Practical Context Awareness for GSM Cell Phones

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Outline

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Traditional Approach

Accelerometer

The traditional approach to inferring activity is via the use of an accelerometer.

Performance

- Reliable.
- Capable of sensing fine-grained activities.
- Fast - real time.

But...

- Requires additional hardware not present on standard GSM cell phones.

Practical Approach

Aim

Infer whether the cell phone carrier is walking, driving or stationary using signals present on a typical GSM cell phone.

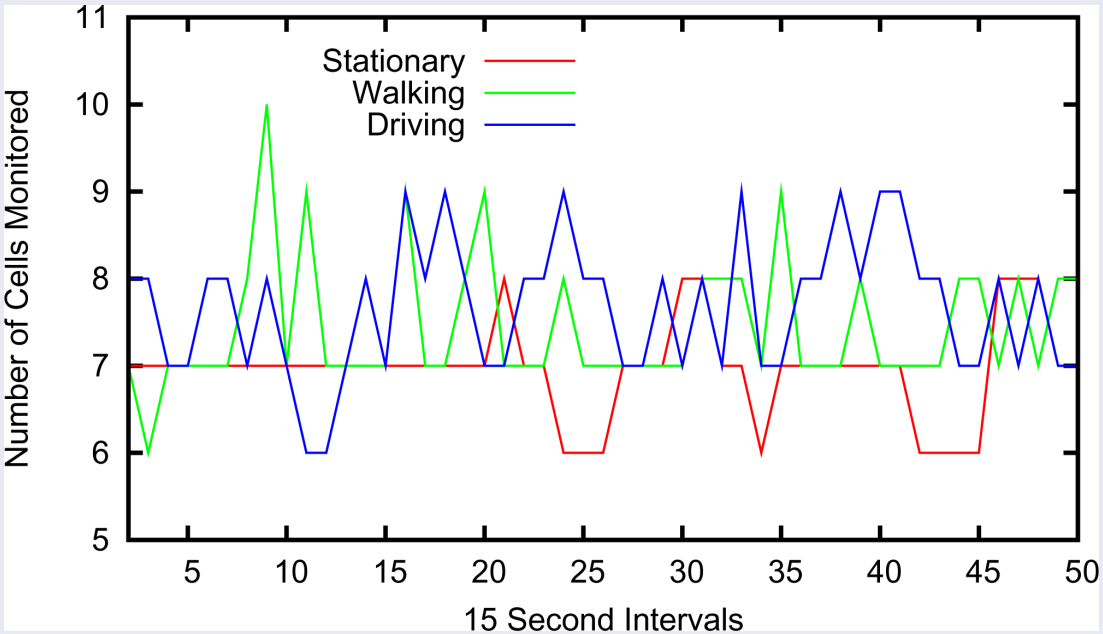
Available Information

- Neighbouring cells.
- Signal strength.
- Serving cells.
- Location area codes.

