Human Activity Recognition Predictive Model

Topic: Internet of Things

Sponsor: Deloitte

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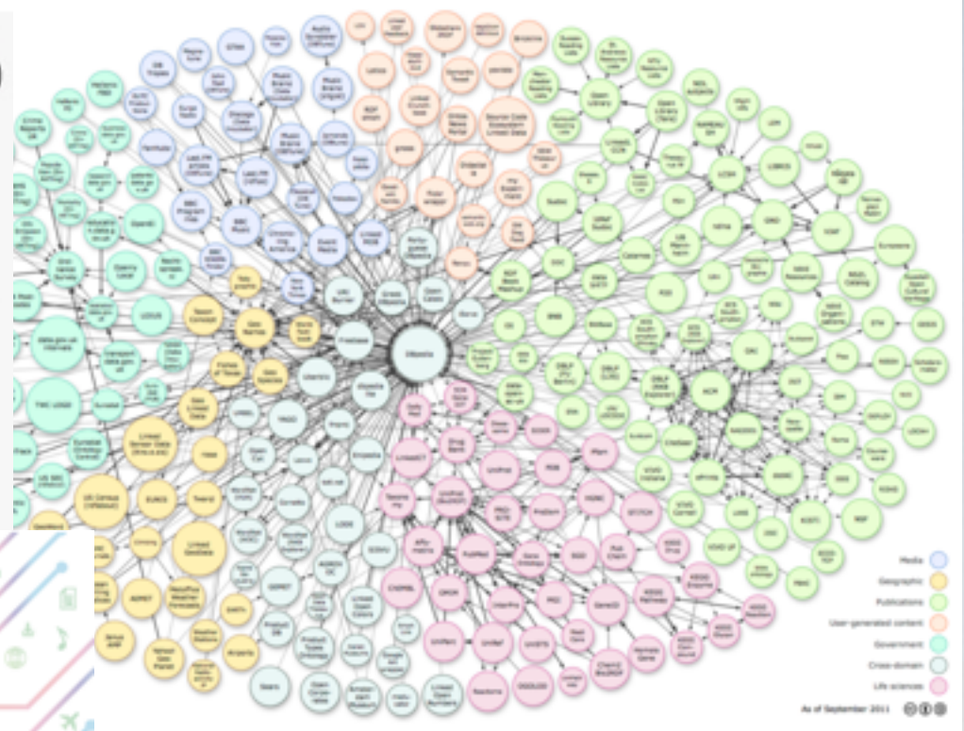
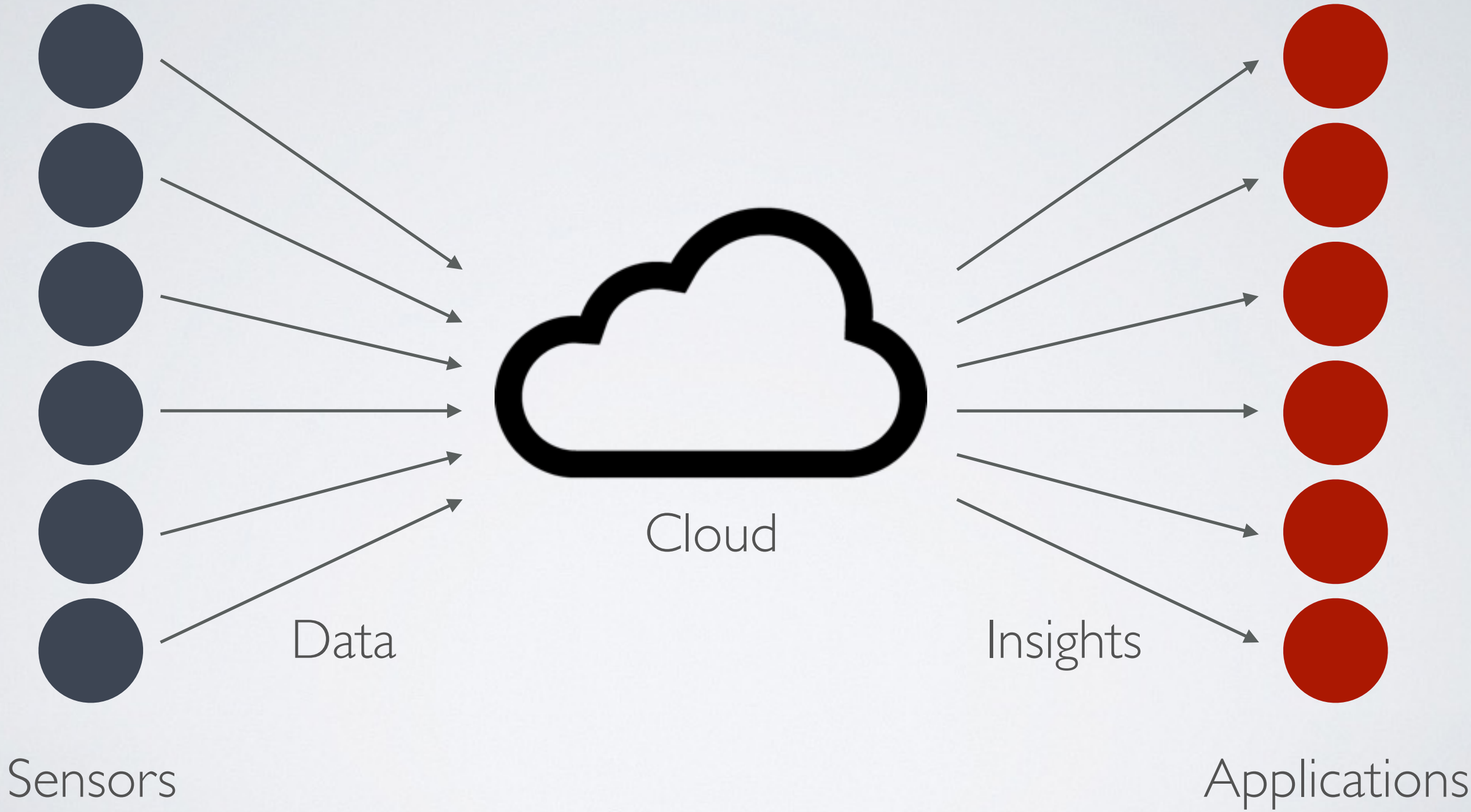
GW MSBA Practicum Project - Spring 2016

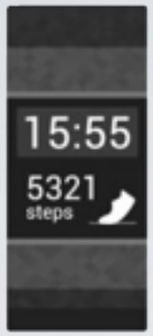
What is the Internet of Things?



The Internet of Things

Internet of Things




15:55
5321
steps


00:24:55
06:45
8.62


1080P
HD

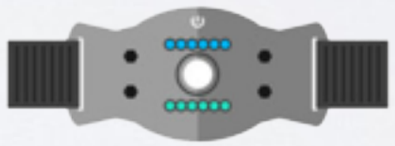

11:42
Wednesday


GPS
tracker


118


John


120




122
70
01♥66
F


5.2
mmol/L
11:35
m
s

*"**Wearables** and the **Internet of Things** (IoT) may give the impression that it's all about the sensors, hardware, communication middleware, network and data but the **real value** (and company valuation) **is in insights**"*

- Scott Amyx, Wired, December 2014


TECH NOIR

What are you actually doing?

