Characterizing a Spring Pendulum with Monte Carlo Methods

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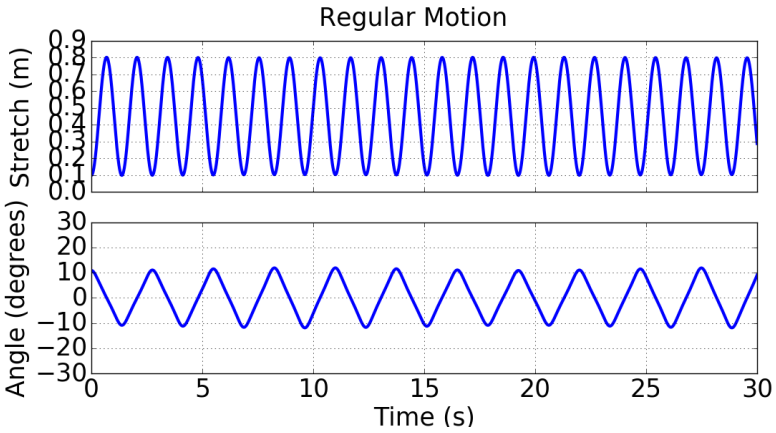
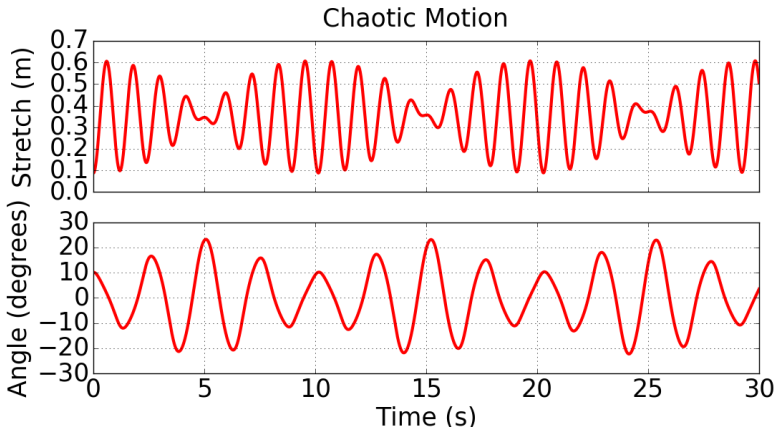
Performance Metric

What is chaotic motion?