GSM Signals

Cell Fluctuation

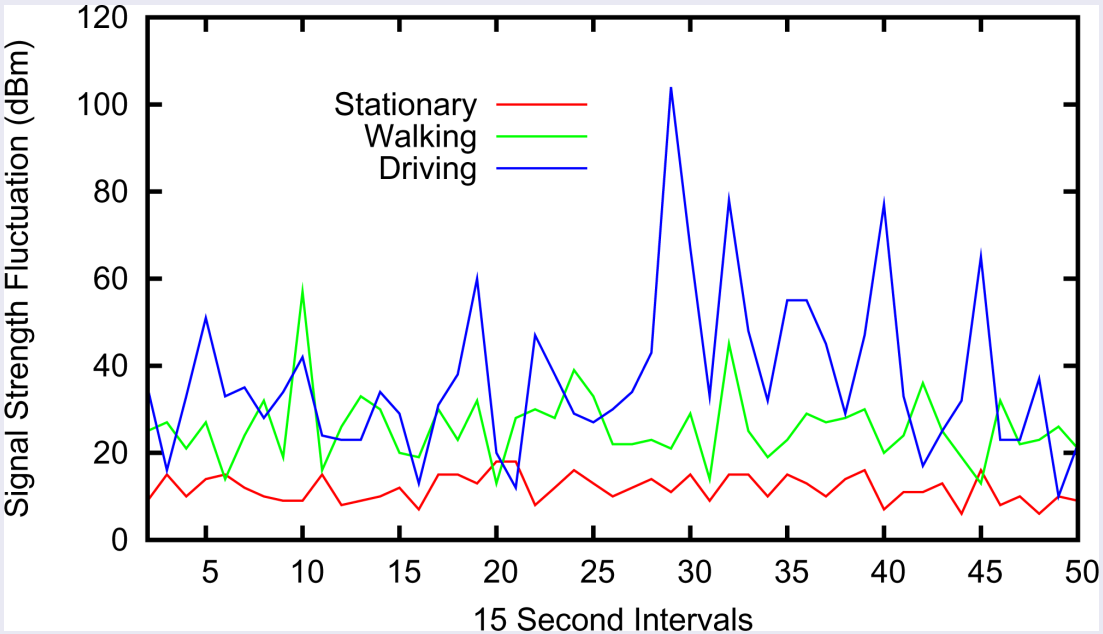
Moving across large geographic spaces results in higher numbers of cells being assessed by the cell phone.



GSM Signals

Signal Strength Fluctuation

Whilst moving at higher speeds the amount of signal strength fluctuation present across the neighbouring and current serving cell increases.



Outline

ANN - Controlled Test

Performance

- 15-minutes of training data, 165-minutes of test data.

Urban Environment

	Stationary	Walking	Driving
Stationary	90 %	10 %	0 %
Walking	15 %	79 %	6 %
Driving	11 %	54 %	36 %

Urban Environment - With Task Knowledge

	Stationary	Walking	Driving
Stationary	96 %	4 %	0 %
Walking	3 %	91 %	6 %
Driving	5 %	15 %	80 %

ANN

Limitations

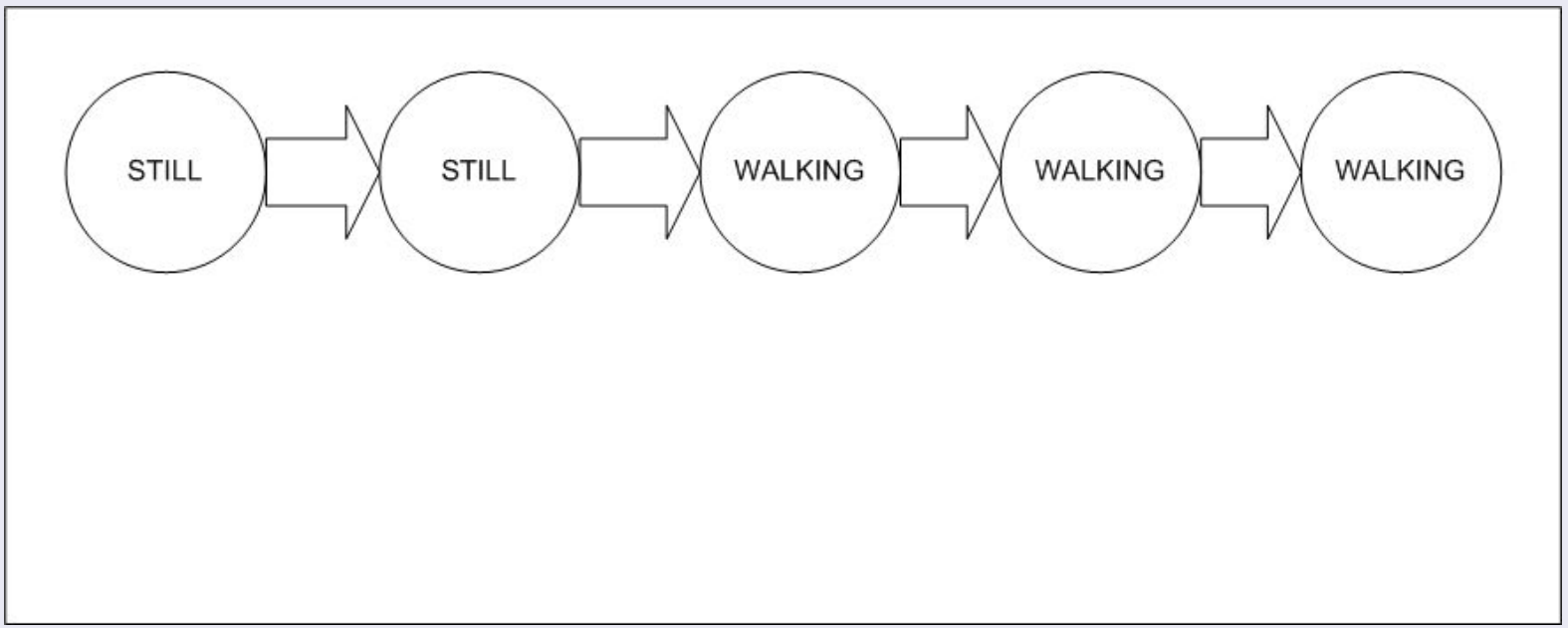
- Trained on desktop PC.
- Works well in the same type of environment but performance quickly degrades when moving into disparate environments.
- Applying task knowledge.
- Supervised training (Tedious!).

