



Remaining Challenges in Content-Based Access to Medical Images



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Overview

- Motivation and goal
 - information logistics
 - image data management
- Feature representation
- System architecture
- PACS integration
- Examples
- Summary




Information Logistics

- History
 - Reichertz, *Method Inform Med* 1977; 16: 125-130
 - Haux, *Method Inform Med* 1985; 28: 69-77
- Information management aims at providing
 - the right information at
 - the right time and at
 - the right place
- ➔ Medical imaging and telemedicine (PACS)
 - information management = image management




Technological Answers to Paradigm

- Right place
 - ✓ digital imaging & archiving
 - ✓ portable networking & telemedicine
- Right time
 - ✓ sophisticated pre-fetching
 - ✓ gigabit networking
- Right information
 - ✓ high-contrasted displays
 - ✓ standardized communication
 - ✗ text-based access to images



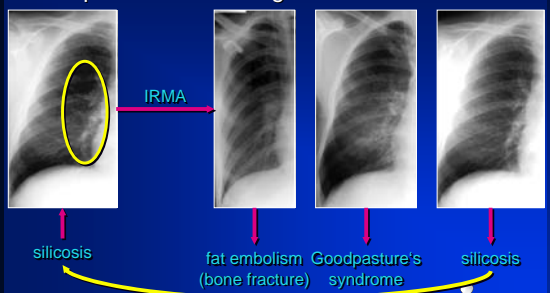
Medical Image Databases

- Approach
 - Content-based image retrieval (CBIR)
 - Content-based Access (CBA)
- Tagare, Jaffe & Duncan
J Am Med Inform Assoc 1997; 4(3):184-98
 - Non-textual indexing
 - Customized dynamic database scheme
 - Similarity & comparison modules
 - Iconic queries & descriptive language
 - multi-modality registration & Image manipulation
- ➔ Impact for diagnostics, research, and education




Example

Computer-assisted diagnosis

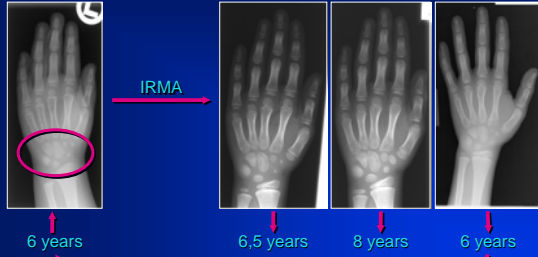


Legend: — physician — computer



Example

Automated bone maturity determination



Legend: — physician — computer

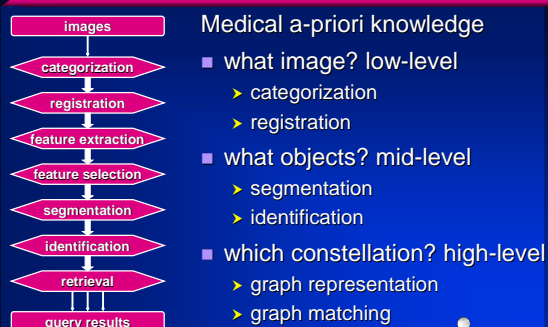


Overview

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- Feature representation
 - Global features
 - Local features
 - Structural features
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IRMA Approach



Low-Level: Global Features

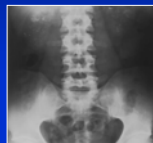
Entire image is represented by one feature vector

- Direct texture measures
 - Tamura et al., *IEEE Trans Sys Men Cyber*, 1978: 8(6): 460-473
 - histogram of 348 bins
 - Jensen-Shannon Divergence
- Re-scaled images
 - Lehmann et al., *Comp Med Imag Graph*, 2005: 29(2): 143-155
 - 16x16 (256 bins) or 32x32 (1024 bins)
 - Image Distortion Model



Global Features: Ground Truth

- Images categorized by skilled radiologists
 - Anatomy (body region)
 - Biosystem (contrast agents)
 - Creation (modality and parameters)
 - Direction (between patient and device)
- Example: 720-500-1121-127
 - abdomen, middle
 - uropoetic system
 - radiography, plain, analog, overview
 - coronal, AP, supine



