Probability map based automatic VOI/ROI delineation

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Background

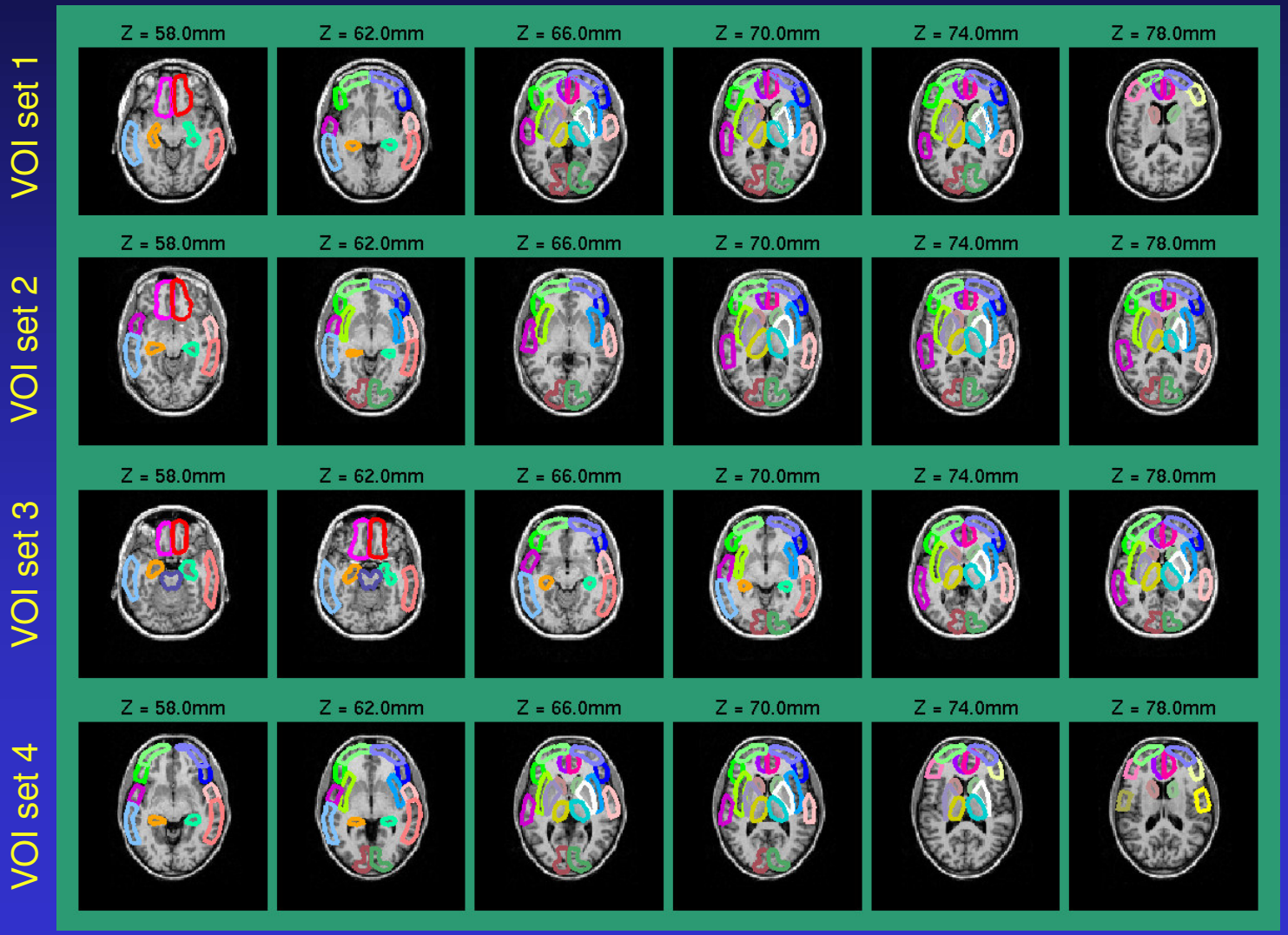
- In patient studies it is often essential to have VOI's (Volumes of Interest) delineated in patients own space for extraction of VOI values in PET/SPECT images
- Manual delineation of VOI's in new subjects space will be:
  - dependent on operator doing delineation, less objective?
  - very time demanding, up to 8 hours for a subject (37 VOI's)?
  - risk of doing errors, problems with left-right or correct annotation?
- An automatic method for application of VOI's to new subjects in a study will be able to take care of some or all of these problems

Idea of proposed method

- Multiple sets of “Regions of Interest” (VOI's) is available. These have manually been delineated at high resolution MR scans (preregistered to the AC-PC line) for a number of template subjects and afterwards carefully been checked for errors
- These VOI sets will automatically be transferred to all new subjects in a study using high resolution MR scans for the template subject and the new subjects
- Is it possible to achieve better results by combining multiple transferred template VOI sets?

