QualityDeepSense: Quality-Aware Deep Learning Framework for Internet of Things Applications with Sensor-Temporal Attention

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DeepSense vs QualityDeepSense

- **DeepSense**
  - Unified neural network framework
  - Proved to be very good for mobile sensing and computing tasks
  - Does not consider noise/heterogenous quality of the sensor data

Solution!!

- **QualityDeepSense**
  - Modification of DeepSense to consider noise in the data
  - Uses sensor-temporal self-attention mechanism
  - Identify the qualities of input by calculating dependencies of their internal representation in DNN
Noise

- Low cost sensors
  - Insufficient accuracy, calibration & granularity
- Heavy multitasking & I/O workload
- May be due to other components of the system
- Noise do not determine the complex dependency between sensing inputs
Network Architecture
Data Flow

- Raw sensor data is divided across time for width t and a fourier transform is applied to each interval--Input of the network
- 3 Individual conv layers for extracting relations within a sensor
- Sensor Attention
- 3 Merge layers to extract relations between sensors
- RNN to extract temporal dependencies
- Temporal attention module
- Output (softmax)
Self-Attention

- Estimate sensing quality
  - Calculate internal dependencies
- Two steps
  - Calculate attention vector $a = \text{Softmax}(1 \cdot (Z \cdot Z^T))$
  - Weighted sum over rows using $a$
    $$y = a \cdot Z$$
- To determine the dependencies among k-vectors
Evaluation

- **Nexus-5**
  - 2.3GHz, 2GB memory, manually set to 1.1GHz

- **TensorFlow-for-mobile**
  - For DNN methods
  - Weka for SVM

- **Dataset**
  - 2-motion sensors-Accelerometer and gyroscope
  - 9 users with 6 activities (un-ordered)
  - Noise-augmented using white gaussian noise on either of time or frequency domain.
Accuracy Improvements

Figure 3: The accuracy of algorithms on HHAR with additive white Gaussian noise on frequency domain.

Figure 4: The accuracy of algorithms on HHAR with additive white Gaussian noise on time domain.
Effectiveness

- **Attention**
  - Multiplication of two attention modules
- **Correlation b/w noise and Attention**
  - Non-linear
  - Difference in sensing measurement
- **Attention is small for strong noise**

**Figure 5:** The correlation between attention and additive noise.
Execution time & Energy consumption

Figure 6: The execution time of algorithms on Nexus 5.

Figure 7: The energy consumption of algorithms on Nexus 5.
Overall

- QualityDeepSense performs better than DeepSense and is able to solve the heterogeneous quality sensing problem.
- It shows lower performance degradation but with the expense of some execution time and energy consumption overhead.
- There is no optimization done. Hyperparameter tuning & more network optimization can be done to reduce the overhead.