Global Features: Training

Manual reference coding



Global Features: Results

- SPIE 2004
 - 6.231 images of 81 categories
 - 14,5% error rate (best match)
 - 7,0% within 5 best matches
 - 4,7% within 10 best matches
- ImageCLEF 2005
 - 10.000 images of 57 categories
 - 41 submissions
 - 12 groups from 9 nations
 - 12,6%, 1 (RWTH Aachen, I6)
 - 13,3%, 2 (RWTH Aachen, IRMA)
 - ...
 - 73,3%, 41 (...)
- Error rates at ImageCLEF
 - 2005: 12,6% – 10,000 / 57
 - 2006: 16,2% – 11,000 / 116
 - 2007: 10,3% – 12,000 / 116 hierarchical structure
 - 2008: score – 12,089 / 197 hierarchical structure
 - 2009: summarizing experiment
 - <http://www.imageclef.org>

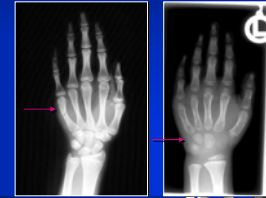


Mid-Level: Local Features

Each region is represented by a feature vector

- Medical pattern
 - diversity
 - soft tissue
 - pathology
 - complexity
 - level of detail
 - context
 - quantity
 - large amount of data

- Example
 - fracture
 - mature



Mid-Level: Local Features

Each region is represented by a feature vector

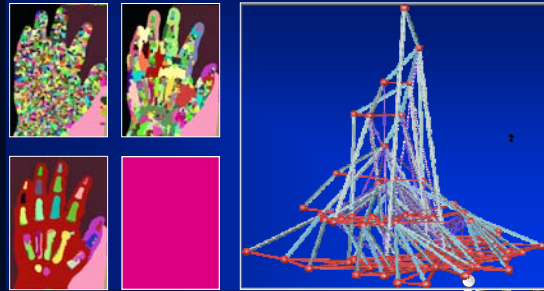
- Medical pattern
 - diversity
 - soft tissue
 - pathology
 - complexity
 - level of detail
 - context
 - quantity
 - large amount of data
- Image partitioning
 - adaptive
 - multiscale
 - unsupervised

➔ Bottom-up region merging scheme



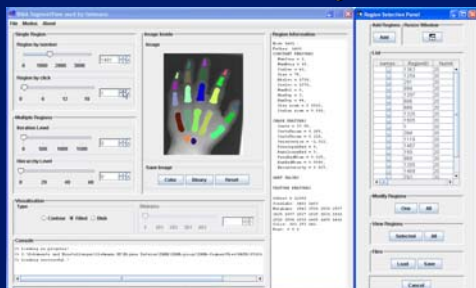
Local Features: HARAG

- Hierarchical attributed region adjacency graph



Local Features: Ground Truth

- Manual selection of relevant regions



Local Features: Example

- Proximal phalanges

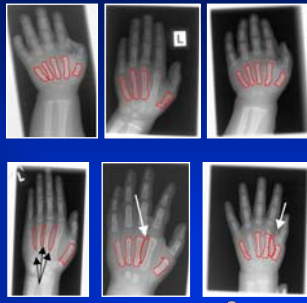


1,0	<Contour Len	<119,00
0,0030	<Relative Size	<0,01
20,00	<Roundness	<41,00
0,9	<Principal Axis Radius	<1,0
0,3	<Centroid Y	<0,5
0,25	<Mean Gray	<0,47



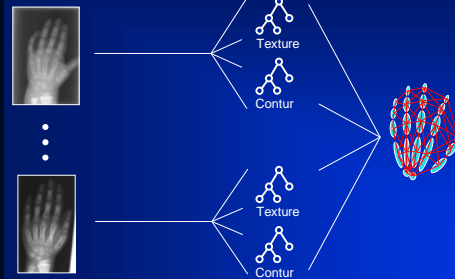
Local Features: Capability

- True positive
 - 225 out of 372
- False positives
 - 203 out of 249,278
- Data mining
 - recall: 60,5 %
 - precision: 52,3 %
- Diagnosis
 - sensitivity: 60,5 %
 - specificity: 99,9 %



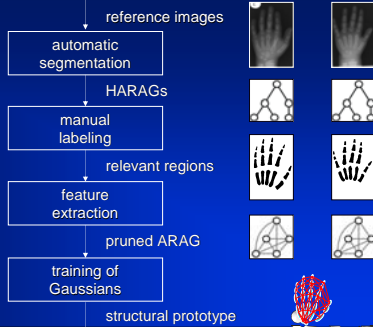
High-Level: Structural Features

- Capture relations between relevant objects



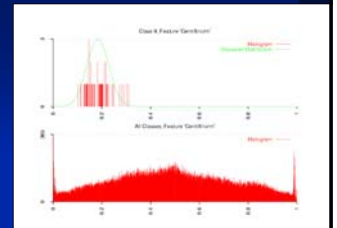
Structural Features: Modeling

- High-level semantics
 - objects
 - relations
- Variability of objects
 - anatomy
 - deformation
 - pathology



