



Automated Spinal Segmented and Remote Monitor Calibration for Surgical Assessment

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Mar. 2nd , Project Plan Presentation

Background

- **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

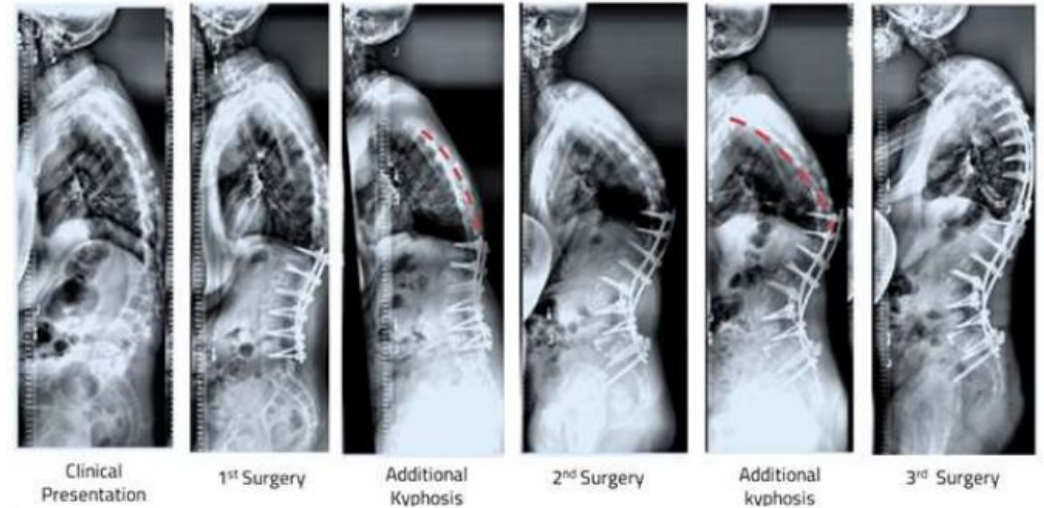


Figure 1 - Patient With multiple revisions [4]

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

Prior Work

- Utilizing DLYSYS trigono wireless sensors to measure the orientation of the spine
- IRB approved studies
 - Adult Spinal Deformity Patient Treatment is Affected by Dynamic Patient Data
 - Understanding Motions of Adult Spinal Deformity Using Motion Sensing Devices

CurveAssure

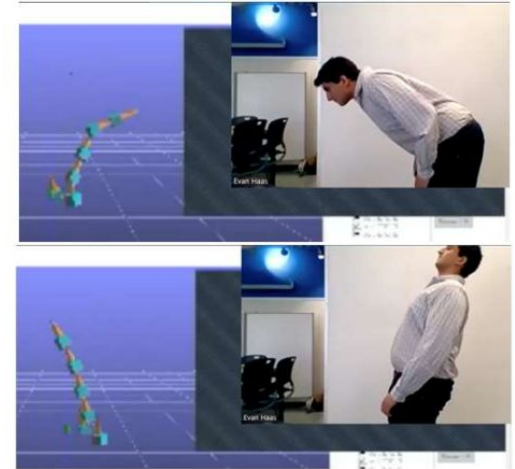


Figure 2 - CurveAssure Prototype

Antony demonstrates curveassure IMU readings when attached to the spine

Goal



High level - Produce a model and transfer function that enables the calibration of the IMUs

Phase 1:

- Estimation of spinal key points of the patient using monocular video + LIDAR (iPad)
- Estimation of the spinal curve of the patient using spinal key points and estimated volumetric meshes

