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A Neural Network Model to Identify Relative Movements from Wearable Devices

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Purpose of Our Research

- Movement tracking is used daily by anyone with fitness-based technology
- When accurate and reliable, can help health experts provide advice

https://images-na.ssl-images-amazon.com/images/I/51VUmODNuOL._AC_SX425_.jpg
https://p7.hiclipart.com/preview/100/919/704/apple-watch-series-2-apple-watch-series-3-apple-watch-series-1-apple.jpg

Our Approach

- Utilizing creative feature engineering
- Neural Networks
- The fast.ai library & PyTorch

fast.ai

PyTorch

https://upload.wikimedia.org/wikipedia/commons/9/96/Pytorch_logo.png
https://buzz-prod-photos.global.ssl.fastly.net/img/87a50dce-a64d-4747-b152-30f2f13e80ef

Experiment Setup

- Apple Watch Health readings from six individuals
- Each performed the following for one minute:
  - Running, walking, working at a computer, walking up and down the stairs, walking and talking, standing, and standing while talking

Collected Data:

- Accelerometer and user acceleration (X,Y,Z)
- Relative Quarternion and Gravitational Motion (X, Y, Z)
- Pitch, yaw, and roll
- Gyroscopic Rotation (X, Y, Z)
- Relative Altitude (m)

Feature Engineering

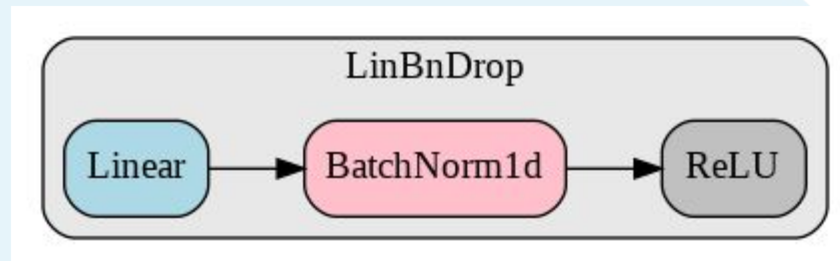
- Based on works by Kodak et al[1]
- 171 new unique features
  - Sum of Squares, Rolling Mean (20 instances), Variance, Root Mean Square
- We introduced a “Time Step”

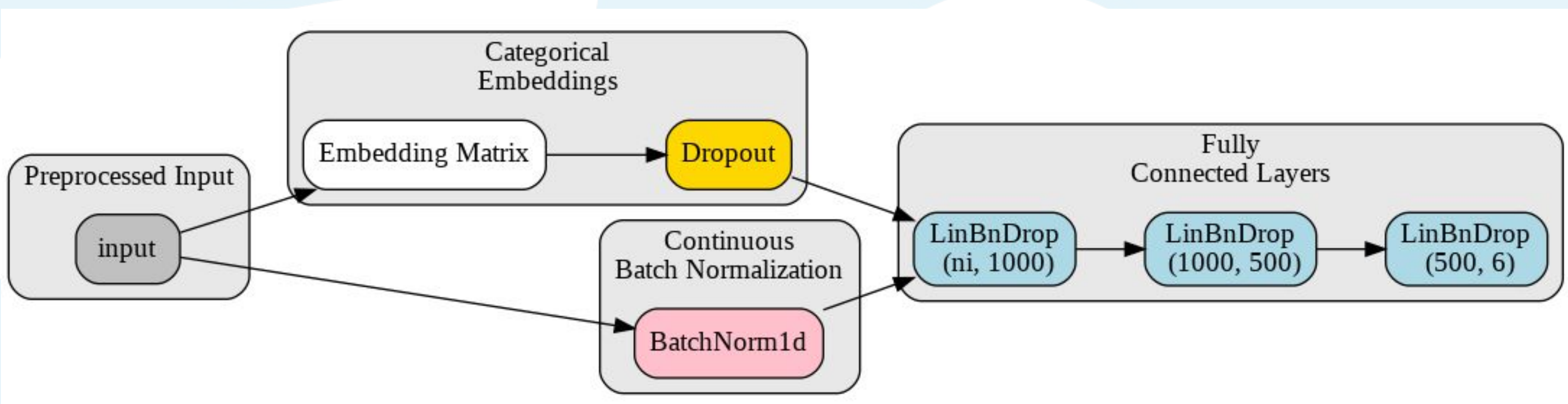
[1] - S. Konak, F. Turan, M. Shoaib, and O. Durmaz Incel, “Feature engi-
neering for activity recognition from wrist-worn motion sensors,”

