IPAL
Image Perception, Access & Language

• Singaporean-French Research Collaboration

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Scientific Themes

Contextual & Mobile Access

Medical Analysis

Multilingual Access to Multimedia Contents

Medical Image Analysis

Medical Image Indexing and Retrieval for Assisted Diagnosis, research and teaching

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Content-Based Medical Image Retrieval (CBMIR)

Query by image - example

CBMIR : retrieval example
CBMIR versus PACS and DICOM

CBMIR (Similarity-based medical image/case access)

PACS (Picture Archiving and Communication Systems)

DICOM (Digital Imaging and Communications in Medicine)

CBMIR and related fields

Medical Image Analysis

Information Retrieval

Artificial Intelligence and Pattern Recognition

Knowledge Management

CBMIR - Applications

- **Medical assistance**
  - Quantitative support for medical diagnosis/treatment
  - Similarity-based retrieval for detection/diagnosis/prognosis/treatment assistance
  - Improve patient healthcare using medical metadata management and case-based similarity

- **Education support**
  - Medical image contextual learning to improve the understanding of a pathology and the related diagnostic/therapeutic issues
  - Automatic assistance for building medical multimedia atlases

- **Medical research**
  - Medical image mining
  - Extract and explore new pathological trends
  - Extract new correlations/co-occurrences between different aspects and influence parameters of a pathology

CBMIR Global approach
Actual challenges in CBMIR

- Objectives
  - Improve medical information access by including visual aspects related to medical images
  - Medical image mining extraction from large databases
  - Context- and medical image navigation and query
  - Reduce the CBMIR gaps (semantic, context, performance, usability, …)
  - Integrate CBMIR systems in Evidence Based Medicine (EBM) framework

- Methods
  - Model a priori medical domain knowledge (diagnosis rules, diagnosis clues, ontologies, interactive systems)
  - Medical image case-based reasoning (CBR/IBR) algorithms
  - Use existing structured updated (on-line) medical ontologies, in order to facilitate the task of the physician (in loop)
  - Intelligent fusion between multimodal medical images and heterogeneous medical information

- Difficulties / challenges
  - The complexity and specificity of the medical domain knowledge
  - Extract specific medical visual concepts from medical images ROI

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From CBMIR to knowledge-guided IBR (Image-Based Reasoning)

- Focus on CBIR semantic and application gaps
- Model a priori medical knowledge related to the MI-based diagnosis
- Improve the medical diagnosis accuracy
  - Reliable second opinion
- Avoid medical diagnosis errors based on MI
- Content & Context-Based medical Image Analysis

From CBMIR to knowledge-guided IBR (Image/Case-Based Reasoning)

Knowledge-based diagnosis assistance Image-Based Reasoning (IBR) system

Image-Based Neuro-Fuzzy Reasoning System using A Priori Medical Knowledge for Hyperacute MCA Stroke Early Diagnosis on Brain CT

MIIRAD/IPAL Collaboration with the Department of Diagnostic Radiology of Singapore General Hospital
ONCO-MEDIA project
The challenge

- **Time window**
  - subtle signs of acute stroke must be detected beyond the 3-hour time
  - detect the first signs of MCA stroke from the first brain CT acquisition (the most useful/available affordable image acquisition), during this time window.

Subtle changes in brain structure - central retarding effecting adjacent sulci, and loss of normal gray-white matter differentiation (compare to opposite side).

Right CT 20hrs later (T0D LATE) - changes are obvious.

The challenge

Initial axial brain CT

Ground truth represented by the 4th late MR acquisition (too late), putting in evidence the obvious stroke in the right part of the brain.

MCA Stroke radiological clues

MCA stroke Radiological Clues

C1: Effacement or Compression of the Sulci/Cisterns
C2: Swelling of the Cortical Ribbon
C3: Striatal Hypodensity
C4: White Matter Hypodensity

A priori diagnosis rules

Knowledge based approach

- **Medical knowledge tree**
  - Medical knowledge
  - Guideline diagnosis rules
- **Image based reasoning**
  - Image classification
  - Feature selection
  - Statistical analysis
- **Medical image processing: analysis**
  - Image Matching
  - MI Segmentation
  - Feature extraction
  - Statistical analysis

A prior medical knowledge tree

Use the radiological knowledge to generate automated diagnostic prognosis.
MCA Stroke early diagnosis (prognosis)

- Medical full knowledge tree
- Contralateral unbalance parameters

MCA Stroke radiologic knowledge model

- Medical full knowledge tree
- Contralateral unbalance parameters

Medical knowledge guided image processing / analysis

- Bilateral Filtering + Expectation Maximisation segmentation
  - Guided by the knowledge tree

- Medical perinatal knowledge tree
  - Contralateral unbalance parameters

Expectation-Maximisation segmentation of the brain

- Medical full knowledge tree
  - Contralateral unbalance parameters

Robust symmetry axis computation

Symmetry axis computation using the moment based centroid and the Occipital Sinuses at the base of the Occipital Bone of the skull.
Statistic analysis of contralateral unbalance parameters

Bipolar Dynamic Propagation Decay Adjustment (BDPDA) learning algorithm

Rule-Based system based on radiological clues and a priori diagnosis rules

Diagnosis assistance approach - second opinion -

Knowledge-Guided Semantic Indexing of Breast Cancer Histopathology Images for Breast Cancer Grading

Challenges, Proposed Solution

- Global challenge:
  + Early detection is an important factor in reducing death caused by breast cancer.
  + Core Biopsy is the actual best method in breast cancer early detection

- Problems:
  + Examining several tenths of cases per day is tedious.
  + Pathologists may have different diagnosis and prognosis for a same patient.

