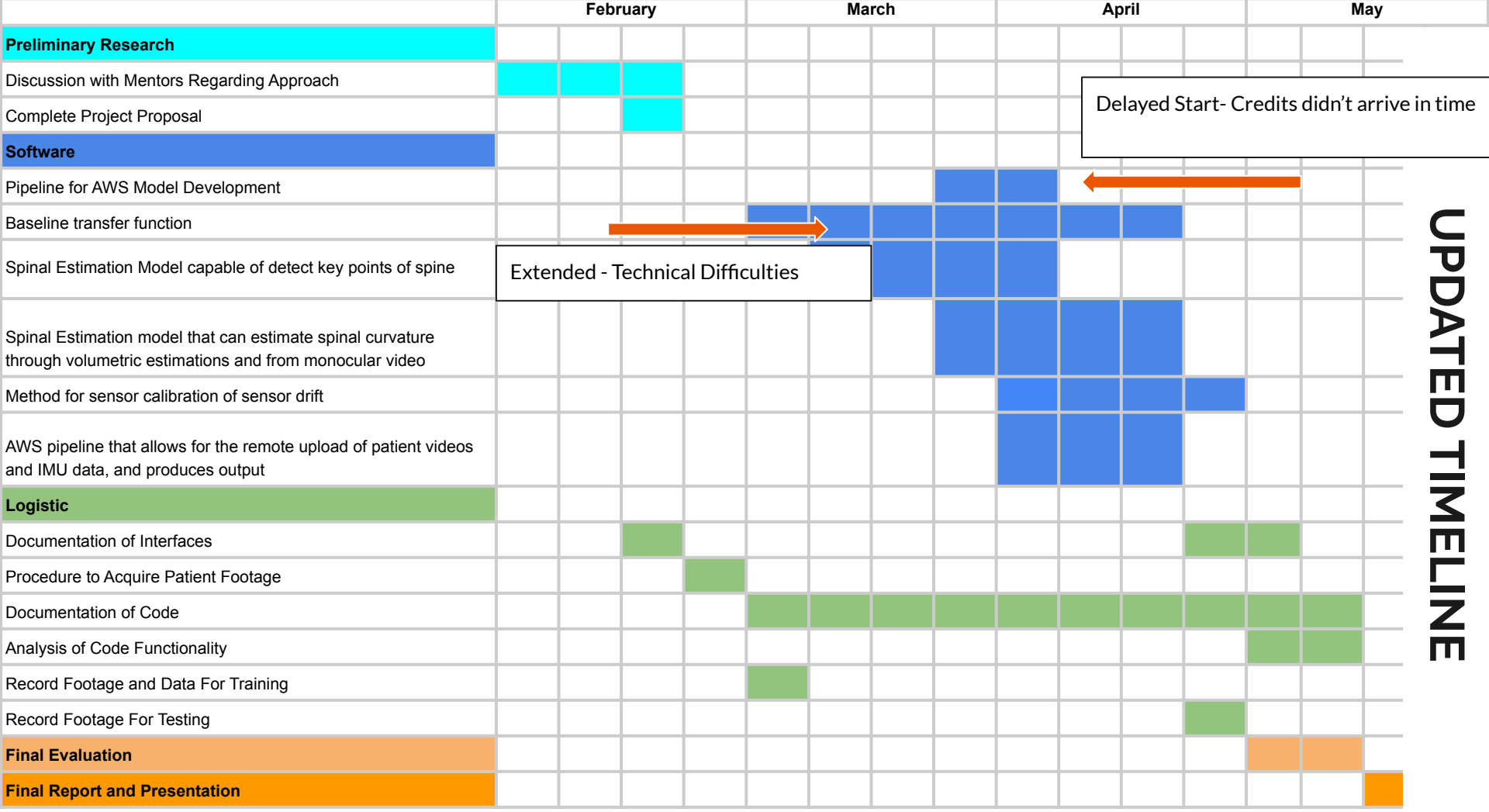


Figure 1 - Patient With multiple revisions [4]

In the example above, a patient had to undergo multiple surgeries, as the first two surgeries did not produce the desired outcome.