Human Activity Recognition

Methodology

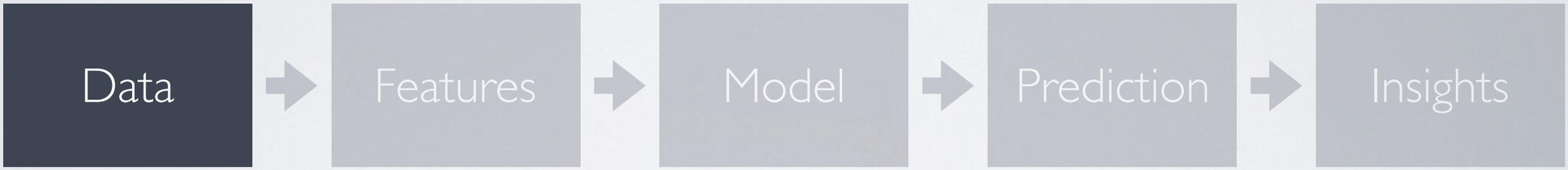
overview
clean-up
exploratory analysis

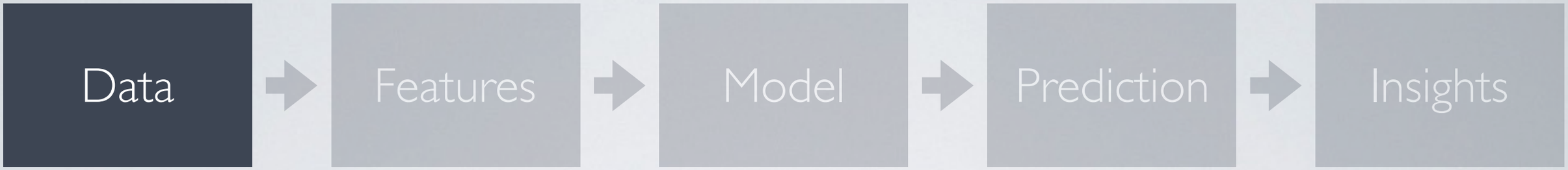
windows
statistical features
structural features

gaussian NB
SVM
KNN
logit regression
random forests
bagging classifier
ADA boosting
gradient boosting

predictive classifier
prediction score

model insights
applications


Data
Features
Model
Prediction
Insights

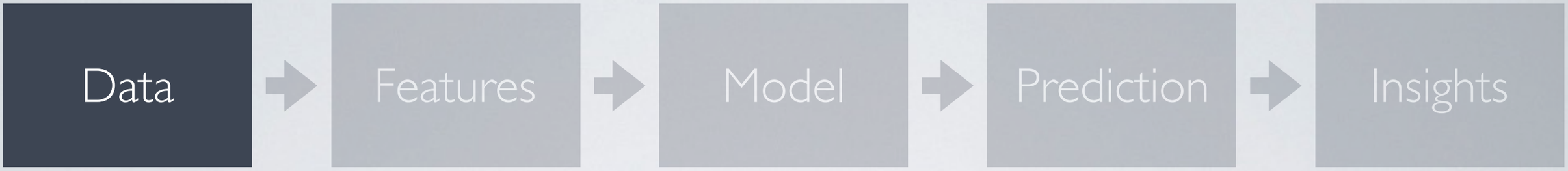


- **Source**: University of California Irvine - Machine Learning Repository
  http://archive.ics.uci.edu/ml/datasets/PAMAP2+Physical+Activity+Monitoring

- **18 activities, 9 individuals, 3 sensors (IMUs)**

- 3.85 million observations x 54 attributes:

  207,900,000 data points



Variables: The following 54 attributes are present in the dataset:

Variables not IMU-specific

- (1 var) Timestamp (s)
- (1 var) Activity ID
- (1 var) Heart Rate (bpm)

IMU-specific variables:

Hand
Chest
Ankle

- (1 var) Temperature (°C)
- (3 var) 3D-acceleration data (ms-2), scale: ±16g
- (3 var) 3D-acceleration data (ms-2), scale: ±6g
- (3 var) 3D-gyroscope data (rad/s)
- (3 var) 3D-magnetometer data (μT)
- (4 var) Orientation

Data → Features → Model → Prediction → Insights

Activities:

Lying

Sitting

Standing

Walking

Running

Cycling

Nordic Walking

Watching TV

Computer Work

Car Driving

Ascending Stairs

Descending Stairs

Vacuum Cleaning

Ironing

Folding Laundry

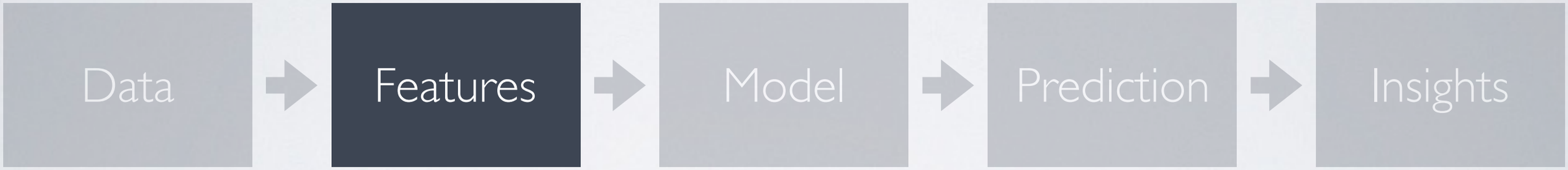
House Cleaning

Playing Soccer

Rope Jumping

and transient activities (actions in between activities)

What does this data look like?


Data
Features
Model
Prediction
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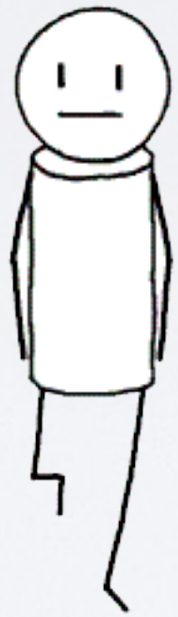
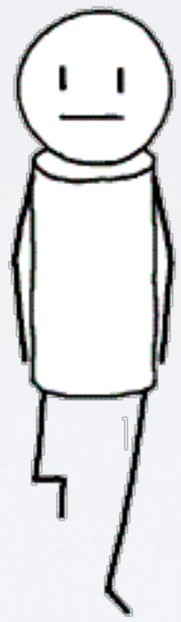
Data → **Features** → Model → Prediction → Insights



Data → **Features** → Model → Prediction → Insights



What do features look like?

