Delaunay Diagram Representations For Use in Image Near-Duplicate Detection

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Abstract and Motivation

Given an image or Delaunay Triangulation diagram representation, we want to identify a near-duplicate in an image database. This is done by computing the corner points of the image under some default settings, using the Voronoi diagram to adjust these settings in order to get better adjusted corner points for the image, and then using the Delaunay Triangulation of the image to identify whether there are possible duplicates in the database. The project investigates Voronoi Diagrams based on a default Harris Corner Detector as an image segmentation technique for adjusting the threshold for the Harris Corner Detector, as well as Delaunay Triangulation Diagrams as a measure of similarity between images.

Image Near-Duplicates

Image duplicates are images that are identical in all respects to one another. Near-duplicates fall into three groups based on the nature of modifications:

- Changes in scene (objects inside the scene change between images)
- Changes in camera (camera perspective changes between images)
- Changes in image (image transformations applied in post-production).

Here, we are only interested in last category: images have same digital source, where transformations are applied later.

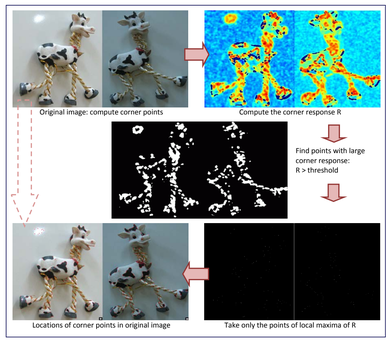
Methodology

Image Transformations Considered

Simple, linear transformations are considered, that can be grouped as:

- Changes in image size/ aspect ratio: cropping, scaling (geometric)
- Changes in image aspect: blurring, contrast, luminosity (photometric)
- Changes in image content: rotation, reflection, horizontal shear (geometric)

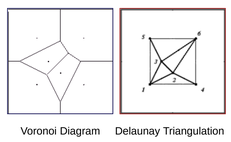
The Harris Corner Points Detector



Voronoi Diagrams

A Voronoi diagram is a decomposition of the metric space determined by distances to specific points in space, such that each point is associated with the region of the plane closest to it.

Delaunay Triangulations



The dual of the Voronoi Diagram is called the Delaunay Triangulation.

Graph Similarity

Near-duplicate graphs can:

- Be isomorphic to the original
- Be subgraphs or induced subgraphs
- Be minors of the original graph
- Have the same chromatic numbers and graph diameter.

Automatic Threshold Adjustment

Conditions Voronoi diagram needs to meet for the accurate threshold:

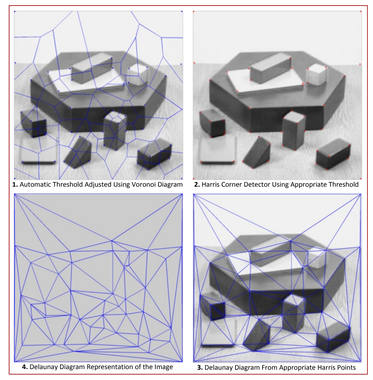
1. $\max(Ac_i) < \frac{A}{4}$
2. $\mathrm{Ac_i} > \frac{A}{numcells^2}$
3. $\sum_i Ac_i < \frac{A}{numcells}$, for all $i =$ $\{1, 2, \ldots, numcells\}$ where $Ac_i < \frac{A}{numcells}$
4. $numcells \geq \frac{\sqrt{A}}{5}$

Condition 4 has to be met even if the others aren't: the program stops execution once it isn't met.

The symbols used above are:

- *numcells* = number of cells in Voronoi Diagram = number of Harris Corner Points
- A = area of image
- Ac_i = area of cell i

Encoding an Image as a Graph: Delaunay Triangulations

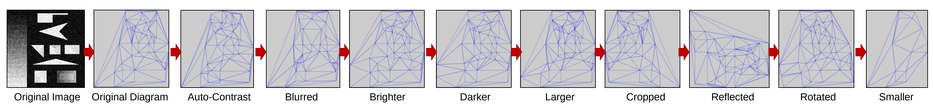


The premise of the project is that images can be encoded as graphs, and that there are some benefits in encoding them as such.

The following algorithm converts an image into a graph:

- Use threshold adjustment algorithm;
- Compute best Harris Points on the image;
- Use the DelaunayTri MATLAB function to compute the Delaunay Triangulation
- Save the result as the graphical encoding of the image –an unweighted graph (for now)

Results



Above you can see the original image, as well as the Delaunay Diagrams of all transformations supported in the project.

The Diagrams were generated using the auto-adjusted threshold, which seems to work very well, albeit very slowly. From the generated data, we can see that the graphs are similar to one another, in ways that were expected (expressed above).

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Conclusions and Future Plans

- Using graphs for image similarity is a plausible approach.
- Delaunay graph representations of images can be useful when searching for near duplicates, especially if the searched image is not-to-be-disclosed to the owners of the database
- Future plans include improving the run-time of the threshold auto-adjustment program, writing code to compare graphs (might involve exporting to Mathematica), using weighted graphs (where the weight is the distance between vertices) etc.
- In order to make machine duplicate-detection more similar to human duplicate-detection, we may design a study in which people are presented with Delaunay Diagrams and asked to say whether the two graphs are encodings of near-duplicates. This will help in identifying what criteria people use to classify those graphs. We might also ask subjects to identify the causing transformations based on the graphs.

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