February
March
April
May
Preliminary Research
Discussion with Mentors Regarding Approach
Complete Project Proposal
Software
Pipeline for AWS Model Development
Baseline transfer function
Spinal Estimation Model capable of detect key points of spine
Spinal Estimation model that can estimate spinal curvature through volumetric estimations and from moncular video
Method for sensor calibration of sensor drift
AWS pipeline that allows for the remote upload of patient videos and IMU data, and produces output
Software that creates a 3D volumetric model of the patient, enabling the demonstration of their posture/activity
Logistics
Documentation of Interfaces
Procedure to Acquire Patient Footage
Documentation of Code
Analysis of Code Functionality
Record Footage and Data For Training
Record Footage For Testing
Final Evaluation
Final Report and Presentation
TIMELINE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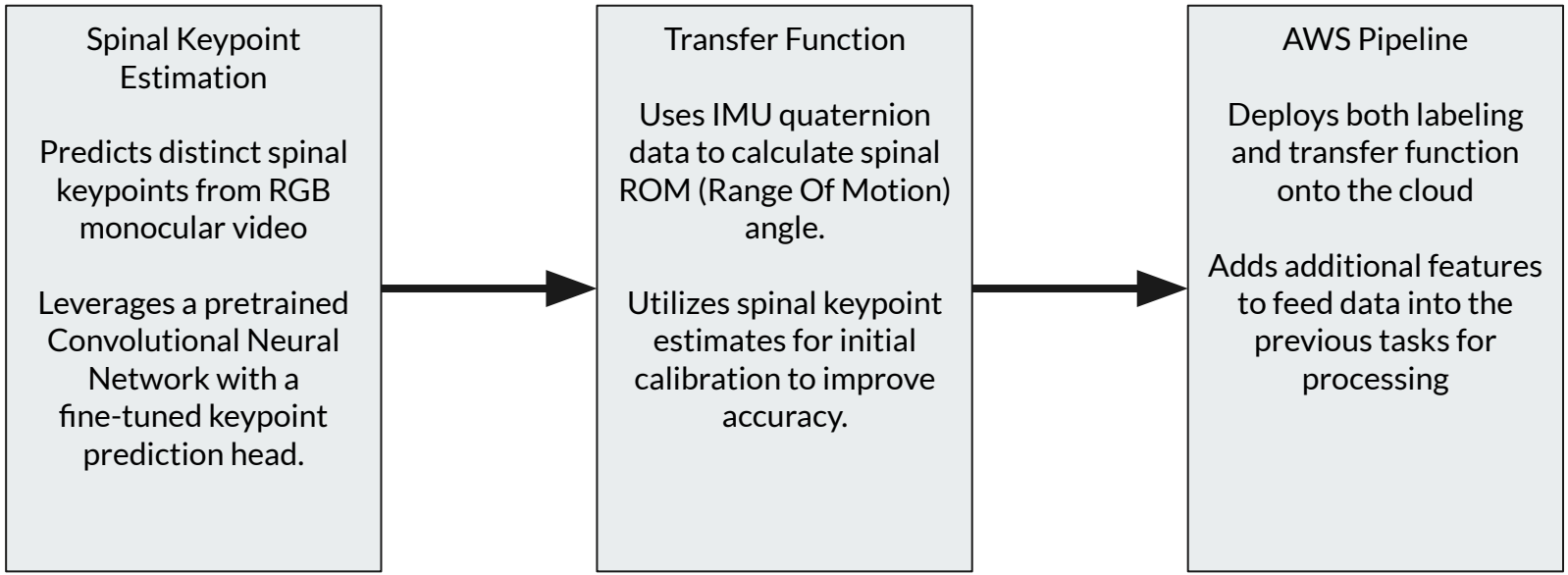
Final Evaluation
Final Report and Presentation
Delayed Start- Credits didn't arrive in time
Extended - Technical Difficulties
UPDATED TIMELINE

	Dependency	Need	Status	Followup	Contingency Plan	Deadline
Software	Amazon Web Services (AWS) - Accounts	Need access to computing platforms	**Acquired**	N/A	Limited Deployment and Utilization of AWS using personal Free Tier Account	Mar 13th
	Pre-trained pose models	Backbones will be used to extract useful image features	**Acquired**	N/A	Project Necessity, no Contingency	Mar 6th
	AWS Credits	Need credits in order to run computing resources	**Acquired**	Contact Evan Haas to request credits	Limited Deployment and Utilization of AWS using Free Tier resources	Mar 13th
Footage for Testing and Validation	Videos for Training Data	Videos will be used to train our spinal keypoint head	**Acquired**	Contact Evan Haas for additional footage	Our team will film our own videos, using agreed upon specifications for filming	Mar 6th
	IMU Data for Training	Data will be used to fit our transfer function	**Acquired**	N/A	If we require additional IMU data, we will ask Evan Haas for some	Mar 6th
	IMU Data for Testing (Validation)	Data will be used to validate accuracy of our transfer function	**In Progress**	N/A	Project Necessity, no Contingency	April 20th
	Video Data for Testing (Validation)	Videos will be used to validate & fine-tune hyperparameters for our spinal keypoint head	**Acquired**	Contact Evan Haas for additional footage	Our team will film our own videos, using agreed upon specifications for filming	April 20th
	Labeled Data	Labelled data for training	**Acquired**	Await Evan for more data/AWS Mechanical Turk	Project Necessity, no Contingency	April 15th
	Labeled Data (for testing)	Labelled data for testing	**In Progress**	Await Evan for more data/AWS Mechanical Turk	Project Necessity, no Contingency	April 20th

