Virtual brain mapping: Meta-analysis and visualization in functional neuroimaging

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ABSTRACT

Results from functional neuroimaging such as positron emission tomography and functional magnetic resonance are often reported as sets of 3-dimensional coordinates in Talairach stereotactic space. By utilizing data collected in the BrainMap database and from our own small XML database we can automatically model and visualize several studies at once. We model a set of 3-dimensional coordinates by a voxelization step where flexible probability density models such as kernel density estimators produce a voxel-volume representation of a study, allowing us to represent all coordinate data in one single data matrix.

By conditioning on elements in the databases other than the coordinate data, e.g., anatomical labels associated with many coordinates we can make conditional novelty detection identifying outliers in the database that might be erroneous entries or seldom occurring patterns. In the BrainMap database we found errors, e.g., stemming from confusion of centimeters and millimeters during entering and errors in the original article. Conditional probability density modeling also enables generation of probabilistic atlases and automatic probabilistic anatomical labeling of new coordinates. By conditioning on the behavioral domains associated with each study, e.g, the words ‘word’ and ‘visual’, we can make virtual brain activations.

Voxelization also permits us to find related volumes, where query volumes are matched with database items and the most related volumes are found and returned in sorted lists. Image-based indices can be created by singular value decomposition and by matching individual volumes against eigenimages.

Individual experiments, sets of experiments as well as results from meta-analyses can be rendered as glyphs, cut-planes or isosurfaces in 3-dimensional Corner Cube Environments or exported as VRML97 and made available on the Internet, see http://hendrix.imm.dtu.dk.
OUTLINE

- Functional neuroimaging
- The BrainMap database
- Modeling “locations”
- Novelty detection
- Functional volumes modeling
- Finding related volumes
  - Novelty
  - SVD
  - Asymmetry
- Database in XML.
- Information visualization
FUNCTIONAL NEUROIMAGING

Figure 1: Locations from (Law, 1996): Saccadic eye movements.

- Functional neuroimaging, brain mapping: Finding cognitive components, e.g., “willed action”.
- 3 different data types + behavior
  - “Paper”: Bibliographic information, PubMed.
  - “Experiment” (contrast/summary image): Description of paradigm (stimulus/response/instructions), scanner, volume or locations.
  - “Location”: 3D stereotactic coordinates (point) in Talairach space, anatomical/functional/Brodmann labels, magnitude.
THE BRAINMAP DATABASE

Figure 2: Behavioral criteria query web-page.

- **Consists of**: Entry + Database + Search and View.
  - “BrainMap Entry”. Limited distribution.
  - Database. Oracle SQL Relational database.
- **Paper** (225), **Experiment** (771), **Location** (7683, 3935 with anatomical and Brodman labels).
- **Superseded with the BrainMap DBJ** http://www.brainmapdbj.org/.
LOCATIONS AND VOLUMES

Figure 3: Voxelization.

- From volume to points:
  - Peak/local maxima
  - Center of gravity/mass.

- From points to volume: “Voxelization”
  - Regard the “locations” as being generated from a distribution $p(x)$, where $x$ is in 3D Talairach space.
  - Models:
    * Simple parametric distribution. Problem with complex distributions, e.g., bimodal.
    * Kernel method. What width and shape.
MODELING “LOCATIONS”

- Finite Gaussian mixture modeled with $K$ determined by AIC and the covariance and center determined on different parts of the data set (Hansen et al., 2000b).
- “Kernel methods” (kernels centered on each object: $K = N$) with homogeneous Gaussian kernel

$$\hat{p}(\mathbf{x}) = N^{-1} \sum_{n} \tilde{p}_n(\mathbf{x})$$  \hspace{1cm} (1)

$$\tilde{p}_n(\mathbf{x}) = (2\pi \sigma^2)^{-3/2} \exp \left( -\frac{1}{2\sigma^2} (\mathbf{x} - \mu_n)^2 \right)$$  \hspace{1cm} (2)
MODELING OF ANATOMICAL LABELS AND 3D TALAIRACH LABELS

- Modeling the relation between 3D Talairach Coordinates (three dimensional continuous value) and anatomical labels (“lobar anatomy” text field BrainMap field).