Activity

Cycling

Heart Rate (bpm)

150
100
50

Gradient: 0.026
Intercept: 22.429

0
10
5
0

IMU Hand Gyroscope X-axis (rad/s)

Mean: 0.048
Std. Dev.: 0.561
Range: 3.249
Kurtosis: 2.291
Skewness: 0.725

Running

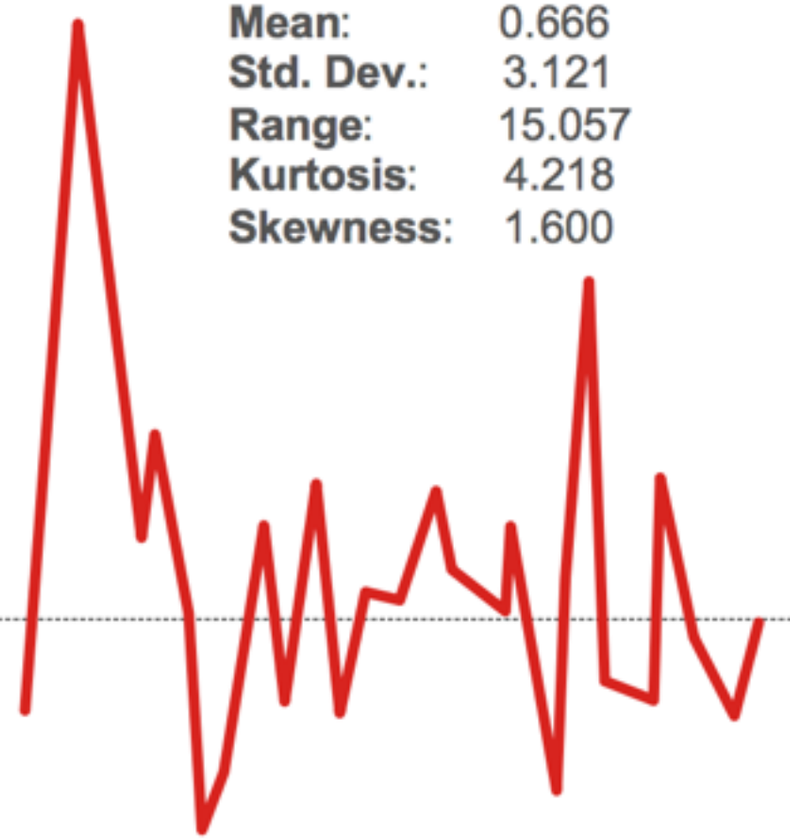
Gradient: 0.664
Intercept: -2493.55

Mean: -0.037
Std. Dev.: 1.899
Range: 6.766
Kurtosis: -0.461
Skewness: 0.351

Rope Jumping

Gradient: 0.548
Intercept: -2134.78

Mean: 0.666
Std. Dev.: 3.121
Range: 15.057
Kurtosis: 4.218
Skewness: 1.600




Data
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Model
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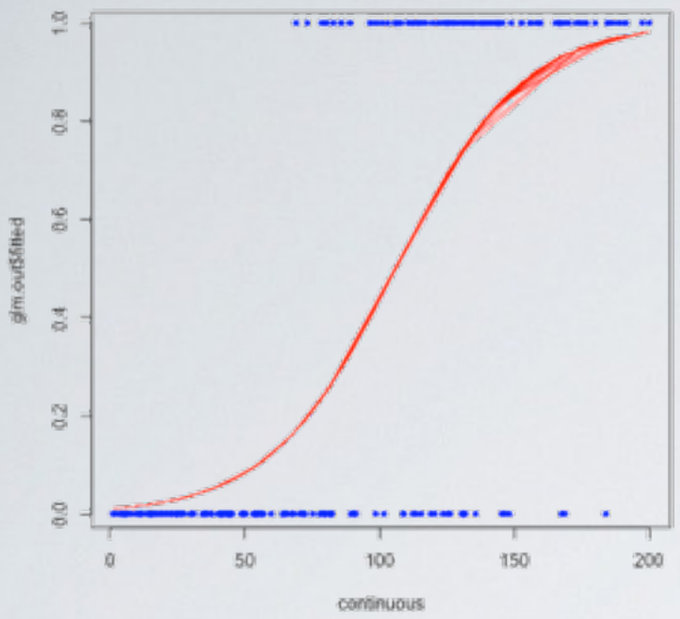
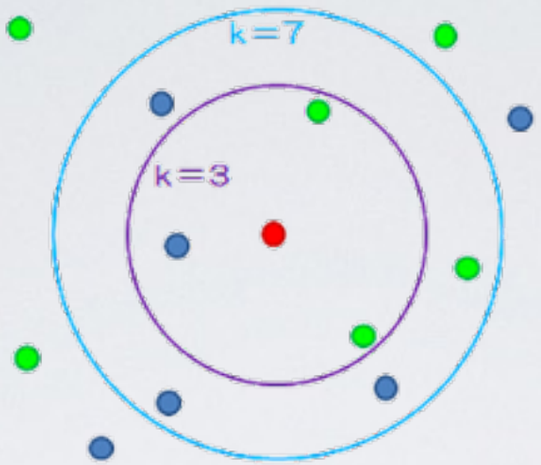
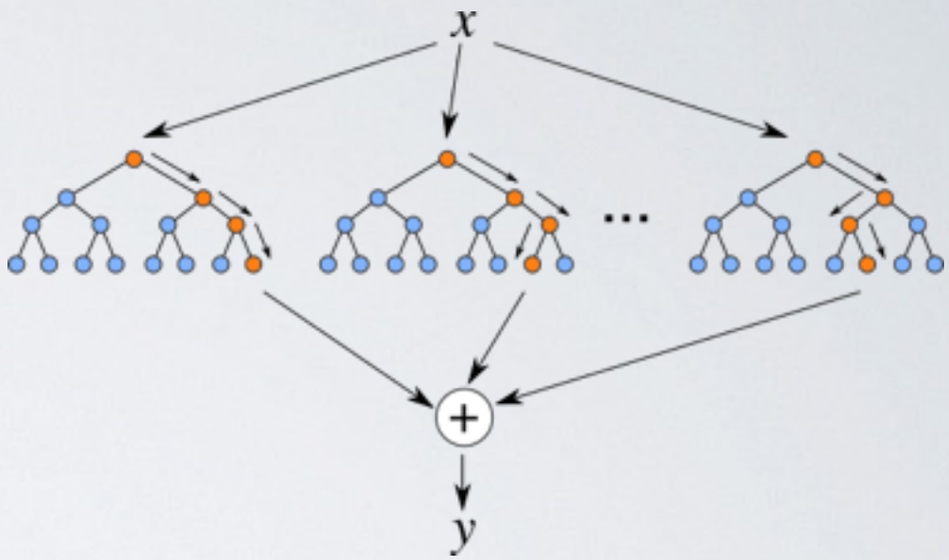


Logistic Regression



K-Nearest Neighbors

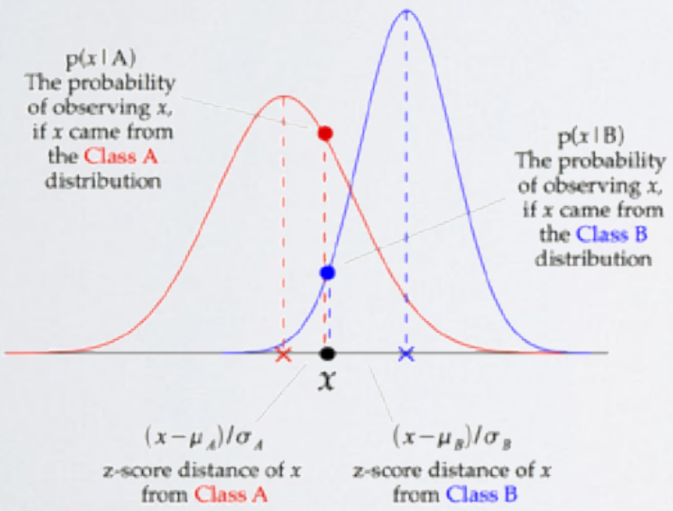


Bagging Classifier

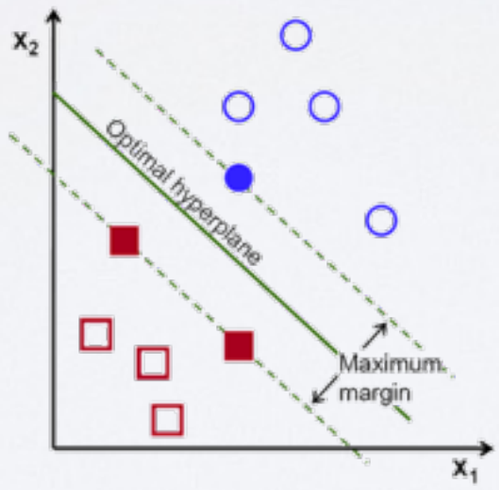
Random Forest

ADA Boosting

Gradient Boosting



Gaussian Naive Bayes



Support Vector Machines

Tune Parameters: use default or best guess values for all parameters but one; alter one parameter per model to see changes in predictive accuracy

