Project 77: Millimeter Wave Radar based Human Activity Recognition

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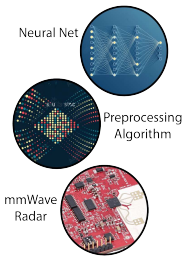
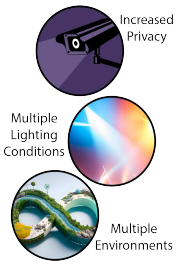
Background

- **Human Activity Recognition** (HAR) is an exciting area of development that allows systems to identify and respond to **Human Actions** and behaviour. **mmWave** radar promises to improve this field with more **Robust** and **Privacy-Focused** tech.
- The focus of our research is the classification of **Multi-Activity Sequences**. These are behaviours that constitute a unique action while being comprised of several **Individual Activities**. Achieving sequence recognition would be a significant step forward for HAR, allowing for more **Complex** and **Practical Implementations**.
- The most significant roadblocks to sequence recognition are accurately **Detecting** when a sequence occurs, and dealing with **Unpredictable** time frames.
- Our system utilises a **Frame Selection Algorithm** to identify patterns in the data and simplify the temporal component of classification.

Applications of HAR



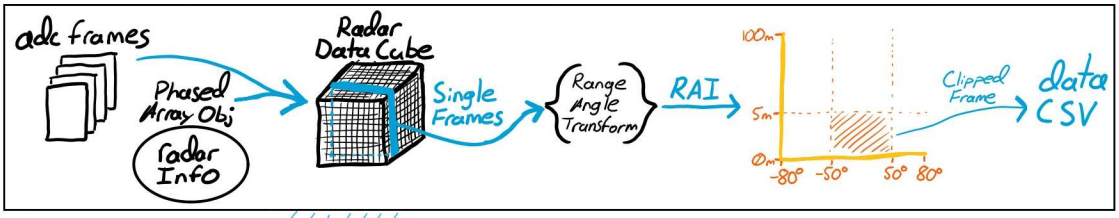
mmWave Technology

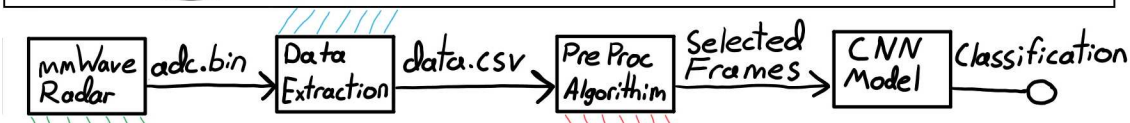


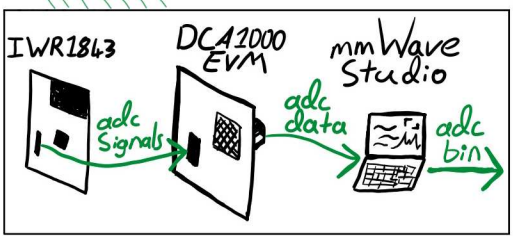
Benefits of mmWave HAR

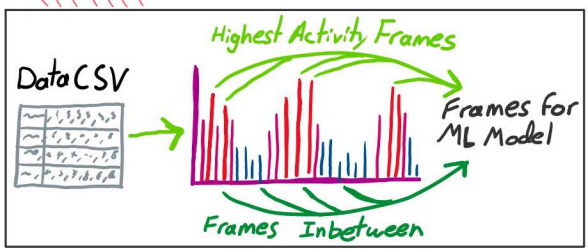
Methodology

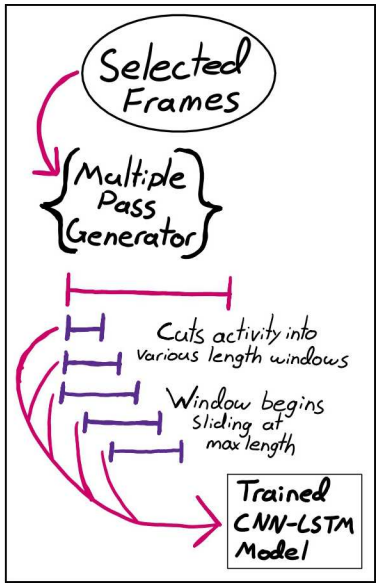
1. Explored possible **System Architectures** for human activity recognition. This included careful consideration of different **Machine Learning Algorithms** such as DSP, CNN, CNN + LSTM, GMM, GANs etc.
2. Decided on a preliminary system architecture. A **Preprocessing Directive** was established for selecting frames from activity sequences and allows for processing of activities of **Different Lengths**.
3. Researched different **Radar Models** and **Data Formats** and examined the **Suitability** of each of these options for our application.
4. Set up the **Radar** according to user documentation.
5. Experimented with different radar settings, both in software and hardware, to find an **Optimal Configuration** for our application.
6. Formulated a process flow for **Data Collection**, as well as a naming convention for raw radar data binaries. **Preliminary Data** collection was performed at this step to help assess the **Preformance** of the designed algorithms.
7. **Designed** and constructed the **Machine Learning Algorithms** (CNN-LSTM and CNN-LSTM+Preprocess) for human activity recognition.
