Using SVMs to Classify Activities

A Brief Study of Passive RFID sensors

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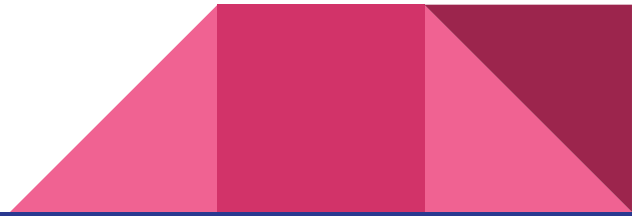
Agenda

- Background
- Method
- Analysis
- Discussion
- Conclusion

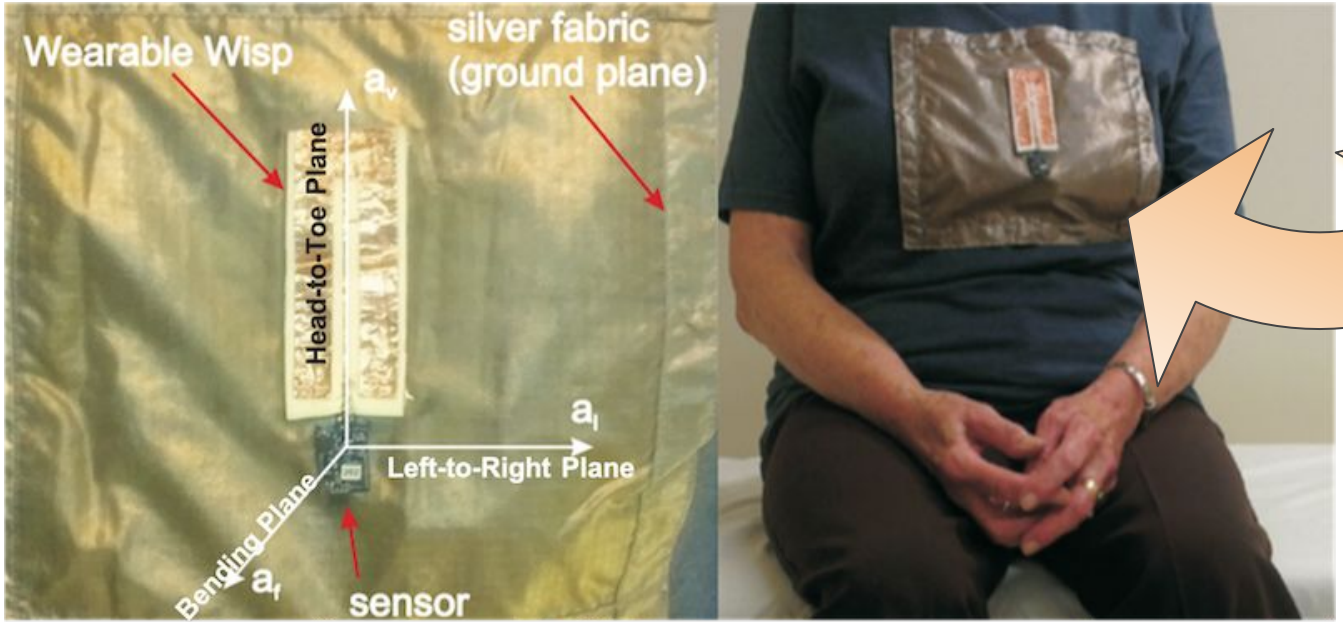


Background: the Challenge

- Can we use Support Vector Machines to accurately classify the movements of people based on imprecise readings of their bodies using three axis measures?
- **Problem Space:**
  - **14 people, 2 different RFID configurations, 8 available features, 75K observations**
  - **Classes:**
  - **1. Sitting on Bed**
  - **2. Sitting on Chair**
  - **3. Laying**
  - **4. Walking**
- **Multi-Dimensional and Multi-Classification problem**

[1]

Background: the Challenge



Wearable Sensor

Sensor Axes	Axes Relative to Person	Axes in Graphs
a_l	Left-to-Right Plane	x-axis
a_f	Bending Plane	y-axis
a_v	Head-to-Toe Plane	z-axis

