Tutorial on Medical Image Retrieval
- IRMA -

medinfo 2004, 8.9.2004
Information Processing

- images
  - raw data layer
  - categorized data layer
  - registered data layer
  - feature layer
  - scheme layer
  - object layer
  - query
  - knowledge layer

- categories
- RST-parameters
- feature vectors
- blob-trees
- feature selection
- indexing
- identification
- retrieval
- query results
Images: IRMA Reference Database

- Arbitrarily taken from routine
  - authentic
- Manually classified
  - reliable
• Standardized nomenclature
  • Systemized Nomenclature in Medicine (SNOMED)
  • Medical Subject Headings (MeSH)
  • Unified Medical Language System (UMLS)
  • Digital Imaging Communications in Medicine (DICOM)

• Example DICOM
  • Tag (0018,0015) *Body Part Examined*, 26 valid entries
    • *Extremity, Hand, Arm, ...*

• Problems
  • coarse, ambiguous, non-hierachical
• IRMA code
  mono-hierarchical, multi-axial
  • Technique, Direction, Anatomy, Biosystem
    (TTTT-TDD-AAD-BBB)

• Example: 1121-127-720-500
  • radiography, plain, analog, overview
  • coronal, AP, supine
  • abdomen, middle
  • uropoetic system
Categorization of Medical Images

- **Pixel data → Semantical meaning**

- **Applications**
  - digital radiology & PACS
  - computer-aided diagnosis (CAD)
  - content-based image retrieval (CBIR)

- X-ray image of skull
- lateral view
- good quality
- no obvious pathology
- …
Categorization: Global Features

- Pixel data → Few numerical values

- Features
  - colour
  - texture
  - shape

```
3.278
1.426
0.450
...
3.26
```
Semantical Gap

- Semantical meaning ↔ Few numerical values

- X-ray image of skull
- lateral view
- good quality
- no obvious pathology
- ...

<p>| | | |</p>
<table>
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<td>3.278</td>
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- Common approaches
  - low number of categories

- IRMA approach
  - mono-hierarchical coding scheme
Categorization: Evaluation

- Classified images at study date
  - 6,335 images, 401 different codes
- Minimum class size
  - 10 images
  - 5 images
- Hierarchical code (TTxx-Dxx-AAx-Bxx)
  - 6,231 images, 81 categories
- Radiographs only (11xx-Dxx-AAx-Bxx)
  - 5,776 images, 57 categories
Texture

- Texture: Tamura Features
  - local features (multi-spectral)
  - histogram (384 bins)

- Distance
  - Jensen-Shannon divergence
• Image Features
  • rescaled images

  ![Images](image1.png)  ![Image](image2.png)  ![Image](image3.png)  ![Image](image4.png)  ![Image](image5.png)

  squared  32 x 32  16 x 16  8 x 8  4 x 4

• Distances
  • cross correlation function
  • image distortion model
  • tangent distance
• **Pixel mapping**
  • scans local neighborhood for best correspondence
  • allows local deformations

• **Improvements**
  • use image gradients
  • evaluate local context
Results (Single Classifiers)

- Leaving-one-out
- 6,231 images (all imaging techniques)
- 81 categories

<table>
<thead>
<tr>
<th>Representation</th>
<th>1-NN</th>
<th>5-NN</th>
<th>within 5</th>
<th>within 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tamura</td>
<td>66.4 %</td>
<td>66.3 %</td>
<td>80.4 %</td>
<td>96.6 %</td>
</tr>
<tr>
<td>CCF</td>
<td>76.1 %</td>
<td>76.4 %</td>
<td>86.6 %</td>
<td>97.7 %</td>
</tr>
<tr>
<td>IDM</td>
<td>82.3 %</td>
<td>80.7 %</td>
<td>90.1 %</td>
<td>97.0 %</td>
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Results (Single Classifiers)

- Leaving-one-out
- 5,776 images (radiographs only)
- 57 categories

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<tr>
<td>Tamura</td>
<td>64.5 %</td>
<td>64.6 %</td>
<td>79.3 %</td>
<td>96.4 %</td>
</tr>
<tr>
<td>CCF</td>
<td>75.4 %</td>
<td>76.1 %</td>
<td>86.4 %</td>
<td>97.9 %</td>
</tr>
<tr>
<td>IDM</td>
<td>81.8 %</td>
<td>80.6 %</td>
<td>90.0 %</td>
<td>97.1 %</td>
</tr>
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Results (Parallel Combination)