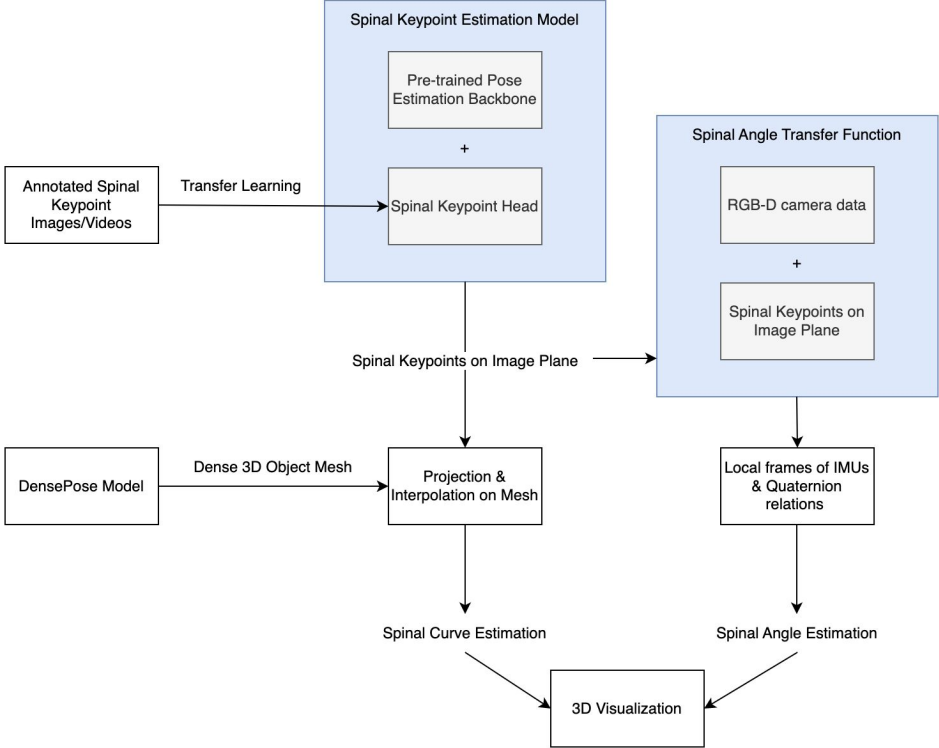
Phase 2:

- Development of a transfer function that maps IMU data to spinal

Phase 3:

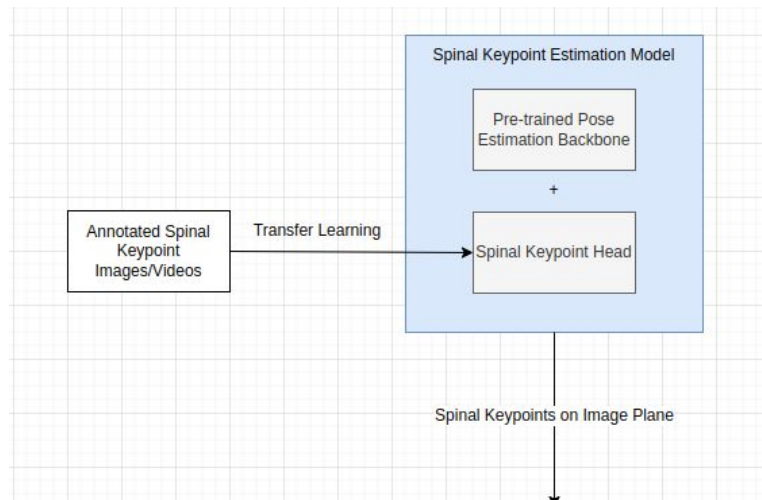
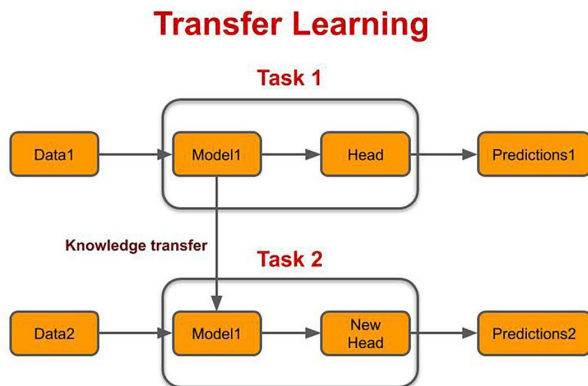
- Cloud deployment that allows users to upload sensor data to cloud and receive quantitative model of the patient's spinal movements.