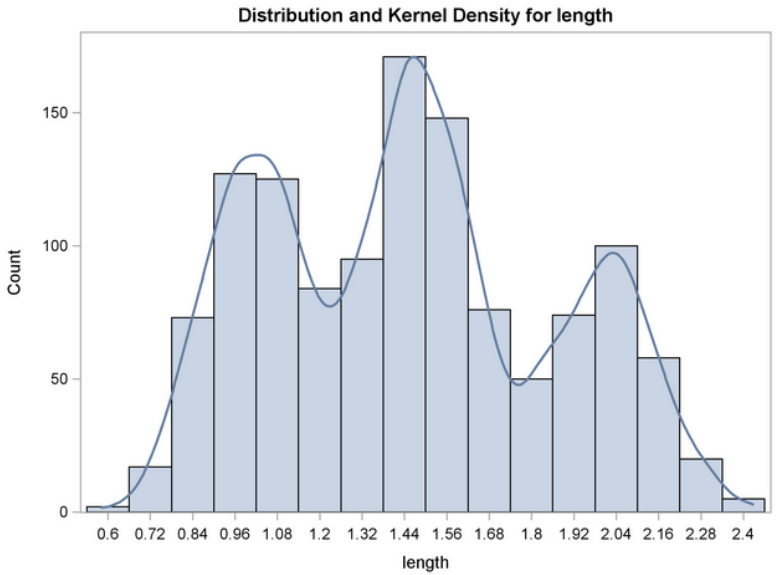


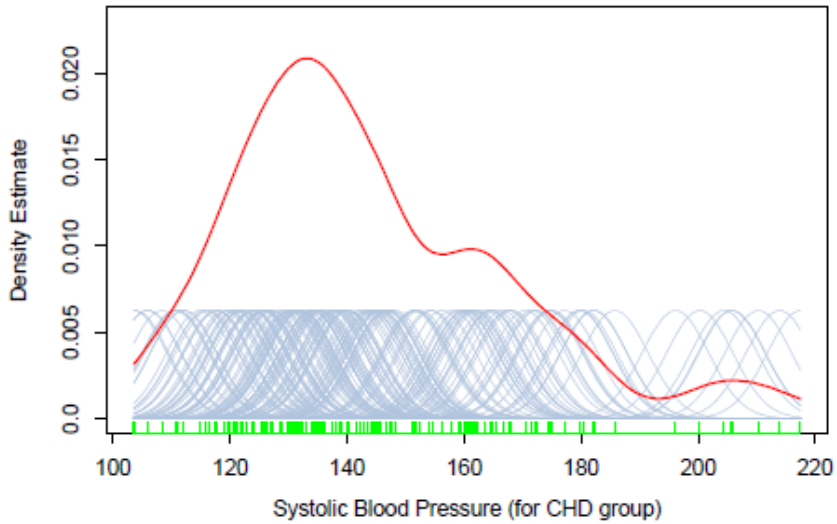
Motion	Gravity	Initial Angle	Initial Stretch	Length	Mass	Spring
Regular	9.57	10.85	0.099	0.8	1.4	29.895
Chaotic	9.73	10.16	0.088	1.065	1.058	29.79

Performance metric: If the max angle exceeds 21°, it is chaotic.

Kernel Density Estimate

What is a kernel density estimate?

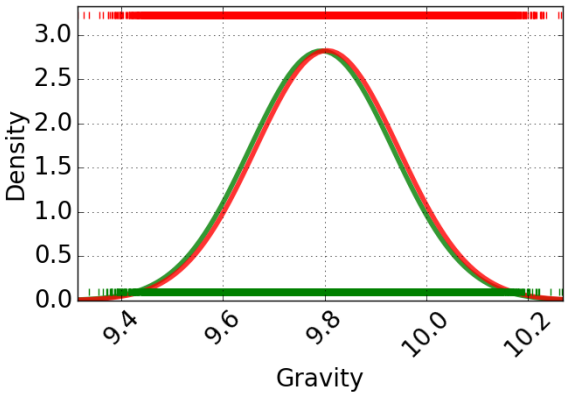


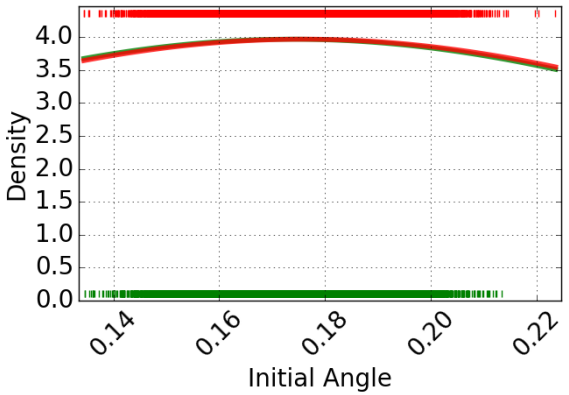


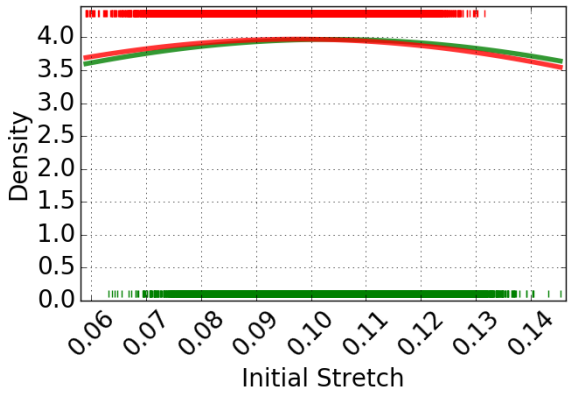
https://support.sas.com/documentation/cdl/en/statug/63033/HTML/default/viewer.htm