- Solution:
  + Automated breast cancer grading
Second opinion for NUH medical doctors

- Provide a second opinion about the possible pathologies in a slide
- Establish robust microscopic breast cancer images analysis, classification and retrieval methods
- Assist establishing a breast cancer grading system

Challenge

- Improving pathologists’ current manual procedures consistency by employing a semantic indexing technique, according to a rule-based decision system related to Nottingham Breast Cancer Grading system

Semantic Indexing in Breast Cancer Grading Context

Knowledge-based Multi-scale Decision Tree

Multi-scale analysis

Micromedical Image Analysis using a Virtual Microscope Platform
**Real Microscope Platform**

- Available devices:
  - Olympus microscope with 4x to 100x magnifications
  - Prior x/y motorized stage and a Z focus
  - MediaCybernetics Mega pixel digital camera

- Microscope stage computer control
  - Traveling area,
  - Pattern selection,
  - Magnification …

- Camera parameters
  - White balance,
  - Exposure,
  - Background and Z axe focus …

- Stitching & blending slices for composite image generation

**Virtual Microscopic Platform**

- Medical image classification
- Micro-Medical Image Indexing
- Pathology similarity-based Retrieval
- Virtual-Real Microscope Feedback control correlation
- Multi-scale techniques to detect features of microscopic images

**BCG Medical Concepts**

- Neoplasm
- Lumina
- Tubules
- Mitosis
- Nuclear Pleomorphism
- …

**Grading Rules Modeling Approach**

- Pathologist rules
  - Tubule Formation (TF) = white lumina surrounded by string of dark cells nuclei
  - Mitosis = very dark dividing cells nuclei from the peripheral area of the neoplasm
  - Nuclear Pleomorphism = size and shape features

**Grading Rules Modeling Approach**

- Medical concepts versus Computer Vision concepts
  - Nouns: Cells, cellsCluster, Blobs,
  - Parameters: Size, Shape, intensity, localization
  - Values: small, medium, big, regular, variation, irregular, White, Dark, VeryDark, eccentricity
  - Operators: $\cup, \cap, \delta, \sum$, Area, count

**Medical concepts versus Computer Vision concepts**

<table>
<thead>
<tr>
<th>Medical Concepts</th>
<th>CV concepts</th>
<th>Concept type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cells</td>
<td>Cells</td>
<td>super class</td>
</tr>
<tr>
<td>CellsCluster</td>
<td>CellsCluster</td>
<td>Class inherited from Cells</td>
</tr>
<tr>
<td>Lumina</td>
<td>WhiteBlobs</td>
<td>Class inherited from WhiteBlobs with hasIntensity property White (instance of Intensity class)</td>
</tr>
<tr>
<td>Tubules</td>
<td>CellsCluster</td>
<td>Class inherited from Cells with hasIntensity property Dark (instance of Intensity class)</td>
</tr>
<tr>
<td>Mitosis</td>
<td>DividingCellsCluster</td>
<td>Class inherited from DividingCellsCluster with hasSize property Small (instance of Size class)</td>
</tr>
<tr>
<td>Nuclear Pleomorphism</td>
<td>CellsCluster</td>
<td>Class inherited from CellsCluster with hasLocalization property Included_In (instance of Localization class)</td>
</tr>
<tr>
<td>GradeLocal</td>
<td>SlideImage</td>
<td>Class inherited from SlideImage with hasInIntensity property White (instance of Intensity class)</td>
</tr>
<tr>
<td>GradeGlobal</td>
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Example of Grading Rules Modeling

\[ \text{DarkCellsCluster} = \{ \text{Cells} \mid \text{VeryDark} < i < \text{White} \} \]
\[ \text{VeryDarkCells} = \{ \text{Cells} \mid i > \text{VeryDark} \} \]
\[ \text{WhiteBlobs} = \{ \text{morph} (\text{WhiteArea}) \} \]
\[ \text{WhiteArea} = \{ \text{Im} \mid i(\text{Im}) > \text{White} \} \]
\[ L = \{ \text{WhiteBlobs}(i, j) \mid \exists \text{DarkCellsCluster}(i, j) \supset \text{WhiteBlobs}(i, j) \} \]
\[ LROI = \cup L \]

PROTEGE model of the Breast Cancer Grading approach

Protégé interface for medical image semantic indexing

Perspectives

- Clinical decision support techniques produce a stronger need to retrieve images that can be valuable for supporting diagnoses:
  - Evidence-based medicine (EBM)
  - Medical Case-based reasoning (CBR)
  - Medical Image-based reasoning (IBR)
- Decision support systems in radiology and CAD/CADx for radiological practice are on the rise and create a need for:
  - Powerful data and meta-data management and retrieval
  - Medical image mining extraction