Method: pre-processing

- Transformations
  - 94 separate data files
  - Features inferred from both directory structure and file names
- Leveraged One-vs.-All encoding for the activity encoding scheme
- Modified 5-fold cross-validation:
  - 5 stratified partitions
  - Best model per activity across 5 partitions

```
t_data <- revised_data %>% dplyr::filter(strat_group == strat_group, pos_activity == act )
```

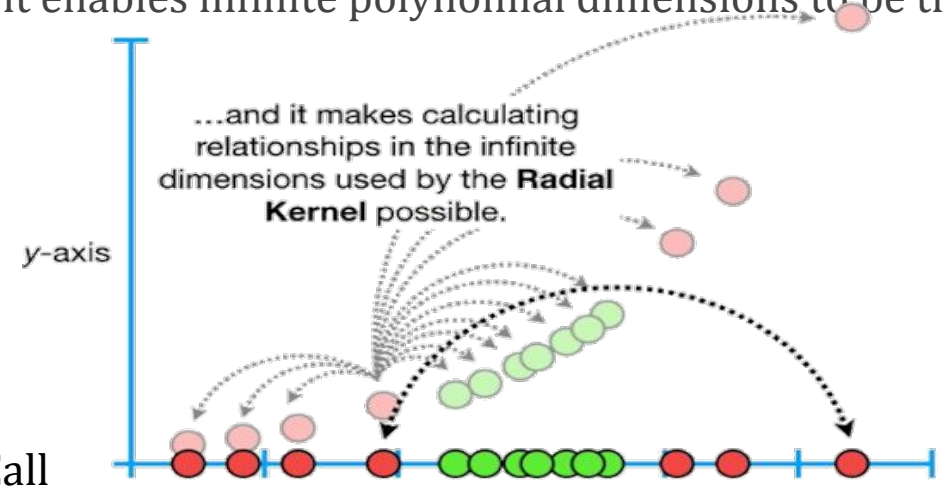
strat_group	pos_activity	time	bending	head_to_toe	left_to_right	sensor_id	signal_strength	phase	frequency	location	gender	activity_class
1	1	138.680	0.2251300	1.03120	-0.0136840	1	-59.0	0.2301000	922.75	one	male	1
1	1	253.750	0.3775600	0.95081	0.0547350	3	-65.0	5.4226000	923.75	one	female	1
•	•	•	•	•	•	•	•	•	•	•	•	•
5	4	172.550	0.1078700	1.04270	0.1003500	4	-65.0	5.8077000	924.75	one	male	1
5	4	59.925	0.2603000	0.99674	-0.0706990	2	-47.5	6.0730000	924.75	one	female	1
5	4	195.700	0.5534400	0.93932	-0.0250870	4	-67.5	1.2349000	920.75	one	female	1

Method: Support Vector Machines

- SVM History
  - Lineage goes back to Ron Fisher with Linear Discriminant analysis
  - However, real roots are in *Theory of Pattern Recognition* [8] and A *Training Algorithm for Optimal Margin Classifiers* [3]
- SVM Basics
  - Main idea in 1 or 2 dimensions of **maximal margin classifier:** draw a line to separate the classes focusing the the closest points to the separating hyperplane; ignore the outliers
  - Main idea in 1 or 2 dimension of **support vector classifier:** maximal margin classifier, but allow for some misclassification
  - **Main idea of SVM** [4]
    - 1. Start with data in a relatively low dimension
    - 2. Move the data into a higher dimension
    - 3. Find a Support Vector Classifier that separates the higher dimensional data into 2 groups

Method: Support Vector Machines

- Kernel Trick
  - Compute the projection of one vector onto another (aka dot product) in the original space and raise the scalar result to a power to functionally compute the dot product in a higher order space [9]
- Radial Basis Function (RBF) is a versatile choice of kernel: $e^{-\gamma||u-v||_2}$
- Functionally, it enables infinite polynomial dimensions to be tried[4]:



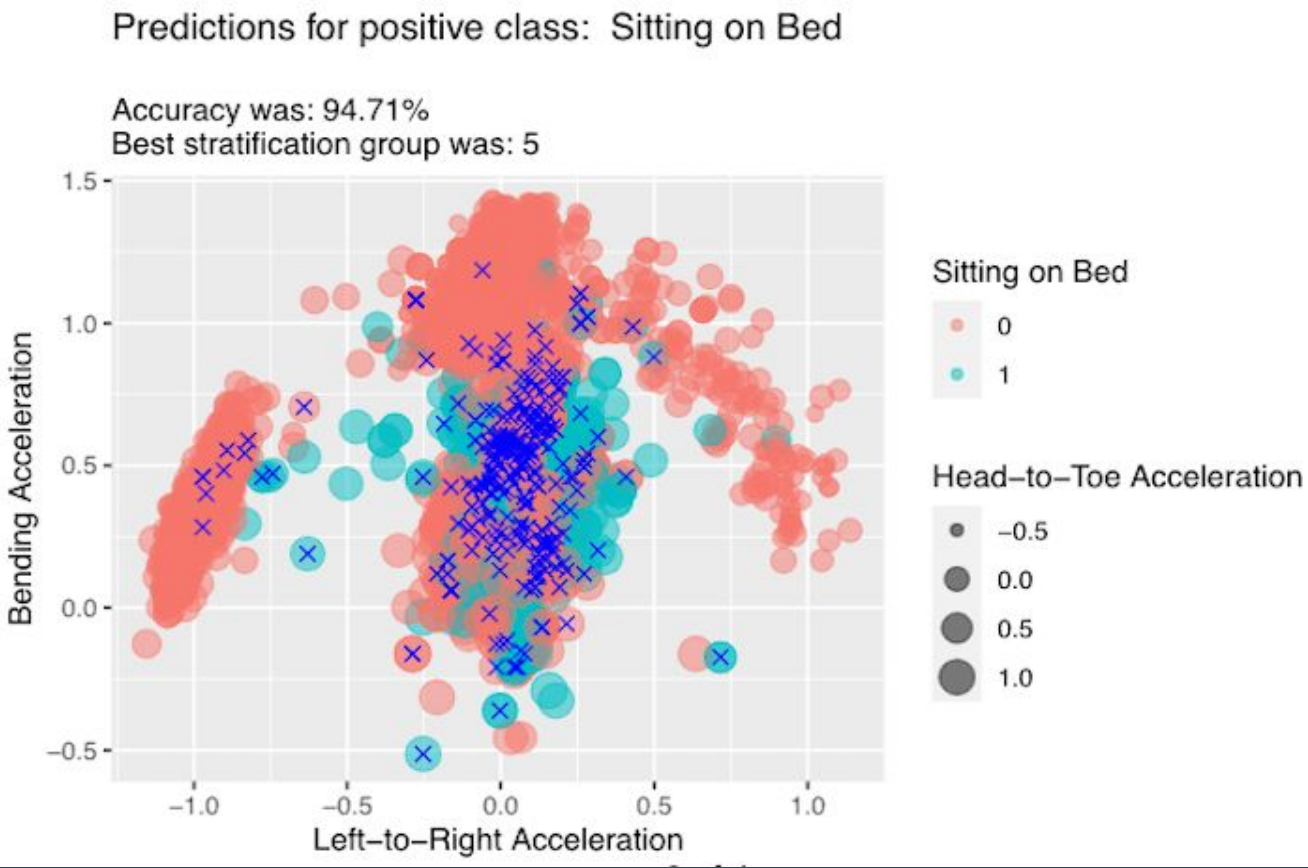
- The Actual Call

```
my_model <- e1071::svm(activity_class ~ bending + head_to_toe + left_to_right + signal_strength,
data = train_df, kernel = 'radial', gamma = 5, cost = 25, scale = FALSE)
```