PECCS, 2016. doi:10.5220/0006007100760084

Neural Network Setup

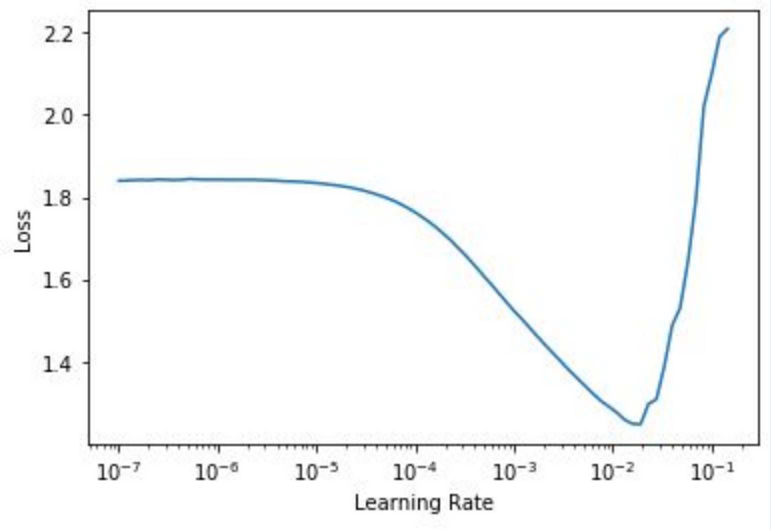
- 7 Layer model with three fully connected layers (1000 and 500 neurons)
- An added embedding matrix post-feature engineering





Neural Network Setup (cont)

- Cross Entropy and Label Smoothing Cross Entropy loss functions were compared
- Adam optimizer and Ranger optimizer were compared
- Trained for five epochs at a found learning rate for each



Results (Adam)

Variation	Total Features	Validation	Test
Base CEL	20	$95.27 \pm 0\%$	$85.14 \pm 0\%$
Base LSCE	20	$94.94 \pm 0\%$	$84.44 \pm 0\%$
Base + T.S. CEl	115	$96.71 \pm 0\%$	$85.75 \pm 0\%$
Base + T.S. LSCE	115	$96.55 \pm 0\%$	$95.99 \pm 1\%$
F.E. CEL	**96**	$\mathbf{99.89 \pm 0\%}$	$\mathbf{87.96 \pm 1.7\%}$
F.E. LSCE	**96**	$\mathbf{99.92 \pm 0\%}$	$\mathbf{92.40 \pm 1.0\%}$
F.E. + T.S. CEL	**191**	$\mathbf{99.87 \pm 0\%}$	$\mathbf{93.35 \pm 1.3\%}$
F.E. + T.S. LSCE	**191**	$\mathbf{99.94 \pm 0\%}$	$\mathbf{94.98 \pm 1.0\%}$

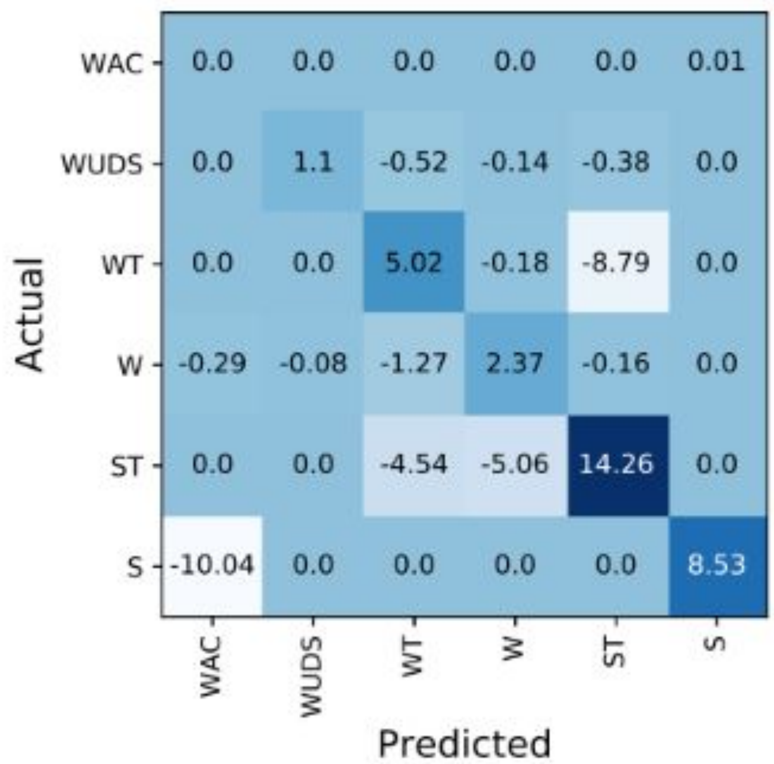
* Cross-Entropy Loss (CEL)
* Label Smoothing Cross-Entropy (LSCE)
* Time Step (T.S.)
* Feature Engineering (F.E.)