Outline

HMM - Structure

Hidden states

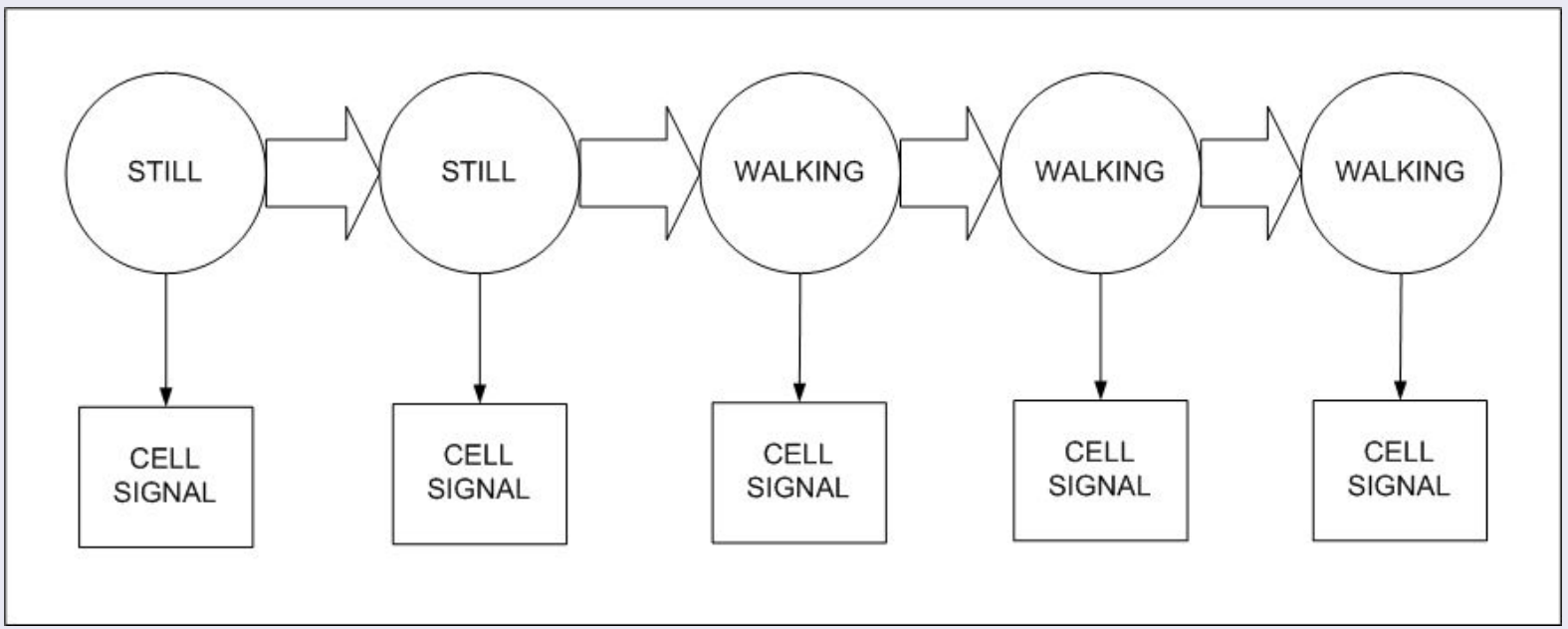
We can’t directly monitor activity.



