Linking CoCoMac and Brede databases

Finn Årup Nielsen

Lundbeck Foundation Center for Integrated Molecular Brain Imaging
at
Informatics and Mathematical Modelling
Technical University of Denmark
and
Neurobiology Research Unit,
Copenhagen University Hospital Rigshospitalet

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Linking CoCoMac and Brede databases

CoCoMac database records anatomical connectivity of the macaque.

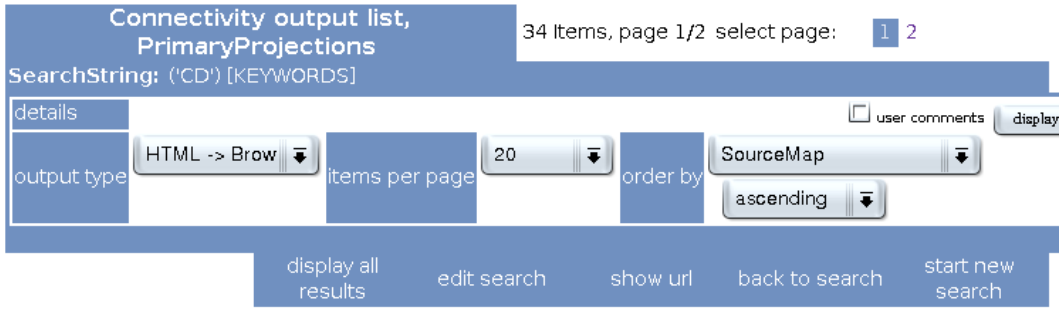
Brede database contains stereotaxic coordinates in the human.

Combining these databases will enable visualization of the 3-dimensional connectivity.

Project with Jesper Rønager, Copenhagen University Hospital Rigshospitalet, Neurology.

Some functionality already exists via the Catacomb and Carat software (Kötter, 2004; Cannon et al., 2003; Van Essen et al., 2001), e.g., a network with 95 nodes and 2402 connections has been constructed (Kaiser and Hilgetag, 2004; Sporns et al., 2004).

CoCoMac connectivity database



Connectivity output list, PrimaryProjections — 34 Items, page 1/2 select page: 1 2

SearchString: ('CD') [KEYWORDS]

details — user comments — display

output type: HTML -> Brow | items per page: 20 | order by: SourceMap | ascending

display all results | edit search | show url | back to search | start new search

Item	SourceSite	PDC	Hemisph.	Density	PDC	Course	TargetSite	PDC	Hemisph.	Laminae
1.	B09-19	D	?	X	-	I	BD77-Cd	A	?	Laminae LS
2.	B09-19	D	?	X	-	I	BD77-Cd	A	?	Laminae LS
3.	B09-18	D	?	X	-	I	BD77-Cd	A	?	Laminae LS
4.	B09-18	D	?	X	-	I	BD77-Cd	A	?	Laminae LS
5.	B09-18	D	?	X	-	I	BD77-Cd	A	?	Laminae LS
6.	B09-18	D	?	X	-	?	BD77-Cd	F	?	Laminae LS
7.	RTMB99-Cd	L	L	0	-	I	RTMB99-PMdr	C	L	Laminae LS
8.	RTMB99-Cd	L	L	0	-	I	RTMB99-PMdr	C	L	Laminae LS
9.	RTMB99-Cd	L	L	0	-	I	RTMB99-46sup	C	L	Laminae LS
10.	RTMB99-Cd	L	L	0	-	I	RTMB99-PMdc	C	L	Laminae LS
11.	RTMB99-Cd	L	L	0	-	I	RTMB99-46inf	C	L	Laminae LS
12.	RTMB99-Cd	L	L	0	-	I	RTMB99-PMvc	C	L	Laminae LS
13.	RTMB99-Cd	L	L	0	-	I	RTMB99-PMv	C	L	Laminae LS
14.	RTMB99-Cd	L	L	0	-	I	RTMB99-PMdc	C	L	Laminae LS
15.	RTMB99-Cd	L	L	0	-	I	RTMB99-PMdc	C	L	Laminae LS
16.	RTMB99-Cd	L	L	0	-	I	RTMB99-PMdc	C	L	Laminae LS
17.	RTMB99-Cd	L	L	0	-	I	RTMB99-SMA	C	L	Laminae LS
18.	RTMB99-Cd	L	L	0	-	I	RTMB99-PMvr	C	L	Laminae LS
19.	RTMB99-Cd	L	L	0	-	I	RTMB99-SMA	C	L	Laminae LS
20.	RTMB99-Cd	L	L	0	-	I	RTMB99-M1	C	L	Laminae LS