Results (Ranger)

Variation	Total Features	Validation	Test
Base CEL	20	$96.07 \pm 1.1\%$	$85.33 \pm 0.3\%$
Base LSCE	20	$86.16 \pm 1.1\%$	$85.19 \pm 0.3\%$
Base + T.S. CEl	115	$97.32 \pm 0\%$	$86.91 \pm 0\%$
Base + T.S. LSCE	115	$97.33 \pm 0\%$	$86.59 \pm 1\%$
F.E. CEL	**96**	$\mathbf{99.98 \pm 0\%}$	$\mathbf{97.09 \pm 0\%}$
F.E. LSCE	**96**	$\mathbf{99.97 \pm 0\%}$	$\mathbf{97.80 \pm 0\%}$
F.E. + T.S. CEL	**191**	$\mathbf{99.87 \pm 0\%}$	$\mathbf{98.17 \pm 0\%}$
F.E. + T.S. LSCE	**191**	$\mathbf{99.97 \pm 0\%}$	$\mathbf{97.89 \pm 0\%}$

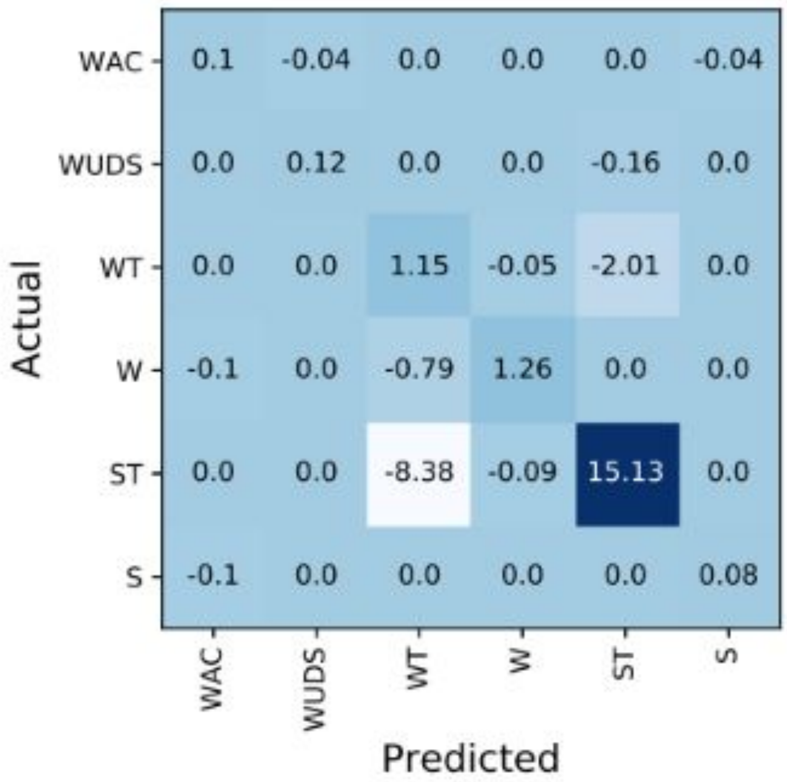
* Cross-Entropy Loss (CEL)
* Label Smoothing Cross-Entropy (LSCE)
* Time Step (T.S.)
* Feature Engineering (F.E.)

Results (cont.)



- Relative Percentage improvement between Ranger and Adam with Feature Engineering and Label Smoothing

Results (cont.)



- Relative Percentage improvement between Ranger and Adam with Feature Engineering and a “Time Step” and Label Smoothing

Important Findings and Future Work

- Performance of Label Smoothing was relative to the number of features used
- Outperformed previous works on this dataset with Random Forests (83%)
- Combining a Neural Network’s embeddings with Random Forest

Extensions to this Research

- Take the last 30 milliseconds
- Perform feature engineering based on the training data
- Feed through the model on either CPU or on a server

Questions?