A Proper Choice of Vertices for Triangulation Representation of Digital Images

Ivana Kolingerova, Josef Kohout, Michal Rulf, Vaclav Uher, Proc. 2010 International Conference on Computer Vision and Graphics: Part II, pp. 41-48, 2010.

Milestones and Advances in Image Analysis

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04. December 2012

Contens

Motivation

Triangulation

- representation of digital images
- enables geometric transformations
- very simple
- low compression in comparison with frequency-based methods

Can we save disk space while preserving a good quality?

Strategy

choose the triangulation vertices randomly

Triangulation

What to do:

1. assess proper number of vertices (computed from compression rate or given by the user)
2. choose set of pixels
3. compute triangulation with Delaunay triangulation
4. decoding

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Triangulation - 2) choose set of pixels

2) choose set of pixels

- in general, choose edge points

Edge Point

A strong change in the grey values within a neighbourhood indicates an edge.

source: IPCV 2011-12

- edge detecting operators:
  - Roberts's operator
  - Laplace operator
  - Gaussian operator

Triangulation - 2) choose set of pixels

Roberts's operator

$$Op_{Roberts}(i,j,f_{i,j}) = |\underbrace{f_{i,j} - f_{i+1,j+1}}_{\begin{array}{|c|c|}\hline 1 & 0 \\ \hline 0 & -1 \\ \hline\end{array}_{f_{i,j}}}| + |\underbrace{f_{i+1,j} - f_{i,j+1}}_{\begin{array}{|c|c|}\hline 0 & 1 \\ \hline -1 & 0 \\ \hline\end{array}_{f_{i,j}}}|$$

[i,j] belongs to the set of vertices if

$Op_{Roberts}(i,j,f_{i,j}) > T$

- picture f
- pixel i,j
- threshold T

Triangulation - 2) choose set of pixels

Laplace operator (Laplace4)

$$Op_{Laplace4}(i,j,f_{i,j}) = \left| \underbrace{f_{i,j-1} + f_{i,j+1} + f_{i-1,j} + f_{i+1,j} - 4f_{i,j}}_{\begin{array}{|c|c|c|}\hline 0 & 1 & 0 \\ \hline 1 & -4 & 1 \\ \hline 0 & 1 & 0 \\ \hline \end{array}\, f_{i,j}} \right|$$

[i,j] belongs to the set of vertices if

$Op_{Laplace4}(i,j,f_{i,j}) > T$

- picture f
- pixel i,j
- threshold T

Triangulation - 2) choose set of pixels

Laplace operator (Laplace8)

$$Op_{Laplace8}(i,j,f_{i,j}) =$$

$$\left|\underbrace{f_{i-1,j-1} + f_{i-1,j} + f_{i-1,j+1} + f_{i,j-1} + f_{i,j+1} + f_{i+1,j-1} + f_{i+1,j} + f_{i+1,j+1} - 8f_{i,j}}_{\begin{array}{|c|c|c|l}\hline 1 & 1 & 1 & \\ \hline 1 & -8 & 1 & f_{i,j} \\ \hline 1 & 1 & 1 & \\ \hline \end{array}}\right|$$

[i,j] belongs to the set of vertices if

$Op_{Laplace8}(i,j,f_{i,j}) > T$

- picture f
- pixel i,j
- threshold T

Triangulation - 2) choose set of pixels

Gaussian operator

$$Op_{Gauß}(i,j,f_{i,j}) = \sum_{k=-v}^{r} \sum_{l=-v}^{r} |f_{i,j} - f_{i+k,j+l} \cdot exp(-\frac{k^2+l^2}{2\sigma^2})|$$

[i,j] belongs to the set of vertices if

$Op_{Gauß}(i,j,f_{i,j}) > T$

- picture f
- pixel i,j
- threshold T
- -v and r: influence factor of the point in this area
- σ : vicinity area, width, standart deviation

Triangulation - 2) choose set of pixels

Figure: The 9-10% pixels with the highest evaluation according to the presented operators, a) Roberts, b) Laplace4, c) Laplace8, d) Gauß

Triangulation - 2) choose set of pixels

Store coodrinates and the intensity of the chosen pixels

Strategy

choose the pixels randomly

$\Rightarrow$ don't have to store coordinates

Reason: coordinates can be recomputed from the seed of the random generator during decoding

- random point: chosen randomly
- edge point: chosen by an edge operator

Triangulation

What to do:

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Triangulation - 4) compute triangulation with Delaunay triangulation

- choose triangles in such a way, that the following property is fulfilled:

empty circumcircle criterion:

the circumcircle of any triangle does not contain any of the given vertices in its interior

- goal: maximize the minimum angle of all the angles of the triangles in the triangulation
- ambiguity: two neighbouring triangles have the same circumcircle
- remedy: choose diagonal with lower intensity gradient

Triangulation

What to do:

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Triangulation - 5) decoding

5) decoding

- values of intensities inside triangles are interpolated from the known vertex intensity values
- coordinates of random points can be reconstructed with the seed of the random generator

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A Proper Choice of Vertices

Comparing edge detection operators using edge points and random points

- goal: highest fidelity and at least some compression
- Laplace:
  - best for a low number of edge points
  - and high number of random points
- Roberts:
  - best for a high number of edge points
  - and low number of random points
- Gauß:
  - worst results
  - slowest operator