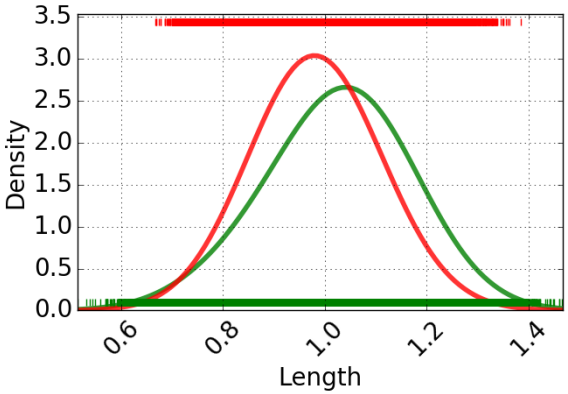
https://web.stanford.edu/ hastie/Papers/ESLII.pdf

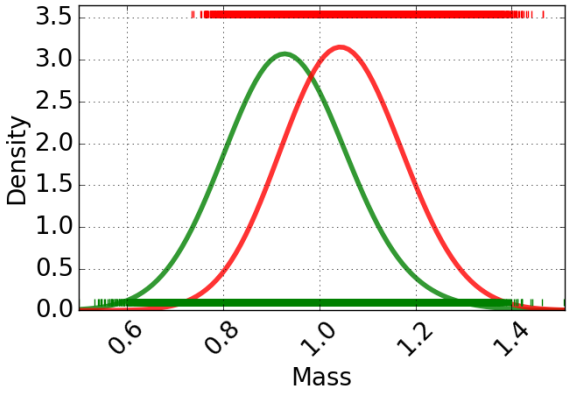
KDE

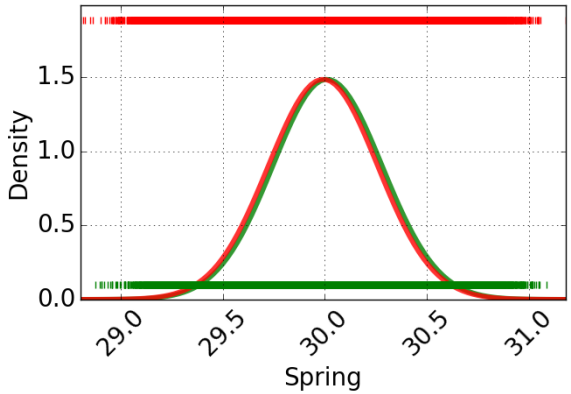

Density
Gravity
9.4
9.6
9.8
10.0
10.2