Different Sensors: hand sensors only, chest sensors only, ankle sensors only

Vary Window Sizes: 3 seconds, 5 seconds, 10 seconds

Validation: Stratified cross-validation (5-fold)

Scoring Metric: accuracy (proportion of true predictions among total predictions, average of 5 accuracy scores)

Modeling Technique	Tuning Parameter	Ankle (3s)	Ankle (5s)	Ankle (10s)	Chest (3s)	Chest (5s)	Chest (10s)	Hand (3s)	Hand (5s)	Hand (10s)
Logistic Regression	C (1/reg. strength) = 0.5									
	C (1/reg. strength) = 1 (default)									
	C (1/reg. strengh) = 2									
Gaussian Naïve Bayes	Feature Set = All									
	Feature Set = Acceleration									
	Feature Set = Means									
Support Vector Machines	C (error term) = 0.5									
	C (error term) = 1									
	C (error term) = 2									
K-Nearest Neighbor	K = 3									
	K = 5 (default)									
	K = 7									
Random Forest	Max n_features = sqrt(n_feat) ≈ 13 (default)									
	Max n_features = 10% of n_feat = 16									
	Max n_features = 25% of n_feat = 40									
Bagging Classifier	N Est = 10 (default)									
	N Est = 50									
	N Est = 100									
ADA Boosting	N Est = 50 (default)									
	N Est = 200									
	N Est = 400									
Gradient Boosting	Max Depth = 2									
	Max Depth = 3 (default)									
	Max Depth = 4									

Modeling Technique	Tuning Parameter	Ankle (3s)	Ankle (5s)	Ankle (10s)	Chest (3s)	Chest (5s)	Chest (10s)	Hand (3s)	Hand (5s)	Hand (10s)
Logistic Regression	C (1/reg. strength) = 0.5	58%	60%	63%	63%	65%	68%	66%	68%	70%
	C (1/reg. strength) = 1 (default)	58%	61%	63%	64%	66%	68%	67%	68%	70%
	C (1/reg. strengh) = 2	58%	61%	63%	64%	67%	69%	67%	69%	70%
Gaussian Naïve Bayes	Feature Set = All	53%	56%	60%	63%	65%	69%	55%	58%	64%
	Feature Set = Acceleration	46%	50%	54%	54%	56%	59%	45%	46%	50%
	Feature Set = Means	52%	53%	54%	51%	54%	57%	48%	51%	55%
Support Vector Machines	C (error term) = 0.5	58%	60%	63%	66%	69%	72%	66%	70%	72%
	C (error term) = 1	58%	59%	62%	65%	68%	72%	65%	70%	72%
	C (error term) = 2	58%	58%	62%	65%	68%	71%	65%	69%	72%
K-Nearest Neighbor	K = 3	58%	61%	63%	62%	66%	68%	63%	67%	69%
	K = 5 (default)	58%	60%	63%	62%	65%	68%	62%	67%	70%
	K = 7	59%	60%	63%	61%	66%	67%	62%	67%	70%
Random Forest	Max n_features = sqrt(n_feat) ≈ 13 (default)	72%	74%	76%	77%	78%	82%	72%	74%	77%
	Max n_features = 10% of n_feat = 16	72%	72%	76%	77%	79%	81%	73%	75%	77%
	Max n_features = 25% of n_feat = 40	73%	74%	77%	76%	78%	82%	70%	74%	77%
Bagging Classifier	N Est = 10 (default)	58%	60%	61%	55%	61%	64%	52%	53%	55%
	N Est = 50	65%	68%	69%	68%	71%	74%	62%	65%	70%
	N Est = 100	66%	68%	72%	71%	74%	78%	65%	68%	73%
ADA Boosting	N Est = 50 (default)	29%	25%	20%	29%	29%	29%	27%	26%	25%
	N Est = 200	29%	24%	20%	29%	29%	29%	27%	26%	25%
	N Est = 400	29%	27%	20%	29%	29%	31%	27%	25%	25%
Gradient Boosting	Max Depth = 2	70%	73%	74%	70%	73%	76%	66%	70%	72%
	Max Depth = 3 (default)	70%	73%	74%	69%	73%	76%	65%	69%	71%
	Max Depth = 4	70%	72%	73%	69%	73%	75%	65%	68%	72%

Data → Features → Model → **Prediction** → Insights

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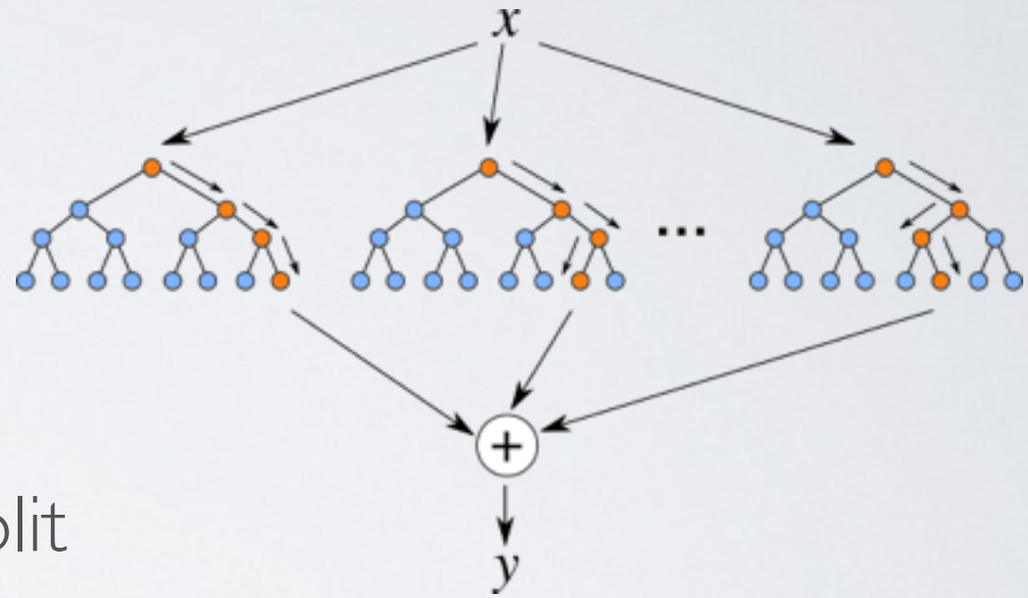
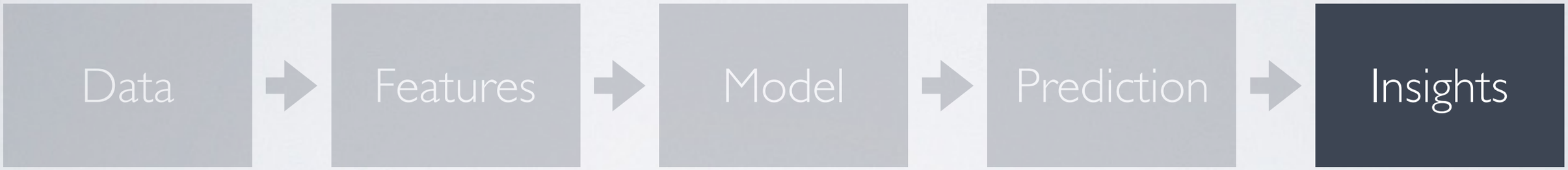
- **Best Model:** Random Forest
  - Hand sensor
  - 25 second intervals
  - 300 decision trees
  - 10% of features randomly chosen at split