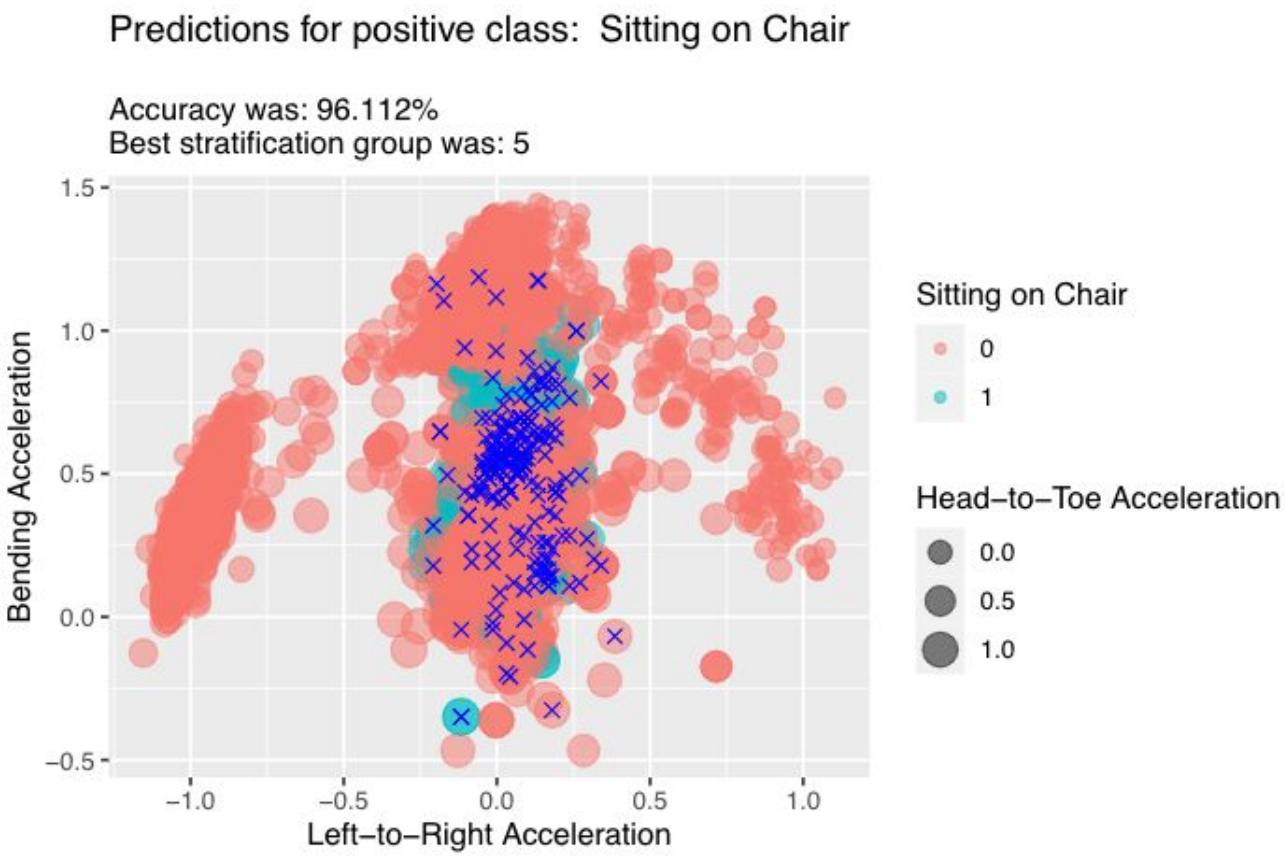
Summary Results

Activity	Stratification Group	Accuracy
Sitting on Bed	1	94.532%
Sitting on Bed	2	94.426%
Sitting on Bed	3	94.142%
Sitting on Bed	4	94.568%
Sitting on Bed	**5**	**94.71%**
Laying	1	99.627%
Laying	**2**	**99.73%**
Laying	3	99.645%
Laying	4	99.663%
Laying	5	99.645%
Walking	1	98.296%
Walking	2	98.42%
Walking	3	98.242%
Walking	**4**	**98.72%**
Walking	5	98.385%
Sitting on Chair	1	96.023%
Sitting on Chair	2	96.059%
Sitting on Chair	3	95.651%
Sitting on Chair	4	95.899%
Sitting on Chair	**5**	**96.11%**

