Clustering of Visual Data using Ant-inspired Methods

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Overview

• Introduction
• Biologically Inspired Optimization Systems
• ACO - based image classifier
  • Ant Colony Optimization (ACO)
  • Subspace clustering by Ants
  • Experimental Results
• Ant-tree for video summarization
  • Ant-tree - new model for clustering
  • Experimental Results
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Image Classification

- **Data Mining tasks:** feature extraction, pattern recognition, segmentation, feature selection, classification, optimization, annotation, ...

- **Image Classification**
  - the task is to learn to assign images with same semantic content to predefined classes
  - two types of classification schemes: *supervised* and *unsupervised*.

- **Supervised classification**
  - requires relevance feedback from a human annotator and training data

- **Unsupervised classification - Clustering**
  - without training or need for knowledge about the data

*The performance of the image classification algorithms relies on the efficient optimisation techniques*
Biologically Inspired Optimisation techniques

- Recent developments in applied and heuristic optimisation have been strongly influenced and inspired by natural and biological systems.

- **Biologically Inspired systems:**
  - Artificial Immune Systems,
  - Particle Swarm,
  - Ant Colony Systems
Ant Colony Optimisation (ACO)

- Meta-heuristic that uses strategies of ants to solve optimization problems.

- An important and interesting behavior of ant colonies is their foraging behavior, and, in particular, how ants can find shortest paths between food sources and their nest, using pheromone driven communication.
Ant Colony System

• The Ant System algorithm (AS) was first proposed to solving the Traveling Salesman Problem (TSP).
  - Given a set of \( n \) points and a set of distances between them, we call \( d_{ij} \) the length of the path between points \( i \) and \( j \).

  o The probability of choosing next \( j \) node:

  \[
  p_{ij}^{k}(t) = \frac{(\tau_{ij}(t))^\alpha (\eta_{ij})^\beta}{\sum_{k \in \text{allowed}} (\tau_{ij}(t))^\alpha (\eta_{ij})^\beta}, \text{ otherwise } 0
  \]

  o Heuristic information:

  \[\eta_{ij} = \frac{1}{d_{ij}}\]

  o Pheromone value:

  \[
  \tau_{ij}(t) = \rho \cdot \tau_{ij}(t - 1) + \Delta \tau_{ij}
  \]

  \[
  \Delta \tau_{ij}^k = \frac{Q}{L_k}, \text{ if } k \text{-th ant use edge}(i, j)
  \]

  \[
  \Delta \tau_{ij}^k = 0, \text{ otherwise}
  \]
• Combination of low-level visual features in Clustering
  • Each group of images may correlate with respect to different set of important features, and each group may contain some irrelevant features
• Ant Colony Optimisation and its learning mechanism is implemented for optimizing feature weights for each cluster of images.

Each ant clusters images according to:

• different local feature weights
• pheromone value from previous solutions
Subspace Clustering using ACO

Multi-feature Combination: \[ D^\alpha(x, \bar{x}) = \sum_{l=1}^{m} \alpha_l D_l(F_l, \bar{F}_l) \]

**Proposed Algorithm**

1. Each ant will assign each image \( x_i, 1 \leq i \leq n \) to the cluster \( \pi_u, 1 \leq u \leq k \), with the probability \( P_{(x_i, \pi_u)} \) obtained from:
   \[
P_{(x_i, \pi_u)} = \frac{\tau(x_i, \pi_u) \eta(x_i, \pi_u)}{\sum_{u=1}^{K} \tau(x_i, \pi_u) \eta(x_i, \pi_u)} \quad \text{with} \quad \eta(x_i, \pi_u) = \frac{B}{D^\alpha_u(x_i, c_u)}
   \]

2. Computation of weights:
   \[
   \alpha_{(u,l)} = \frac{e^{-R \cdot AD_{(u,l)}}}{\sqrt{\sum_{s=1}^{m} e^{-2R \cdot AD_{(u,s)}}}} \quad \text{and} \quad AD_{(u,l)} = \frac{1}{|\pi_u|} \sum_{x \in \pi_u} D_i(x, c_u)
   \]

3. Computation of centroids.

4. Pheromone Update:
   \[
   \tau_{(x_i, c_u)}(t) = \rho \cdot \tau_{(x_i, c_u)}(t - 1) + \sum_{A=1}^{S} \Delta \tau_{(x_i, c_u)}^A(t)
   \]
   \[
   \Delta \tau_{(x_i, c_u)}^A = \begin{cases} 
   \frac{\Lambda^A(\alpha_u)}{n \cdot \Gamma^A(\alpha_u)}, & \text{if } x_i \text{ belongs to cluster } \pi_u \\
   0, & \text{otherwise}
   \end{cases}
   \]
**Experimental Evaluation**