Technical Approach - Diagram



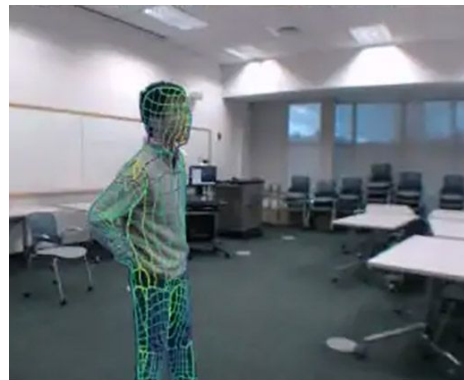
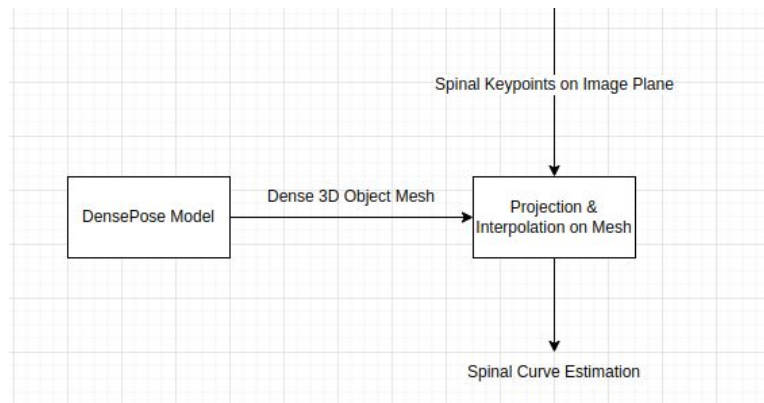
Approach - Spinal Keypoint Estimation

- **Problem:** Estimate spinal key points from monocular video
- **Issue:** Limited dataset
- Transfer learning on Spinal Keypoint Estimation Model
 - Freeze backbone, SpotTune [8], Surgical Fine-tuning [9]



Approach - Spinal Curve Estimation

- **Problem:** Estimate spinal curve from spinal keypoints and dense volumetric mesh
- **Inputs:** Spinal Key points in image coordinates, Volumetric mesh
- Interpolation of key points on mesh
 - Bilinear interpolation, Spline interpolation, Inverse-distance weighting



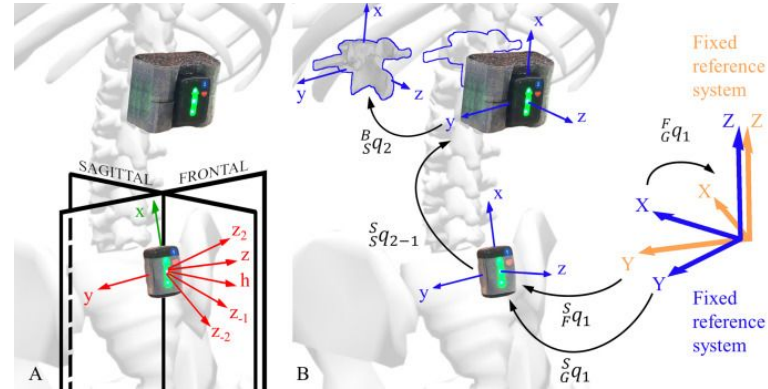
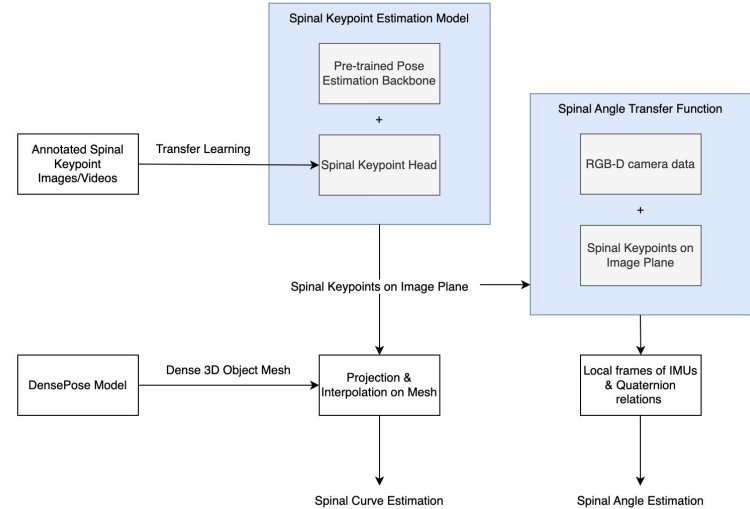
Approach - Transfer Function

- **Problem:** Convert IMU data to spinal angles
- **Inputs:** Spinal key points projected into 3D space using Apple ARKit
- Estimate local frame of IMU
 - Projected keypoints and bounding boxes in 3D allow for frame estimation from the center of the IMU
 - Joint angles obtained through quaternion multiplication and transformed into clinical angles

