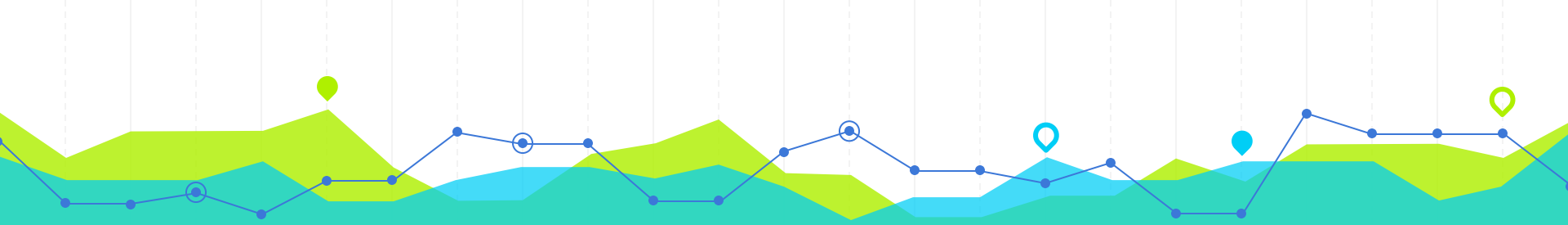


Eye Movement Classification with K-Means Clustering

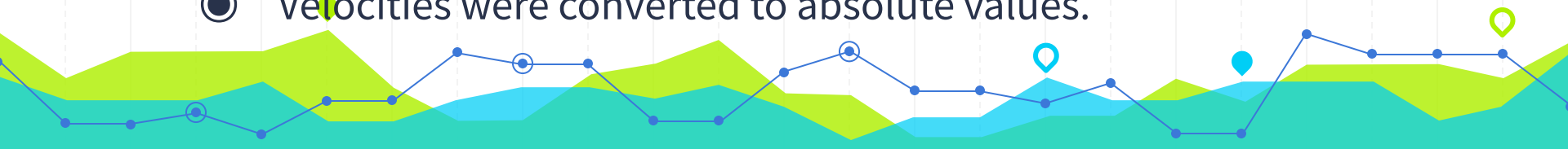
Gentry Atkinson

Introduction:

- Eye tracking depends on rapid and accurate classification of eye movements into fixations and saccades.
- Clustering techniques learn division within data based on some distance measure.
- K-Means is one of the oldest and most well established clustering algorithms.

K-Means:

- First developed in 1967
- Defines k "centroids" in a dataset.
- Iteratively assigns points to a centroid and then adjusts centroids to fit points.
- Running with k=2 is best suited to finding fixations and saccades.
- O(n) amongst friends.
- Provided by Matlab (and many other sources).
- Velocities were converted to absolute values.



K-Means Algorithm:

Given set of data points $s=\{s_1,...,s_n\}$
Randomly initialize set $c=\{c_1,...,c_k\}$ of k centroids
Initialize a set of results $r=\{r_1,...,r_n\}$ to zeros

Loop until c does not change:
  for i = 1 to n:
    min_cluster = 0
    min_distance = MAX_FLOAT
    for j = 1 to k:
      calculate distance(s_i, c_j)
      if (distance < min_distance):
        min_cluster = j
        min_distance = distance
    r_i = min_cluster

  for i = 1 to k:
    calculate the centroid of each cluster i
    set c_i = to centroid i