Template VOI sets available

20 VOI sets (37 VOI's) have manually been delineated at high resolution structural MR images (2x2x2 mm voxels) for 10 healthy controls and 10 MCI patients by Karine Madsen and Steen Hasselbalch, NRU

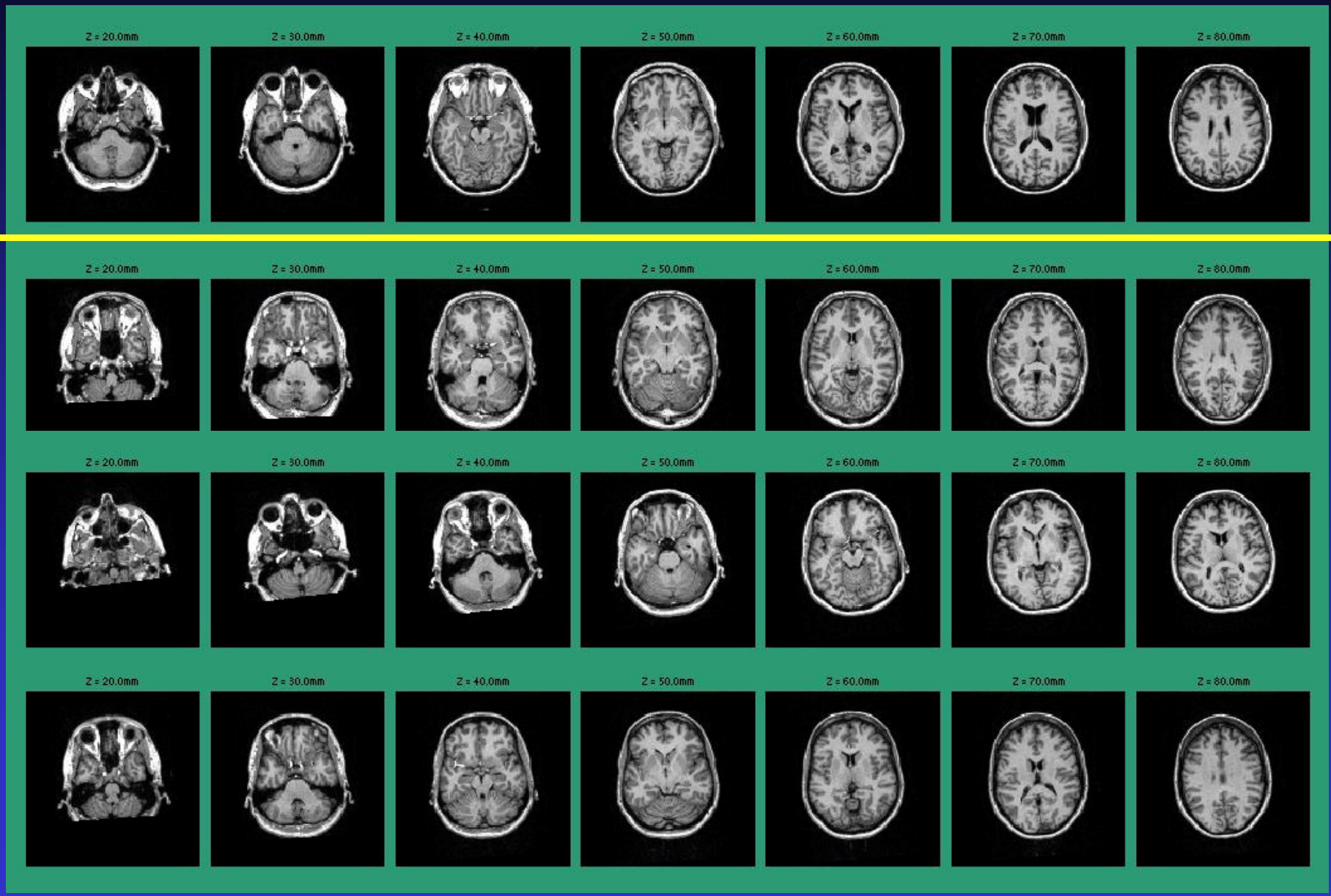


Transformations used

- Align the structural scans for each template as “optimal” as possible to each new subject using an affine transformation - 12 parameter AIR method (Software by Woods et. al, JCAT, 1992, 1993)

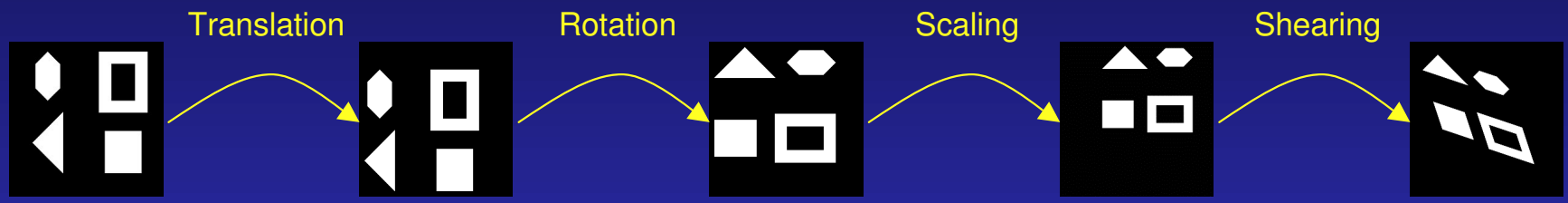
- Following the affine transformation the MR’s are transformed using a soft transformation a so-called warping algorithm (Software by Kjems, IEEE TMI, 1999)

New subject MR and three MR templates. Templates in original space.