- **IDM + Tamura**
- **Improvement (radiographs)**
  - **Correctness:** 81.8% → 85.0%
  - **Within 5:** 90.0% → 92.8%

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<tr>
<th>Setup</th>
<th>1-NN</th>
<th>5-NN</th>
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<th>within 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>All images</td>
<td>85.5 %</td>
<td>85.4 %</td>
<td>93.0 %</td>
<td>95.3 %</td>
</tr>
<tr>
<td>(81 categories)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiographs</td>
<td>85.0 %</td>
<td>85.0 %</td>
<td>92.8 %</td>
<td>95.2 %</td>
</tr>
<tr>
<td>(57 categories)</td>
<td></td>
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</table>
Reasons for Misclassifications

- Absolute distance not evaluated
- Inhomogeneous category size
- High intra-category variability
  - grouped code
- Low inter-category variability
  - misclassified body region
  - misclassified direction
- Collimation fields and shutters
Inhomogeneous Category Size

• e.g.: radiographs only, min. 5 images

![Bar chart showing the images in category and recognition rates](chart.png)

- 99.45% recognition rate
- 99.84% recognition rate
- 0.00% recognition rate
- 14.29% recognition rate

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• e.g.: IRMA-code 1121-120-800-700
  • plain radiography
  • coronal, posterior-anterior direction
  • abdomen
  • musculoskeletal system
Inter-Category Similarity (Direction)

- Axial, craniocaudal (xxxx-310-xxx-xxx)

- Other, oblique (xxxx-410-xxx-xxx)
• Elbow (xxxx-xxx-44x-xxx)

• Knee (xxxx-xxx-94x-xxx)
• Query image

• System response
Conclusion

- 85% correctness
  - ~6,000 radiographs, ~80 categories
  - scaled representations, parallel combined classifier
- 98% correctness
  - within 10 most similar references
- Global features applicable for many categories if sufficient references are available
Example: 99.5% Recognition

- Thorax images in frontal view (1,278 images)

- Nearest neighbors
Information Processing

- Raw data layer
- Registered data layer
- Feature layer
- Scheme layer
- Object layer
- Query knowledge layer

Images

Categorization

Categories

RST-parameters

Feature extraction

Feature selection

Indexing

Identification

Retrieval

Query results
Information Processing

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• **Preprocessing**
  - categorization based on global features
  - registration onto category prototypes
  - local feature extraction
    (explosion of data volume)

• **Abstraction**
  - significant reduction of information
• Local Features
  • Each pixel → One feature vector
  • Example: Blobworld features

- gray value
- polarity
- anisotropy
- contrast
• Information abstraction
  • image
  • pixels
  • regions
  • blobs
Hierarchical modeling

- blobs $\rightarrow$ graph
- (edge preserving) region growing
Structured Analysis of Image Content

- Example

- image → pixel → regions → blobs → graph
Information Processing

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Exemplary Applications

- IRMA Database Browser
  - visual overview of all images
- IRMA Query
  - extended query refinement
- IRMA Code Definition
  - define IRMA code items
- IRMA Code Editor
  - manual reference coding of images
- IRMA Code Browser
  - access images by IRMA code
• German / English interface to code database
• 738 entities in four axes
• history logging
- Reference categorization of images
- History logging of changes currently over 15,000 history entries
- Browsing the reference database by IRMA code
  - e.g., anteroposterior chest radiographs (1123-111-500-000)
• IRMA
  • general concept for medical image retrieval
  • any modality or body region (categorization)
  • any level of details (hierarchical representation)
  • successful evaluation of categorization
  • good results in the ImageCLEF evaluation
Acknowledgments

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  • Department of Medical Informatics
  • Department of Diagnostic Radiology
  • Chair of Computer Science VI

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➤ http://irma-project.org
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Information Processing

Retrieval = Similarity of graphs

- Quantitatively: Graph matching

- Qualitatively: Visualization