A Millimeter-Wave Wireless Sensing Approach for At-Home Exercise Recognition

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Motivation

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- Increase in demand for telemedicine and at-home personal documentation.
- Activity monitoring enables many applications such as remote physical therapy and remote personal training.
- Approaches that rely on cameras are privacy-invasive, and approaches using wearable sensors are costly and cumbersome.
- Many existing wireless signal based activity monitoring systems focus on reconstructing silhouettes or skeletons of the human body, which may still raise privacy concerns.

Objective and Intuition

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- Classify and provide temporal assessment of activities using millimeter-wave (mmWave) wireless signals, without using high-resolution image.

Intuition

- The small wavelength and high bandwidth of mmWave signals allow for finer-grained tracking compared to lower-frequency wireless approaches.
- Activities produce distinct patterns in mmWave reflection signals.
  - The spatial and temporal information embedded within the reflected signals can be used directly for activity monitoring.

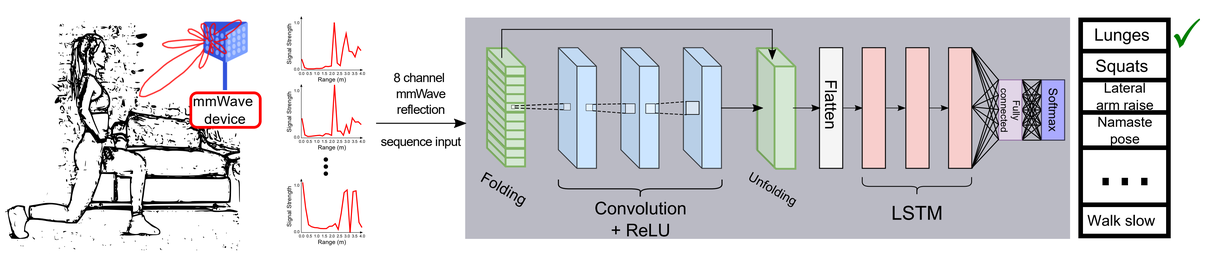
System Design

Classification

- Classification between 18 exercises, including dynamic and static activities.
- Convolutional Neural Network (CNN) with Long Short-Term Memory (LSTM) classifies the activity, taking the 8-channel reflections as input.

Repetition Estimation

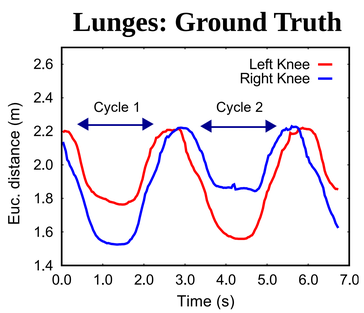
- Dynamic activities produce a phase difference between receive antennas.
- We find the variance of phase difference over time of each frequency and set a threshold of 80% of max. variance to filter out weak reflections.
- A sliding window of 1.2 seconds with 90% overlap is applied to the signal to compute the variance over time and identify the repetitions.

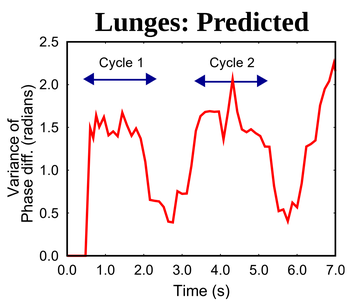


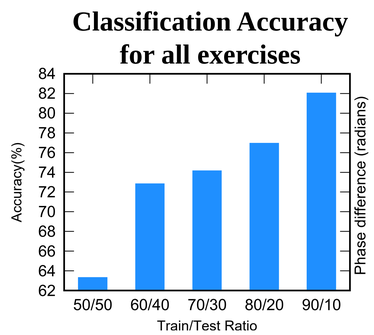
Results and Future Works

Results

- Classification network is trained and tested with different train/test ratios.
  - Prediction accuracy of 82% with just 331 total training samples.
- The duration and number of repetitions predicted using the variance of the phase difference correspond with the ground-truth.







Future Works

- Classify activity between different individuals.
- Provide more temporal assessments for activity, such as work to rest ratio.
- Experiment with different signal representations, such as range-doppler.