Affine transformation

- Affine transformation (translation, rotation, stretching, and shearing)
- Straight parallel lines are straight parallel lines after transformation, but length and angles can be changed



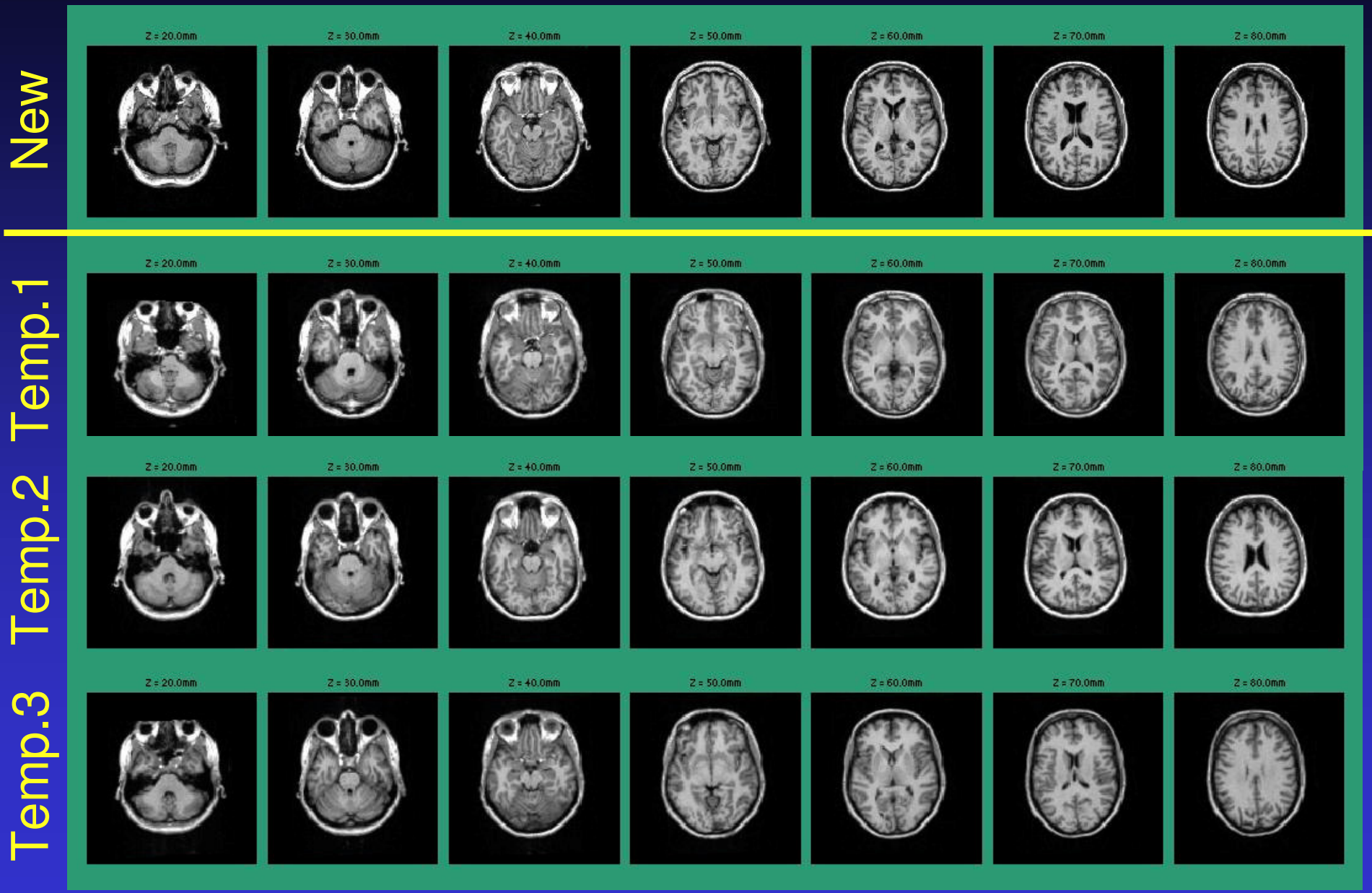
Mathematical formulation:

$$\begin{bmatrix} X' \\ Y' \\ Z' \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & c & m_x \\ d & e & f & m_y \\ g & h & i & m_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

x, y and z are voxel coordinates before transformation
x',y' and z' are voxel coordinates after transformation

