Comparison of Salient Point Detection Methods for 3D Medical Images

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Overview

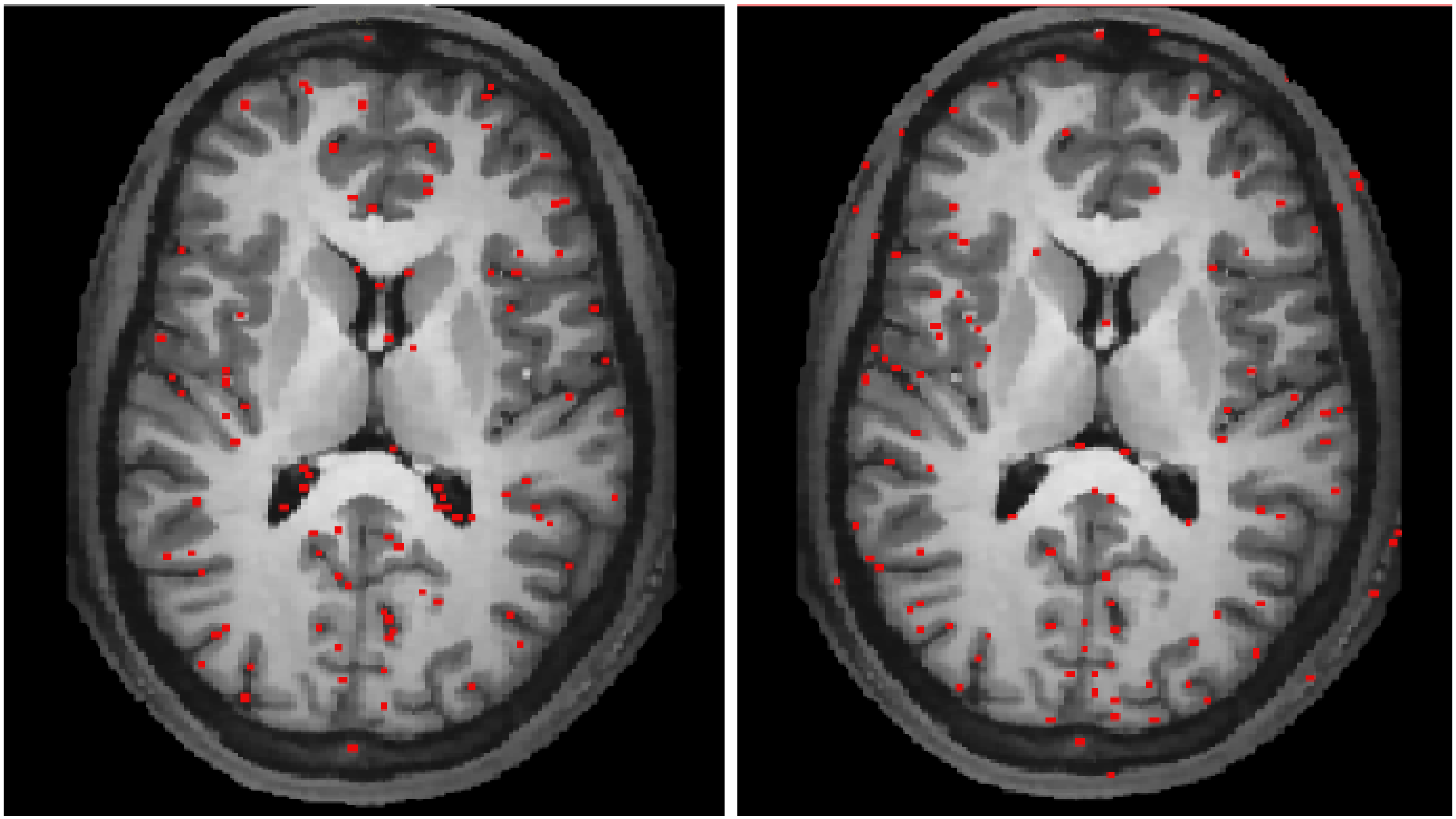
- Describe two salient feature detectors
- Validate their effectiveness for Medical Imaging tasks

