Combined Radiology and Pathology Classification of Brain Tumors
Rozpoznanie guza mózgu na podstawie obrazu radiologicznego i patologicznego

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Outline

1. The problem
2. State of the art
3. Proposed approach
4. Achieved results
Definitions

Cancer

- Cancer occurs when abnormal cells grow out of control

Brain tumor

- Benign or Malignant
- Over time, a low-grade tumor can become a high-grade tumor
- Brain tumors are classified as grade I, grade II, or grade III, or grade IV
Brain tumor - Survival rate (5 years or more)

FIGURE – Based on data from SEER 18 2005-2011, cancer.gov
Brain tumor - Survival by stage

Figure – Ovarian cancer, Five-year stage-specific relative survival rates, adults (ages 15-99), Anglia Cancer Network, 1987-2008
Brain tumor - Diagnosis process

General Practitioner
  \|-- Neurologist
  \   \|-- MR or CT - Radiologists
         (tumor confirmed) (clear image)
  \   \|-- Neurosurgeon
         Benign        Malignant
         \|-- Pathologist        \|-- 2 Pathologists
            (final diagnosis)        (final diagnosis)
Diagnosis problems

Problems

- Diverse shapes, sizes and appearances of tumors
- Relies on histopathologic examination (biopsy examination)
- Waiting for tests and to start treatment
- Radiology imaging is used only to establish location, size and whether it is benign and malignant tumor

**Figure** – Glioblastoma cells

**Figure** – Oligodendroglioma cells
Diagnosis problems

Problems

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Targets in the UK

No more than 2 months wait between the date the hospital receives an urgent GP referral for suspected cancer and starting treatment
Aims & Limitations

Aims

- Research & build a segmentation mechanism for the MRI scans (ROI selection)
- Research & build a classifier based on the segmented radiological images
- (if possible) Combine the Pathology-based classification with radiology-based classifier

Limitations

- Limited access to the MRI samples with the diagnosis provided by the doctor
- Conservative environment - only non-black box models
Related work

Brain tumor segmentation

- The topic of brain segmentation is relatively popular thanks to BraTS challenge
- Several supervised and unsupervised algorithms were proposed
  - Random Decision Forest that classifies voxels
  - Fuzzy C-means clustering
  - Mean Shift and K-means clustering

Brain tumor classification

- Slightly less popular subject (current diagnosis fully rely on histopathology imaging)
- Feature extraction
  - Extraction of structure information
  - Feature selection
- GLCM (Gray-Level Co-occurrence Matrix)
Influential articles

- Joana Festa and Sérgio Pereira and José António Mariz and Nuno Sousa and Carlos A. Silva
  Automatic Brain Tumor Segmentation of Multi-sequence MR images using Random Decision Forests
  *Proceedings of NCI-MICCAI BRATS 2013*, Nagoya, Japan, 2013

- Nitish Zulpe and Vrushsen Pawar
  GLCM Textural Features for Brain Tumor

- Hassan Khotanlou, Olivier Colliot, and Isabelle Bloch
  Automatic brain tumor segmentation using symmetry analysis and deformable models
  *Nationale Superieure des Telecommunications*, 2007
Brain tumor - Modified diagnosis process

General Practitioner

Neurologist

MR or CT - Radiologists & piece of software

(tumor confirmed & partial diagnosis)  (clear image)

Neurosurgeon

Benign

Pathologist

(final diagnosis)

Malignant

2 Pathologists

(final diagnosis)
Data set

FIGURE – Plots of different attributes of the data set

FIGURE – Viewing angles of MRI scan
Data set

Summary

- 27 cases with lower grade glioma tumors
- 13 of them with Oligodendroglioma and 14 with Astrocytoma
- Each case has 3 or 4 MRI scans (T1, T1C, FLAIR, and T2)
- Provided samples were taken using different hardware

**Figure** – Plots of different attributes of the data set

**Figure** – Viewing angles of MRI scan
Pre-processing

**FIGURE** – Process of skull extraction

**FIGURE** – Skulls properties in FLAIR and T2
Pre-processing

**Figure** — Median filter effect on image histogram
Segmentation - K-Means

The silhouette coefficient values
Cluster label
0
1
2
3

The visualization of the clustered data.

**FIGURE** – Silhouette analysis for K-Means(k=5)
Segmentation - Combined

FIGURE – Segmentation with results
Segmentation - Alternatives

**FIGURE** – Mini K-Means

**FIGURE** – Agglomerative clustering

**FIGURE** – K-Means with position
Classification

Tested methods

- Feature extraction & evaluation
- Texture features extraction with Gray-Level Co-Occurrence Matrix
- Texture features extraction with Local Binary Pattern

Classification algorithms

- SVM (Support vector machine)
- Gaussian Naive Bayes
- Logistic Regression
- Random Forest
**Classification - Feature extraction & evaluation**

**Selected features (out of 59)**

- Tumor volume (in $mm^3$)
- Tumor position (x,y,z) calculated from the middle of the brain
- Metrics intensity of tumor area
- 8 bins of intensity histogram

**FIGURE** – Selected features extracted from data set

**FIGURE** – Tumor positional features
Classification - Texture features extraction with GLCM & LBP

**FIGURE** – Co-occurrence matrix features for Oligodendroglioma and Astrocytoma
# Radiology imaging

## Tumor segmentation

<table>
<thead>
<tr>
<th>METHOD</th>
<th>BEST SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini Batch K-Means (5 clusters)</td>
<td>89.027% (std : 5.408)</td>
</tr>
<tr>
<td>K-Means (5 clusters)</td>
<td>88.168% (std : 5.264)</td>
</tr>
<tr>
<td>K-Means with position (5 clusters)</td>
<td>86.026% (std : 5.282)</td>
</tr>
<tr>
<td>Agglomerative Clustering</td>
<td>88.956% (std : 10.632)</td>
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</tbody>
</table>

## Cancer classification

<table>
<thead>
<tr>
<th>METHOD</th>
<th>BEST SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Forest Classifier</td>
<td>87.000% (std : 12.991)</td>
</tr>
<tr>
<td>Logistic Regression</td>
<td>81.297% (std : 5.744)</td>
</tr>
<tr>
<td>Logistic Regression (texture)</td>
<td>68.285% (std : 0.082)</td>
</tr>
</tbody>
</table>
FIGURE — Comparison of Pathology and Radiology results (average estimations of Oligodendroglioma cancer for each sample)
Results

Conclusion

- Random Forest classifier validated with k-fold cross validation had average accuracy of 87.0%
- Pre-processing of the input data is a hand-crafted process, that had to be performed
- K-Means had the best score out of Mini Batch K-Means, K-Means with modified input vector (with position), and Agglomerative clustering
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