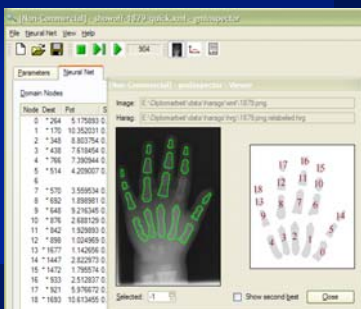
Structural Features: Training

- Attributes for nodes
 - intensity
 - texture
 - shape
 - hierarchy
- Attributes for edges
 - normalized distance
 - angulation of position
 - angulation of major axes
 - relative intensity



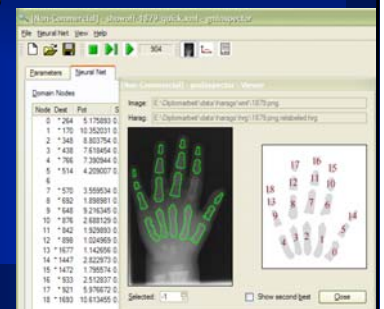
Structural Features: Capability

- Schädler & Wysotzki, *Appl Intell* 1999; 11: 15-30
- Graph matching
 - neural network
 - large graphs



Structural Features: Capability

- Schädler & Wysotzki, *Appl Intell* 1999; 11: 15-30
- Graph matching
 - neural network
 - large graphs
- Properties
 - fast
 - robust

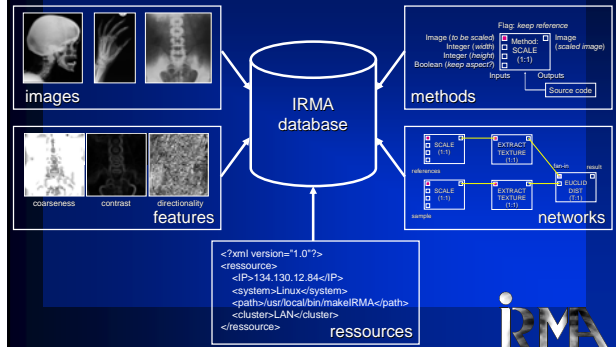


Overview

- Motivation and goal
- Feature representation
- System architecture
 - Database structure and elements
 - Server and client components
 - Distributed query processing
- PACS integration
- Examples
- Summary

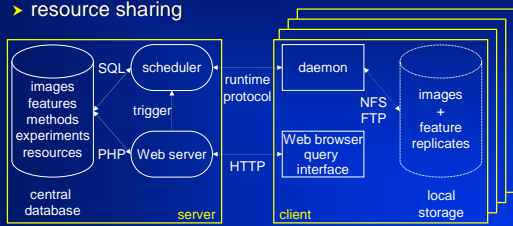


Database Structure and Elements



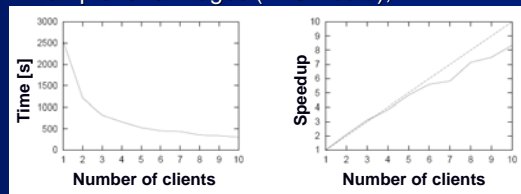
Server and Client Components

- Support
 - grid computing
 - resource sharing



Distributed Query Processing

- Data flow model produces jobs to be scheduled
- Example: 549 images (~2GB data), 2 x 1:1



- Mainly useful for offline feature extraction (method type 1:1)



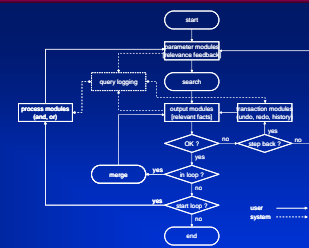
Overview

- Motivation and goal
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 - User interfacing
 - System interconnection
 - Workflow management
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PACS Integration: User Interfacing

- Web-based
 - modular concept
 - using database
 - complete logging of interactions



PACS Integration: User Interfacing

Web-based

- modular concept
- using database
- complete logging of interactions

Best Paper Award

- J Digit Imaging 2008
- First Place (Technical)
- Society of Imaging Informatics in Medicine (SIIM)
- Deserno TM et al.:
Extended query refinement for medical image retrieval