- **Prediction Accuracy:**
  - Training (60%) v. Testing (40%)= 91% chest, 89% hand, 84% ankle
  - Max one-subject-out = 96% hand, 90% chest, 83% ankle

What do predictions look like?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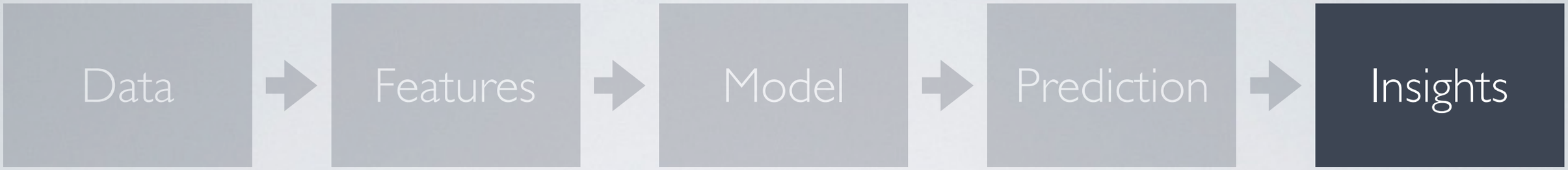
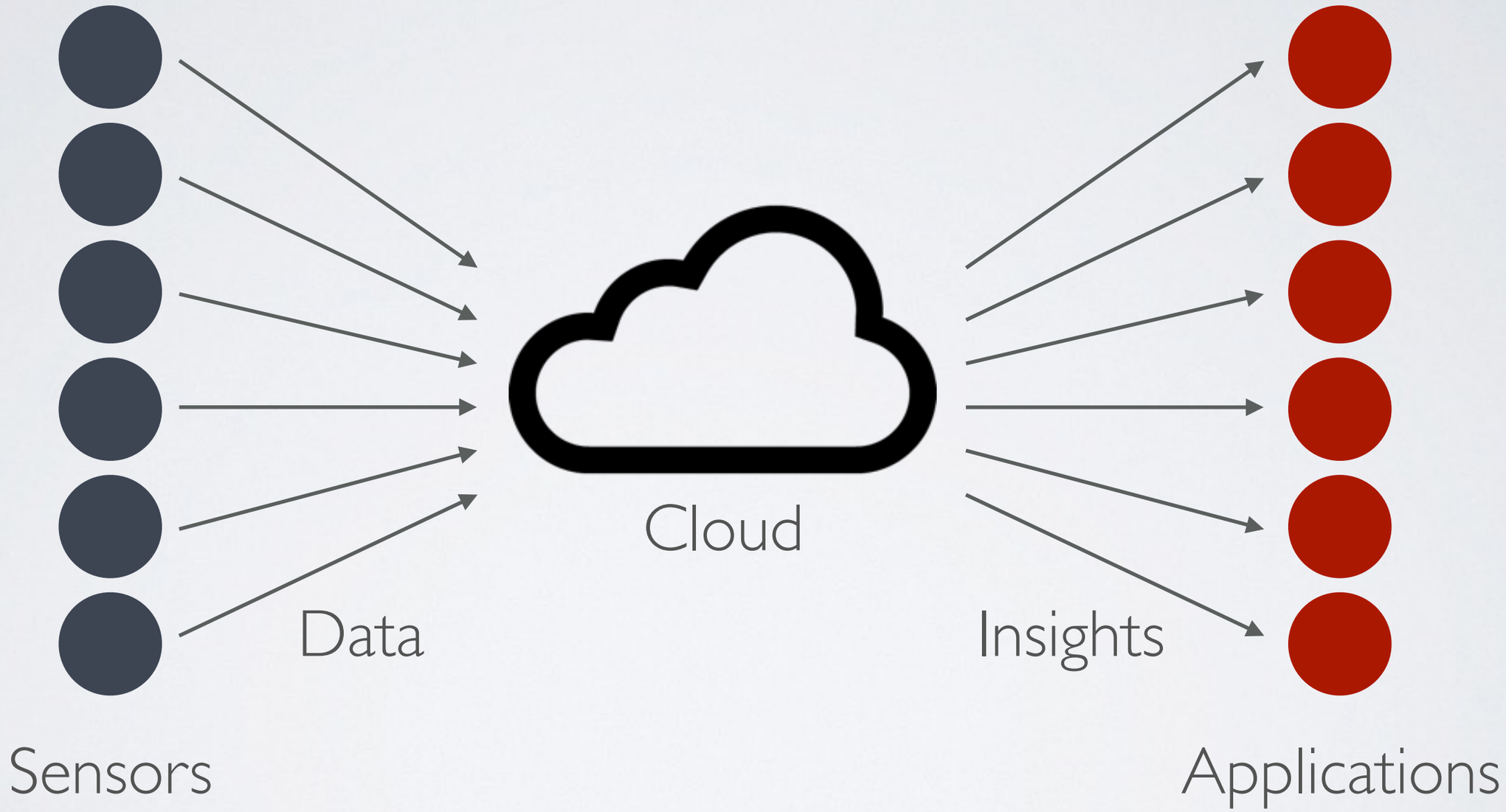