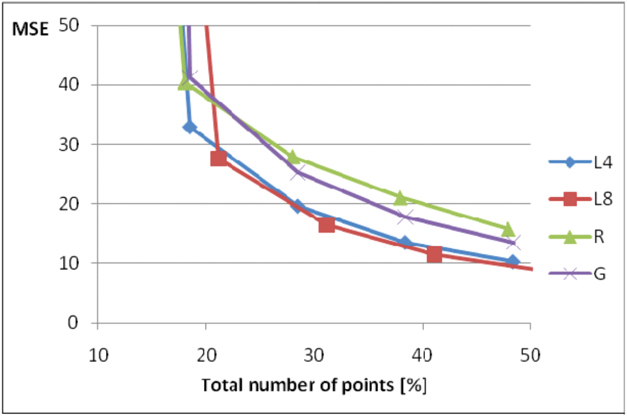

Figure: The image Fruits: Dependence of MSE on the total number of points of which 8-10% are edge points

A Proper Choice of Vertices

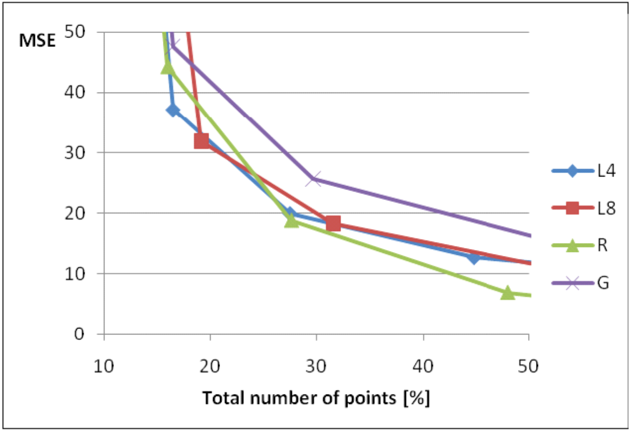

Figure: The image Fruits: Dependence of MSE on the total number of points of which 8% are random points

A Proper Choice of Vertices

Why not choose only random points?

Figure: The image Fruits

Figure: 20% of points: only random points (MSE 99.11)

A Proper Choice of Vertices

Choosing only edge points

Figure: The image Fruits

Figure: 20% of points: only edge points (MSE 131.94)

A Proper Choice of Vertices

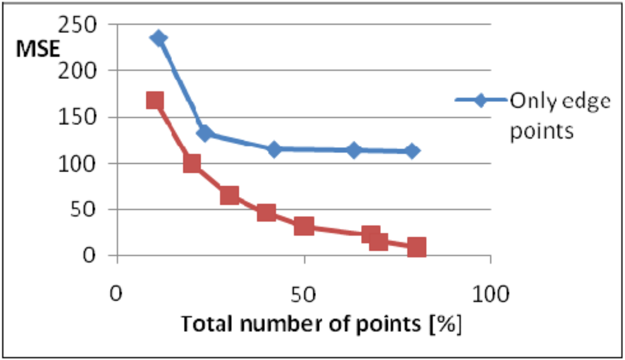

Figure: The image Fruits: Only random and only edge points

A Proper Choice of Vertices

Proper choice with acceptable quality and some compression:

- for most common images:
  - number random points: $10 - 15\%$ of the image size
  - number edge points: $5 - 10\%$ of the image size

- for images with many edges:
  - number random points: $10 - 15\%$ of the image size
  - number edge points: $15 - 20\%$ of the image size

A Proper Choice of Vertices

Figure: The image Fruits; a) input, b) result - 11% of edge points, 15% of random points, MSE=20.65

A Proper Choice of Vertices

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Summary

- triangulation is simple and good for geometric transformations
- points for vertices of triangles can be chosen randomly, because the coordinates can be reconstructed during decoding
- to keep high quality of the image, one has to find a proper rate of random and edge points
- the Laplace-operator is best since we want to achieve a high number of random points while preserving the quality

References

- Ivana Kolingerova, Josef Kohout, Michal Rulf, Vaclav Uher: A proper choice of vertices for triangulation representation of digital images. Proc. 2010 International Conference on Computer Vision and Graphics: Part II, pp. 41-48, 2010.
- Lecture-Notes: IPCV 2011/12 and 2012/13
- Josef Kohout, On Digital Image Representation by the Delaunay Triangulation.Department of Computer Science and Engineering, University of West Bohemia, Univerzitni 22, 306 14 Plze, Czech Republic besoft@kiv.zcu.cz
- De Berg, M., van Kreveld, M., Overmars, M., Schwarzkopf, O.: Computational geometry. In: Algorithms and applications. Springer, Heidelberg (1997)
- Milan Sonka, Vaclav Hlavac, Roger Boyle: Image Processing, Analysis, and Machine Vision. ITP (1999)
- Galic, I., Weickert, J., Welk, M.: Towards PDE-based Image Compression. In: Para- gios, N., Faugeras, O., Chan, T., Schn orr, C. (eds.) VLSM 2005. LNCS, vol. 3752, pp. 3748. Springer, Heidelberg (2005)