Qdec:
A group-analysis tool for Freesurfer

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What is Qdec?

- An application included in the FreeSurfer software package used to conduct a group analysis of morphometric and other types of data
- Graphical User Interface (GUI)
- Powered by a GLM-fitter
- Optimized for display of results on the cortical surface
What problem does it solve?

- There is an ever-growing collection of subjects processable by Freesurfer’s ‘recon-all’ stream: eg. 400+ OASIS subjects, 300+ ADNI subjects, 1000+ FHS subjects

- Researchers need a GUI tool to allow easy exploration of the morphometric data found in this and other subject groups
Explore data correlations

- Does subject age correlate with cortical thickness?
- Does hippocampal volume correlate with cortical thickness in a particular region?
- Is there a gender-diagnosis interaction in the thickness-age correlation?
What is FreeSurfer?

- Cortical reconstruction and subcortical segmentation of T1 MRI images (single subject)
- Morphometric data: cortical thickness, subcortical structure volume
- Surface-based registration: alignment to another subject’s cortical folds
Cortical thickness

- Distance between white and pial surfaces
- One value per vertex
Subcortical structures

- Caudate
- Pallidum
- Putamen
- Amygdala
- Hippocampus
- Lateral Ventricle
- Thalamus
- White Matter
- Cortex
Surface-based registration
So what is QDEC???

- Query (a subject database)
- Design (matrix, of data points, for GLM)
- Estimate (regression coefficients, GLM)
- Contrast (matrix, hypothesis)
Is Thickness correlated with Age?

```
<table>
<thead>
<tr>
<th>Thickness</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>y1</td>
<td>x1</td>
</tr>
<tr>
<td>y2</td>
<td>x2</td>
</tr>
</tbody>
</table>
```

Independent Variable

Dependent Variable, Measurement

Subject 1

Subject 2
Linear model

Intercept: \( b \)
Slope: \( m \)

Thickness

Age

System of Linear Equations
\[
y_1 = 1 \cdot b + x_1 \cdot m \\
y_2 = 1 \cdot b + x_2 \cdot m
\]

Matrix Formulation
\[
\begin{bmatrix}
y_1 \\
y_2
\end{bmatrix} = \begin{bmatrix} 1 & x_1 \\ 1 & x_2 \end{bmatrix} \cdot \begin{bmatrix} b \\ m \end{bmatrix}
\]

Intercept = Offset

\( X = \) Design Matrix
\( \beta = \) Regression Coefficients
\( = \) Parameter estimates
\( = \) “betas”
\( = \) Intercepts and Slopes
\( = \) beta.mgh (mri_glmfit)
Hypotheses and contrasts

Is Thickness correlated with Age?
Does \( m = 0 \)?
Null Hypothesis: \( H_0: m=0 \)

Thickness

Intercept: \( b \)
Slope: \( m \)

\[
\begin{bmatrix}
  y_1 \\
  y_2
\end{bmatrix} = \begin{bmatrix}
  1 & x_1 \\
  1 & x_2
\end{bmatrix} \begin{bmatrix}
  b \\
  m
\end{bmatrix}
\]

\[
m = \begin{bmatrix}
  0 & 1
\end{bmatrix} \begin{bmatrix}
  b \\
  m
\end{bmatrix}
\]

\[
\beta = \begin{bmatrix}
  b \\
  m
\end{bmatrix}
\]

\[
\gamma = C^*\beta \neq 0
\]

\( C = [0 \ 1] \): Contrast Matrix
Two groups

Do groups differ in Intercept?
Does \( b_1 = b_2 \)?
Does \( b_1 - b_2 = 0 \)?
\( C = [+1 -1 0 0], \gamma = C \ast \beta \)

Do groups differ in Slope?
Does \( m_1 = m_2 \)?
Does \( m_1 - m_2 = 0 \)?
\( C = [0 0 +1 -1], \gamma = C \ast \beta \)

Is average slope different than 0?
Does \( (m_1 + m_2)/2 = 0 \)?
\( C = [0 0 0.5 0.5], \gamma = C \ast \beta \)
t-test and p-values

\[ Y = X^*\beta \]
\[ \gamma = C^*\beta \]

\[ t = \frac{C^*\beta}{\sqrt{\sigma^2 C^* (X^T X)^{-1} C^T}} \]

p-value/significance
• value between 0 and 1
• closer to 0 means more significant

FreeSurfer stores p-values as \(-\log_{10}(p)\):
• 0.1=10^{-1} \rightarrow \text{sig}=1, \ 0.01=10^{-2} \rightarrow \text{sig}=2
• sig.mgh files
• Signed by sign of \(\gamma\)
• p-value is for an unsigned test
More GLM stuff…

For a more thorough treatment of the GLM, and FreeSurfer’s implementation of it in the ‘mri_glmfit’ utility, see these resources:

- [Group analysis PowerPoint slides](#)
- [Group analysis mri_glmfit tutorial](#)
Qdec demo

- Flash movie on next slide...
- Also see:
  - [http://surfer.nmr.mgh.harvard.edu/fswiki/FsTutorial/QdecGroupAnalysis](http://surfer.nmr.mgh.harvard.edu/fswiki/FsTutorial/QdecGroupAnalysis)
Future features

- Greater number of factors
- Contrast selection
- Subcortical structure volumes, and volumetric maps
- fMRI, PET, EEG/MEG surface data
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