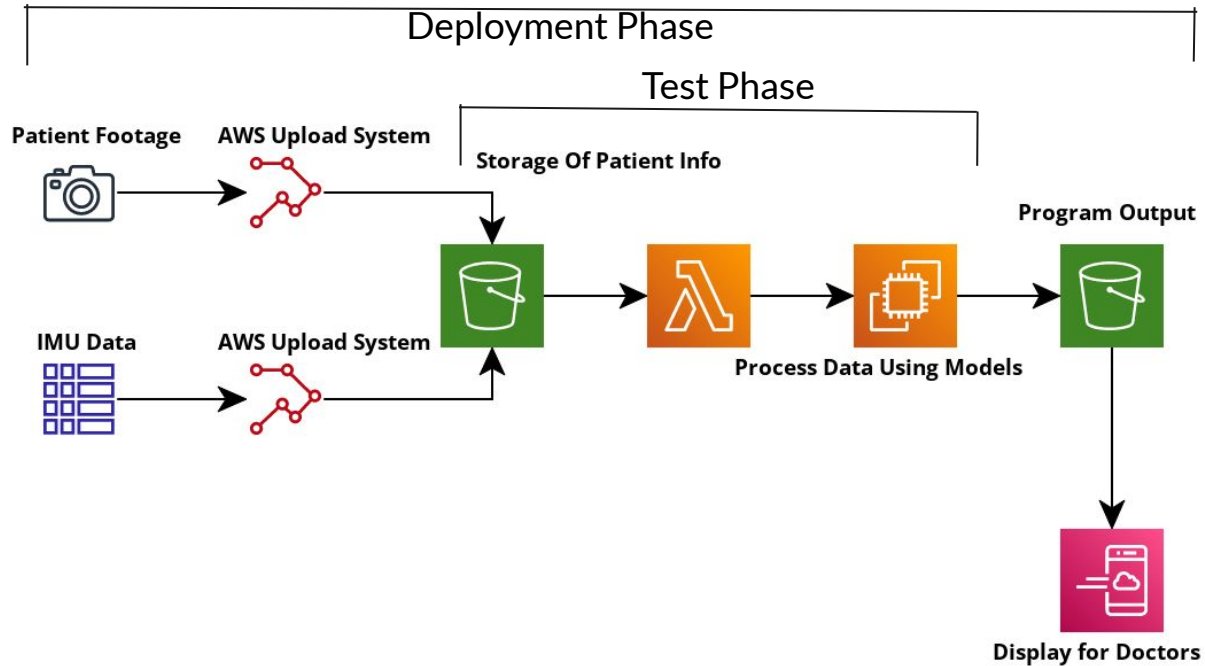
$$\theta = \tan^{-1} \left(\frac{x_y}{x_x} \right) \quad \phi = \tan^{-1} \left(\frac{x_y \sin \theta + x_x \cos \theta}{x_z} \right)$$

$$F = \phi \cos \theta \quad L = -\phi \sin \theta$$

$$T = -\tan^{-1} \left(\frac{-z_z \sin \theta - y_z \cos \theta}{z_z \cos \theta - y_z \sin \theta} \right)$$