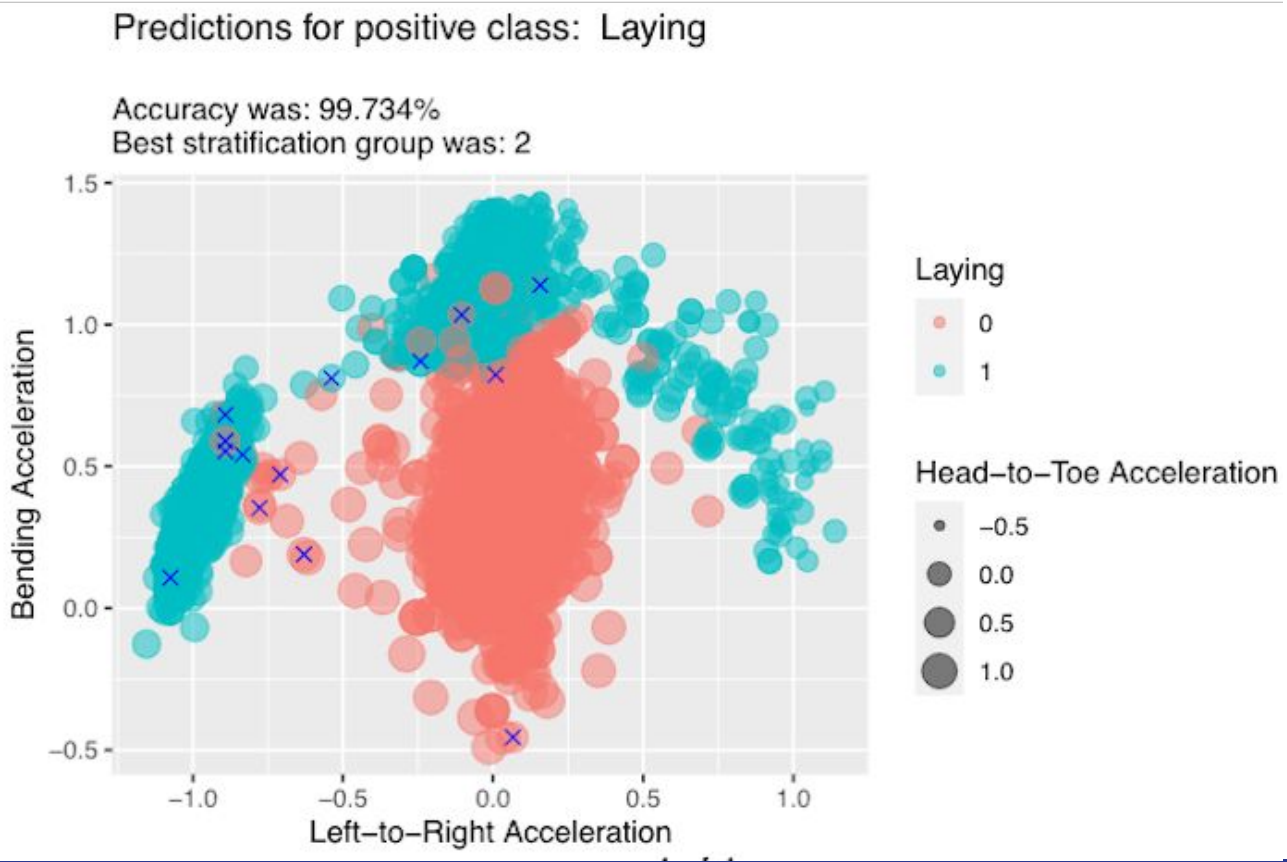
Results: Sitting on Bed



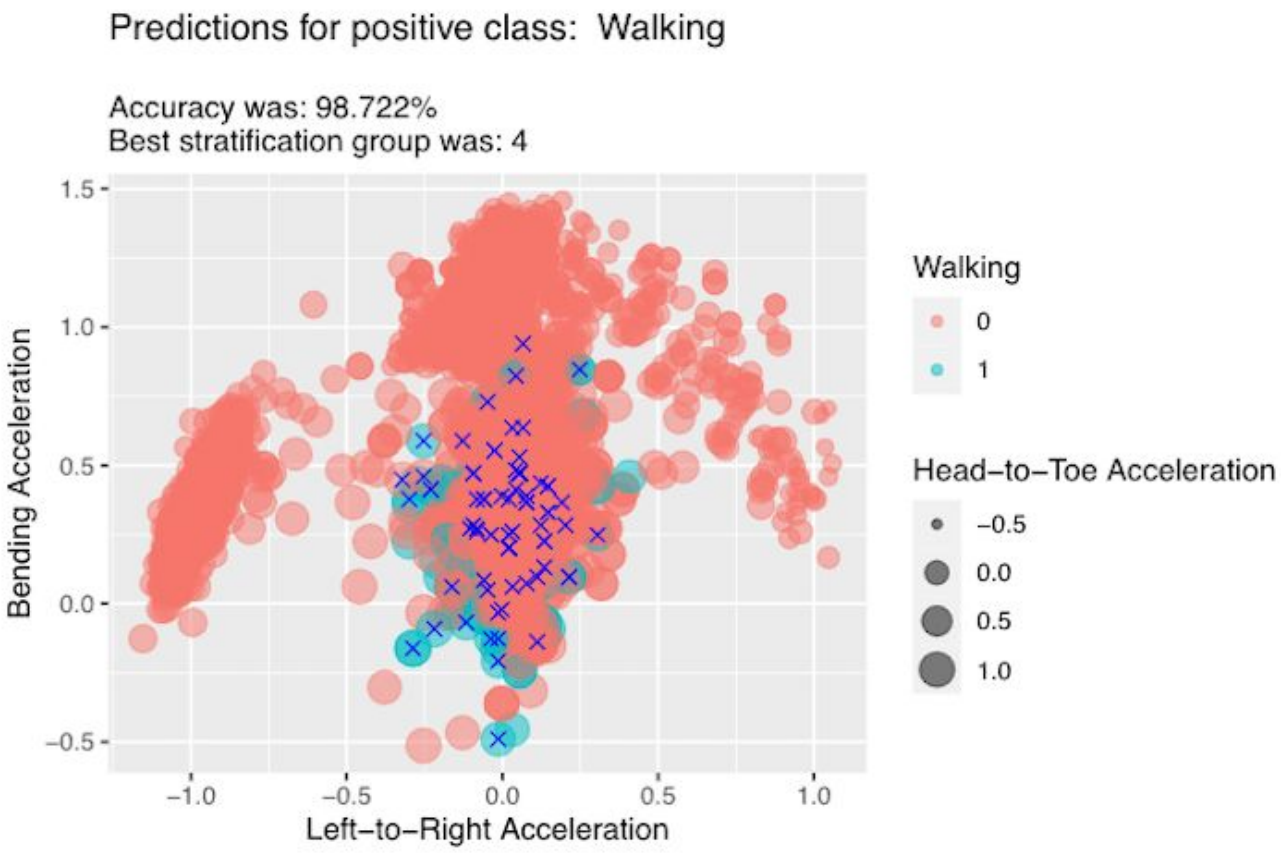
Results: Sitting on Chair



Results: Laying



Results: Walking



Discussion

- Accuracy 94.71% to 99.73% looks great, but is it really?
- Potential Shortfalls:
  - Small sample effective sample size with 14 patients even though we we looking at 75,000+ observations
  - No time series analysis even though the samples were in time intervals from 0.025 sec to 10 sec
  - Inductive Bias with RF signal strength; assumed it gave more weight to good results so added it in; does it?
- Future Analysis:
  - AB Tests between the two room configurations
  - Explicit outlier analysis (as SVMs exclude the outliers by design)

Wait...how would you even use it?

- 4 models were developed...so, how you choose the best one?
- Fundamentally, they are binary classifiers, so you can just nest them
- Example:

time	bending	head_to_toe	left_to_right	sensor_id	signal_strength	phase	frequency	location	gender	activity_class
136.38	0.24858	0.33072	-1.0172	2	-49	2.4866	921.25	two	female	3

- Running through all the models:

```
For actual: Laying:
     predicted WAS NOT Sitting on Bed
     predicted WAS Laying
     predicted WAS NOT Walking
     predicted WAS NOT Sitting on Chair
```

Conclusion

- Overview of problem space and methodology
- Overview of SVMs
- Verified SVMs do provide a robust solution for classification in this problem space
- Provided an overview of the analysis
- Identified potential shortcomings and future work
- Provided an operational example

References

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