Comparison of Human Ratings and Motion Capture for Material Handling Ergonomics

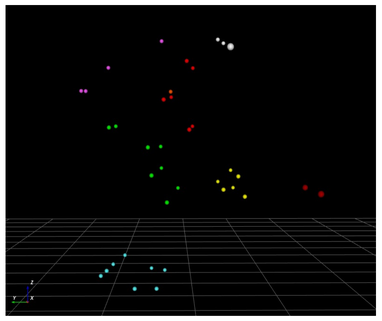
Joshua Avery and Kathryn Perry

Emmett & Miriam McCoy College of Business Administration

Motion Capture and Digital Twins

Current Applications for Motion Capture
- Human Biomechanics
- Sports
- Engineering
- Entertainment

Manual Material Handling and Motion Capture
- 114 million people employed in the Warehousing and Storage Industry Group in 2018
- 22% classified as Laborers and Freight, Stock & Material Movers
- 17% work in stocking, order filling or packaging by hand
- Goal is to detect fatigue before injuries occur



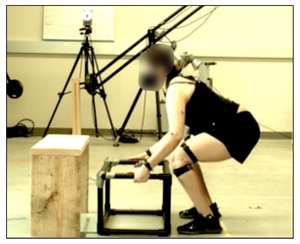
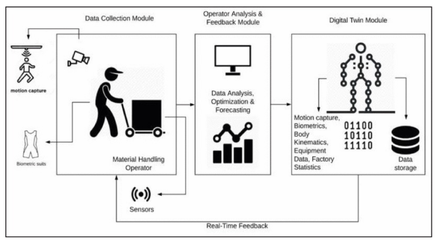


Image below depicts the digital twin framework used

Digital Twin
- Represents assets in the physical world with a digital model
- Looks and feels like the real environment

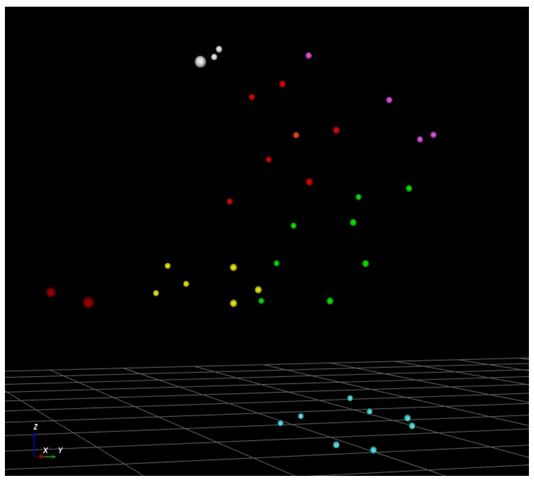


"How well do the evaluators rate in comparison to the actual motion?"

What we wanted to know:
- Are human evaluators adept at correctly identifying movement

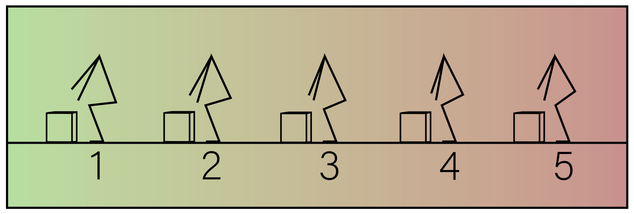
Who we studied:
- Raters of novice and expert subjects performing lifting movements

Why it is important:
- Results can be used across multiple fields of interest



Data and Methodology

For each clip, we are given the angle of a subject's knee bend and how three raters have rated the angles, on a scale of one to five, as shown in the graphic on the right.



In this experiment we approach the topic in two ways. We first asked:

"Can we predict a rating based on the actual angle?"

To answer this question, we utilized an Ordinal Logistic Regression. We predict the rating level with the equation below, where R-hat is rater "i" and "j" is the rating level.

$$logit(P(\hat{R}_i \leq j)) = \ln(\frac{P(\hat{R}_i \leq j)}{P(\hat{R}_i > j)}) = \beta_0 + \beta_1 \psi_{Knee}$$

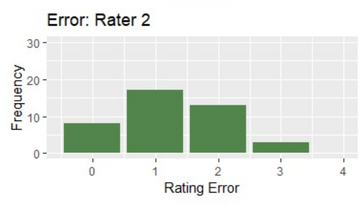
Our second question turned the first one on its head. We then asked:

"Can we predict the actual angle based on the Ratings?"