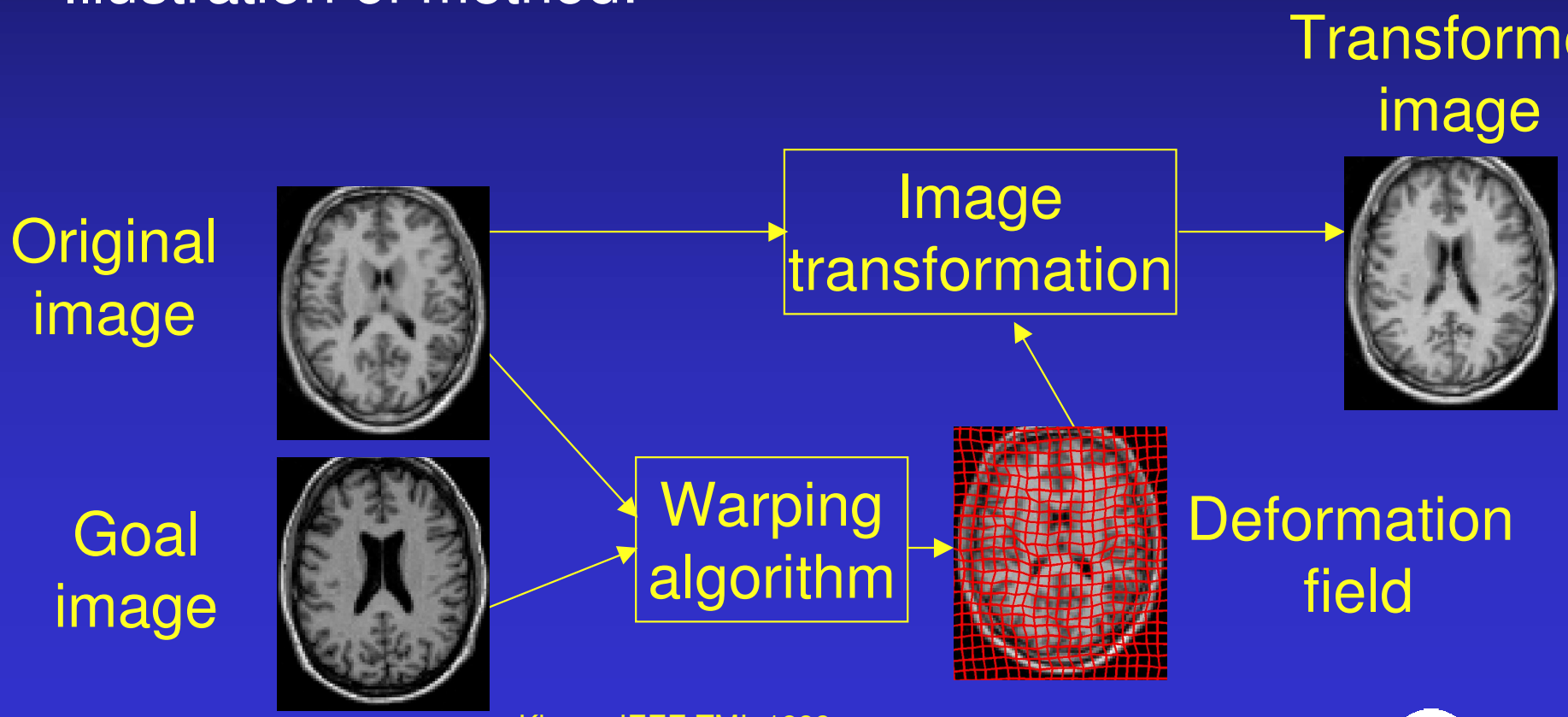
Woods, JCAT, 1992

New subject MR and three MR templates. Templates after affine transformation.