8. Wrote **Auxiliary Scripts** according to the designed process flow to help **Streamline** the training process for the algorithms.
9. **Data Collection**, wherein a more complete data set of activity data was recorded for **Training** the designed algorithms.





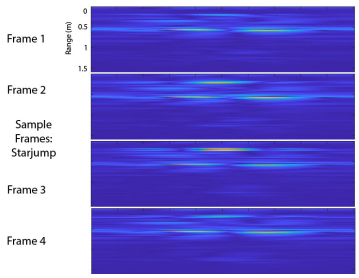


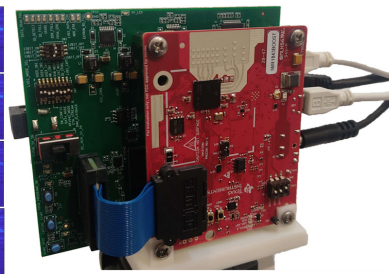




Frame Selection

- **Existing Methods** of HAR dealing with **Activity Segmentation** typically employ a **Sliding Window**, whereas our approach proposes a **Novel Method** of segmentation, utilising **Frame Selection**, which is detailed below.
- At the start of a **New Activity**, the window from which frames are to be selected is **Anchored** and extended as the activity is performed, up to a certain threshold, after which the window will start **Sliding**.
- When an activity is **Detected** by the classification algorithm, the window **Resets** and becomes anchored at the end of the **Last Activity**.
- Each window capture is **Divided** into sections at every time step, and from each of these sections, the frames with the **Highest Average Variance** (calculated as an average of the complex modulus represented by pixel values), as well as **In-Between Frames** are sent to the CNN-LSTM algorithm for **Classification**.
- **Multiple Passes** containing sections of the **Captured Activity Data** from each window are sent to the **Classification Algorithm**, where voting takes place, and a classification can be given.
- Individual passes are **Computationally Inexpensive** due to the lower frame count, which allows for multiple passes to be made in a reasonable amount of time.
- An advantage of this approach is that **Data Augmentation** techniques flow naturally from taking subsets of activity sequences in the recognition step.





Data Processing

- Data is captured by the **Radar Board** and passed to the **Streaming Board**. This data is transferred over ethernet and processed into a binary file by **mmWave Studio**
  - » The streaming board ensures that we can access to the **Raw ADC Values**
- MATLAB **Data Extraction** script reads the binary file and corrects any frame errors
  - » These can be errors with missing or out of order **Data Frames**
- Data is stored as a **Radar Data Cube**, and a **Range-Angle Transform** is computed
  - » This is a more **Visual Format** for the data, better suited for the Neural Network
- Range-Angle **Frames** are **Clipped** to preset range and angle values
- Clipped frames are stored in a **CSV File** then additionally processed in **Python**.