- Novelty detection: Discover unusual entries.

![Diagram](Figure 5: Processing scheme for finding outliers in BrainMap)

- Download BrainMap web-page with a Perl/Matlab script.
- Construct a matrix $Z(N \times P) = [X, Y]$ that contains $N$ rows corresponding to $N = 3935$ locations.
- Extract submatrix $X$ that contains Talairach coordinate for a given phrase.
- Construct probability density estimates (PDE) for each submatrix.
- Rank locations according to their density values.
Figure 6: Extraction of data from a “location”.

- Extraction of Talairach coordinate. Example (3.6, -7.6, 1.2).
- Extraction of each word and phrase from the field “Lobar anatomy”.
- Example “lateral superior parietal” → {“lateral”, “superior”, ”parietal”, “lateral superior”, “superior parietal”, “lateral superior parietal”}.
- Multiple data generated for one location.
MODELING OF ANATOMICAL LABELS
AND 3D TALAIRACH LABELS

Distribution of estimated sigma

Sigma as function of words

Distribution of sigma depending on $N_w$

Time consumption for estimation

Figure 7: Sigma: width of kernel

- Conditional probability: $p(x|c)$, where $c$ is a word/phrase.
- Optimize kernel width $\sigma$ with leave-one-out cross-validation.
- Robust estimate of $p(x)$ by excluding the 5% most extreme locations (as determined by their density value) in a two-stage scheme.
PDFS FOR LOCATION LABELS

Figure 8: Densities from cerebellum locations. Yellow “points” are the Brain-Map locations.

- **Condition on anatomical label:**
  \[ p(x|c = \text{cerebellum}). \]

- **Corner Cube Environment (Rehm et al., 1997).**
- **Yellow glyphs:** Original BrainMap locations.
- **Grey wireframe:** Isosurface in the first level probability density estimate.
- **Green surface:** Isosurface in the second level.
RANKING OF OUTLIERS

Figure 9: Densities from cerebellum locations.

- Automatic generated list.
- Entries sorted according to novelty.
- 2nd and 3rd entry: More information in a phrase than in a word.
**Table 1: BrainMap outliers.** The entries are ordered according to novelty. The second column indicates the paper, experiment and location identifier of the BrainMap database. The third to fifth column are x, y and z with the “reported” coordinates from BrainMap (not the corrected “Talairach 1988” coordinates).