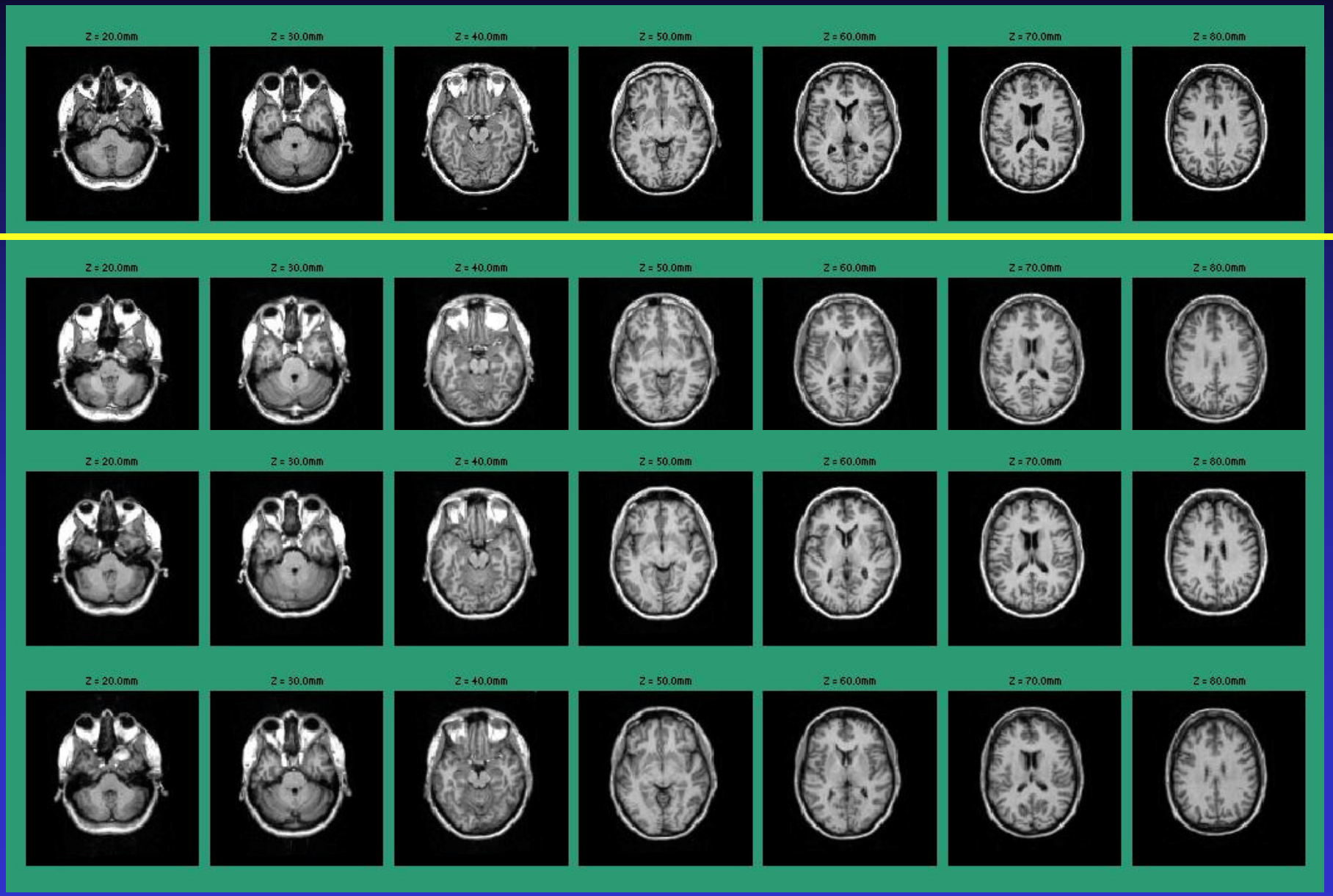
Warping algorithm

- Warping algorithm translates/rotates/stretch the image elements (voxels) individually
- Straight lines are not straight lines after this transformation
- Illustration of method:



Kjems, IEEE TMI, 1999

New subject MR and three MR templates. Templates after affine+warp transformation.

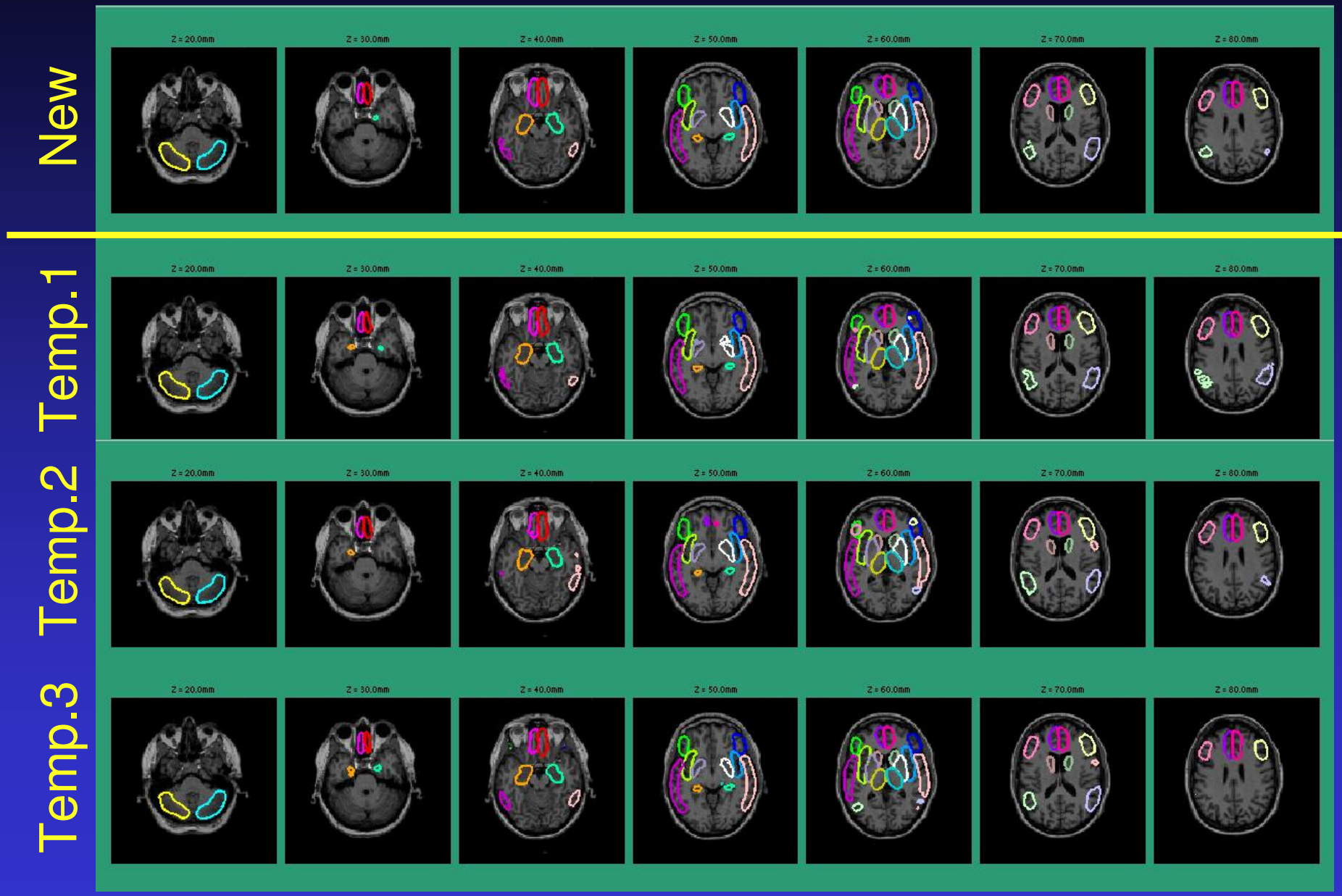


How is VOIs transformed

- We have identified a non-linear transformation between template space and new subject space.