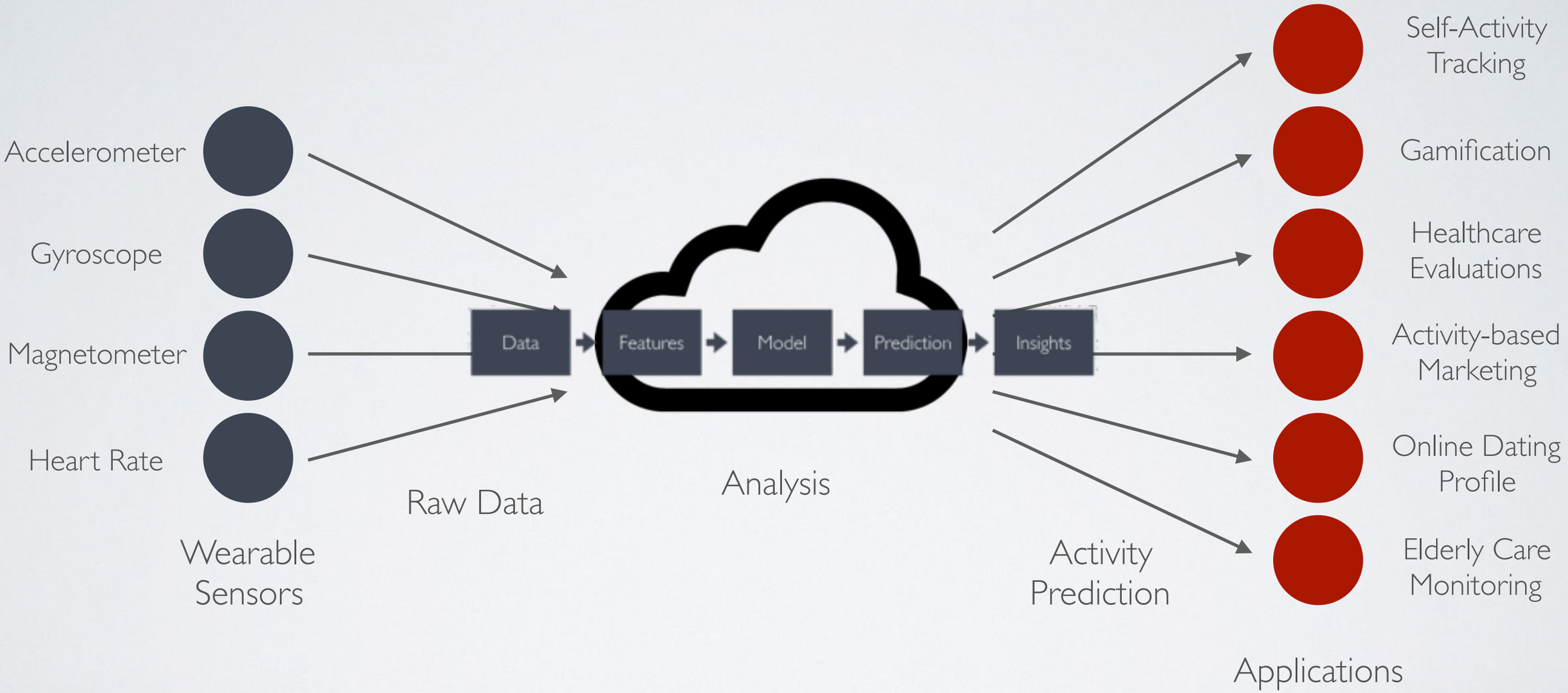
- **Activity recognition is possible!**
- Chest and hand sensors are good (better than ankle)
- Bigger windows of time are better, but limits your observations
- Misclassification can be improved through other sensors (eg. GPS)
- Activity aggregation for similar activities: ironing vs. folding laundry, house cleaning vs. vacuuming
- Get a diverse sample (poor prediction for female chest sensor)

What is the big picture?

