A Classification Committee Approach for Improving the Accuracy of Image Query Systems

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AGENDA

- Introduction.
- System architecture and requirements.
- Image Preprocessing.
- Base Classifiers.
- Committee Rules.
- System Engineering Considerations.
INTRODUCTION

- Image annotation is a key component of image retrieval systems.

- Manual annotation of images is expensive and error prone, leading to the interest in automated image annotation systems.

- Theoretically, if all images came with detailed and accurate annotation, retrieval would be an easy task.
INTRODUCTION CONTINUED

- Automatic image annotation is currently the main area of research in CBIR (Content Based Image Retrieval) systems.

- In this approach, we try to identify objects in an image and generate descriptions of the image based on pre-defined sets of keywords.

- Accurate description of images using keywords is the goal of the systems of interest in this project.
Introduction Continued

- Automated image annotation relies on available images and their textual annotations from hosting sites such as Flickr.

- These human annotations are used for training classification algorithms that should then be able to generate annotations for new untagged images.

- The accuracy of the generated annotations depends directly on the classifier.
The goal of this proposal is to present a new system for image classification that relies on combining the annotations of a number of “base” classifiers.

The underlying assumption, is that combining the predictions of a number of individual classifiers will lead to improved accuracy of the final annotation system.
Two necessary and sufficient conditions are needed for this assumption to be true:

- Each individual classifier in the committee has prediction accuracy superior to a random classifier (more than 50% accuracy).

- The individual base classifiers are diverse in their annotations. If the base classifiers agree on their annotations, there would be no benefit in having a committee in the first place.
SYSTEM REQUIREMENTS

- The system shall reduce the amount of time spent in image searching.
- The system shall be more dependable by the users.
- The system shall define the image based on the color, text, and pixels.
- The system shall use a voting committee to ensure that the problem is solved from different perspectives.
- The system should ensure that the proposed ensemble of classifiers exceeds the level of accuracy for the single machine learning based annotation system in the report.
SYSTEM REQUIREMENTS CONTINUED

- Image annotation performance shall be evaluated by comparing the captions automatically generated for a test set of images, with the human-produced annotation (ground-truth).

- The two main measures of annotation power are defined as the recall and the precision of the system.

  - Recall (R) = Correct Annotated Images / Total Human
  - Precision (P) = Correct Annotated Images / Total Assigned
# Evaluations Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Average per-word precision</td>
</tr>
<tr>
<td>R</td>
<td>Average per-word recall</td>
</tr>
<tr>
<td># words NZR</td>
<td>Number of words with non-zero recall (measures the level of learning achieved)</td>
</tr>
</tbody>
</table>
CURRENT ACCURACY VALUES

- The level of accuracy recently reported for a Supervised Machine Learning Annotation model is given below as an example for the values expected:

<table>
<thead>
<tr>
<th>Method</th>
<th>P</th>
<th>R</th>
<th># Words NZR</th>
</tr>
</thead>
<tbody>
<tr>
<td>SML</td>
<td>0.13</td>
<td>0.21</td>
<td>424</td>
</tr>
</tbody>
</table>
SYSTEM ARCHITECTURE

Image Collection

Training Set

Test Set

Region Segmentation

Pixel Density Filter

PCA

Preprocessor

Individual Classifiers

Neural Networks Classifier

kNN Classifier

Support Vector Machine Classifier

Tree bagging Classifier

Voting Committee

Keywords

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DATA SET DIVISION

- The total images available are divided into two sets:
  - Training set: 80% of the number of annotated images available
  - Test Set: 20% of the number of annotated images available
  - The training set is used for training the base classifiers
  - The test set is used for out-of-sample testing of the base classifiers. The weights given to any base classifier in the committee decision depends on its accuracy in annotating the test set.
IMAGE PREPROCESSING

The preprocessing phase takes place in three steps:

- Image region segmentation
- Image size reduction using a Pixel Density Filter
- Variable reduction using Principal Component Analysis
IMAGE SEGMENTATION

- Images are segmented using the Normalized Cuts algorithm [40] which segments images by pixel color, similarity and proximity.

- The more segments used, the more accurate the representation will be, but the problem size will increase as well.

- In this study, we limit ourselves to 100 segment per image as shown in the figure next.
IMAGE SEGMENTATION

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**Pixel Density Filter**

- In classifying images, a set of features are selected to characterize each image.

- Selecting a large number of features will lead to more accurate characterization, but will make the problem size too large for even the most efficient algorithms.

- The Pixel Density Filter suggested in this study resolves this issue by using the most predominant pixel in each segment of the image.
Pixel Density Filter - Continued

- The goal is to provide a representative set of feature for the original image without exceeding a maximum number of variables.

- Using the most predominant (mode) pixel value in a given region will give a more accurate representation of the content of the image than using the average over the region [10].
PRINCIPAL COMPONENT ANALYSIS

- PCA is a linear transformation that is commonly used to reduce the size of a data set by identifying its most important components and ignoring the less important ones.

- PCA has been successfully applied in many fields such as face recognition, signal processing and others [29].

- Other subspace methods can be used for the same purpose, but PCA is used in this project for its simplicity.
DATA PREPROCESSING FLOW CHART

Training Data set

Pixel Density Filter

PCA

Transformation Matrix

Output selected feature subset
SELECTING AND TRAINING BASE CLASSIFIERS

- The task of a base classifier is to use the feature vector provided by the pre-processor to assign the image to a category.

