Today

Early vision on a single image

• Features
Reminder: Abstract of Final Project

Friday, Feb 26 at 11:59pm, EST. Late submission penalty applies.

Include

– Title and names of the team member
– Topic: a research project or a survey
– Brief introduction on the background
– Timeline and project management for a teamwork

At most one page

Each team only needs one abstract
Final Project Topics

Option 1: A complete research project
- Introduction (problem formulation/definition)
- literature review
- the proposed method and analysis
- experiment
- conclusion
- reference

Option 2: A survey research
- A well-defined problem or topic
- a complete list of previous (typical) work on this problem
- clearly and briefly describe it
- analyze each methods/groups and compare them
- give the conclusion and list of references
Final Project Requirement

Special requirements
• Decide topic and write a one-page abstract
• Progress report (discuss with the instructor)
• Research work and report writing
• Oral presentation (class, vision seminar, etc.)

Teamwork (2-person team) is acceptable ONLY for Option 1
• talk to the instructor first
• under a single topic, each member must have his/her own specific subtopic
• a combined report, but each member needs to clearly show his/her own contributions
• combined presentation if necessary
Project Requirement

Notes:

• you are encouraged to incorporate your own expertise in, but the project topic must be related to the content of this course
• discuss with the instructor on topic selection, progress, writing, and presentation
• use the library and online resource

Major research journals and conferences on computer vision

• International Conference on Computer Vision (ICCV)
• IEEE International Conference on Computer Vision and Pattern Recognition (CVPR)
• IEEE Trans. Pattern Analysis and Machine Intelligence (PAMI)
• International Journal on Computer Vision (IJCV)
• You may find useful literature in them for your project
Announcement

Homework #3 has been posted in Blackboard.
Due on 11:59pm EST, Tuesday, March 2nd.
Edge
- Mark points along the curve where the magnitude is biggest.
- Look for a maximum along a slice normal to the curve (non-maximum suppression). These points should form a curve.

Two questions:
- How do we define the slice direction
- Where is the next one
At $q$, we have a maximum if the value is larger than those at both $p$ and at $r$. Interpolate to get these values.
Assume the marked point is an edge point. Then we construct the tangent to the edge curve (which is normal to the gradient at that point) and use this to predict the next points (here either $r$ or $s$).
Remaining Issues

Check that maximum value of gradient value is sufficiently large
  • use a high threshold to start edge curves and a low threshold to continue them.

Notice:
  • Something nasty is happening at corners
  • Scale affects contrast
  • Edges aren’t bounding contours
Fine scale, high threshold
Coarse scale, high threshold
Coarse scale, low threshold
Second-order based Edge Detection: Laplacian of Gaussian (LOG)

Another way to detect an extrema in first derivative is to look for a zero-crossing in second derivative (Laplacian)

Bad idea to apply a Laplacian without smoothing
- smooth with Gaussian, and then apply Laplacian
- this is the same as filtering with a Laplacian of Gaussian filter

Now mark the zero-crossing points where there is a sufficiently large derivative, and enough contrast

$$\nabla^2 G(x, y) = \left[ \frac{x^2 + y^2 - 2\sigma^2}{\sigma^4} \right] e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Figure from “Digital Image Processing”, Gonzalez and Woods
\textbf{LOG zero crossings}

\begin{itemize}
  \item \textbf{sigma=2}
  \item \textbf{contrast=1}
  \item \textbf{sigma=4}
  \item \textbf{contrast=4}
\end{itemize}
We still have unfortunate behavior at corners.
Orientation Representations

The gradient magnitude is affected by illumination changes
• but its direction isn’t

We can describe image patches by the swing of the gradient orientation

Important types:
• constant window
  – small gradient magnitudes
• edge window
  – few large gradient mags in one direction
• flow window
  – many large gradient mags in one direction
• corner window
  – large gradient magnitudes that swing
Representing Windows

Four Types

• constant
  – small eigenvalues

• Edge
  – one medium, one small

• Flow
  – one large, one small

• corner
  – two large eigenvalues

\[
H = \sum_{\text{window}} (\nabla I)(\nabla I)^T \\
= \sum_{\text{window}} \left\{ \left( \frac{\partial G_\sigma}{\partial x} \otimes I \right) \left( \frac{\partial G_\sigma}{\partial x} \otimes I \right) \right\} + \left\{ \left( \frac{\partial G_\sigma}{\partial y} \otimes I \right) \left( \frac{\partial G_\sigma}{\partial y} \otimes I \right) \right\} \\
= \sum_{\text{window}} \left\{ \left( \frac{\partial G_\sigma}{\partial x} \otimes I \right) \left( \frac{\partial G_\sigma}{\partial x} \otimes I \right) \right\} + \left\{ \left( \frac{\partial G_\sigma}{\partial y} \otimes I \right) \left( \frac{\partial G_\sigma}{\partial y} \otimes I \right) \right\}
\]
From Edges to Boundary

Object boundary is a closed curve

The detected edges are just segments of boundaries. They are not connected

Edges may also come from noise

How to find the full object boundary from edge-detection output?

Edge-linking, edge-grouping, …
Suggested Reading


http://www.cse.sc.edu/~songwang/document/pami05.pdf
Corner Detection

Corners are important 2D geometrical features
- Applications in matching images, representing textures, representing objects

Corners are located in a region with large intensity variations

Good corners:
- High contrast \rightarrow Large gradients
- Change direction sharply \rightarrow Gradient direction changes

Corner detection procedure:
- Localize centers
- At each center, estimate scale, and then orientation
Corner Detection: Harris Corner Detector

Build a matrix for a point \( p \) in its neighborhood

\[
G_x = \frac{\partial G_\sigma}{\partial x} \otimes I
\]

\[
H = \begin{bmatrix}
\sum_{N(p)} G_x^2 & \sum_{N(p)} G_x G_y \\
\sum_{N(p)} G_x G_y & \sum_{N(p)} G_y^2
\end{bmatrix}
\]

\( \lambda_1 \) and \( \lambda_2 \) are two eigenvalues of \( H \)

If \( \min(\lambda_1, \lambda_2) > \text{threshold} \), the point \( p \) is a corner

How about one or both eigenvalues are zero?

In practice, look for big values of

\[
\det(H) - k \left( \frac{\text{trace}(H)}{2} \right)^2
\]

\[
\det(H) = \lambda_1 \lambda_2 \quad \text{trace}(H) = \lambda_1 + \lambda_2
\]

Don’t need eigenvalue decomposition
Examples

Invariant to scaling and rotation
Desired Feature Properties

Invariant to

• Translation, rotation, scale, illumination

Why? Robust matching or interest point detection in real world
SIFT Feature

Scale Invariant Feature Transform (SIFT)

- Invariant to uniform scaling and orientation
- Partially invariant to affine transformation and illumination changes

Algorithm overview

- Scale-space extrema detection
- Keypoint localization
- Keypoint descriptor