CoCoMac records anatomical connectivity in the Macaque brain with data from presently 410 papers (Stephan et al., 2001).

Brain region ontology (Stephan et al., 2000).

Stores “from”, “to” and how strong the link is, what tracer, etc.

Database on the Internet with output as HTML or XML.

Connectivity in CoCoMac

Connectivity entry:

AI92-23 A L 0 - I AI92-Bi A L

means

Area 23 of (Amaral and Insausti, 1992) in the left (L) hemisphere has zero connection (0) to "intermediate part of the basal amygdaloid nucleus" (Bi) of (Amaral and Insausti, 1992) in the left (L) hemisphere. Both areas are named explicitly (A).

Both mapping and connectivity are available as XML

Studies with human brain mapping

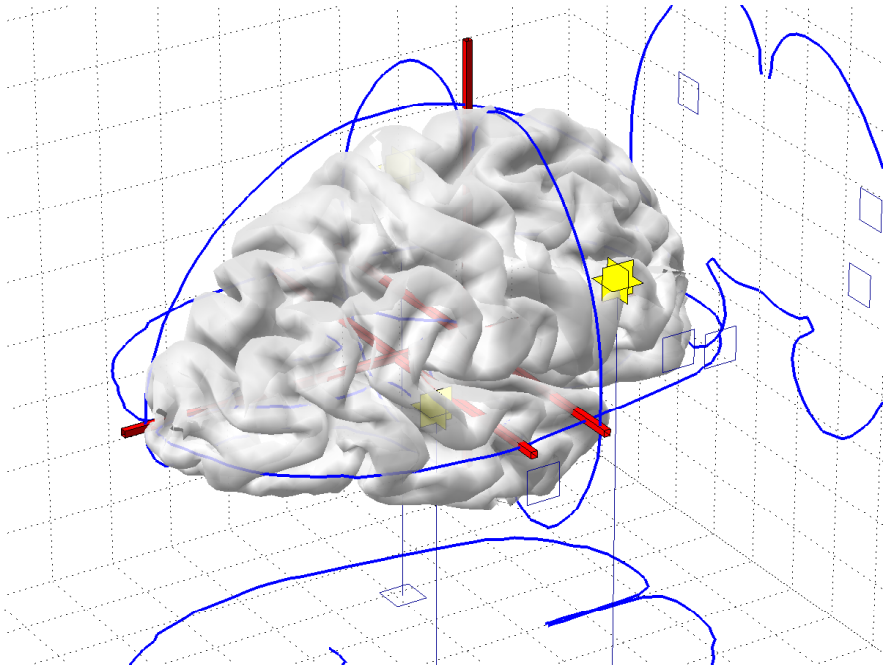


Figure 1: Results from a human brain mapping study (Balslev et al., 2005) with a "Visible Human" surface (Drury et al., 1996) displayed in a 3-dimensional corner cube environment. Two of three reported activations are visible.

Positron emission tomography or functional magnetic resonance brain scans of the human brain while subjects are engaged in the investigated mental processes.