<table>
<thead>
<tr>
<th>No.</th>
<th>BrainMap</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>BrainMap label</th>
<th>Comment</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>267, 2, 1</td>
<td>-5</td>
<td>7</td>
<td>540</td>
<td>SMA</td>
<td>Millimeter and centimeter for z-coordinate confused during BrainMap entry</td>
<td>(Buckner et al., 1996, table 4, entry 1)</td>
</tr>
<tr>
<td>2</td>
<td>29, 10, 8</td>
<td>48</td>
<td>-23</td>
<td>-51</td>
<td>Lateral superior parietal</td>
<td>Resolved: Transcription mistake.</td>
<td>(Corbetta et al., 1993, table 5)</td>
</tr>
<tr>
<td>3</td>
<td>141, 1, 10</td>
<td>35</td>
<td>150</td>
<td>28</td>
<td>Dorsolateral pre-frontal</td>
<td>Millimeter and centimeter for y-coordinate confused during BrainMap entry</td>
<td>(Kossyn et al., 1994, table 2, entry 10)</td>
</tr>
<tr>
<td>5</td>
<td>280, 1, 9</td>
<td>24</td>
<td>-70</td>
<td>-24</td>
<td>Dorsal parietal cortex</td>
<td>Is labeled “Right cerebellum” in the article</td>
<td>(Schlösser et al., 1998, table 1, entry 9)</td>
</tr>
<tr>
<td>6</td>
<td>4, 2, 7</td>
<td>-6</td>
<td>42</td>
<td>-8</td>
<td>Cerebellum — superior anterior</td>
<td>Not possible to find the foci in the article.</td>
<td>(Petersen et al., 1988)</td>
</tr>
<tr>
<td>7</td>
<td>280, 1, 7</td>
<td>38</td>
<td>24</td>
<td>-8</td>
<td>Dorsolateral parietal</td>
<td>Is labeled “Right orbitofrontal cortex” in the article</td>
<td>(Schlösser et al., 1998, table 1, entry 7)</td>
</tr>
<tr>
<td>8</td>
<td>249,1,29</td>
<td>-2</td>
<td>26</td>
<td>16</td>
<td>Limbic Lobe</td>
<td>Correct</td>
<td>S. K. Braman, 1997, Unpublished</td>
</tr>
<tr>
<td>9</td>
<td>277, 3, 3</td>
<td>-50</td>
<td>-42</td>
<td>-14</td>
<td>Inferior frontal gyrus, posterior</td>
<td>Is labeled “inferior temporal gyrus posterior (area 37)” in the article</td>
<td>(Owen et al., 1996, table 2, entry 3)</td>
</tr>
<tr>
<td>10</td>
<td>115, 2, 5</td>
<td>-38</td>
<td>54</td>
<td>0</td>
<td>Middle temporal gyrus</td>
<td>Not resolved.</td>
<td>(Shaywitz et al., 1996, page 155)</td>
</tr>
<tr>
<td>11</td>
<td>192,17</td>
<td>24</td>
<td>-47</td>
<td>38</td>
<td>Frontal</td>
<td>Not resolved</td>
<td>(Pardo et al., 1991, Table 1a, entry 17)</td>
</tr>
<tr>
<td>12</td>
<td>47,4,1</td>
<td>-36</td>
<td>32</td>
<td>28</td>
<td>Medial frontal lobe</td>
<td>Correct</td>
<td>(George et al., 1994)</td>
</tr>
<tr>
<td>13</td>
<td>65, 2, 23</td>
<td>57</td>
<td>26</td>
<td>45</td>
<td>Anterior cingulate</td>
<td>Millimeter and centimeter for x-coordinate confused during BrainMap entry.</td>
<td>(O’Sullivan et al., 1994, table 4, entry 10)</td>
</tr>
<tr>
<td>14</td>
<td>52, 1, 2</td>
<td>36</td>
<td>-46</td>
<td>36</td>
<td>Inferior frontal gyrus</td>
<td>Probably misunderstanding of the text during entry. The foci is around supramarginal gyrus and the denoted “BA40”.</td>
<td>(Becker et al., 1994, page 287)</td>
</tr>
<tr>
<td>15</td>
<td>61, 1, 12</td>
<td>-24</td>
<td>42</td>
<td>4</td>
<td>Temporal/insular</td>
<td>Resolved: Transcription mistake.</td>
<td>(Tulving et al., 1994, table 1)</td>
</tr>
</tbody>
</table>
THE WORD “LOBE”

Figure 10: Probability density estimation of “lobe”. The blue/magenta wire-frame model is the second stage probability density estimate at a $P_{HPD} = 0.5$ threshold, and the orange glyphs are the “lobe” BrainMap locations.

<table>
<thead>
<tr>
<th>Count</th>
<th>Lobar Anatomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>inferior parietal lobe</td>
</tr>
<tr>
<td>10</td>
<td>superior parietal lobe</td>
</tr>
<tr>
<td>6</td>
<td>midline occipital lobe</td>
</tr>
<tr>
<td>2</td>
<td>limbic lobe</td>
</tr>
<tr>
<td>1</td>
<td>subgyral frontal lobe</td>
</tr>
<tr>
<td>1</td>
<td>paracentral parietal lobe</td>
</tr>
<tr>
<td>1</td>
<td>medial occipital gyrus/temporal lobe</td>
</tr>
<tr>
<td>1</td>
<td>medial frontal lobe</td>
</tr>
</tbody>
</table>

• “Lobe” location is focused in specific areas.
OTHER BRAIN ATLASES

Figure 11: Talairach cerebellum.