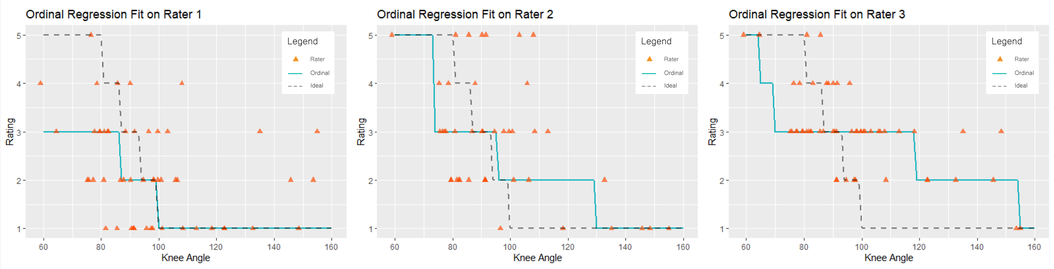
To answer this question, we created various Multiple Linear Regression models using subsets of raters (e.g. just rater 1, rater 1 and rater 2, all three raters, etc.). Below is the full equation for the full model.

$$\widehat{\psi}_{Knee} = \beta_0 + \beta_1 R_{1,1} + \beta_2 R_{1,2} + \cdots + \beta_k R_{i,j} + \cdots + \beta_{15} R_{3,5}$$

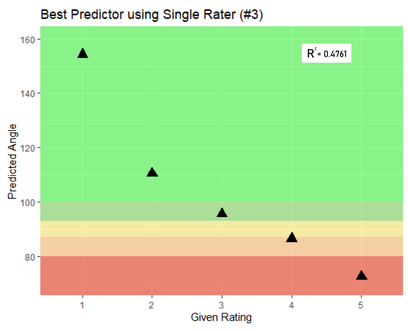
We aim to gain insight on how much variance in the raters' responses can be explained by the data at hand.

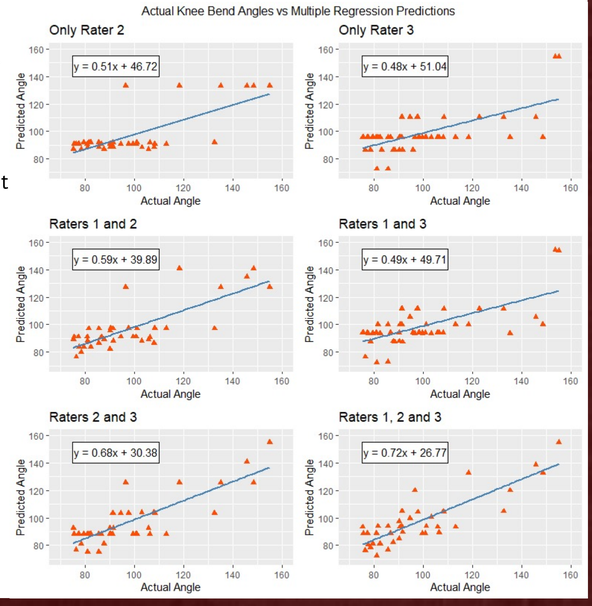


Results



- The ordinal regression fit on Rater 3 performed the best, although still noticeably off.
- The best multiple regression model was (unsurprisingly) the model with all three raters. its R^2 was 0.7218, so we were able to explain only 72.18% of the variation of the knee bends at which may be considered undesirable.





Conclusion

- Human raters are not as accurate at assessing range of motion as motion capture software – not surprising
- Human raters are more accurate in rating a movement as middle ground – good, fair, bad – versus the extreme of very good or very bad

Recommendations & Future Work

- Human raters should be used with caution if trying to gauge precise joint angle bends
- Continue to study and invest in the use of motion capture to assist with the prevention of fatigue and injury in the MMH Industry
- Look into Marker-less motion capture procedures
- Repeat with more data and different raters

References

1. Jeter, S., Stapleton, T., Fuentes, R., Mendez, F. A., Valles Molina, D., Knudson, D., & Rolfe, R. K. (2022, Feburary 1-3). Development of An Artificial Intelligence System to Prevent Overexertion Injuries at the Workplace. Virtual: American Statistical Association
2. Sharotry, A. (2020). *A Digital Twin Framework of a Material Handling Operator in Industry 4.0 Environments (Unpublished thesis).* Texas State University, San Marcos, Texas. Retrieved from https://digital.library.txstate.edu/handle/10877/12924
3. Snook, S. H. (1978). The Design of Manual Handling Tasks. *Ergonomics*, 963-985

Acknowledgements

This presentation is done as part of a project for QMST 4320 Data Analytics class, which is supervised by Dr. Tahir Ekin. We also acknowledge the support of Dr. Francis Méndez Mediavilla, Abhimanyu Sharotry, Summer Jeter, Trent Stapleton, Rosa Fuentes, and the entire Industry 4.0 team for making this project possible, and Gregg Professorship.

Texas State University
The rising STAR of Texas