Result represented in the literature with lists of "locations", i.e., three dimensional coordinates (in standardized "Talairach" brain space, of the hot spot activations, e.g.,

(x, y, z)	z-score
$-38, 0, 40$	4.91
$48, -42, 8$	4.66
$52, 14, 38$	4.07

Brede Database

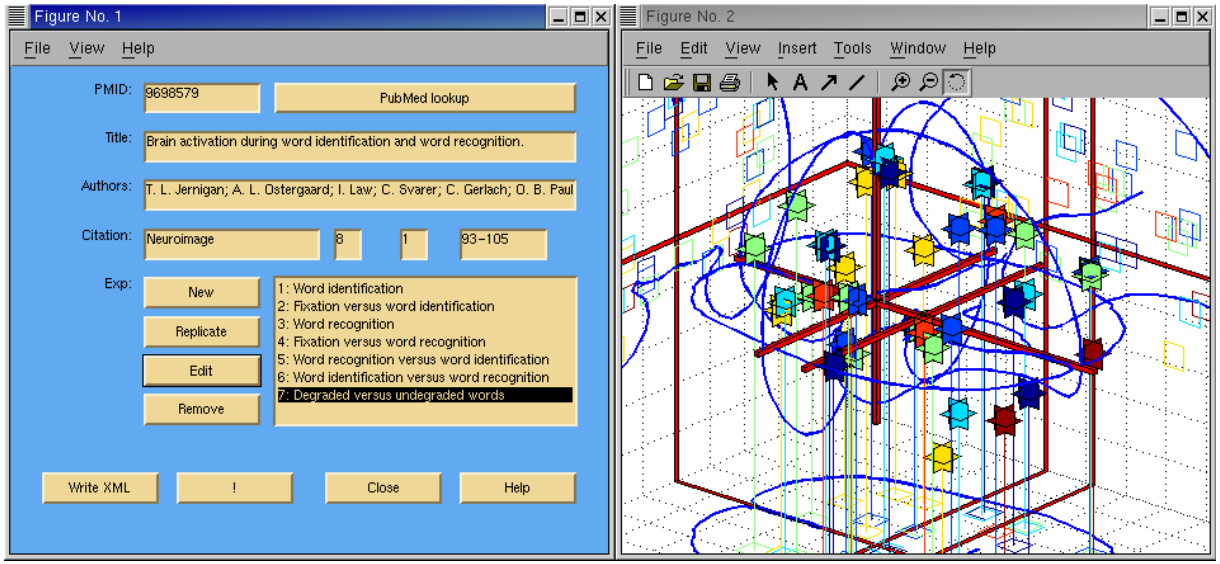


Figure 2: Screenshot of a program for entering data. Here with a study of (Jernigan et al., 1998).

Brede Database (Nielsen, 2003) typed in with a Matlab program and available on the Internet as XML files.

Every studie saves, e.g., author, article title, abstract, scanner, number of subjects, coordinates, anatomical names, topic under study.

Taxonomy for brain regions and topics

Brede Database coordinate information

x	y	z	Lobar anatomy	Functional area
-50	-2	36		Left frontal eye field
42	-8	48		Right frontal eye field
4	-10	60		Left and right supplementary eye field
-20	-14	4	Left putamen and thalamus	
22	-8	8	Right putamen	
20	-20	16	Right thalamus	
16	-64	-20	Vermis	
-20	-54	-32	Floccolus region	
-6	-38	-4	Mesencephalon	
-18	28	-20		Left orbit (eye muscles)
20	28	-20		Right orbit (eye muscles)
-12	-86	32	Left cuneus	
8	-86	32	Right cuneus	

Interesting fields here: 3906 "location" structures with 3D stereotaxic coordinates, lobar anatomy and functional area textual labels and Brodmann areas.

Functions in the Brede Toolbox (Nielsen and Hansen, 2000) are able to find all coordinates with a given lobar anatomy label.