Figure 12: MNI cerebellum.
ANATOMICAL ATLASES

(precuneus) precuneus

Asymmetry: -0.07005 (left: -1, right: +1)

SPM ANALYZE volume (MNI, symmetric,
Sigma=4.44789mm, 79 x 95 x 68, 2.0mm x 2.0mm x 2.0mm)
- precuneus-mni-sym.hdr (1 Kb)
- precuneus-mni-sym.img (2042 Kb)

VRML2 file (250 Kb)

<table>
<thead>
<tr>
<th>Talairach</th>
<th>BrainMap</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>Paper</th>
<th>Exp</th>
<th>Loc</th>
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</thead>
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<tr>
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<td>27</td>
<td>2</td>
<td>8</td>
<td></td>
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<td>2</td>
<td>9</td>
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<td>14</td>
<td>-46</td>
<td>36</td>
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<td>4</td>
<td></td>
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</tr>
<tr>
<td>12</td>
<td>-55</td>
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<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-57</td>
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<td>6</td>
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<td></td>
</tr>
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<td>-57</td>
<td>53</td>
<td>29</td>
<td>11</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>-42</td>
<td>45</td>
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<td>11</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-18</td>
<td>-48</td>
<td>47</td>
<td>29</td>
<td>11</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-59</td>
<td>51</td>
<td>29</td>
<td>11</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

82 coordinates (total)

Figure 13: “Posterior cingulate” web-page.

- Collaborative efforts sometimes better than individual experts
  - In modeling of fMRI with “consensus models” (Hansen et al., 2000a) where the average model perform better the individual models.
  - Information (artificial) markets (Pennock et al., 2001a; Pennock et al., 2001b) where Internet games (Foresight Exchange, HSX) make good predictors.
AUTOMATIC LABELING. PRIOR WORK

- Talairach coordinate → Neuroanatomical label.
- Digital brain atlas based:
  - Talairach Daemon based on Talairach and MNI atlas (Lancaster et al., 2000b; Lancaster et al., 1997). Java-based Internet service and stand-alone Java program (Lancaster et al., 2000a).
  - ANIMAL (Collins et al., 1995).
AUTOMATIC LABELING

Figure 15: Probability density of “Inferior temporal gyrus”.

- Automatic labeling through labeling in the literature via BrainMap.
- Generate densities for each of anatomical label. Here fixed width kernel density modeling and coarse sampling: 8mm.
- Sort on densities.
- Or generate distribution: $P(x) = \sum_{p(x') > p(x)} p(x')$ and sort that.
AUTOMATIC LABELING: EXAMPLE

<table>
<thead>
<tr>
<th>Labeler</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christian Gerlach</td>
<td>R. Inferior temporal gyrus</td>
</tr>
<tr>
<td>TD (50, -64, -12)</td>
<td>Right Cerebrum, Temporal Lobe, Fusiform Gyrus, White Matter,*</td>
</tr>
<tr>
<td>TD (49.5, -62.5, -7)</td>
<td>Right Cerebrum, Occipital Lobe, Sub-Gyrals, White Matter,*</td>
</tr>
<tr>
<td>TD (50, -64, -12)</td>
<td>Temporal Lobe 100.00</td>
</tr>
<tr>
<td>TD (49.5, -62.5, -7)</td>
<td>Occipital Lobe 7.70, Temporal Lobe 62.35</td>
</tr>
</tbody>
</table>

Table 2: An example location: Talairach Daemon labeling. (Gerlach et al., 2000, table 1, entry 1): “R. Inferior temporal gyrus”, (50, -64, -12), BA37. Brett’s nonlinear transformation: MNI → (Brett) → Talairach: (49.5, -62.5, -7).