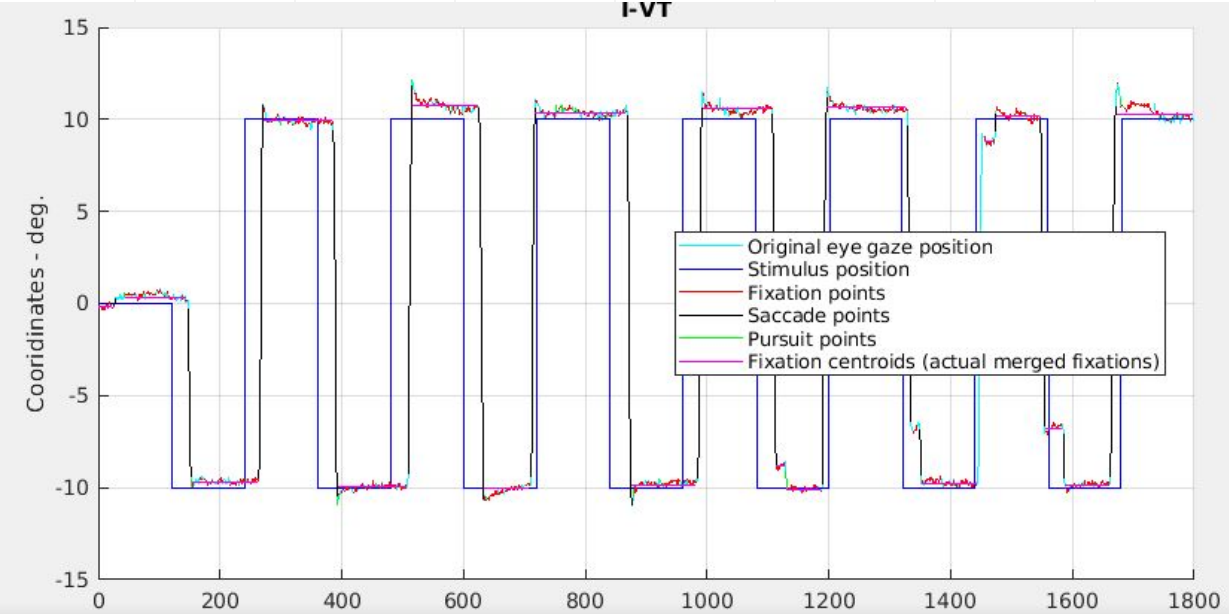
Return sets c and r. R is the cluster for each point in s, and c is the centroid of each cluster.

Table 1: The K-Means Algorithm

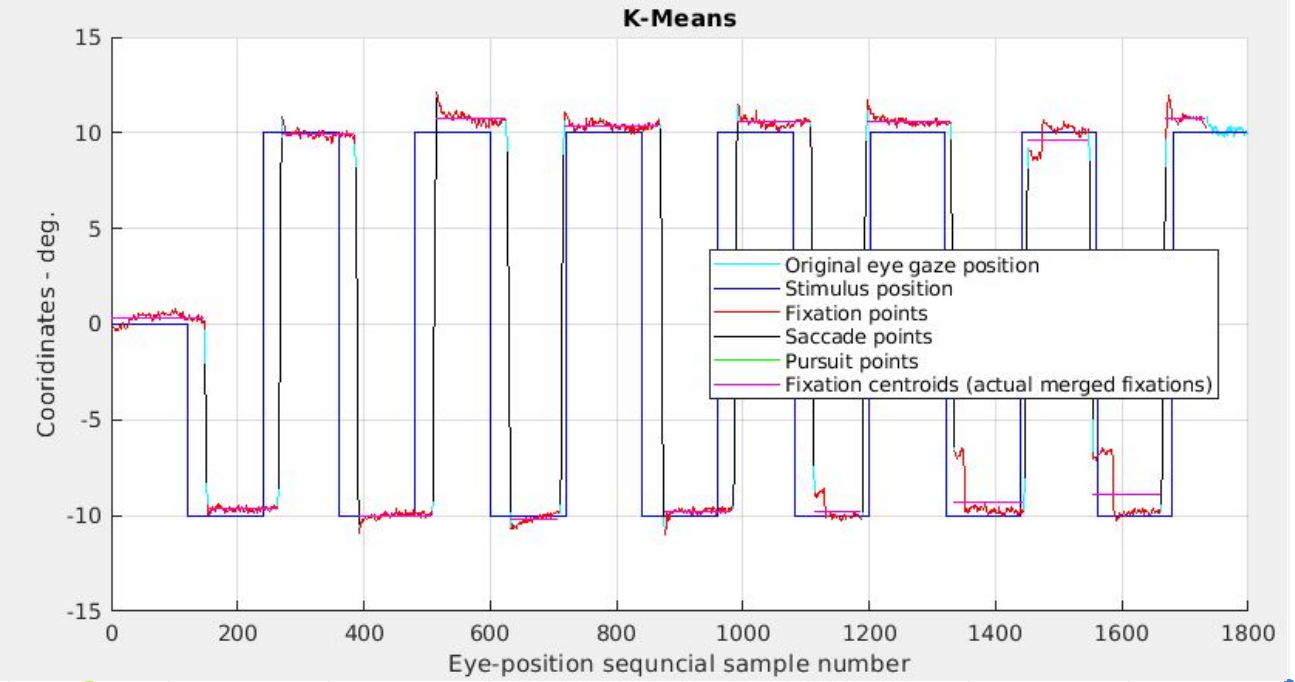
I-VT vs. K-Means:

I-VT	K-Means
Depends on predefined threshold.	Learns divisions from data.
Only considers velocity.	Can scale to arbitrary dimensions.
Tailored to eye movement classification.	Can be applied to any data.