- This transformation is applied to the VOI's defined in template space to transform them to new subject space

New subject MR with own VOIs and three examples of transformed template VOIs



Result of transformation from template spaces

- Some variation is seen between the three sets of transformed template VOI's
- This variation will lead to different results when subtracting VOI values from the PET/SPECT images.

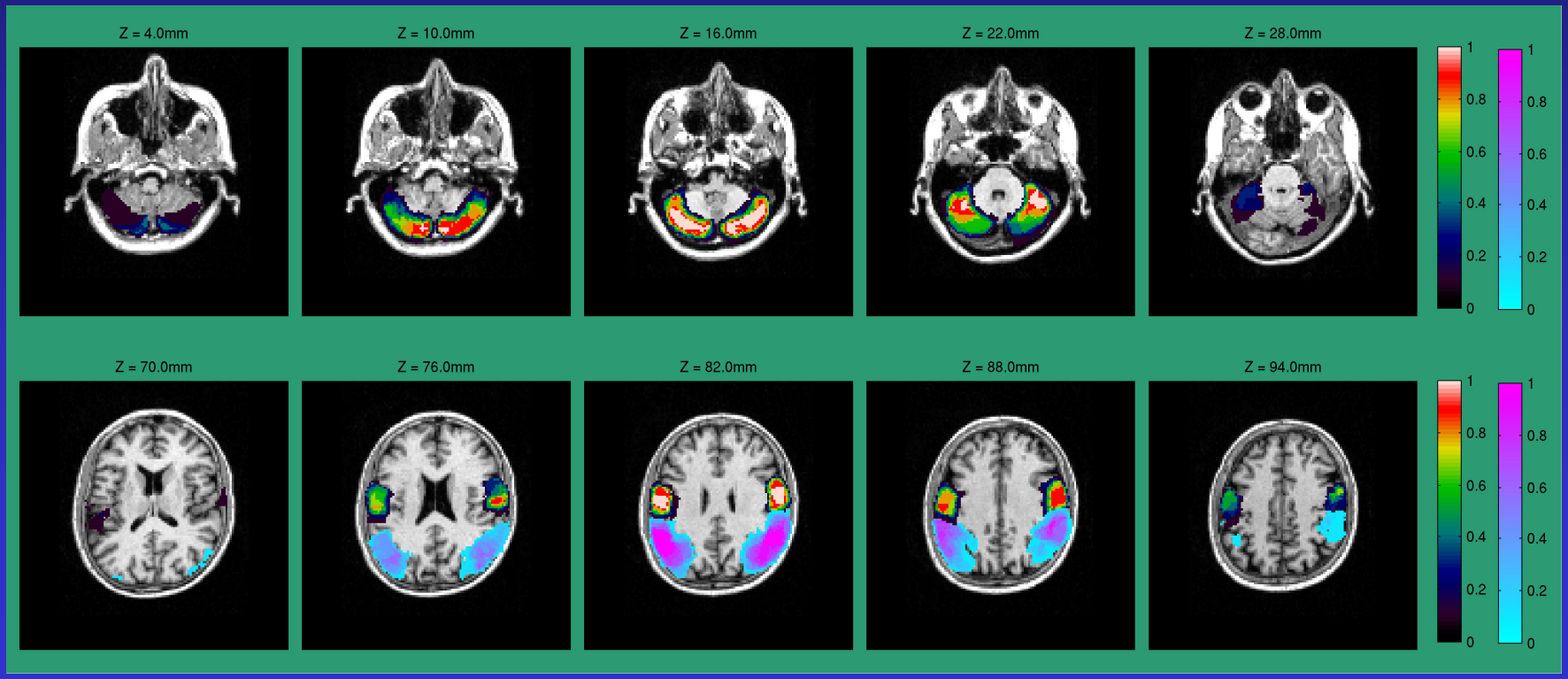
- Can we combine the transformed VOI sets into one VOI set with the purpose of lowering the variation?

Idea of combining multiple VOI sets

- A probability map for voxel's being included in the final VOI set is created for each VOI.
- Proposed method:
  - for each template VOI set transformed the probability being in the VOI is 1 for voxels inside the VOI and 0 outside
  - create a common probability map by averaging probability maps for all transformed VOI sets
  - threshold the probability map so the volume of the created VOI's are equal to the mean of the transformed template VOI's

Probability MAP used for generating common VOI set

- Upper panel: Probability map for cerebellum
- Lower panel: Probability map for sensory motor cortex and parietal cortex
- As expected voxels in the middle of the VOI's have the highest probability while more exterior voxels have lower probabilities



How to threshold the probability map when generating new VOI's

- Calculate the mean volume of the transferred template VOI's in new subject space and compare this to the volume of the common VOI's varying the probability threshold.
- As seen the probability threshold should be lower than 50% and optimized individually for each VOI to be sure to preserve the volume of the VOI's