<table>
<thead>
<tr>
<th>Density</th>
<th>P-value</th>
<th>#</th>
<th>Lobar anatomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1247.234</td>
<td>0.934/557/264</td>
<td>5</td>
<td>occipital</td>
</tr>
<tr>
<td>10143.67</td>
<td>0.932/029/335</td>
<td>37</td>
<td>inferior temporal gyrus</td>
</tr>
<tr>
<td>15590.43</td>
<td>0.926/436/136</td>
<td>4</td>
<td>occipital temporal</td>
</tr>
<tr>
<td>2528.44</td>
<td>0.916/305/567</td>
<td>367</td>
<td>inferior</td>
</tr>
<tr>
<td>3917.70</td>
<td>0.907/573/1229</td>
<td>48</td>
<td>ventral</td>
</tr>
<tr>
<td>9671.07</td>
<td>0.902/681/9368</td>
<td>66</td>
<td>inferior temporal</td>
</tr>
<tr>
<td>15375.41</td>
<td>0.802/408/7613</td>
<td>7</td>
<td>ventral surface</td>
</tr>
<tr>
<td>15375.41</td>
<td>0.802/408/7613</td>
<td>7</td>
<td>surface</td>
</tr>
<tr>
<td>1200.74</td>
<td>0.788/344/6267</td>
<td>762</td>
<td>gyrus</td>
</tr>
<tr>
<td>9475.11</td>
<td>0.771/328/6841</td>
<td>22</td>
<td>inferior occipital</td>
</tr>
<tr>
<td>3607.68</td>
<td>0.863/524/0291</td>
<td>48</td>
<td>ventral</td>
</tr>
<tr>
<td>16900.23</td>
<td>0.854/498/0115</td>
<td>3</td>
<td>inferior temporal gyrus posterior</td>
</tr>
<tr>
<td>2091.93</td>
<td>0.843/802/8002</td>
<td>367</td>
<td>inferior</td>
</tr>
<tr>
<td>20796.17</td>
<td>0.827/344/7873</td>
<td>5</td>
<td>inferior lateral</td>
</tr>
<tr>
<td>8450.12</td>
<td>0.822/563/714</td>
<td>6</td>
<td>temporal gyrus posterior</td>
</tr>
<tr>
<td>1862.94</td>
<td>0.808/377/5236</td>
<td>99</td>
<td>lateral</td>
</tr>
<tr>
<td>7395.51</td>
<td>0.781/876/7138</td>
<td>37</td>
<td>inferior temporal gyrus</td>
</tr>
<tr>
<td>6982.64</td>
<td>0.753/370/1307</td>
<td>66</td>
<td>inferior temporal</td>
</tr>
<tr>
<td>8632.66</td>
<td>0.710/631/6973</td>
<td>22</td>
<td>inferior occipital</td>
</tr>
<tr>
<td>7242.96</td>
<td>0.696/589/7412</td>
<td>7</td>
<td>gyrus posterior</td>
</tr>
</tbody>
</table>

Table 3: An example location: Labeled through BrainMap. With Brett’s transformation above the line. # is the number of locations defining the volume.
“FUNCTIONAL VOLUMES MODELING”

- Condition on “behavior”.
- “Functional volumes modeling” (Fox et al., 1997; Fox et al., 1999; Fox et al., 2001). Single Gaussian on location for mouth area.
- Kernel density modeling on locations for single word reading (Turkeltaub et al., 2002; Turkeltaub et al., 2001).
- Discrimination between to sets of locations: Hotelling’s $T^2$ statistics (Christoff and Grabieli, 2000, page 176), Multidimensional Kolmogorov–Smirnov (Duncan and Owen, 2000).
- Language studies with Brodmann areas (Indefrey and Levelt, 2000; Indefrey, 2001).
- Problem:
  - Behavior annotation is on the level of the experiment
  - Abstract and other bibliographic information are on a yet higher level.
Figure 16: Densities from “Vision” and “Audition” behavioral paradigm, e.g., \( p(x|\text{behavior} = "\text{vision}" ) \). VRML97 screenshot.
Figure 17: Densities from the word “word”.
IMAGE RETRIEVAL