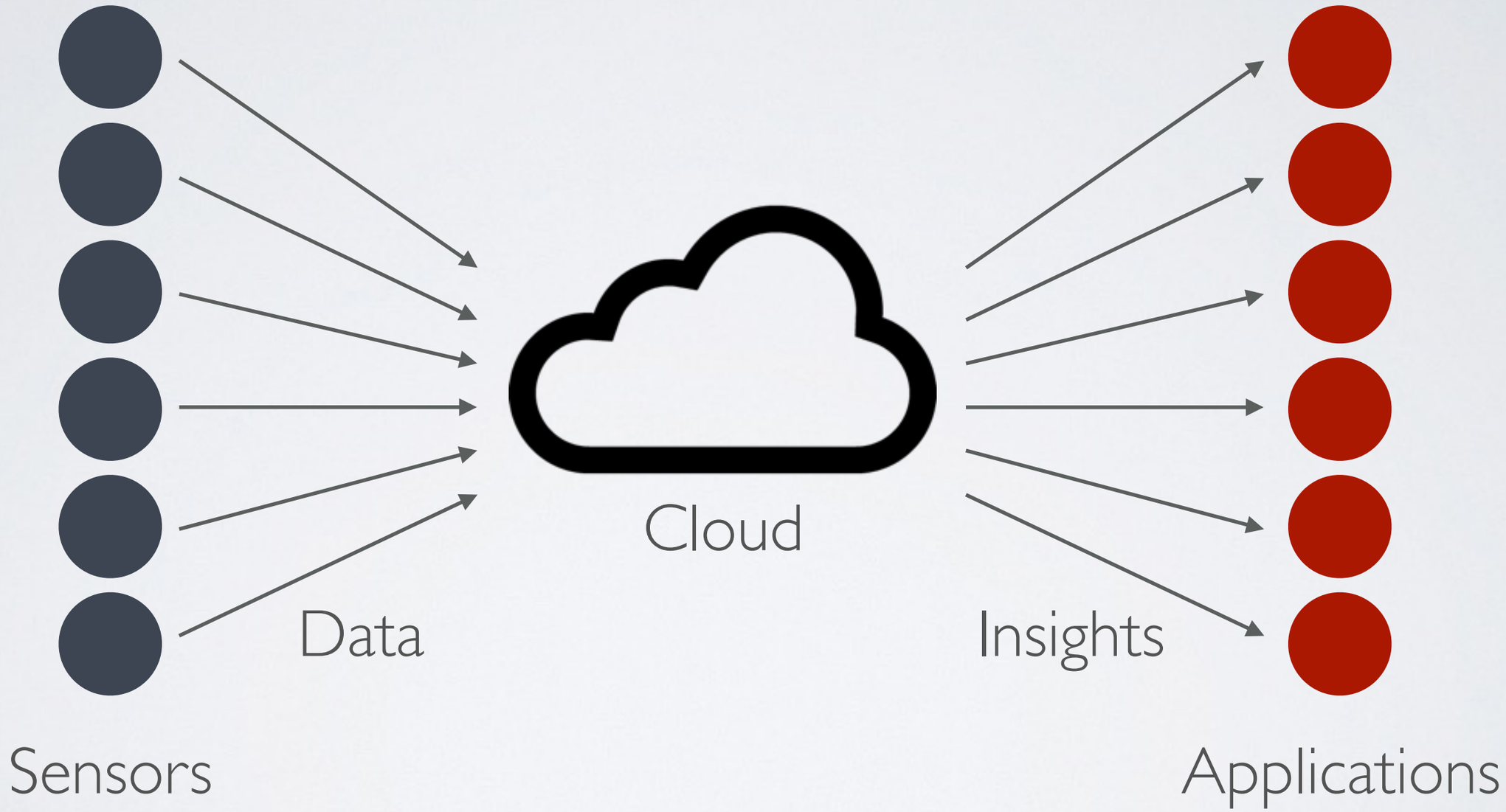
Internet of Things



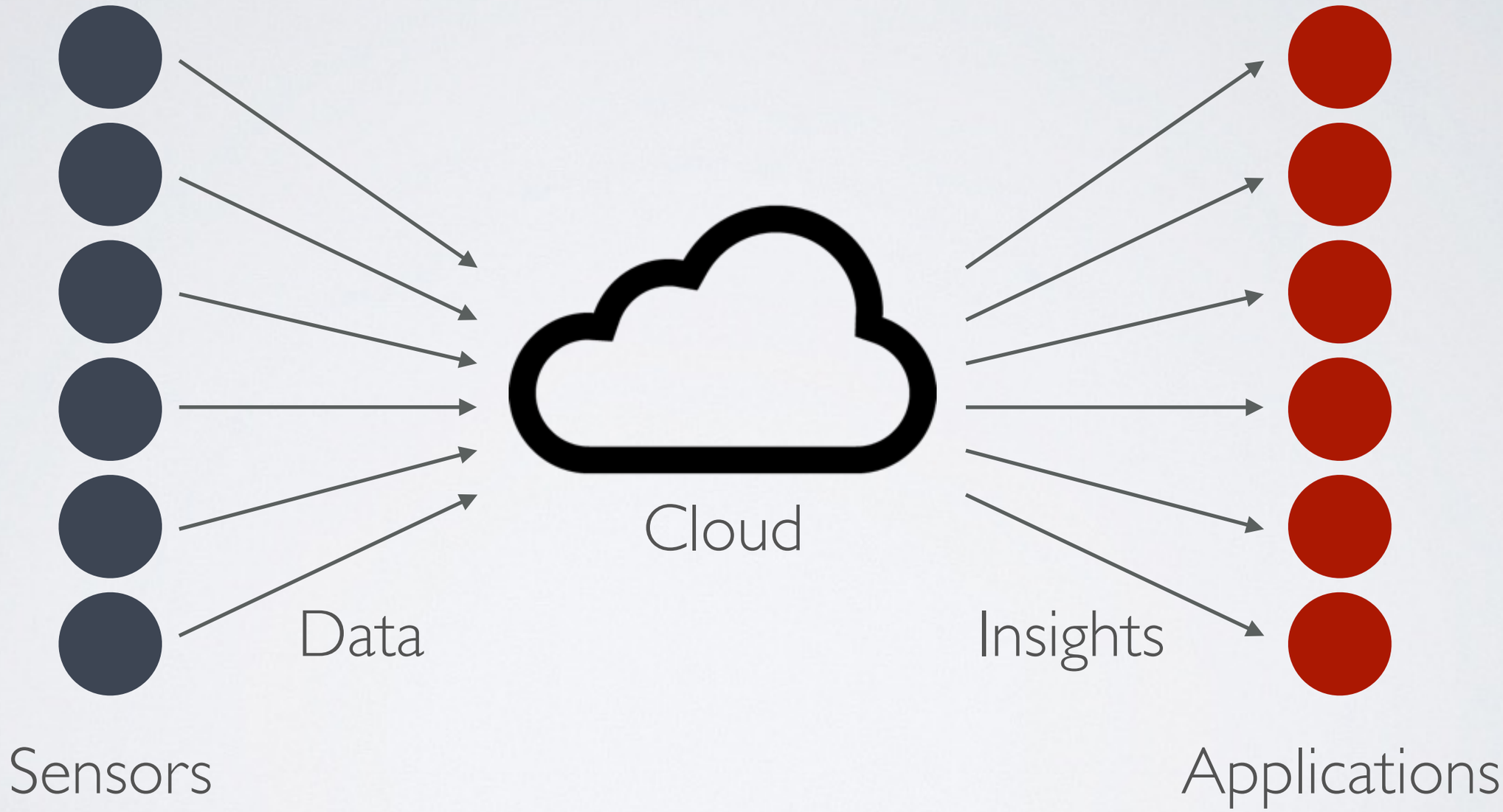
Human Activity Recognition



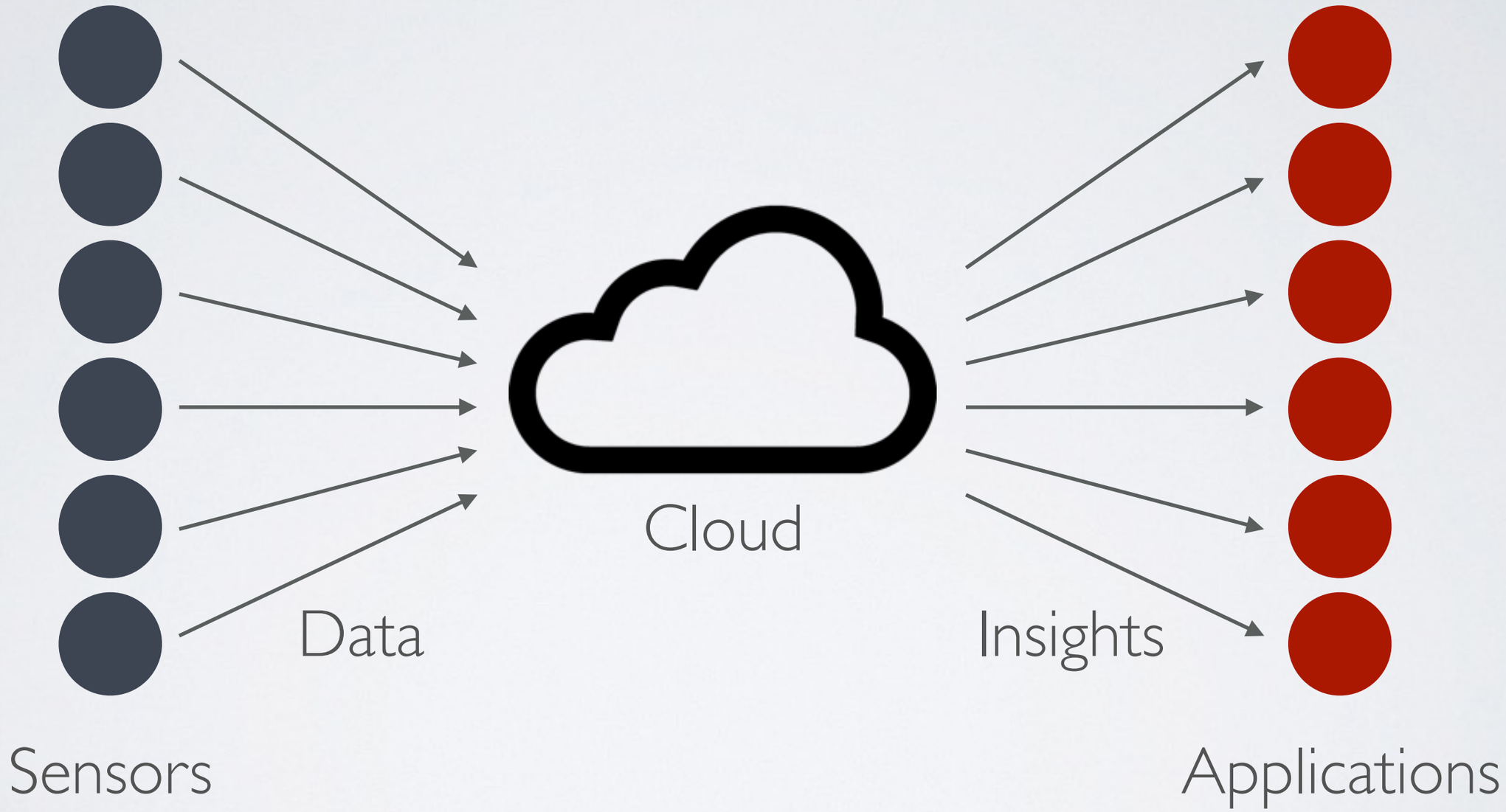
Smart Parking



