3D Texture Analysis of Magnetic Resonance Imaging in Paediatric Neuro-oncology

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Problem

UK Childhood Cancer Statistics:

<table>
<thead>
<tr>
<th>Cancer Type</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin Other CNS and Intracranial Tumours</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>Lymphoma</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Soft Tissue Sarcoma</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Sympathetic Nervous System (SNS) Tumours</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Renal Tumours</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Bone Sarcoma</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Carcinomas and Malignant Melanomas</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Germ Cell and Gonad Tumours</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Retinoblastoma</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Hepatic Tumours</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Other and Unspecified Tumours</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Average Number of Cases per Year

27%

Two cases of paediatric brain tumours:

a. Medulloblastoma
b. Ependymoma

T2-weighted images obtained from: CCLG e-Repository

Initial characterisation of tumours from MRI scans is usually performed via radiologists’ visual assessment. However, different brain tumour types do not always demonstrate clear differences in physical appearance. Using conventional MRI to provide a definite diagnosis would lead to inaccurate results. Hence, the current diagnosis gold standard is invasive histopathological examination of biopsy samples taken through surgery. This gives rise to the need for a quantitative, accurate and non-invasive diagnostic aid.

Following diagnosis, determination of prognosis is an important step in tumour management, with implications that determine treatment options. Therefore, non-invasive prediction of tumour prognosis has the potential to advance clinical management of patients for therapy and the possibility to support more informed discussions with the patient’s family.

Texture Analysis

Texture is generally considered a vague term with no universal definition that is agreed upon. However, in medical image processing texture is defined as the spatial variation of pixel intensities.

Based on pixel intensities → Quantitative → Captures patterns beyond human vision

There is a range of different texture analysis (TA) methods that can be used, the most common of which is histogram analysis.

Another common method is grey-level co-occurrence matrix (GLCM) which aims to compute the number of pixel pairs that have a certain sequence (Haralick et al 1973)

Refer to the review paper by Castellano et al 2004 for a summary of common TA methods in the medical imaging field.

Technical Work

Diagnostic classification

We recently conducted an experiment on clinical MRI data to assess the efficacy of 3D texture analysis (TA) in diagnostic classification of common paediatric brain tumours. The data comprised pre-contrast T₁ and T₂-weighted MRI series obtained from forty-eight children diagnosed with brain tumours (medulloblastoma, pilocytic astrocytoma, and ependymoma). 3D and 2D TA were performed on regions of interest segmented from the scans. Various supervised machine-learning classifiers were trained and tested with the data using leave-one-out cross-validation. 3D trained support vector machine (SVM) was able to yield 86% classification accuracy.

Survival analysis

There has been a push for tumour characterisation using non-invasive MR image analysis methods, such as texture analysis (TA) over the past decade. The recent studies reported by Rodriguez Guiterrez et al 2013 and Orphanidou-Vlachou et al 2014 are great examples of such applications in the field. Such work raises an interesting question: If textural features could capture powerful patterns that aid the diagnosis of tumours, can they also be used to predict patients’ survival prognosis?

We carried out another study in order to assess the performance of TA in predicting tumour prognosis. The dataset comprised pre-contrast T₁ and T₂-weighted MRI series obtained from thirty-two children attending Birmingham Children’s Hospital and diagnosed with medulloblastoma. We were able to identify 15 significant features using the log-rank test. The test results showed that these features were able to successfully differentiate between good and poor survival prognoses. All features were variations of sum variance, sum of squares and angular second moment, with different inter-pixel distances and directions of analysis.

Conclusion

TA was successfully used to differentiate between the three most commonly occurring brain tumours in children, with 3D TA showing an improved performance compared to 2D TA. Additionally, 3D textural features were able to predict the survival of childhood medulloblastoma.

References

D. Rodriguez et al, AJNR (2014) 35: 1109-1210
F. Jepson et al, Computer Methods and Programs in Biomedicine (2003) 74: 127-139