HMM - Structure

Observations

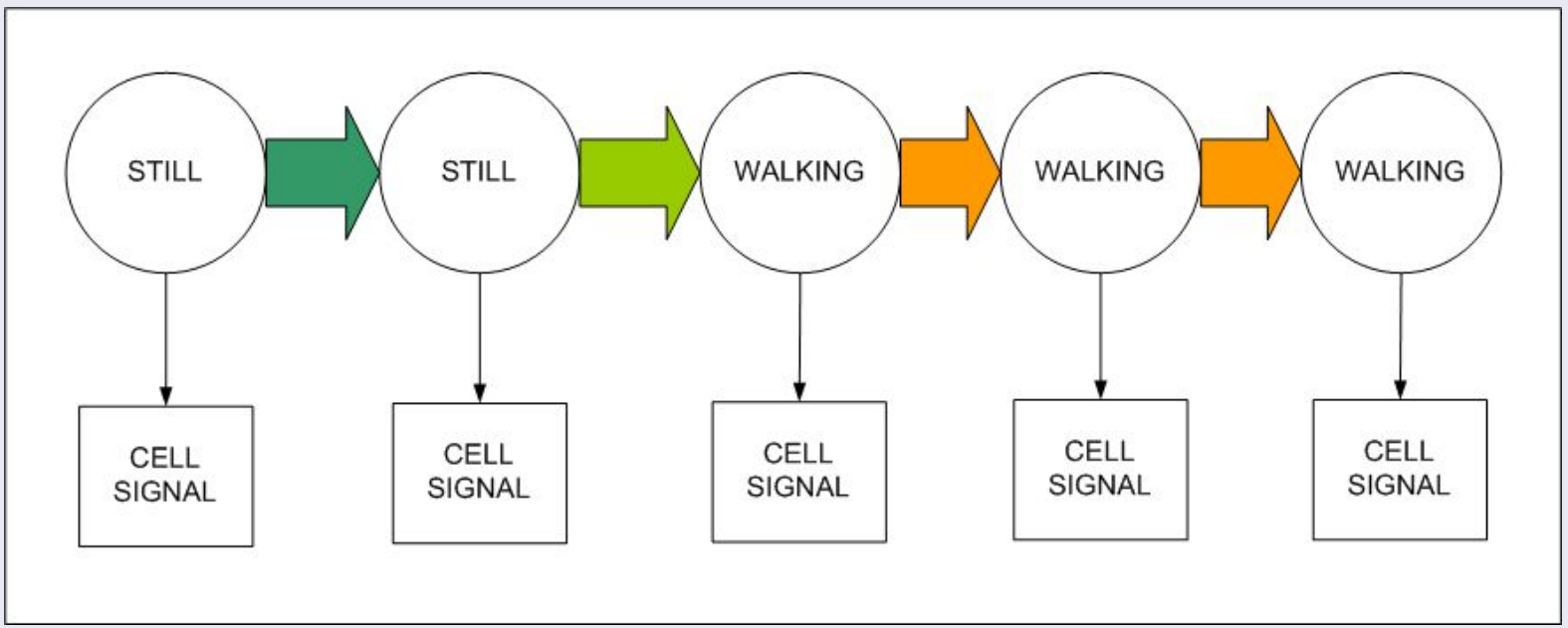
We can observe cell and signal strength fluctuations.