- “Find related experiments”.
- Image based retrieval systems typically extract features, such as texture and color and/or surrounding text (Rui et al., 1999; Djeraba and Bouet, 1997).
- QBIC, commercial system by IBM (Flickner et al., 1995), example at http://www.hermitagemuseum.org.
- Web-based image retrieval systems
  - AltaVista, text-based search
  - WebSEEK (Smith and Chang, 1996a; Smith and Chang, 1996b)
- Medical image retrieval
  - CT-scans, query image with “stroke” or “acute blood” (Liu and Dellaert, 1998a; Liu and Dellaert, 1998b)
  - Other (Ford et al., 2001; Comaniciu et al., 1998)
FINDING RELATED VOLUMES

Figure 18: A processing scheme for finding related BrainMap experiments based on volume comparisons.

- Data
  - Point data as “Experiments” from BrainMap with sets of locations.
  - Volumes, small set from a cluster analysis in PET (Balslev et al., 2002).
- Point data voxelized with Gaussian kernel on a coarse grid (8mm).
- Compute distances between volumes as the normalized inner product.
- Generation of static web-pages with sorted list of similar volumes and with links to BrainMap and Pubmed.
- For efficiency: Compute the distance in a subspace, or between the points.
Figure 19: Query volume formed from (Sergent et al., 1992) — a letter and object (visual) processing paper with the 5 original points and an isosurface in the volume.

Figure 20: Result list: All vision experiments.
(108) Shift R in R vis. field
A PET study of visuospatial attention.
[BrainMap: paper 23 | exp 12]

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>-25</td>
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<td>-8</td>
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<td>45</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>45</td>
</tr>
</tbody>
</table>

(99) Shift L in R vis. field
A PET study of visuospatial attention.
[BrainMap: paper 25 | exp 11]

(98) Shift R in L vis. field
A PET study of visuospatial attention.
[BrainMap: paper 25 | exp 10]

(296) Saccades/anti-prostimulus
[BrainMap: paper 108 | exp 10]

Figure 21: Result page with automatically generated corner cube visualization (Corbetta et al., 1993). Two cluster of activations.
**IMAGE-BASED INDICES: NOVELTY**

<table>
<thead>
<tr>
<th>Novelty</th>
<th>Entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2795242</td>
<td><strong>66</strong> McSinnis S. – ROI Template II.</td>
</tr>
<tr>
<td>1775454</td>
<td><strong>67</strong> McSinnis S. – ROI Template II.</td>
</tr>
<tr>
<td>1649295</td>
<td><strong>68</strong> McSinnis S. – Anxiety Metaanalysis., 1998.</td>
</tr>
<tr>
<td>1192062</td>
<td><strong>72</strong> McSinnis S. – ROI template I.</td>
</tr>
</tbody>
</table>

Figure 22: The top of the novelty list.

- **Novelty for an experiment, here:** The normalized inner product with the mean volume, i.e., related to the angle between volume and mean volume.
- **Unconditional novelty:** Should not be as sensitive as a conditional novelty.
- **Highest scoring:**
  - (Allison et al., 1994): Only EEG study in the database, only $x$ and $y$ coordinates are given.
  - (Balslev et al., 2002): Perhaps a motion artifact.
Figure 23: Both ends of the second eigenimage $v_2$.

- **Singular value decomposition of the (experiment $\times$ voxel) data matrix:** $ULV^T = \text{svd}(X)$. Columns of $V$ is called eigenimages.

- **Second eigenimage:** One end interpreted as sensorimotor (“upper extremity movements”, “thumb-finger opposition”), other end as visual (“Watch virtual reality right hand grasping objects”).

