**Iowa Initiative for Artificial Intelligence**

**Final Report**

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| Project title: | Soft Tissue Artifact Mitigation for Optical Motion Capture Technologies through Physics Informed Machine Learning |
| Principal Investigator: | Rachel Vitali and Xueyu Zhu |
| Prepared by (IIAI): | Yanan Liu |
| Other investigators: | |
| Date: | |

| | |
|---|---|
| Were specific aims fulfilled: | Y |
| Readiness for extramural proposal? | Y |
| If yes … Planned submission date | 9/29/2023 |
| Funding agency | Pharmaceutical Manufacturers Association (PhRMA) Foundation |
| Grant mechanism | |
| If no … Why not? What went wrong? | |

**Brief summary of accomplished results:**

We have developed and validated a neural network model to accurately predict 3D position data of soft tissue artifacts (STAs). Small values of mean errors and mean absolute errors were achieved between predictions and ground truth.

**Research report:**

**Aims (provided by PI):**

The specific aims of this project are to employ purely data-driven neural networks and physics-informed neural networks to mitigate the substantial effects of STAs in optical motion capture by leveraging the aforementioned STA database.

**Data:**

A relatively large STA database that consists of 31 different data collections was used (Table 1). This database contains optical motion capture data from skin-mounted markers as well as ground truth reference data.

**Table 1:** Description of the database. The total number of data points is derived from the number of frames associated with the number of markers.

| Name | Body Seg | Markers | Frames | Name | Body Seg | Markers | Frames |
|---|---|---|---|---|---|---|---|
| Cam2013 | Thigh | 12 | 2133 | Stag2005 | Thigh/Shank | 19/10 | 13 |
| Akb2010 | Thigh/Shank | 7/3 | 36 | Rein1997 | Thigh/Shank | 5/6 | 115 |
| Bon2014 | Thigh/Shank | 12/4 | 1328 | Ben2006 | Thigh/Shank | 4/4 | 375 |
| Akb2010 | Thigh/Shank | 7/3 | 37 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 1945 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Tsai2009 | Thigh/Shank | 6/4 | 120 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 1760 |
| Stag2005 | Thigh/Shank | 19/10 | 15 | Char2014 | Hum/Shoulder | 4/57 | 27 |
| Akb2010 | Thigh/Shank | 7/3 | 15 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 1584 |
| Bar2013 | Lower Limbs | 80 | 929 | Char2014 | Hum/Shoulder | 4/57 | 23 |
| Tsai2009 | Thigh/Shank | 6/4 | 89 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 1607 |
| Ben2006 | Thigh/Shank | 4/4 | 120 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 4491 |
| Ben2006 | Thigh/Shank | 4/4 | 66 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 2044 |
| Tsai2009 | Thigh/Shank | 6/4 | 146 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 2270 |
| Kuo2011 | Thigh/Shank | 6/4 | 303 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 9967 |
| Stag2005 | Thigh/Shank | 19/10 | 18 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 1734 |
| Akb2010 | Thigh/Shank | 7/3 | 57 | Dal2015 | Scap/Hum/Thor | 9/7/6 | 2749 |
| Tsai2011 | Thigh/Shank | 6/4 | 145 | **Total Number of Data Points:** | | | **804,103** |

**AI/ML Approach:**

In this study, supervised machine learning algorithm was implemented for STA prediction using neural network in Python. Different markers were separately for training and validation and 3D position results were evaluated vs. ground truth. Training: validation split was 80%/20% for each marker.

**Experimental methods, validation approach:**

Three different inputs were used for a neural network: The raw data, naïve processed data (i.e., low-pass filtered), and physics-based processed data (i.e., least squares pose estimator). The output variables were the 3D position data for skin-mounted markers whose STAs have been mitigated.

**Results:**

The results in Fig. 1 illustrate our preliminary progress towards using machine learning to eliminate STAs from the optical motion capture data. The (blue) curve denotes ground truth data, the (green) curve denotes input data, and the (red) curve denotes the prediction results (see Table 2).

