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Identifying Manual Material Handling Tasks using wearable sensors with Machine Learning

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In the United States, work-related musculoskeletal disorders (WMSDs) such as lower back pain and carpal tunnel syndrome account for about 30% of all non-fatal workplace injuries resulting in days away from work each year. Assessing the risk associated with various jobs is the first step toward mitigating WMSDs. This is typically accomplished by observing workers in their occupational setting, which is imprecise and consumes much research time. Wearable sensors, specifically Inertial Measurement Units (IMUs), represent a promising new data collection method that can measure worker kinematics. Accurately and automatically identifying work tasks using these machine learning models will play a vital role in achieving accurate, fast, and non-invasive risk assessment.

This research attempted to investigate the use of deep learning to distinguish between one-handed and two-handed manual material handling tasks. An additional goal was to create a deep learning model that was easily trainable and generic enough to fit future ISE research.

Relevant research was found published by Bassani, which informed the initial machine learning models and provided an initial dataset. The data was generated using 17 IMU sensors, 14 subjects, and 37 trials consisting of 7 task types. The IMU sensor placement is shown in Figure 1. The undergraduate research developed classification convolutional neural network models using TensorFlow Keras API for machine learning. An example of model architecture is shown in Figure 2. The models consistently produced an accuracy greater than 95% on the provided dataset, as shown in Figure 3. Because the (training) accuracy did not increase beyond the validation accuracy, the model was shown to not overfit the training data.

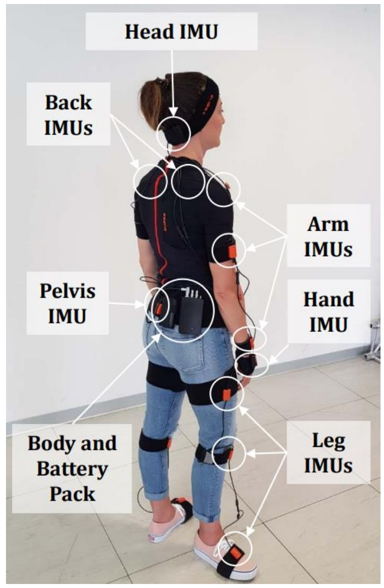

Fig. 1 Sensors were placed at 17 locations in Bassani's dataset.

```
Layer (type)                 Output Shape
=================================================
conv1d_36 (Conv1D)           (None, 1998, 64)

conv1d_37 (Conv1D)           (None, 1996, 64)

dropout_10 (Dropout)         (None, 1996, 64)

max_pooling1d_17 (MaxPooling (None, 998, 64)

flatten_17 (Flatten)         (None, 63872)

dense_34 (Dense)             (None, 100)

dense_35 (Dense)             (None, 7)
=================================================
Total params: 6,542,311
Trainable params: 6,542,311
Non-trainable params: 0
```

Fig. 2 Convolutional neural networks require feature extraction through Conv1D layers and neural node creation through Dense layers.

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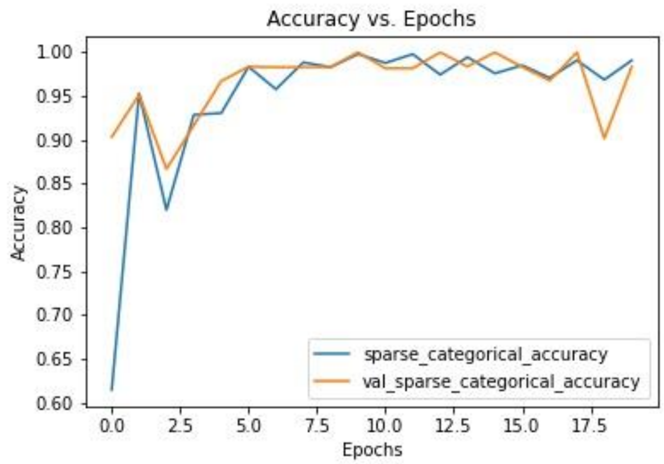

Fig. 3 Accuracy increases during the training process.

After developing successful data preparation methods and machine learning models, IMU data was collected using the researcher as the subject, as shown in Figure 4. The data was generated using 6 IMU sensors. The subject repeated a trial 30 times which consisted of 7 task types. The trial was performed with both hands, the right hand and the left hand. This data was collected to investigate the use of machine learning and IMU sensors to distinguish between right-handed, left-handed, and two-handed tasks. Models besides CNN were investigated using generic settings for more than 15 classification architectures. This research is still ongoing, but initial results allude to accuracies greater than 75%. The ultimate goal is to perform this classification with only one sensor.

Fig. 4 IMU data was collected using the researcher as a subject.

Statement of Research Advisor

One-handed manual material handling is an under-researched field of study that contributes to workplace injuries. Sensor systems exist for measuring the motion patterns of a worker throughout the day. But these systems are lacking in their ability to categorize specific tasks, including one-handed material handling. Mr. Michael developed a machine learning algorithm to classify various manual material handling tasks using wearable sensors using a combination of open source and lab-collected data.

- *Dr. Howard Chen, Department of Mechanical Engineering*

References

[1] G. Bassani, A. Filippeschi and C. A. Avizzano, “A Dataset of Human Motion and Muscular Activities in Manual Material Handling Tasks for Biomechanical and Ergonomic Analyses,” in IEEE Sensors Journal, vol. 21, no. 21, pp. 24731-24739, 1 Nov.1, 2021, doi: 10.1109/JSEN.2021.3113123.

Authors Biography

Daniel D. Michael is a senior-year student pursuing a B.S. degree in Mechanical Engineering at Auburn University. He has completed a co-op at Southern Research Institute in the Space Propulsion and Systems Department. He plans to pursue a Ph.D. in Mechanical Engineering at Duke University in the Fall.

Howard Chen is a Research Assistant Professor at Auburn University in the Mechanical Engineering Department. He completed his Ph.D. at the University of Iowa in Industrial Engineering and has performed key research in sensor-based ergonomics research.

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