• Low-level features (descriptors) used for visual representation of images:
  • Colour Layout (CLD),
  • Colour Structure (CSD),
  • Dominant Colour (DCD),
  • Edge Histogram (EHD)
  • Grey Level Co-occurrence Matrix (GLC)

**Synthetic Data**

![Image of synthetic data](image)

**Results:**

<table>
<thead>
<tr>
<th>Feature Weighting</th>
<th>CLD</th>
<th>DCD</th>
<th>EHD</th>
<th>GLC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group A</strong></td>
<td>0.03</td>
<td>0.01</td>
<td>0.91</td>
<td>0.05</td>
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<tr>
<td><strong>Group B</strong></td>
<td>0.11</td>
<td>0.76</td>
<td>0.08</td>
<td>0.05</td>
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<tr>
<td><strong>Group C</strong></td>
<td>0.05</td>
<td>0.01</td>
<td>0.10</td>
<td>0.84</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Average Error Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC-ACO</td>
<td>0.06±0.02</td>
</tr>
<tr>
<td>PROCLUS</td>
<td>0.09±0.04</td>
</tr>
<tr>
<td>GFS-K-Means</td>
<td>0.62±0.07</td>
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<tr>
<td>K-Means</td>
<td>0.33±0.08</td>
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Experimental results

- **The Corel image database** - 600 images with 6 semantic concepts

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<tr>
<th>Method</th>
<th>Average Error Rates</th>
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<tbody>
<tr>
<td>SC-ACO</td>
<td>0.30±0.02</td>
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<tr>
<td>PROCLUS</td>
<td>0.37±0.05</td>
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<td>GFS-K-Means</td>
<td>0.47±0.07</td>
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<tr>
<td>K-Means</td>
<td>0.52±0.09</td>
</tr>
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</table>
Experimental results

- **Flickr Image Database** - 500 images segmented into regions.

- **Semantic Concepts**: Sand, Sea, Vegetation, Building, Sky, Person, Rock, Tree, Grass, Ground, and.

<table>
<thead>
<tr>
<th>Method</th>
<th>Average Error Rates</th>
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<tbody>
<tr>
<td></td>
<td>5 concepts</td>
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<tr>
<td>SC-ACO</td>
<td>0.21±0.03</td>
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<tr>
<td>PROCLUS</td>
<td>0.28±0.06</td>
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<td>GFS-K-Means</td>
<td>0.36±0.07</td>
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<tr>
<td>K-Means</td>
<td>0.39±0.08</td>
</tr>
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</table>
Ant-tree for video summarisation

**Ant-Tree clustering method**

- Inspired by self-assembling behavior of African ants and their ability to **build chains (bridges)** by their bodies in order to link leaves together.

- We model the ability of ants to build live structures with their bodies in order to discover, in a distributed and unsupervised way, a **tree-structured organisation** and summarisation of the video data.
**AntTree: New model for clustering**

### General principles
- Each ant \(a_i\) represents a node of the tree (data).
- Outgoing link: \(a_i\) can maintain toward another ant.
- Incoming links: other ants maintain toward \(a_i\).
- \(a_0\) supports \(apos\), the position of the moving ant.

### Main algorithm
1. All ants placed on the support; initialization: \(T_{sim}(a_i) = 1\), \(T_{dissim}(a_i) = 0\).
2. While there exists a non-connected ant \(a_i\) Do
   1. If \(a_i\) is located on the support Then (Support case)
   2. Else \(a_0\) is connected to \(a_i\) Then
      1. Connect \(a_i\) to \(a_0\)
   3. Else \(a_i\) is located on the support Then
   4. Else \(a_0\) is connected to \(a_i\) Then
      1. Let \(a_{pos}\) denote the ant on which \(a_i\) is located.
      2. Let \(a_k\) denote a randomly selected neighbour of \(a_{pos}\).
      3. If \(Sim(a_i, a_+) > T_{sim}(a_i)\) Then connect \(a_i\) to \(a_{pos}\).
         Else decrease \(T_{dissim}(a_i)\), increase \(T_{sim}(a_i)\) and move \(a_i\) toward \(a_k\).
   5. Else randomly move \(a_i\) toward \(a_k\) (Ant case).
Surveillance video

- Each cluster is represented by a support (representative) frame.

- To make a summary of the whole video, one video segment is taken from each cluster, starting with the support frame.

- To determine the length of the video segment, the maximum number of negative clustered frames going consecutively is used as the threshold.

- Maximum length of the video segment is 10 seconds.
Summarization results (PETS2001)

Camera video – 4 min 30 sec (duration)

Video summary – 53 sec
Future work

- Improvement of SC Method
  Pheromone driven mechanism of ACO will be used for optimization of clustering task by searching for number of clusters that leads to best clustering.

- Implementation of FS for Video Summarization and Scene Detection
  The aim of this task is to detect and classify events from video using intelligent combination of multiple low-level visual features.
Thank you for your attention!

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