Salient Feature Detectors

- “corner detectors”
- most research concentrates on 2D salient point detectors
- recently some methods generalise to 3D points

Medical Image Analysis

- Often there aren't distinct "corners"
- e.g. MR Images of the brain



Main Directions

- extracting edges, maximal curvature
- derivatives of the pixel intensities and using a “cornerness measure”
- compute features from images at multiple scales

Properties of Salient Features

- Invariant under transformations (e.g. geometric, photometric, scaling)
- accuracy of registering points (localising)
- distinctiveness of the detected points in the local environment

Comparing Two Methods

- both involve an operator on the derivatives of the image intensities
- *curvature*
- *correlation*

The DET operator

- Beaudet propsed the determinant of the Hessian = DET operator

$$K = \frac{f_{xx}f_{yy} - f_{xy}^2}{1 + f_x^2 + f_y^2} = \frac{DET}{1 + f_x^2 + f_y^2}$$

- is also the numerator of the Gaussian curvature — look for extrema

Gaussian Curvature

- recall *curvature*: reciprocal of radius of best approximating circle (positive if circle is to the left of the curve, negative if to the right)
- Normal Section curvature: for a surface, the curvature in the plane formed by a direction on the tangent plane, the point and the normal to the surface
- Gaussian Curvature is the product of the maximum and minimum normal section curvature

Extension to 3D

- Monga et al. give a 3D equivalent
- estimate the curvature as the curvature of an isointensity surface in the 3D image

$$K = \frac{f_x^2\left(f_{yy}f_{zz} - f_{yz}^2\right) + 2f_x f_{xz}\left(f_y f_{yz} - f_z f_{yy}\right) + cycl.\,(x,y,z)}{f_x^2 + f_y^2 + f_z^2}$$

Autocorrelation Function

- proposed by Harris and Stephans, extended to 3D by Rohr
- estimate the autocorrelation function using first derivatives of image intensities
- Eigenanalysis gives information about how intensities are changing locally

$$\mathbf{C}_g = E\left[\mathbf{g}(\mathbf{x})\ \mathbf{g}(\mathbf{x})^T\right]$$

Eigenanalysis

- large eigenvalues imply structure
- low eigenvalues imply not much change in that direction
- Salient points should have high
  - determinant (product of eigenvalues)
  - trace (sum of eigenvalues)

$$\Sigma_g = \frac{\sigma_n^2}{m} \mathbf{C}_g^{-1}$$

- Rohr relates covariance matrix to correlation matrix
- eigenvalues of $\sum_g$ correspond to uncertainty — error ellipsoid
- look for points with a small volume ellipsoid

Autocorrelation operator

- $det(C_g)$ as cornerness measure (as proposed by Rohr)
- locate local maxima of the cornerness measure
- use thresholding for both operators to get reduce number of points and get rid of low responses

Evaluation

- Distinctiveness (high local entropy)
- Invariance to transformation
- robust to scale change
- repeatability (occur for same subject at different scan times)

Test Set

- Thirteen MR images were taken
- used two MR techniques

Tests

- compute entropy
- checked repeatability by scaling using different amount of smoothing
- checked repeatability between two registered image pairs, same and different modality

Results

- entropy was roughly the same
- Correlation tended to do better on repeatability
- did poorly on images from differing modalities

Method	entropy	repeatability rate at different scales (13 cases)	repeatability rate for registered images (same modality, 1 case)	repeatability rate for registered images of different modality (3 cases)
Curvature	0.528	0.68 ± 0.10	0.69	0.30
Correlation	0.532	0.78 ± 0.03	0.76	0.28

Conclusion

- Two salient point detectors for 3D images were described
- Both methods use differentials of image intensities
- Validation using MR images show that correlation works better than curvature for images of the same modality
- These salient point detectors were poor at registering images of different modalities