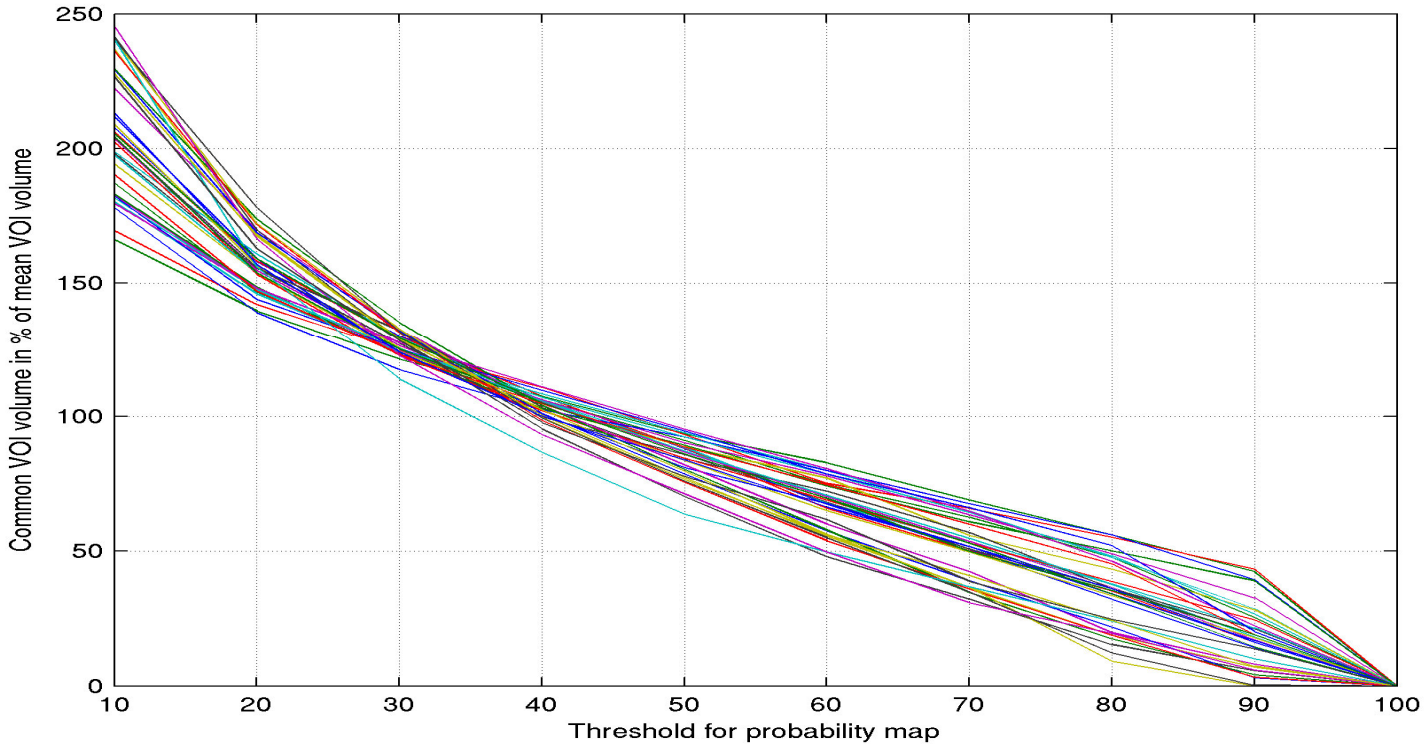


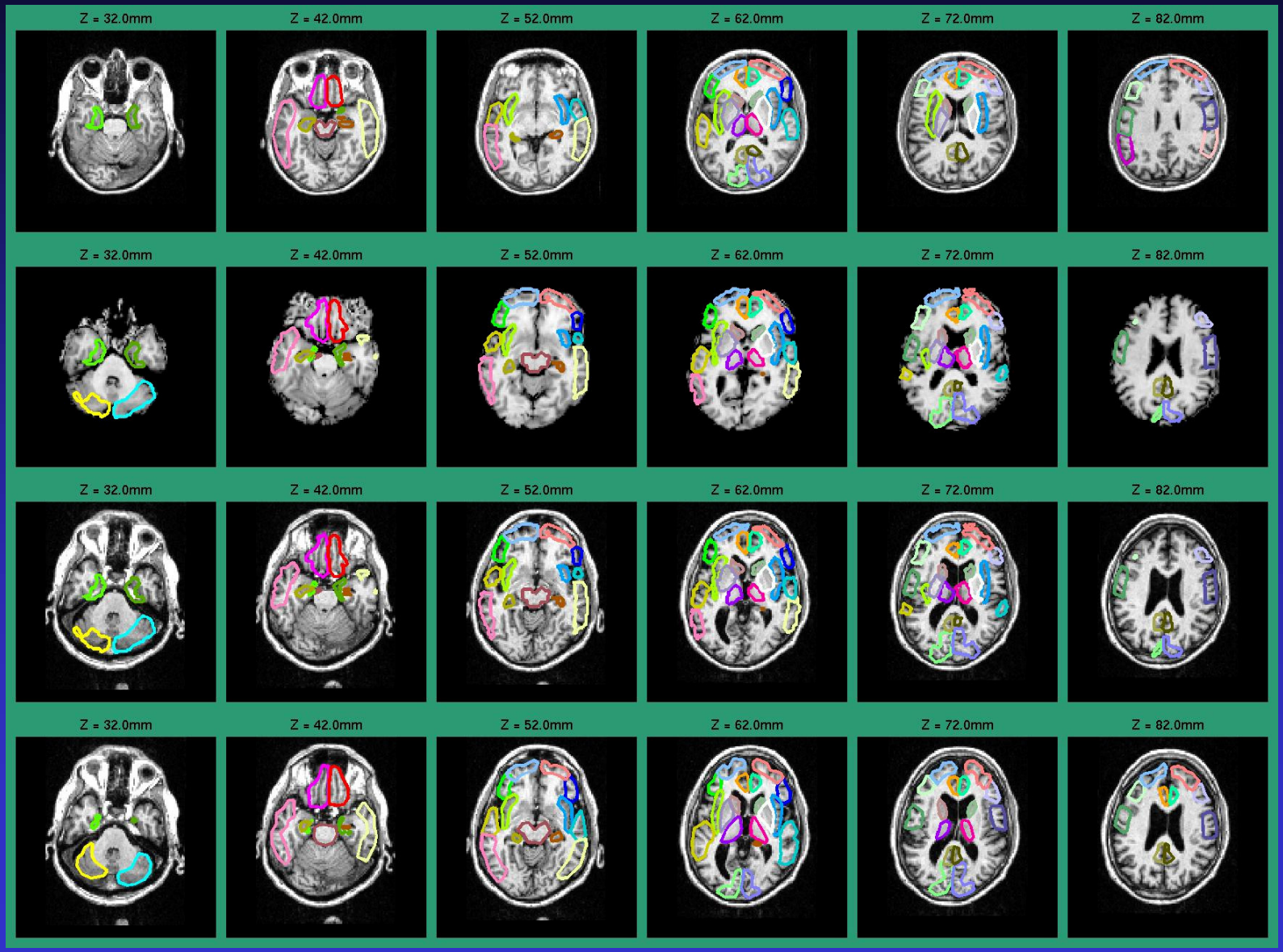
Illustration of transformation of a set of VOIs