Density
Initial Angle
0.14
0.16
0.18
0.20
0.22


Density
Initial Stretch
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14

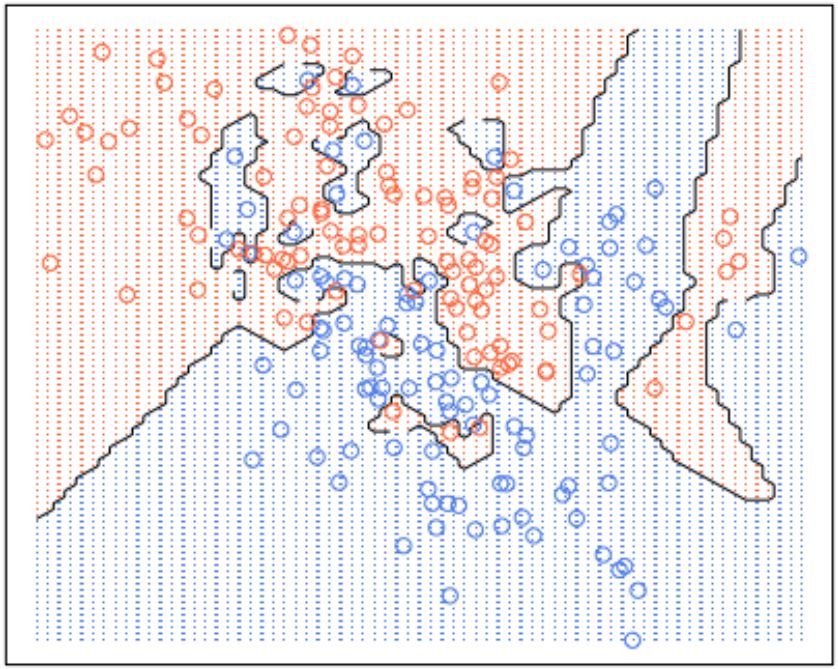

Density
Length
0.6
0.8
1.0
1.2
1.4