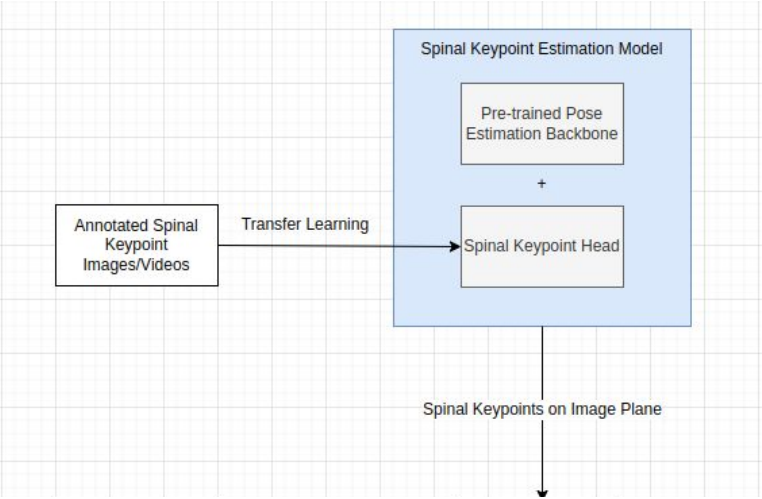
	Deliverable	Done?
Minimum (4/7)	Linear transfer function for translating IMU data to estimated spinal joint angles	**Ongoing**
	Spinal estimation model capable of detecting key points on the spine from monocular video	**Done**
	Detailed documentation of interface and code structure between the two major components (transfer function & spinal estimation)	**Done**
Expected (4/28)	Spinal estimation model that can estimate spinal curvature and segment spinal sections through volumetric estimation and interpolation from monocular video	**Ongoing**
	Amazon Web Services (AWS) workflow and infrastructure for model training and testing for future development	**Done**
	Detailed procedure for clinical use of the product including patient orientation, patient movement, and sensor location designed to produce the most descriptive spinal model of the patient	**Ongoing**
Maximum (TBD)	AWS pipeline that allows for the remote upload of patient videos and IMU data and performs analysis in the cloud, returning the spinal model's output	**Ongoing**
	Detailed procedure and method for sensor calibration, so as to reduce the impact of sensor drift and position prediction errors over the 48 hour data collection period	**Ongoing**

Approach


Spinal Keypoint Estimation
Predicts distinct spinal keypoints from RGB monocular video
Leverages a pretrained Convolutional Neural Network with a fine-tuned keypoint prediction head.
Transfer Function
Uses IMU quaternion data to calculate spinal ROM (Range Of Motion) angle.
Utilizes spinal keypoint estimates for initial calibration to improve accuracy.
AWS Pipeline
Deploys both labeling and transfer function onto the cloud
Adds additional features to feed data into the previous tasks for processing

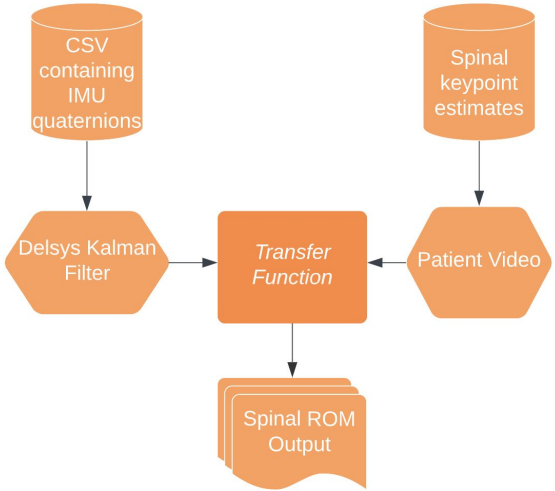
Spinal Keypoint Prediction

- Pre-trained Resnet50 Convolutional Neural Network as backbone
- Image embeddings are fed into Spinal Keypoint Head (Multi-layer Perceptron)
- Backbone is frozen, Keypoint head is trained