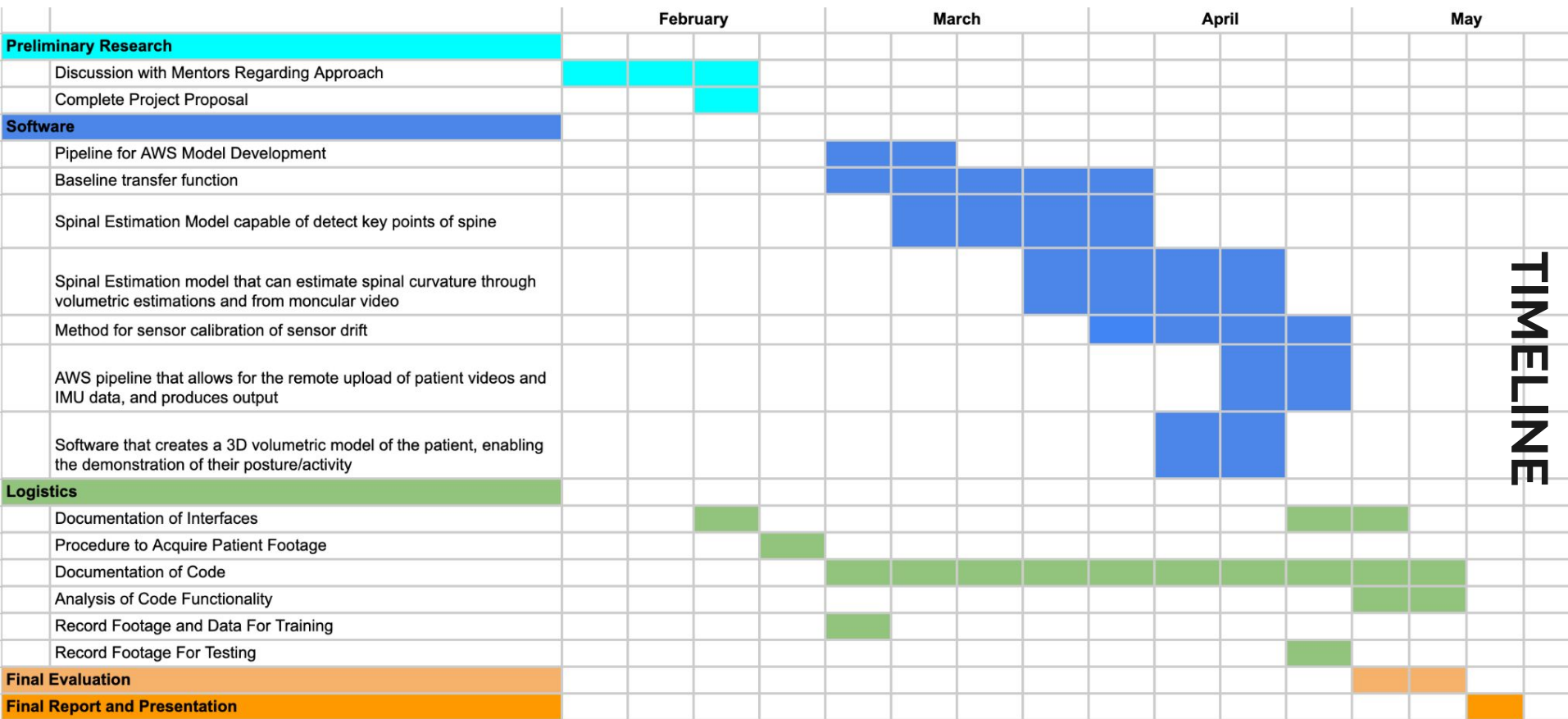


Approach - Cloud



	Deliverable
Minimum (4/7)	Linear transfer function for translating IMU data to estimated spinal joint angles
	Spinal estimation model capable of detecting key points on the spine from monocular video
	Detailed documentation of interface and code structure between the two major components (transfer function & spinal estimation)
Expected (4/28)	Spinal estimation model that can estimate spinal curvature and segment spinal sections through volumetric estimation and interpolation from monocular video
	Amazon Web Services (AWS) workflow and infrastructure for model training and testing for future development
	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
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
	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
	Software that creates a 3D volumetric model of the patient, enabling the demonstration of their posture/activity to surgeons utilizing either Blender or Maya

	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	Awaiting AWS Contact to provide credits	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	Awaiting	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	Acquired	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	Awaiting	Contact Evan Haas for additional footage	Our team will film our own videos, using agreed upon specifications for filming	April 20th



TIMELINE

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
 - Develop iOS workflow for ARKit -> Lambdas -> Sagemaker
 - Implement visualization for spinal angle ROM results
- **Jonathan Young**
 - Lead development on AWS infrastructure and pipeline for testing and deployment.
 - Includes setting up and managing virtual instances, file storage/sharing systems, etc.
 - Assist in the development of the transfer function

Shared Roles: Documentation

Reading List



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6. Güler, Rıza Alp, Natalia Neverova, and Iasonas Kokkinos. "Densepose: Dense human pose estimation in the wild." *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2018.

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8. Guo, Yunhui, et al. "Spottune: transfer learning through adaptive fine-tuning." *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition.* 2019.
9. Lee, Yoonho, et al. "Surgical fine-tuning improves adaptation to distribution shifts." *arXiv preprint arXiv:2210.11466* (2022).
10. Osokin, Daniil. "Real-time 2d multi-person pose estimation on cpu: Lightweight openpose." *arXiv preprint arXiv:1811.12004* (2018).
11. Kendall, Alex, Matthew Grimes, and Roberto Cipolla. "Posenet: A convolutional network for real-time 6-dof camera relocalization." *Proceedings of the IEEE international conference on computer vision.* 2015.
12. Güler, Rıza Alp, Natalia Neverova, and Iasonas Kokkinos. "Densepose: Dense human pose estimation in the wild." *Proceedings of the IEEE conference on computer vision and pattern recognition.* 2018.