Performance Evaluation of a Real-Time Clustering Algorithm

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Github code repository: https://github.com/gjf2a/flairs2018
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Overview

Real-Time Clustering

- One iteration of training
  - O(1) (constant) time
  - Cannot depend on prior number of training samples
- To train n samples, O(n) is okay
  - After each sample
    - Algorithm must be updated and ready to go.
  - To train n samples, we meet n deadlines.
  - No amortized time!

Performance Evaluation

- One input
  - Sum-of-squared-differences (SSD) between that input and its best-matching cluster
- Set of inputs
  - Mean SSD between each input and its best-matching cluster
- Evaluation Baseline: K-Means++ [2]

Bounded Self-Organizing Clusters (BSOC) [1]

```
setup(max-nodes)
  edges = new min-heap
  nodes = array of inputs

lookup(input)
  for each node
    find distance from input to node
  return (node-index, distance) of
     closest node

train(input)
  insert(input, 1)
  if number of nodes exceeds max-nodes
     edge = edges.remove(smallest edge)
     (n1, n2) = endpoints of edge
     Remove n1 and n2 and their edges
     insert(merged(n1,n2),
            n1.count + n2.count)
```

```
insert(image, count)
  add (image, count) to nodes
  for each existing node n
     d = distance from image to n
     Create and insert a new edge:
     - First vertex is image
     - Second vertex is n
     - Weight is d * max(count(image),
                         count(n))

merged(n1, n2)
  w1 = n1.count / (n1.count + n2.count)
  w2 = n2.count / (n1.count + n2.count)
  img = w1 * n1.image + w2 * n2.image
  return img
```

Random Incremental Clusters (RIC)

```
setup(max-nodes)
 nodes = array of max-nodes inputs
 attempts = 0

lookup(input)
  for each node
    find distance from input to node
  return (node-index, distance) of
     closest node

train(input)
  i = random # from [0, attempts]
  if i < capacity of nodes
    nodes[i] = input
  attempts += 1
```

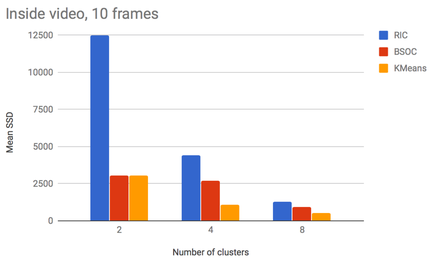
Experiments

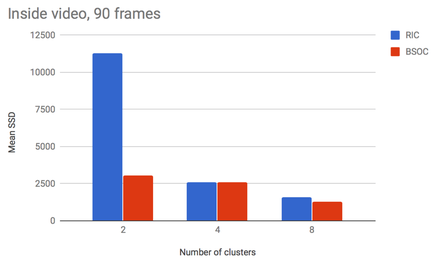
Clustering Problem: Color Clustering

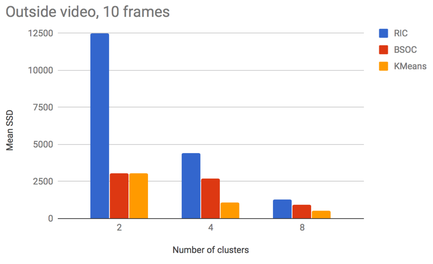
- RGB Image Colors
  - Extremely large variety in a video sequence
- Perform clustering to reduce the total number of colors
  - Each clustered input is an RGB triple

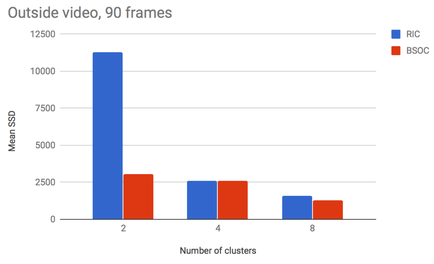
Data

- Two 45-second video sequences
  - Outside - Filmed outdoors on college campus
  - Inside - Filmed indoors in office environment
- Frame dimensions: 1920 x 1080
- Short version - 10 frames, sampled every 4.5 seconds
  - All three algorithms
  - 20,736,000 total pixels clustered
- Long version - 90 frames, samples twice per second
  - Real-time algorithms only
  - 186,624,000 total pixels clustered
  - Memory issues with k-means++ implementation
- Mean SSD for each RIC data point is the mean of ten runs









Conclusions

- In all cases, performance improves with increasing numbers of clusters
- K-Means++ best at minimizing SSD
- BSOC is fairly close to K-Means++
  - Relatively minimal “penalty” for real-time operation
  - Much better memory utilization than K-Means++
- RIC often performs well at larger numbers of clusters

Citations

[1] Gabriel J. Ferrer. "Real-Time Unsupervised Clustering." In *Proceedings of the 27th Modern Artificial Intelligence and Cognitive Science Conference (MAICS-2016)* (Dayton, OH, April 22-23, 2016).

[2] Arthur, D.; Vassilvitskii, S. (2007). "*k*-means++: the advantages of careful seeding.” In *Proceedings of the 18th annual ACM-SIAM symposium on Discrete algorithms*. Society for Industrial and Applied Mathematics Philadelphia, PA, USA. pp. 1027–1035.