HMM - Structure

Markov Chain

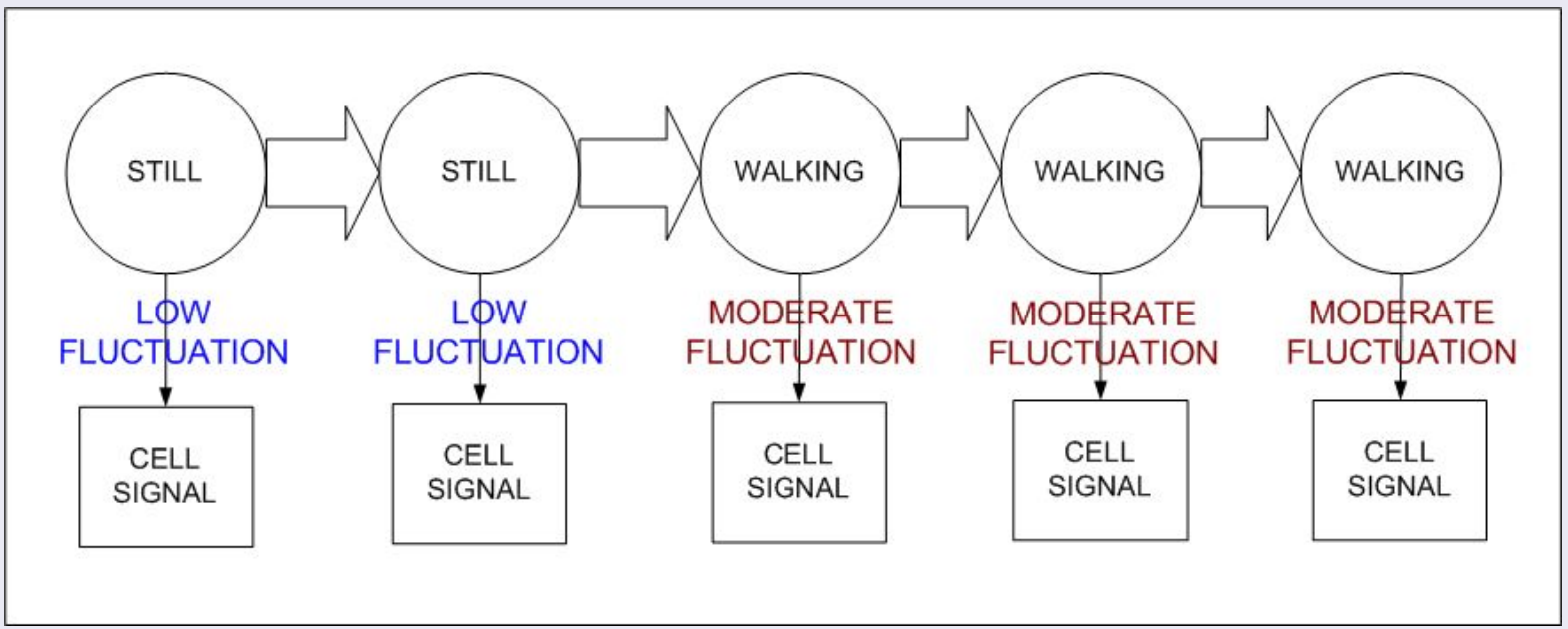
Transitions between states are dependent upon the prior state.