Brede brain region taxonomy

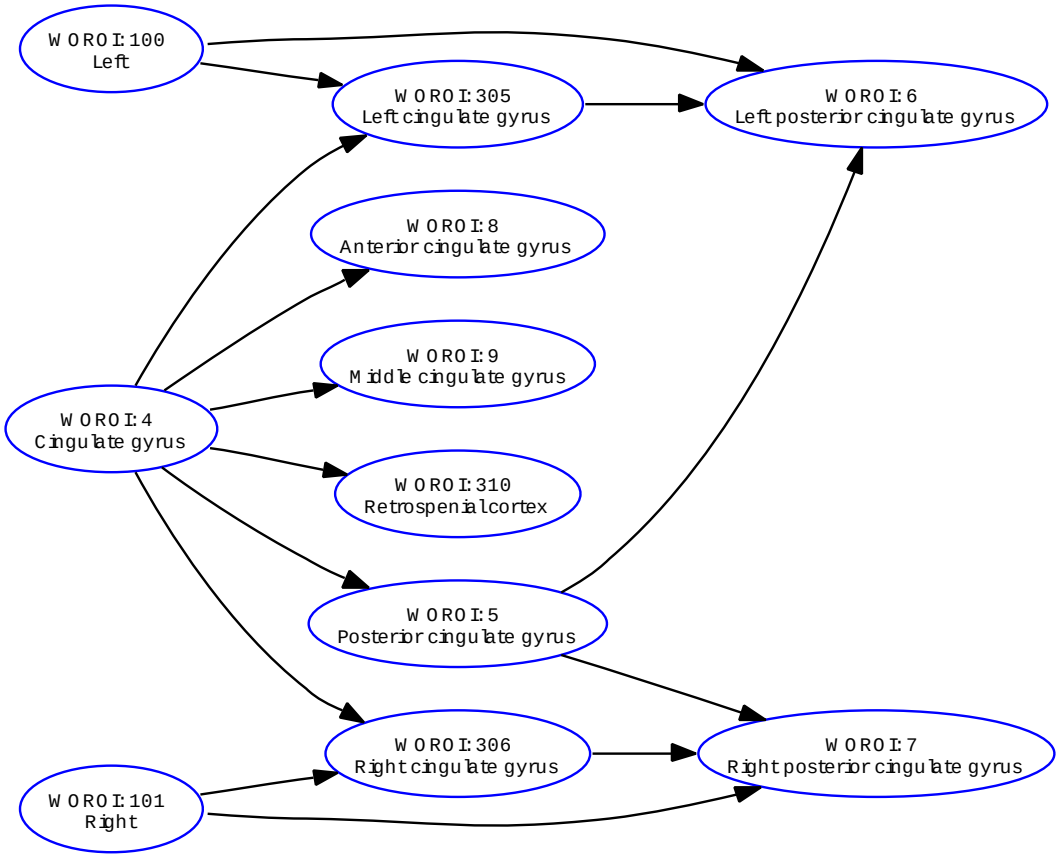


Figure 3: Brede brain region taxonomy at cingulate gyrus.

Organizes brain areas in a hierarchy.

Variations on naming of a brain area.