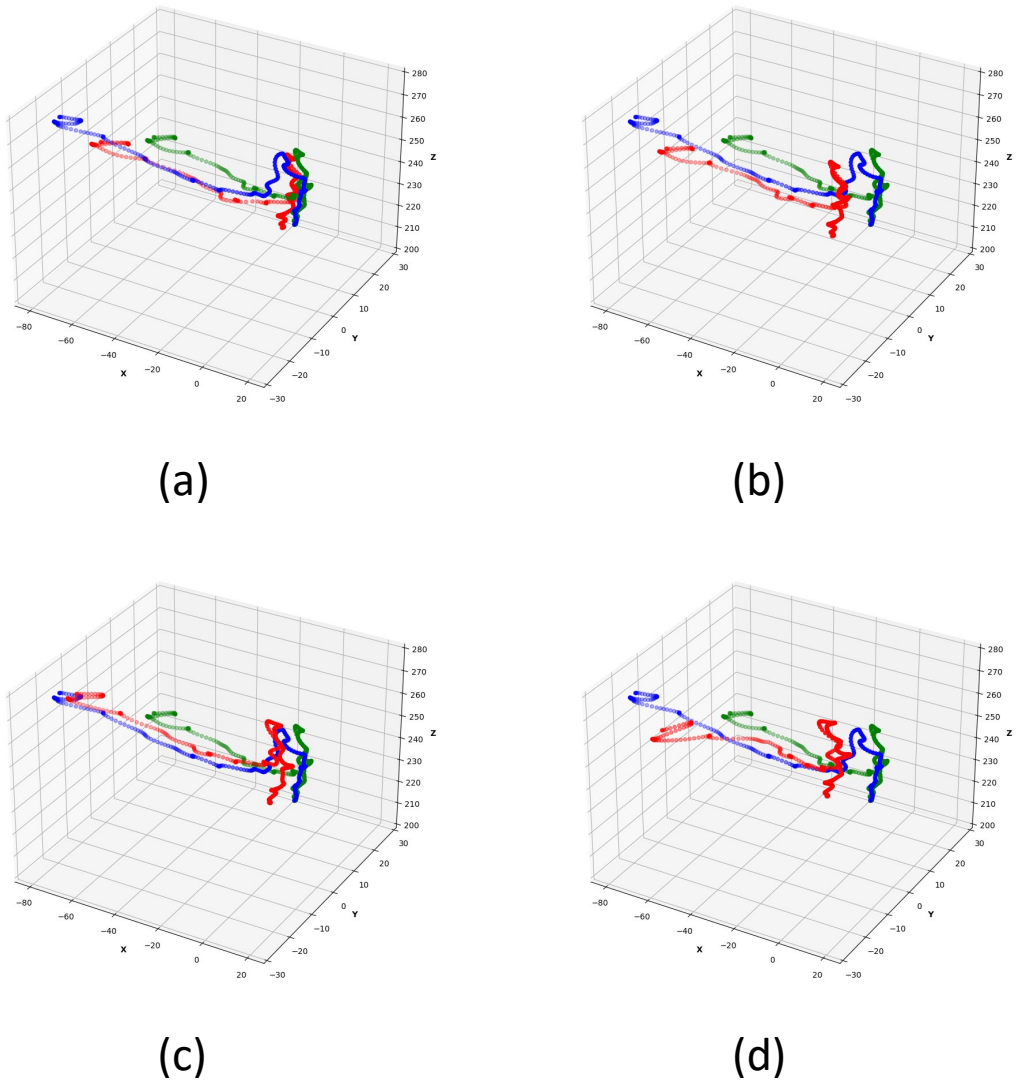


Figure 1. Illustration results of Marker 2 trajectory. (a) The raw data (b) naïve processed data (c) physics-based processed data (d) combination of raw data and physics-based processed data. The (blue) curve denotes ground truth data, the (green) curve denotes input data, and the (red) curve denotes the prediction results.

**Table 2:** Preliminary soft tissue artifact mitigation results. The raw data, naïve processed data (i.e., low-pass filtered), and physics-based processed data (i.e., least squares pose estimator) are used as inputs to a neural network, whose outputs are compared to ground truth data.

| M02 | **Raw** | **Naïve** | **Physics** | **Raw+Physics** | Original error |
|---|---|---|---|---|---|
| **Mean Error [mm]** | 60.60 | 46.17 | 11.38 | 55.07 | 128.86 |
| **Mean Absolute Error [mm]** | 6.65 | 5.43 | 2.67 | 6.09 | 7.73 |

From the results illustrated in Fig. 1 and documented in Table 2, we can see a neural network model to accurately predict 3D position data of soft tissue artifacts (STAs). Small values of mean errors and mean absolute errors were achieved between predictions and ground truth.

**Ideas/aims for future extramural project:**

This project utilizes physics informed machine learning to mitigate soft tissue artifacts (STAs) to generate synthetic wearable sensor data (with different hardware characteristics) to enable researchers to explore and develop translational digital biomarkers. Previous research has derived many gait-based biomarkers from optical motion capture data, but digital biomarkers from wearables still need to be developed, validated, and correlated with these historical biomarkers. Wearable sensors are more accessible to wider populations, including those that have historically been underserved like those residing in rural communities.

**Publications resulting from project:**

None