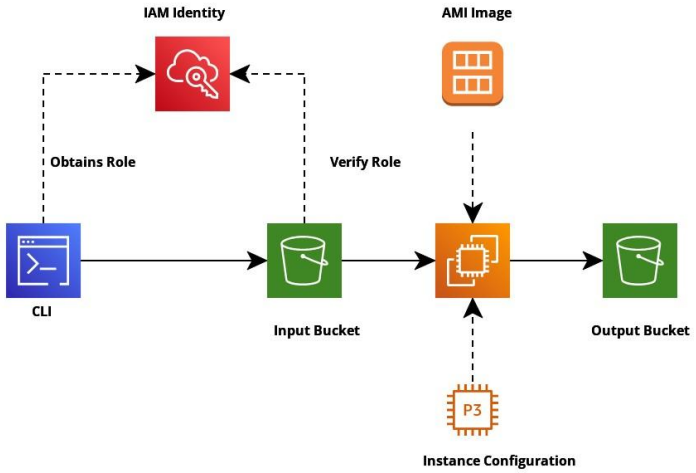


Transfer Function

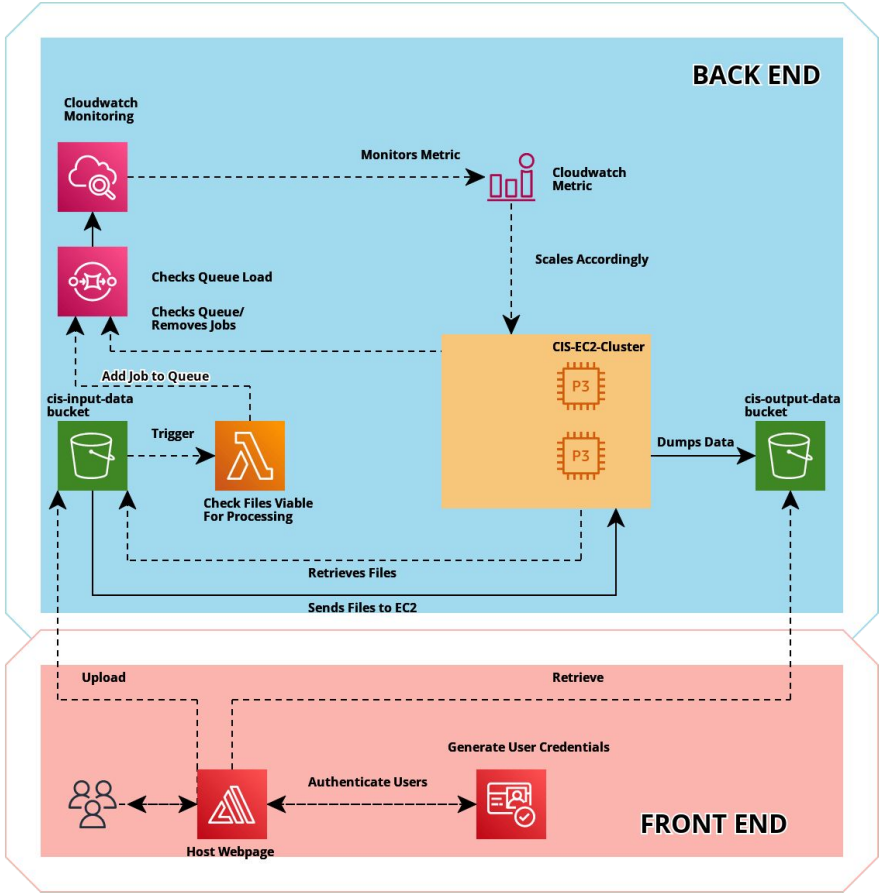
- MATLAB code derived from Franco et al., 2021
- IMU quaternion data fed into function as csv files
- Initial calibration bounds computed using spinal keypoint estimates projected over patient video