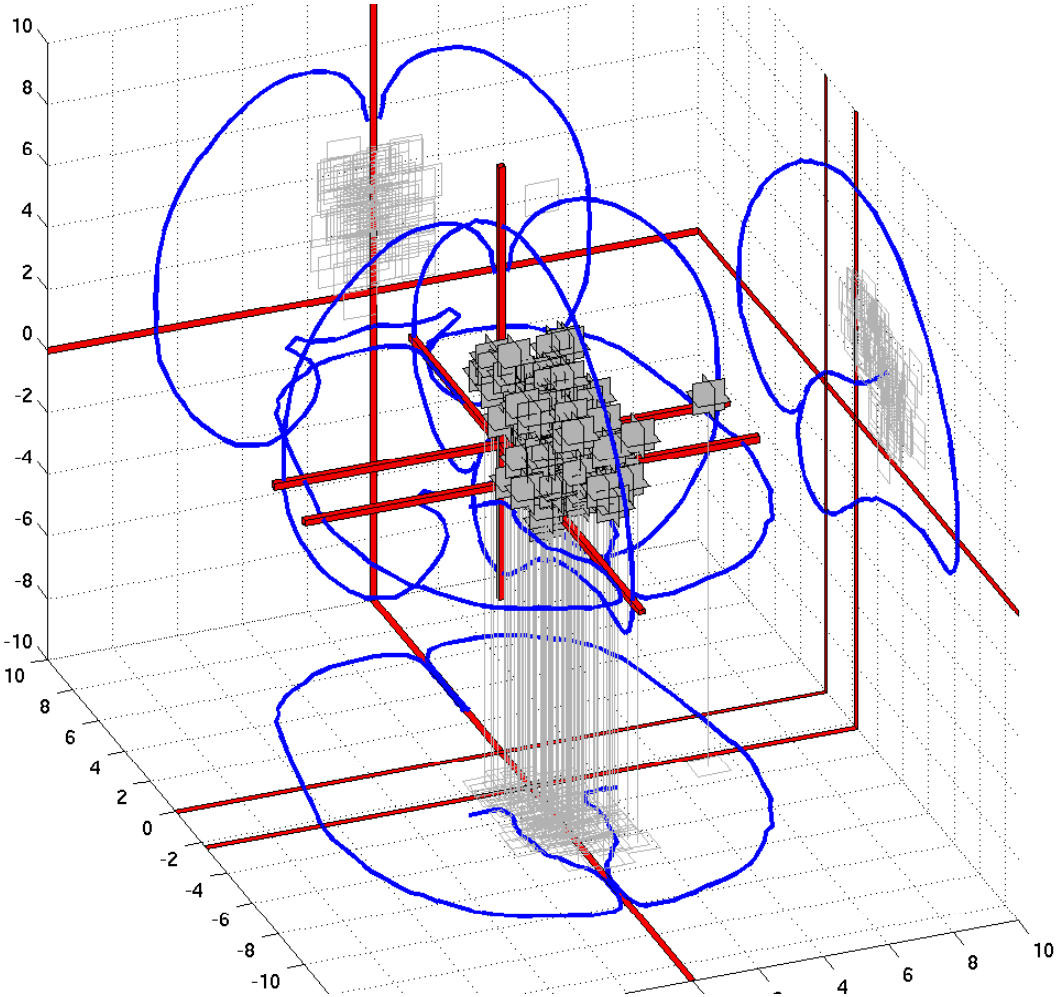
Extended significantly to link to the detailed brain areas from CoCoMac.

Links to stereotaxic volumetric definitions of brain area (Tzourio-Mazoyer et al., 2002; Hammers et al., 2002).

Example entry in XML of the Brede Database

```
<Roi>
  <woroi>5</woroi>
  <name>Posterior cingulate gyrus</name>
  <abbreviation>PCgG</abbreviation>
  <abbreviation>CGp</abbreviation>
  <brainInfo>144</brainInfo>
  <cocomacSite>OMG96-CGp</cocomacSite>
  <type>roi</type>
  <variation>Posterior cingulate</variation>
  <variation>Posterior cingulate area</variation>
  <variation>Posterior gyrus cinguli</variation>
  <variation>Posterior cingulate cortex</variation>
  <parent>4</parent>
</Roi>
```

Finding a representative coordinate



Search on lobar anatomy, if no coordinates are found try parent (supra-region).

Problem with, e.g., 8a and 8b which fall back on coordinates labeled BA8.

Model the distribution of stereotaxic coordinates with kernel density modeling (Nielsen and Hansen, 2002) and pick the coordinate with the highest probability density.

Matching brain areas in CoCoMac and Brede

Explicitly (manually) added individual CoCoMac brain sites to their specific entry in the Brede brain region taxonomy.

Helped by NeuroNames (Bowden and Martin, 1995), atlases (Mai et al., 1997) and texts with human/macaque comparative studies, e.g., (Van Essen, 2003; Scott and Johnsrude, 2003).