Results I-VT:


I-VT
Cooridinates - deg.
15
10
5
0
-5
-10
-15
0
200
400
600
800
1000
1200
1400
1600
1800
Original eye gaze position
Stimulus position
Fixation points
Saccade points
Pursuit points
Fixation centroids (actual merged fixations)

Results K-Means:



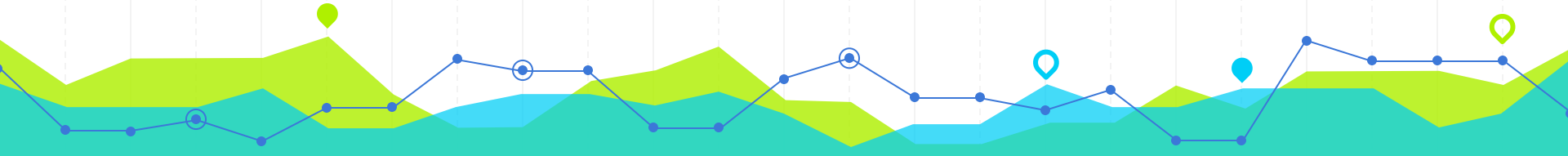
Results Scoring:

	Saccade Quantitative	Fixation Quantitative	Fixation Qualitative
I-VT	94.8	66.67	0.31
K-Means	89.77	79.71	0.46

Table 2: Scoring of the two classification algorithms

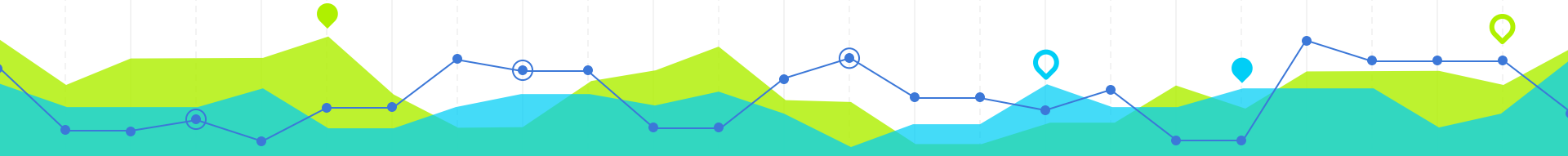
Results Analysis:

- K-Means found "smoother" fixations.
- I-VT was 5% better on the saccade quantitative score and 0.15 better on the fixation qualitative score.
- K-Means was 13% better on the fixation qualitative score.
- K-Means found one saccade that I-VT missed entirely.
- K-Means struggled at boundary points.



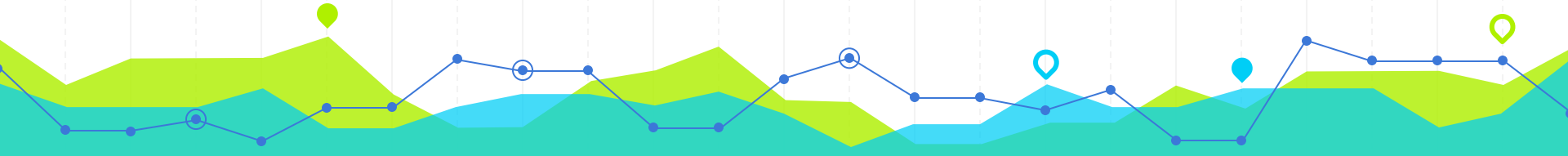
Conclusions:

- K-Means is viable for eye movement classification with refinements.
- I-VT depends on defined thresholds and so may not function on data collected from pathological subjects.
- K-Means can take arbitrary dimensions of input, so merely looking at velocity is limiting.
- Ground truth comparisons may not be the best metric for judging classification algorithms.



Future Work:

- Hierarchical clustering might allow the detection of more nuanced features.
- Density based clustering is very good at compensating for noise.
- A larger feature space could reasonably improve the performance of any clustering algorithm.
- Measures of cluster validity might provide insight into the fitted-ness of an eye movement classification.



Questions or Comments?