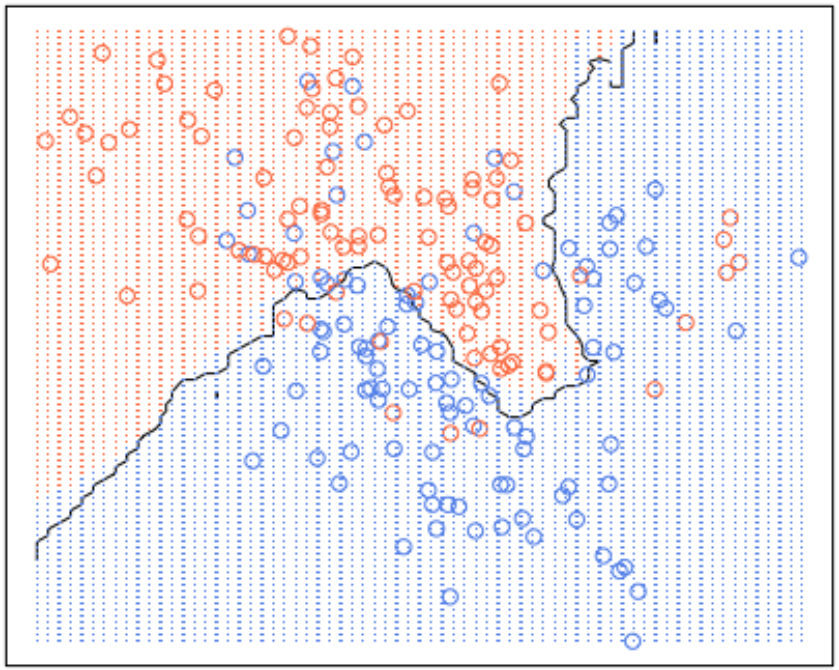

Density
Mass
0.6
0.8
1.0
1.2
1.4


Density
Spring
29.0
29.5
30.0
30.5
31.0

K-Nearest Neighbors

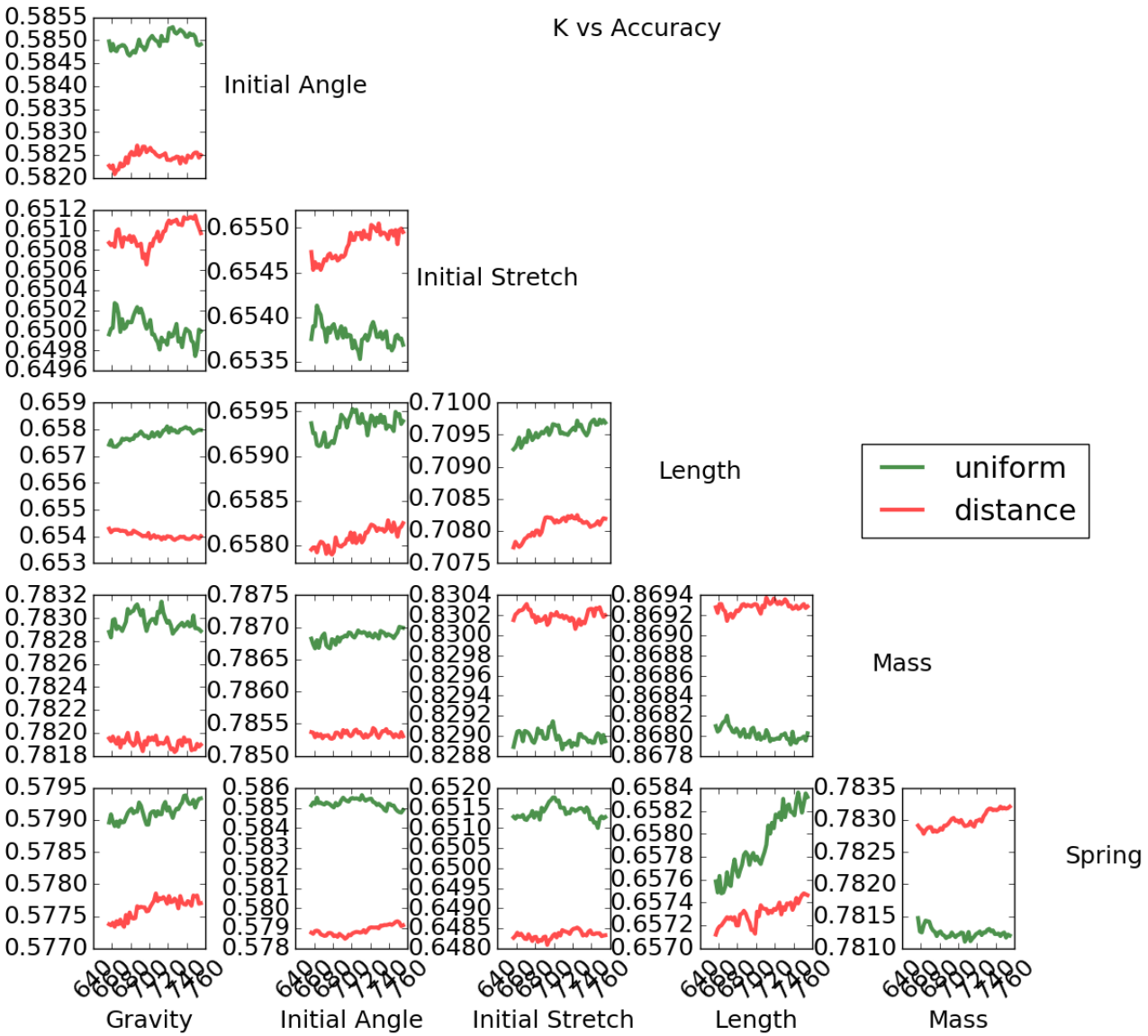
What is the k-nearest neighbor method?