AWS -



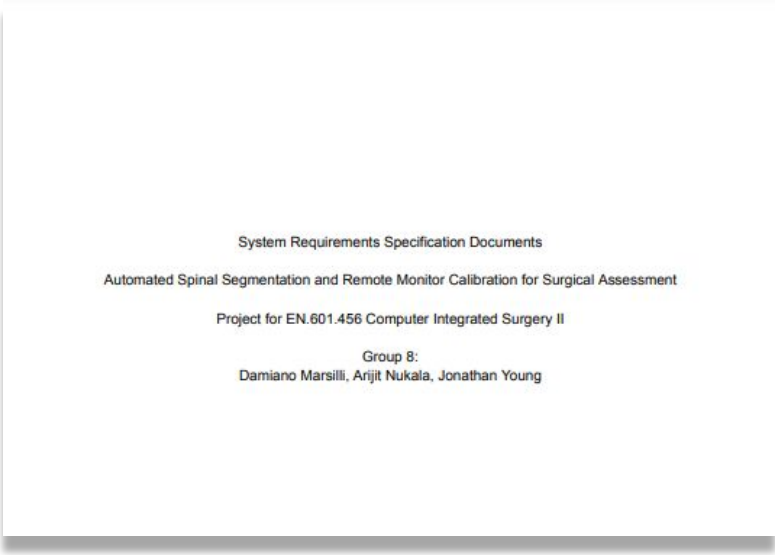
Pipeline for Model Training



Full Pipeline

Documentation: Software Requirements

- **Product Features**
  - Spinal Keypoint Estimation
  - Transfer function for IMU data and Computer Vision Data
  - Cloud-based pipeline for spinal keypoint estimation, transfer function, and uploading/downloading data
  - *Link in wiki page*
- **Documentation (sub-components)**
  - *Link in wiki page*


System Requirements Specification Documents

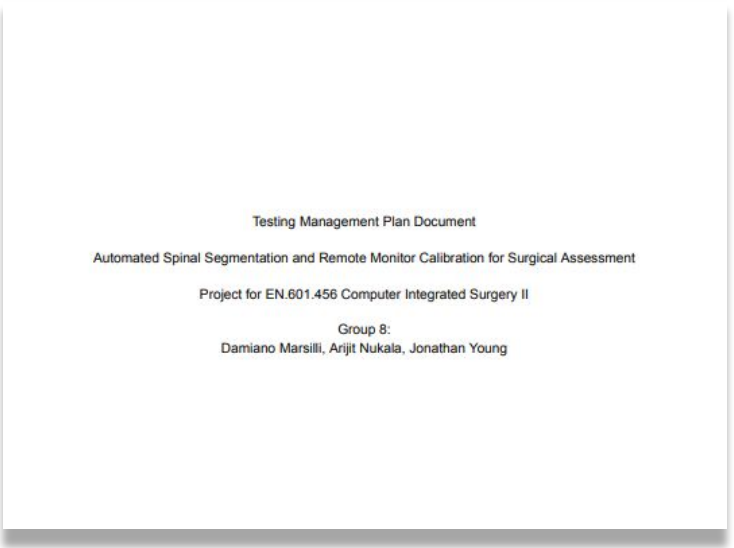
Automated Spinal Segmentation and Remote Monitor Calibration for Surgical Assessment

Project for EN.601.456 Computer Integrated Surgery II

Group 8:
Damiano Marsilli, Arijit Nukala, Jonathan Young

Documentation: Testing

- **Spinal Keypoint Estimation**
  - Held-out test dataset
  - Mean-Squared-Error as metric
- **Transfer Function**
  - Hand-tested accuracy
  - Bland-Altman as metric
- **Cloud**
  - *Subsystem (service) Monitors*
    - Unit Test(s)
    - Cloudwatch Monitor
  - *Entire pipeline*
    - Unit Test(s)
    - Cloudwatch Monitor



Testing Management Plan Document

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Management Plan

Meetings:

- Weekly meetings with Evan Haas and Antony Fuleihan 4 PM on Fridays via zoom.
- Additional meetings with Evan and Antony will be scheduled as needed.
- Team meeting/collaboration time once a week, on a need to meet basis.

Data:

- Test footage and data stored on Onedrive and S3
- Code and documentation management on GitHub

Responsibility Distribution

- **Damiano Marsili**
  - Lead development on the spinal keypoint model
  - Lead development on the spinal curve estimation model
  - Define data collection requirements for train and test data
- **Arijit Nukala**
  - Lead development on the transfer function model
  - Implement visualization for spinal angle ROM results
- **Jonathan Young**
  - Lead development in creating AWS infrastructure for training/running models and data management.
  - Lead development in AWS pipeline for uploading IMU data, processing data, and generating output for doctors

Shared Roles: Documentation