Example: Web-based Interfaces

Five components

- header bar
- navigation bar
- parameter field
- status bar
- output field



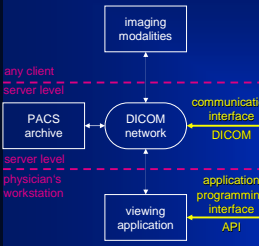
Construction rules

- optional components
- in fixed order
- with adaptive navigation

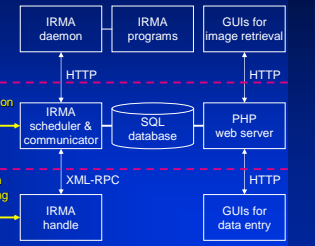


PACS Integration: System Interconnection

PACS



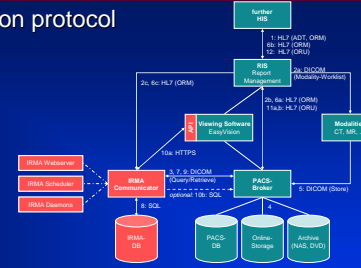
IRMA



PACS Integration: System Interconnection

Communication protocol

- DICOM
- HL7



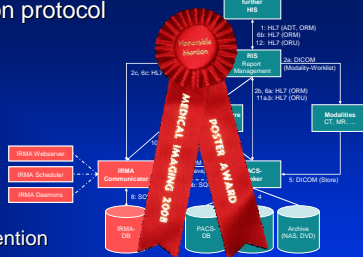
PACS Integration: System Interconnection

Communication protocol

- DICOM
- HL7

SPIE 2008 Poster Award

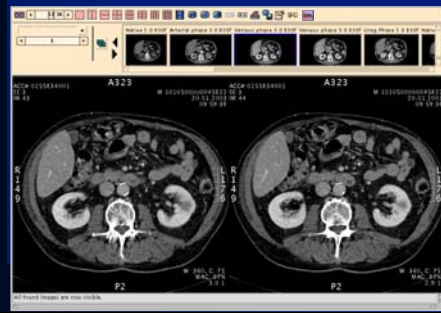
- Honorable Mention
- Society of Photo-optical Instrumentation Engineering
- Deserno TM et al.:
Integration of a CBIR system into radiological routine



PACS Integration: Workflow Management

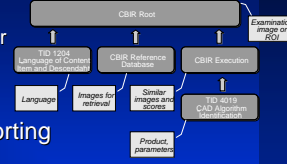
Just another symbol to the button bar

- e.g., EasyWeb, Mitra Corp. (Philips OEM)



PACS Integration: Workflow Management

- IHE-conformant workflow management
 - Evidence Creator
 - Post-Processing Manager
 - Image Manager/Archive
 - Image Display
- DICOM Structured Reporting



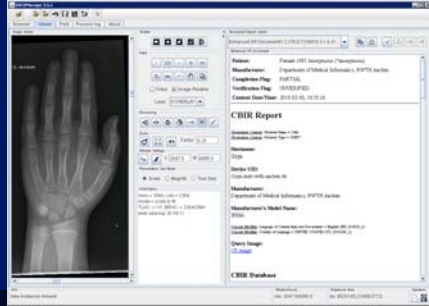
PACS Integration: Workflow Management

- IHE-conformant workflow management
 - Evidence Creator
 - Post-Processing Manager
 - Image Manager/Archive
 - Image Display
- DICOM Structured Reporting
- CARS 2010 EuroPACS Poster Award
 - First Price
 - Computer-Assisted Radiology and Surgery
 - Welter P et al.: Workflow management of content-based image retrieval for CAD support in PACS environments based on IHE



Example: DICOM SR CBIR Templates

- OFFIS DICOMscope, <http://dicom.offis.de>



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 - Off-line demonstration http://irma-project.org/onlinedemos_en.php
 - CBIR-CAD
 - Other applications
- Summary