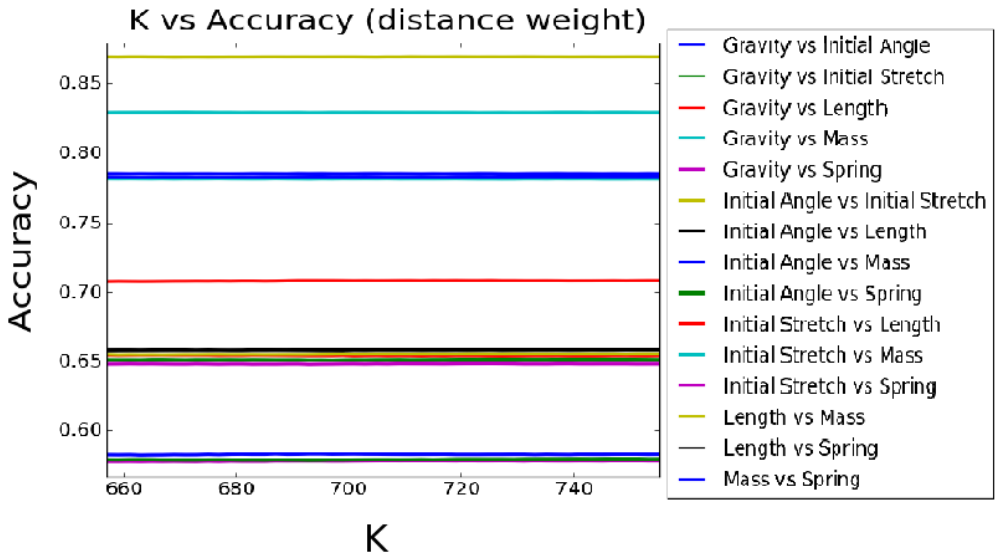


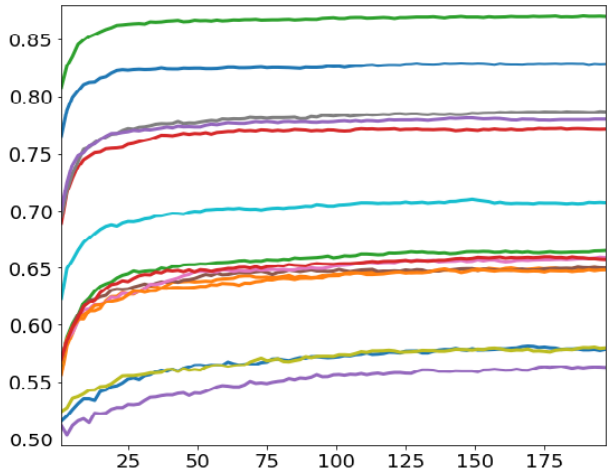
https://kevinzakka.github.io/2016/07/13/k-nearest-neighbor/