HMM - Structure

Observation Occurrence

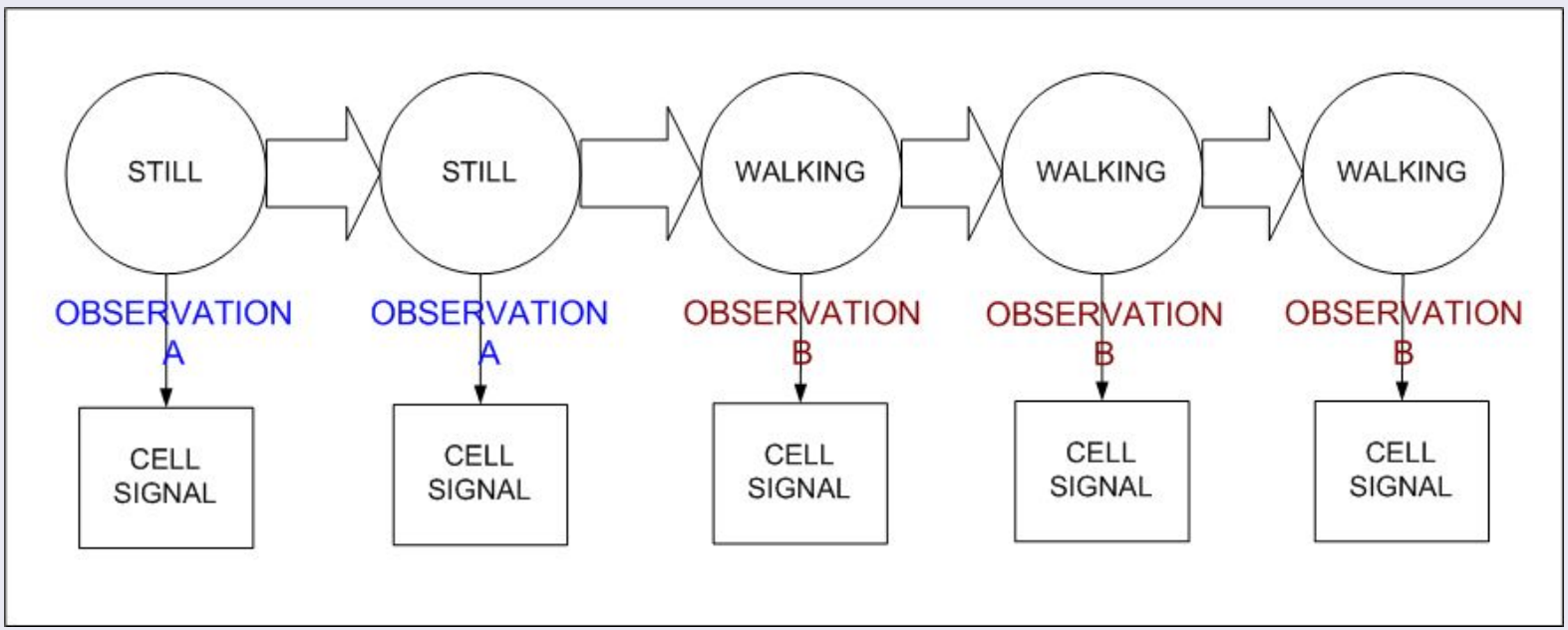
Certain observations occur frequently in specific hidden states.