- The degree of difficulty of the classification problem depends on the variability in the feature values for images in the same class.

- The variability of features of images in the same class could be due to complexity of the image content or due to noise.
BASE CLASSIFIERS - CONTINUED

- Noise impacts classification algorithms in different degrees, and thus the idea of training multiple base classifiers and using an ensemble to find the final annotation.

- Base Classifier performance is measured by the classification error rate, the percentage of new images that are assigned the wrong annotation keyword.

- The “super classifier” or committee of base classifiers will achieve an optimum decision.
Classifier Training (Supervised Learning)

- Creating a base classifier involves selecting an algorithm and using training patterns to learn, or estimate the unknown parameters of the model.

- Learning refers to the classifier adjusting the model parameters in order to reduce the classification error rate.

- In supervised learning, the “teacher” provides the keywords for each pattern in the training set and seeks to adjust the model parameters to reduce the total error over that set.
In supervised learning, we have to pay particular attention to over-fitting (the system is memorizing rather than learning from the training patterns).

Over-fitting can lead to small classification error in the training set but large error in out of sample test sets.
BASE CLASSIFIER 1 – ARTIFICIAL NEURAL NETWORKS

- ANN are based on the principles of biological neural networks.

- ANN allow for the modeling and analysis of complex nonlinear system.

- The main advantage of ANN is their ability to "learn" from the data rather than needing to be programmed with specific pre-conceived rules.
BASE CLASSIFIER 1 – ARTIFICIAL NEURAL NETWORKS - CONTINUED

- Just like human brain, ANN learn by example and continuously adjust to better fit the training data presented to them.

- One main advantage of ANN, is their ability to learn from noisy, incomplete or distorted training data.

- Each ANN is composed of an input layer, a number of hidden layers, and an output layer.
**Base Classifier 2 – Nearest Neighbor**

- In this algorithm, a new image is classifier based on the distance to the nearest training image.

- The annotation of the new image is then based on the annotation of the nearest training image (nearest neighbor).

- The k-NN algorithm, extends this concept by using the annotations of the “k” nearest points, where k is usually 3 or 5.
**Base Classifier 2 – Nearest Neighbor - Continued**

- The k-NN algorithm belongs to the family of non-parametric classifiers as it requires no prior training.

- Advantages of k-NN include:
  - Handling large number of classes
  - Avoids over-fitting of parameters (no parameters to estimate)
  - Requires no learning phase (which can take few days in large dynamic databases for algorithms such as ANN).
BASE CLASSIFIER 3 – SUPPORT VECTOR MACHINES

- Support Vector Machines (SVM) belong to the family of binary linear classifiers that assign each image to one of two classes.

- To apply SVM to a multi-class problem similar to the one addressed in this project, we have to combine a number of SVM classifiers $K$ (where $K$ is the number of classes) in parallel.

- The main advantage of SVM is its ability to perform better in terms of not over-fitting the training data leading to better out-of-sample accuracy.
Base Classifier 4 - Decision Trees

- In this algorithm, each image is classified based on a sequence of questions, in which the next question asked depends on the answer to the current question.

- The questions (nodes) are connected in a tree diagram until we reach a terminal or leaf node which has no further links.

- The classification of any pattern begins at the root node and ends at a leaf node which has no further questions.
BASE CLASSIFIER 4 – DECISION TREES - CONTINUED

- Each leaf node bears a category label (annotation keywords) and the new pattern is assigned the same label as the leaf reached.

- The main advantage of decision trees, is the interpretability, as classification is based on a set of logical questions.

- Another advantage of decision trees is that they lead to rapid classification, employing a sequence of simple queries.
ENSEMBLE OF BASE CLASSIFIERS

○ The base classifiers are combined together using a measurement-based approach where the weight of each base classifier depends directly on its measured performance in out-of-sample testing.

○ The improvement in accuracy of the ensemble of classifiers depends directly on the diversity of the base classifiers that make up the ensemble.

○ Diversity of base classifier in this project is achieved through the selection of four different learning algorithms.
Ensemble of Base Classifiers - Continued

- Multiple learning algorithms help protect the ensemble from being burdened by poor performance of any single base classifier.

- The only disadvantage of this approach is the need to program and train different learning algorithms which can be costly and challenging.
ADDITIONAL SYSTEM CONSIDERATIONS – LEAN ELEMENTS

- Specify value from the standpoint of the end customer
- Identify all the steps in the value stream eliminating every step and every action that does not create value
- Make the remaining value-creating steps occur in an integrated sequence, so the product flows smoothly to the customer
- As flow is introduced, let customers pull value from the next upstream activity
- Pursue perfection through continuous improvement
ADDITIONAL SYSTEM CONSIDERATIONS – SOFTWARE QUALITY ELEMENTS

- Functionality → Accuracy, Compliance, Security, Suitability
- Reliability → Fault tolerance, Maturity, Recoverability
- Efficiency → Resource behavior, time behavior
- Usability → Learnability, Operability, Understandability
- Portability → Adaptability, Installability, Replaceability
- Maintainability → Changeability, Stability, Testability
The four main ethical issues to consider in this project are:

- Using open-source code without properly crediting the source.
- Using illegal software
- Reverse engineering code to find out how a process works
- Not addressing known bugs
REFERENCES


REFERENCES

42. The official website of the https://www.corel.com. Photo CD's can also be purchased from third parties such as Amazon.com or Ebay.com.

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REFERENCES