KNN

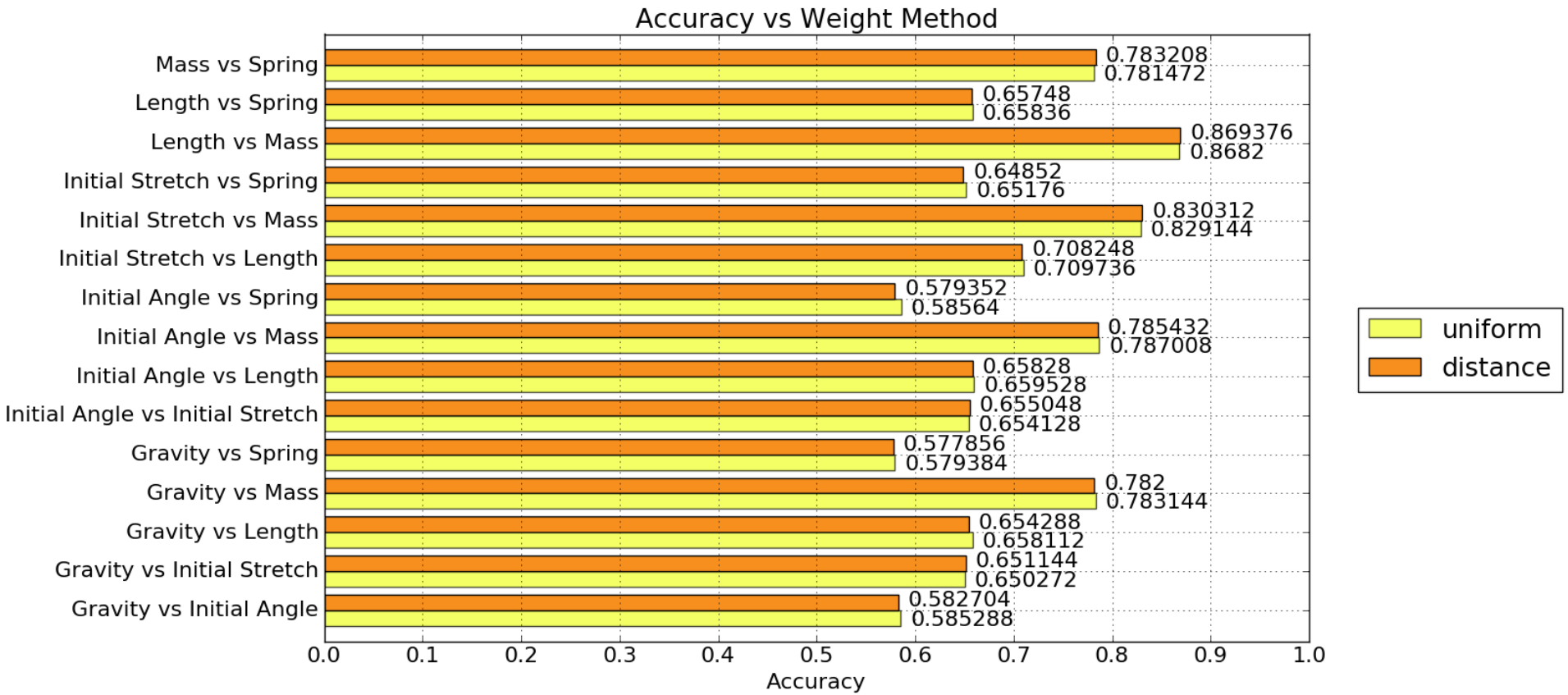

K vs Accuracy
Initial Angle
Initial Stretch
Length
Mass
Spring
Gravity
Initial Angle
Initial Stretch
Length
Mass
uniform
distance