HMM - Structure

Observation Alphabet

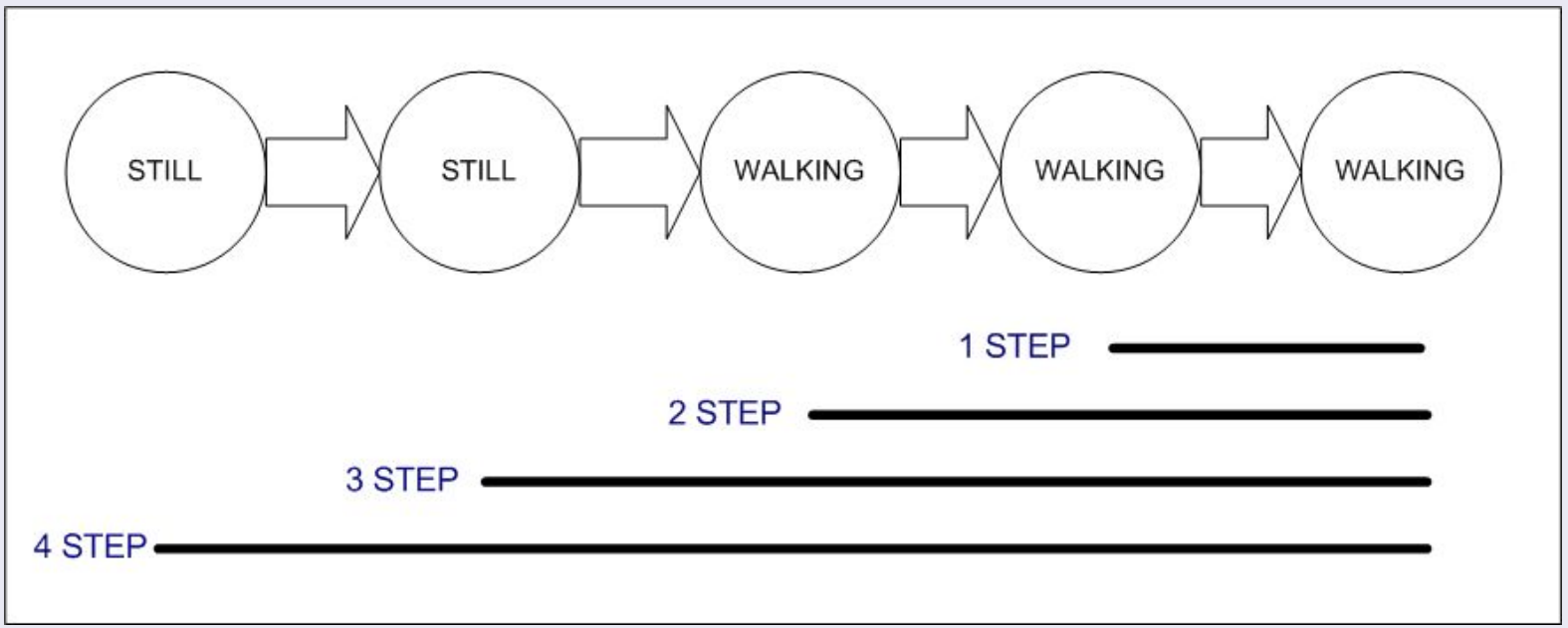
Convert continuous signals to discrete observations.



HMM - Structure

Task Knowledge

Look *n* steps back to apply task knowledge.



HMM - Structure

Observations to States

To infer the most-likely state sequence given a sequence of observations we can use the Viterbi algorithm.

Training

Calibration

- Populate the state transition matrix.
- Populate the probability of observations occurring in specific hidden states.
- Populate the initial probability distribution.

Baum-Welch

Automated learning of these probabilities.

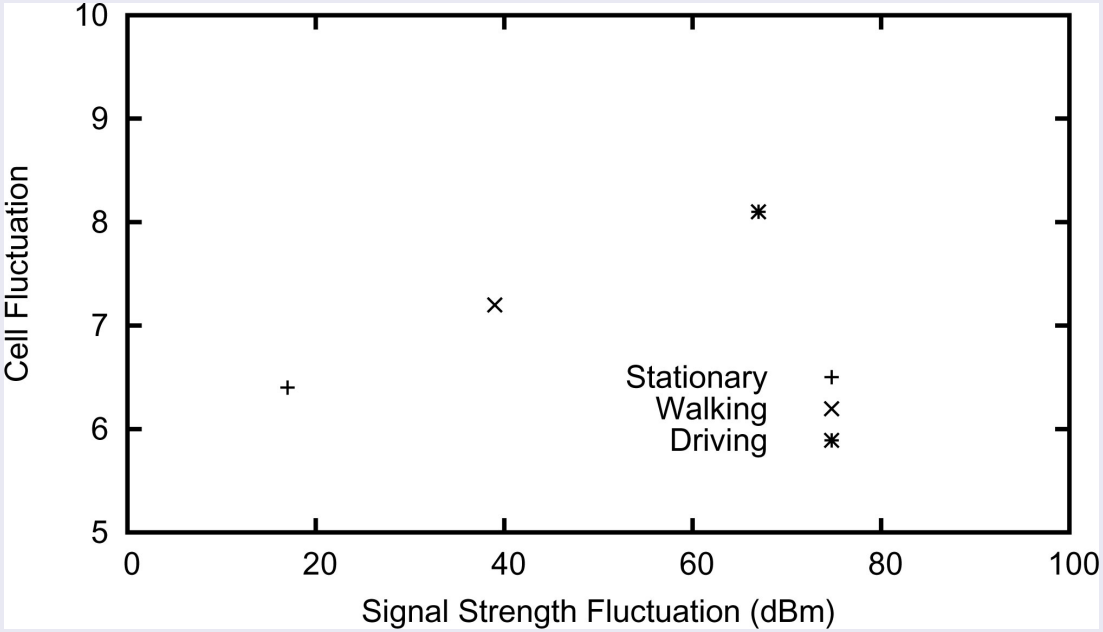
But...