- **Higher components have increasing spatial frequency.** Orthogonality problem. ICA?
**IMAGE-BASED INDICES: ASYMMETRY**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Probability</th>
<th>Total</th>
<th>Left</th>
<th>Right</th>
<th>Anatomical label</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00171</td>
<td>13</td>
<td>1</td>
<td>12</td>
<td>anterior cerebellum</td>
</tr>
<tr>
<td>2</td>
<td>0.00183</td>
<td>44</td>
<td>12</td>
<td>32</td>
<td>vermis</td>
</tr>
<tr>
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<td>0.00195</td>
<td>9</td>
<td>0</td>
<td>9</td>
<td>calcarine sulcus</td>
</tr>
<tr>
<td>4</td>
<td>0.00591</td>
<td>20</td>
<td>4</td>
<td>16</td>
<td>calcarine</td>
</tr>
<tr>
<td>5</td>
<td>0.00693</td>
<td>38</td>
<td>11</td>
<td>27</td>
<td>cerebellar vermis</td>
</tr>
<tr>
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<tr>
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<td>127</td>
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<tr>
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<td>5</td>
<td>0</td>
<td>5</td>
<td>homologue</td>
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<tr>
<td>12</td>
<td>0.05923</td>
<td>15</td>
<td>4</td>
<td>11</td>
<td>colliculus</td>
</tr>
</tbody>
</table>

Table 4: Right dominant brain asymmetry.

- **“Experiment” left/right asymmetry:** Count the number of locations in the left side $X$

\[
P_{\text{Bin}} = \sum_{0}^{X} \binom{N}{X} 0.5^N
\]  

(3)

Normalize the value to $[-1; +1]$ range

\[
a = 1 - 2P_{\text{Bin}}
\]  

(4)

- For anatomical labels the measure will be biased due to correlated entries: an author within a paper tend to use the same labeling scheme


- Right dominate (+1): ‘anterior cerebellum’
A DATABASE IN XML

... 
<title>Functional localization of pain perception in the human brain studied by PET.</title> 
<u1>97235324</u1> 
<volume>8</volume> 
<year>1997</year> 
<Exp> 
<type>exp</type> 
<capsuleDescription> Painful stimulation of the left hand </capsuleDescription> 
<freeFormDescription> Painful stimulation of the left hand by laser </freeFormDescription> 
<specificTask> Painful stimulation </specificTask> 
<numberOfSubjects> 6 </numberOfSubjects> 
<labOfExperiment> Kyoto University - Kyoto, Japan </labOfExperiment> 
<modality> PET </modality> 
<measuredVariable> CBF </measuredVariable> 
<tracer> 0-15 Water </tracer> 
...

• “Poor man’s XML” (pXML): no attributes, no empty tags, only letters allowed in element tag names, two types (either simple text field or structure). A subset of XML as Minimal XML (Park, 2000) and Canonical XML (Boyer, 2001).

• Relatively easy to read with a recursive extended regular expression: 3–9 lines of Perl. Validation with definition DTD.

• Easy to distribute database

• Extensible definitions

  <author>Van Essen, D. J.</author> 
  <Author> 
    <surname>Van Essen</surname> 
    <firstname>David</firstname> 
    <initials>DJ</initials> 
  </Author> 

• Matlab program to type in the information.
Figure 24: Information visualization as a process: Initial hypothesis, scanning, analysis and lastly interpretation, which links to the initial hypothesis.

- Information visualization example (Nielsen and Hansen, 1997): Visualize every kind of data that is generated in a neuroimaging study — supplement to textual information.

- Second item in Jakob Nielsen’s: Top Ten Mistakes in Web Design”: “Gratuitous Use of Bleeding-Edge Technology” (Nielsen, 1996)?
CONCLUSION

- Modeling 3D Talairach coordinates with kernel density estimators.
- Visualization with Corner Cube Environments
- Novelty detection, finding related experiments, functional volumes modeling.
- Brede neuroinformatics toolbox: Primarily written in Matlab. Includes a small XML database of results from functional neuroimaging.
- Results available on the Internet from hendrix.imm.dtu.dk more specifically hendrix.imm.dtu.dk/services/jerne/.
References


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