What to do about certain area (macaque and human brains are not completely homologous), e.g., Brodmann areas 13, 14, 15 and 16 are defined for monkeys — not humans?

Examples on presently missing matches:

"PBK86-region 1", VV19-4a, RACR99-V1_V (i.e., layer five of visual area 1), SA94b-ECL (Caudal limiting field of entorhinal cortex), PK85-1_Face (i.e., face area of Brodmann area 1), . . . and 625 others.

Example on connectivity matrix

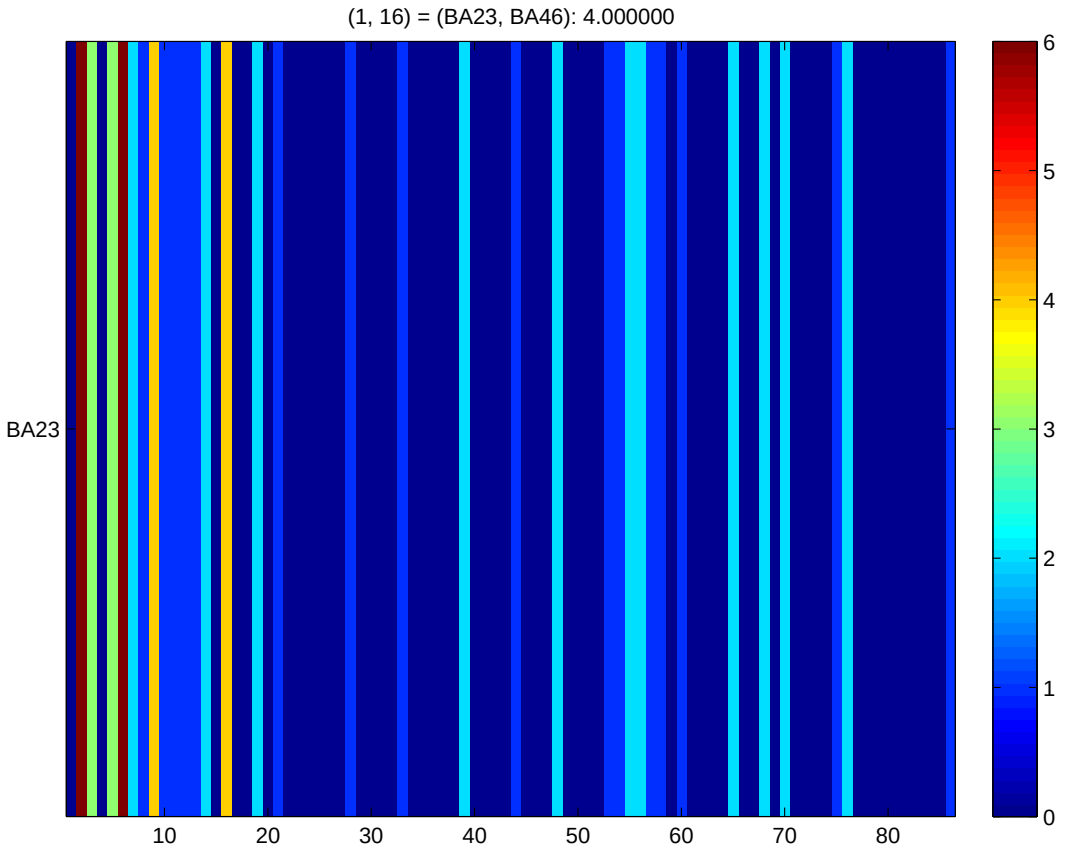


Figure 4: Connection-"matrix" from BA23.

Download and reading of CoCoMac XML information

308 entries for area 23 (i.e., BA23) as source brain site when querying CoCoMac.

27 unmatched to Brede brain region taxonomy.

86 brain areas left.