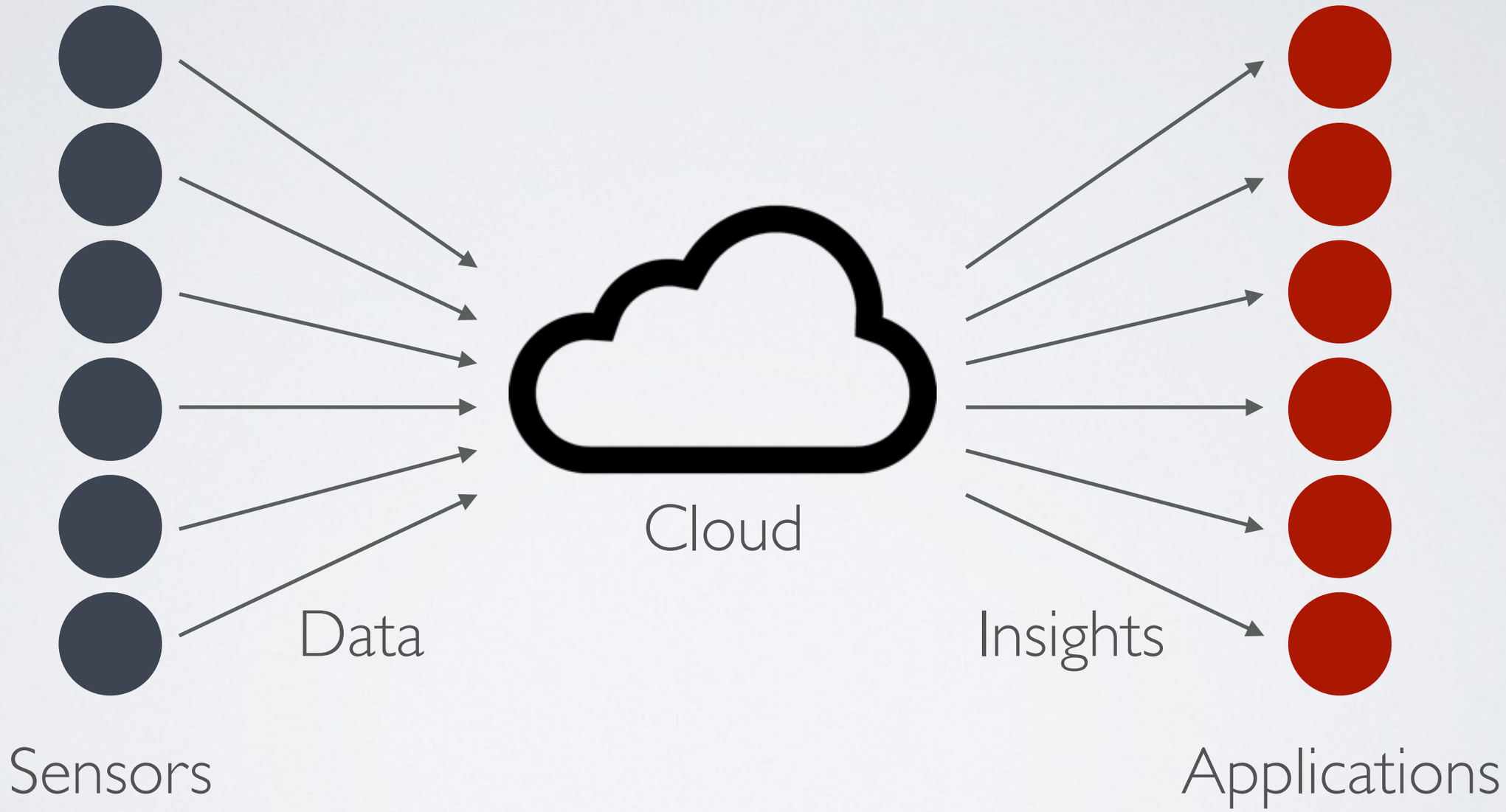
Forest Fire Detection



Home Energy Efficiency



Crop Yield Management



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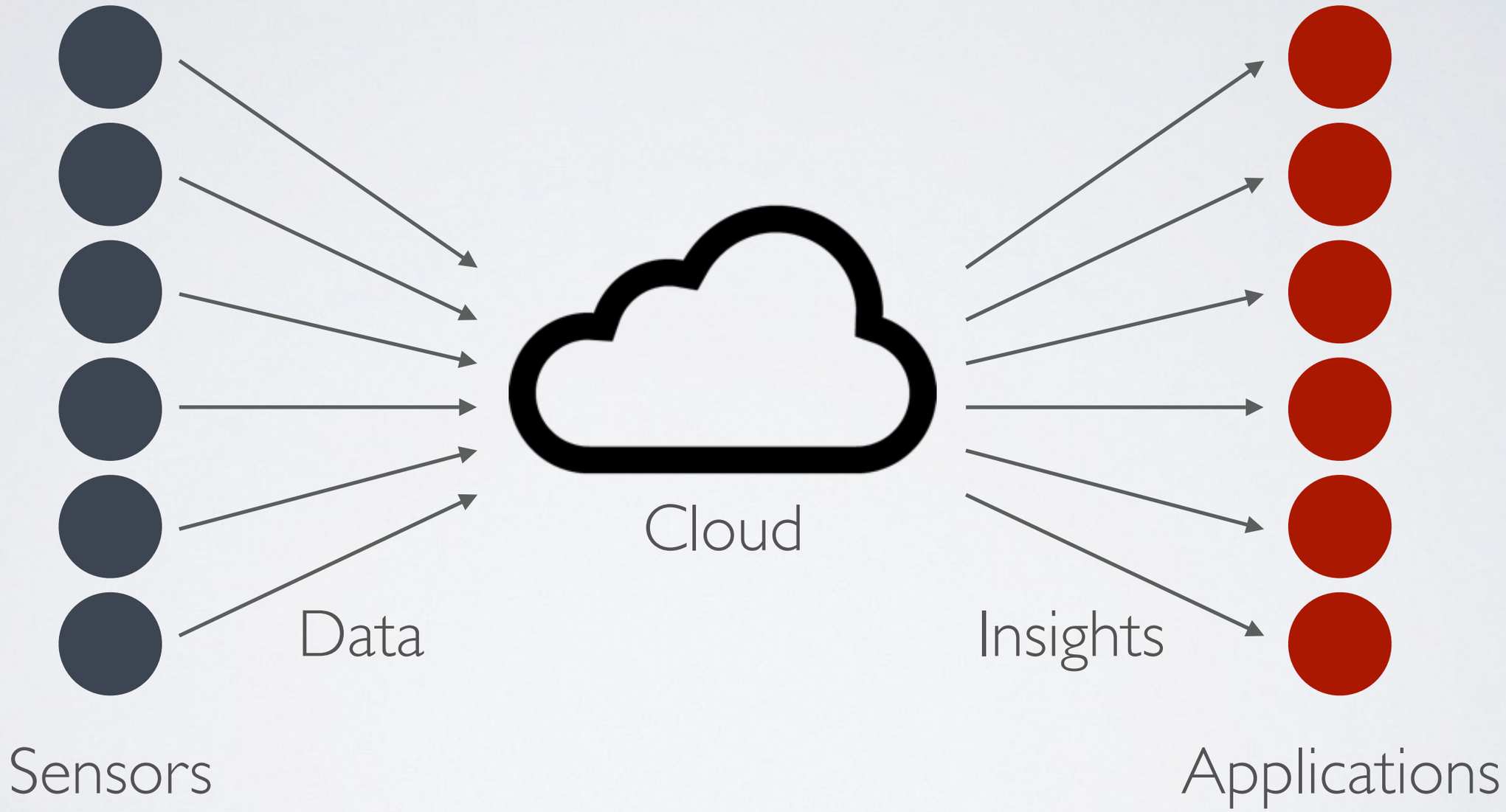

Thank You