How do you consistently map GSM signals to the observation alphabet in heterogeneous environments?

Learning Signal Behaviour

Process

- Find the mean values for each activity.
- Use the distance from the means to map to the observation alphabet.



Learning Signal Behaviour

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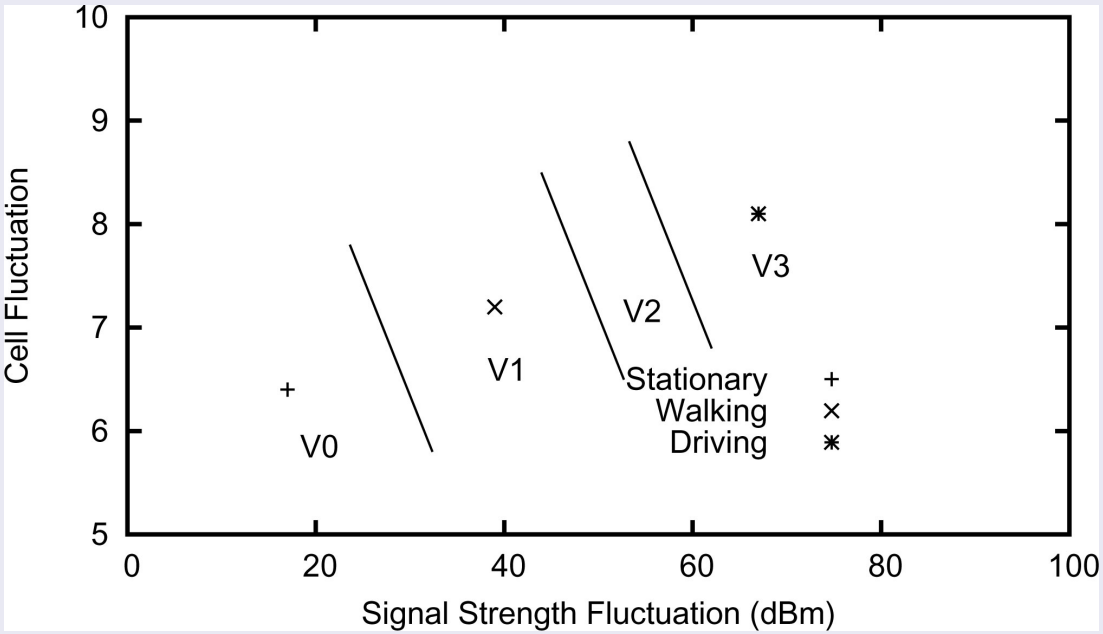

Performance

Results

- Driving is still hard!
- Performance quickly degrades when moving into disparate environments.

Metropolitan Environment

	Stationary	Walking	Driving
Stationary	92 %	8 %	0 %
Walking	12 %	80 %	8 %
Driving	4 %	22 %	74 %

But...

- Easy calibration!

Environment Change

Detection

Cellular beacons are static hence there are multiple approaches to detecting changes to position.

Techniques

- Location fingerprinting.
- Serving cell.
- Neighbouring cell clusters.
- Location Area Code.

Outline

Summary

HMM

- Easy calibration.
- Training process can run directly on the cell phone.
- Better representation of task knowledge.

Issues

- Determining when the environment has changed.

Summary

Thank You