33 brain areas with non-zero connections

Matlab commands

Four matlab commands to readin, convert, display and print the CoCoMac data with the Brede Toolbox:

```
S23 = brede_read_xml_cocomac('cocomac_connectivity_23.xml');
M23 = brede_cocomac_connectivity2mat(S23);
brede_ui_mat(M23)
print -depsc /home/fnielsen/fnielsen/eps/Nielsen2006Linking_ba23.eps
```

Example 3D visualization

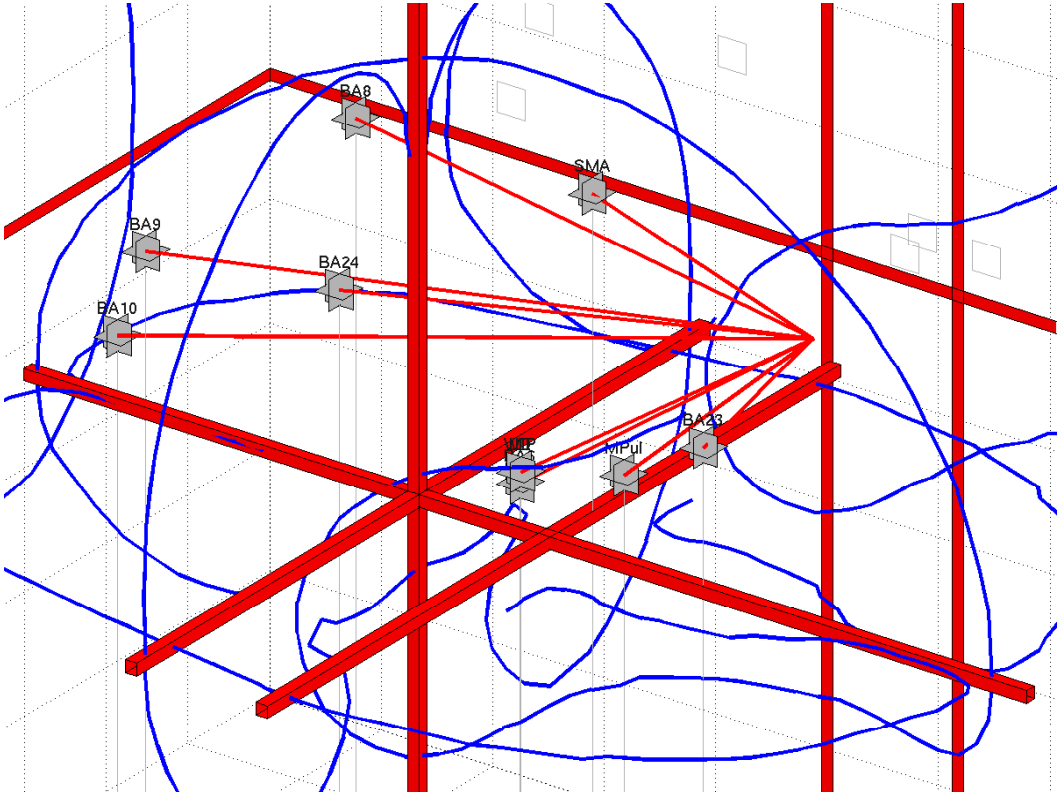
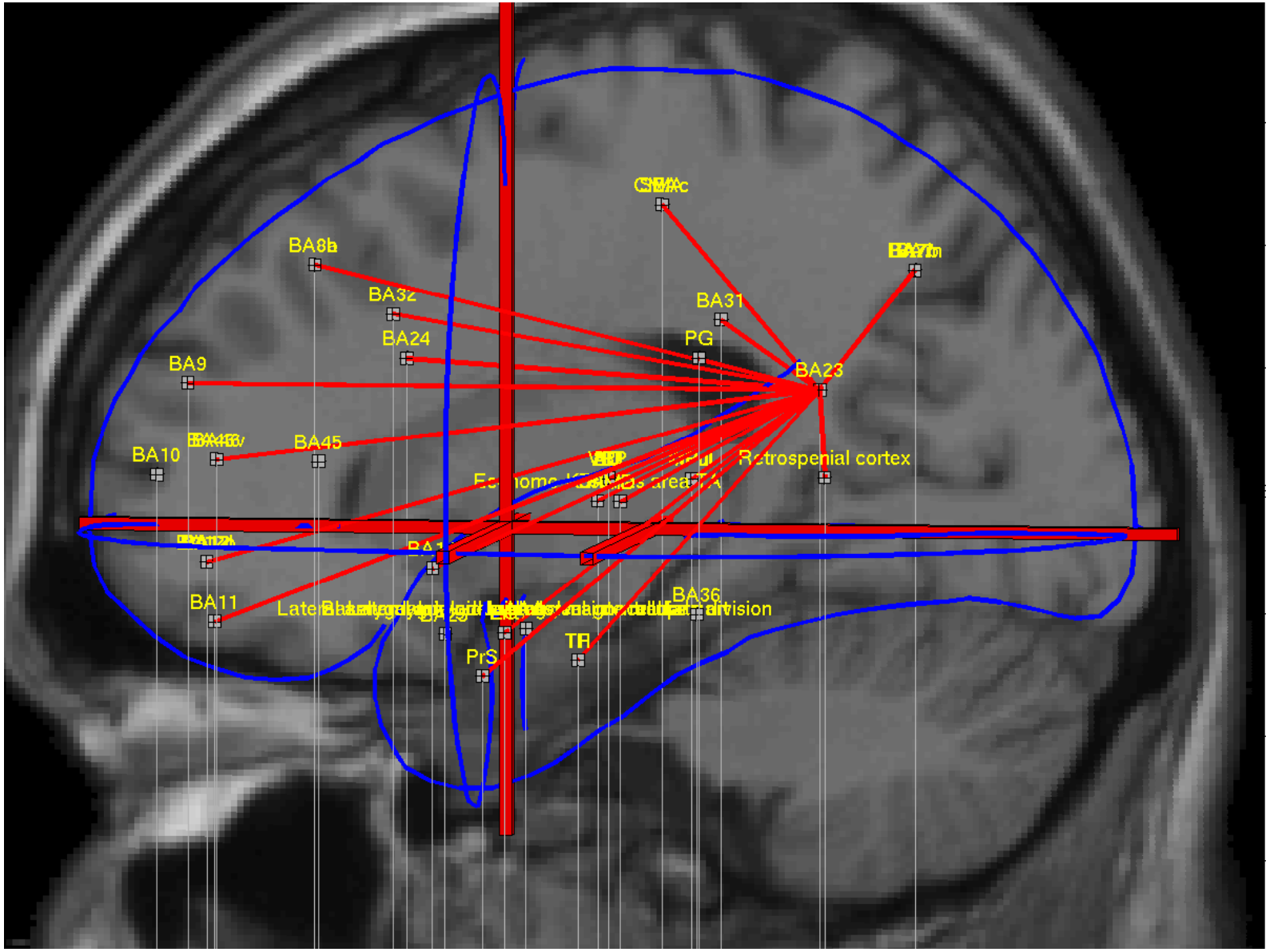


Figure 5: Connections from BA7. 3D plot from left posterior.

Query CoCoMac database for connections *from* BA7 (precuneus).

Here no distinction between left and right.


BA8
BA32
BA24
BA9
BA10
BA45
BA31
PG
BA23
Retrospenial cortex
BA11
BA36
PrS
TF

Summary

Brain region taxonomy in the Brede Database orginally developed for human molecular neuroimaging extended to accomodate (many) brain sites of CoCoMac.

Brede Toolbox extended to handle CoCoMac data and match it against information in the Brede Database.

It is difficult/problematic to match all brain areas.

The major part of macaque connections in CoCoMac can be plotted in 3D human stereotaxic space.

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