KNN

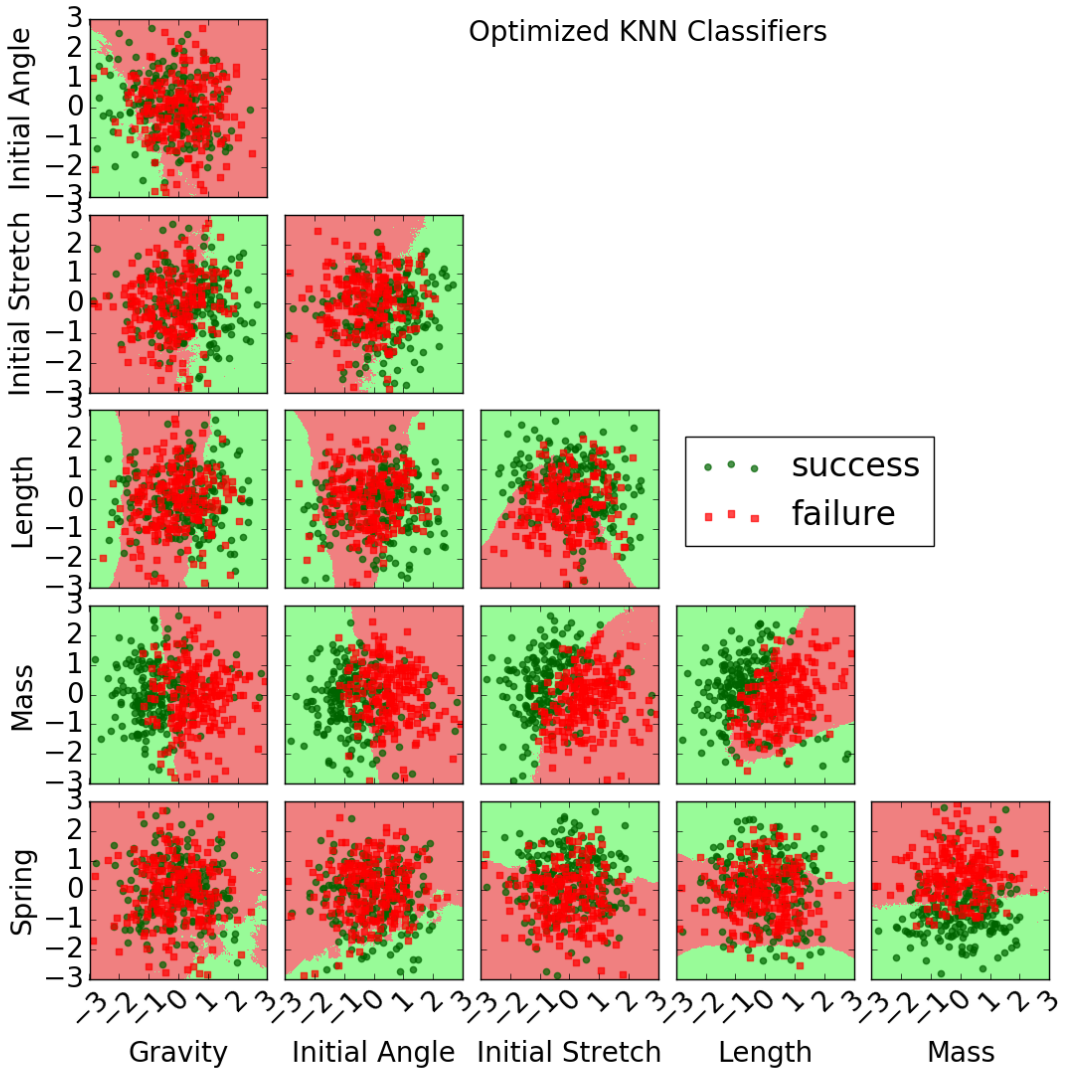

K vs Accuracy (distance weight)
Accuracy
K
0.85
0.80
0.75
0.70
0.65
0.60
660
680
700
720
740
Gravity vs Initial Angle
Gravity vs Initial Stretch
Gravity vs Length
Gravity vs Mass
Gravity vs Spring
Initial Angle vs Initial Stretch
Initial Angle vs Length
Initial Angle vs Mass
Initial Angle vs Spring
Initial Stretch vs Length
Initial Stretch vs Mass
Initial Stretch vs Spring
Length vs Mass
Length vs Spring
Mass vs Spring


0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
25
50
75
100
125
150
175

KNN


Accuracy vs Weight Method
Mass vs Spring
Length vs Spring
Length vs Mass
Initial Stretch vs Spring
Initial Stretch vs Mass
Initial Stretch vs Length
Initial Angle vs Spring
Initial Angle vs Mass
Initial Angle vs Length
Initial Angle vs Initial Stretch
Gravity vs Spring
Gravity vs Mass
Gravity vs Length
Gravity vs Initial Stretch
Gravity vs Initial Angle
0.783208
0.781472
0.65748
0.65836
0.869376
0.8682
0.64852
0.65176
0.830312
0.829144
0.708248
0.709736
0.579352
0.58564
0.785432
0.787008
0.65828
0.659528
0.655048
0.654128
0.577856
0.579384
0.782
0.783144
0.654288
0.658112
0.651144
0.650272
0.582704
0.585288
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Accuracy
uniform
distance

KNN


Optimized KNN Classifiers
success
failure
Gravity
Initial Angle
Initial Stretch
Length
Mass
Spring

Accuracy

Parameters	Accuracy
Mass vs Length	86.94%
Mass vs Initial Stretch	83.03%
Mass vs Initial Angle	78.70%
Mass vs Spring	78.32%
Mass vs Gravity	78.31%
Length vs Initial Stretch	70.97%
Initial Angle vs Length	65.95%
Length vs Spring	65.84%
Length vs Gravity	65.81%
Initial Angle vs Initial Stretch	65.50%
Initial Stretch vs Spring	65.18%
Initial Stretch vs Gravity	65.11%
Initial Angle vs Spring	58.56%
Initial Angle vs Gravity	58.53%
Spring vs Gravity	57.94%

Further Investigation

- Step sizes, computation time, and error
- Parallel processing