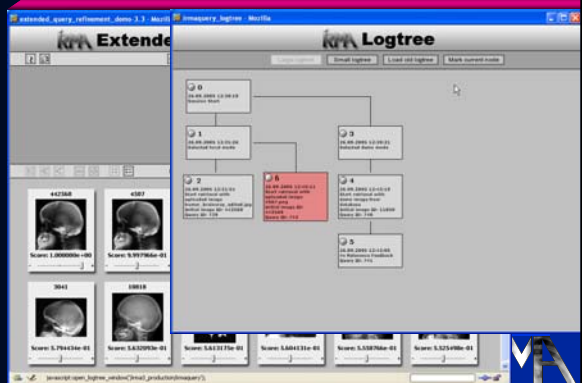


Off-line Demonstration

- <http://irma-project.org>



Extended Query Refinement



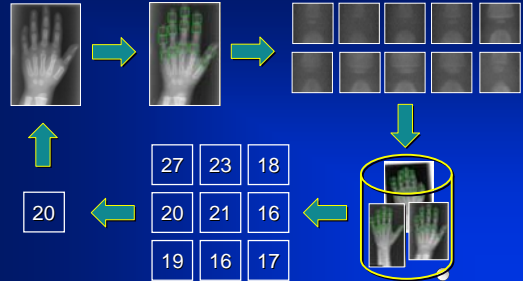
Example: NIH, USA, Shape Retrieval

- Database
 - ~ 50,000 spine x-ray
 - Hosted in both systems
- User Interface
 - IRMA
- Similarity computing
 - SPIRS
- Online interconnection



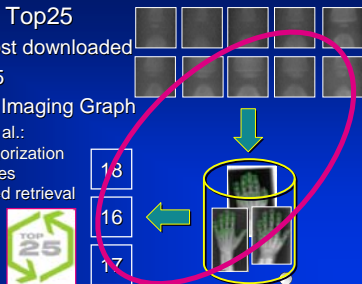
CBIR-CAD

Automatic Bone Age Assessment

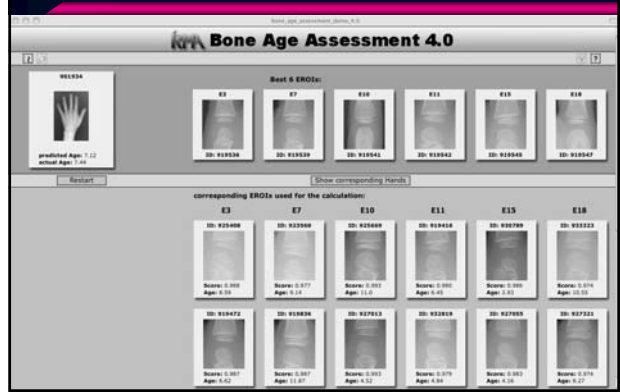


CBIR-CAD

- Automatic Bone Age Assessment
- ScienceDirect Top25
 - place 9 of most downloaded
 - Jan-Mar 2005
 - Comput Med Imaging Graph
 - Lehmann TM et al.: Automatic categorization of medical images for content-based retrieval and data mining



CBIR-CAD



Other Applications (non medical)

- Automatic sewer assessment
 - shape & texture
 - 30,000 m



Other Applications (non image)

- Scientific literature
 - text retrieval
 - ~ 1,500 PDF



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 - IRMA
 - Information logistics
 - Future challenges



Summary

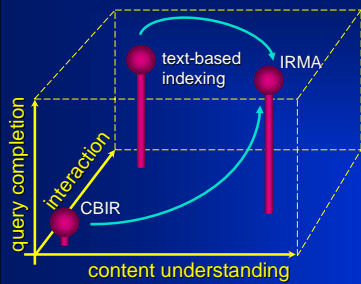
IRMA - Image Retrieval in Medical Applications

- Content-based image management
- Three levels of semantics
 - global
 - local
 - structural
- Applications
 - diagnostics
 - research
 - teaching



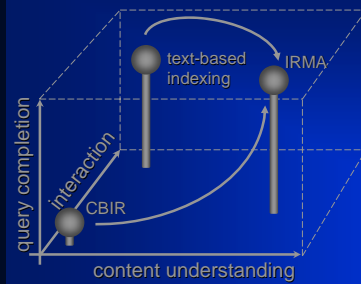
Information Logistics

- Tagare et al., *JAMIA* 1997; 4: 184-198



Information Logistics

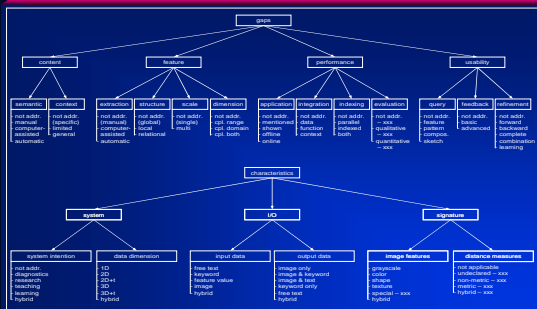
- Tagare et al., *JAMIA* 1997; 4: 184-198



IRMA:
right information
in right time
at right place



Future Challenges



Future Results

- PubMed Entrez today



Future Results ...

■ PubMed Entrez tomorrow



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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