Template MRI with VOI's

Template MRI with VOI's transformed to new subject space

New subject MRI with transformed VOI's from template space

New subject MRI with VOI's originally defined in this space



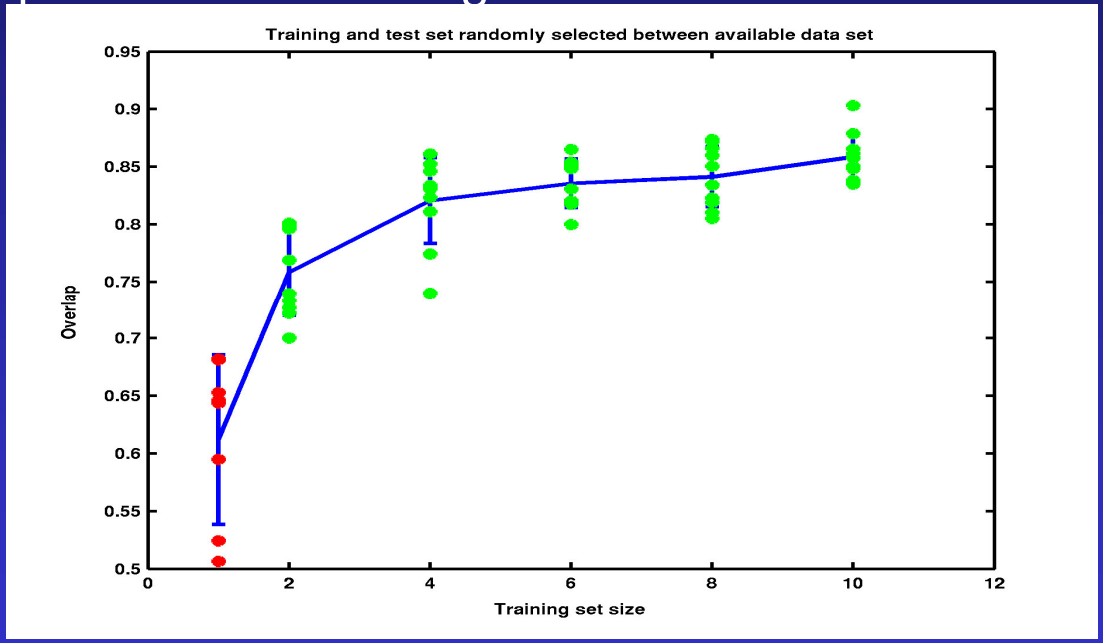
Comparison of individual transformation of VOIs and combined approach

Table: Percentage voxel overlap between VOI's in different VOI sets for the same subject. Occ. Cor.: Occipital cortex; Par. Cor.: Pariatal cortex. Values are shown as overlap mean±SD. First row is mean of probability map transferred VOI sets (only one template used as train and test set). Second row is mean of probability map transferred VOI sets (ten randomly selected for generation of the train set and ten for the test set).

VOI	Occ. Cor.	Par. Cor	Putamen	Midbrain	Caudate	Average
Voxel overlap transforming only one VOI template to "new subject space".	48.3±25.6%	50.1±27.9%	75.3±13.6%	76.6±16.3%	80.6±12.3%	62±15%
Voxel overlap transforming ten VOI templates to "new subject space" and use of probability maps	79.4±9.2%	87.7±6.7%	97.2±2.1%	94.5±2.8%	91.1±4.2%	86±2%

Learning curve, how many VOI sets shall be used for generating common VOI set

- 20 VOI sets available, randomly split into two groups of 10 VOI sets (training and test set)
- From the 10 VOI sets in training set is randomly chosen from 2 to 10 of the VOI sets and a common VOI set is generated
- From the 10 VOI sets in the test set a common VOI set is generated
- The voxel overlap between the two generated VOI sets is calculated

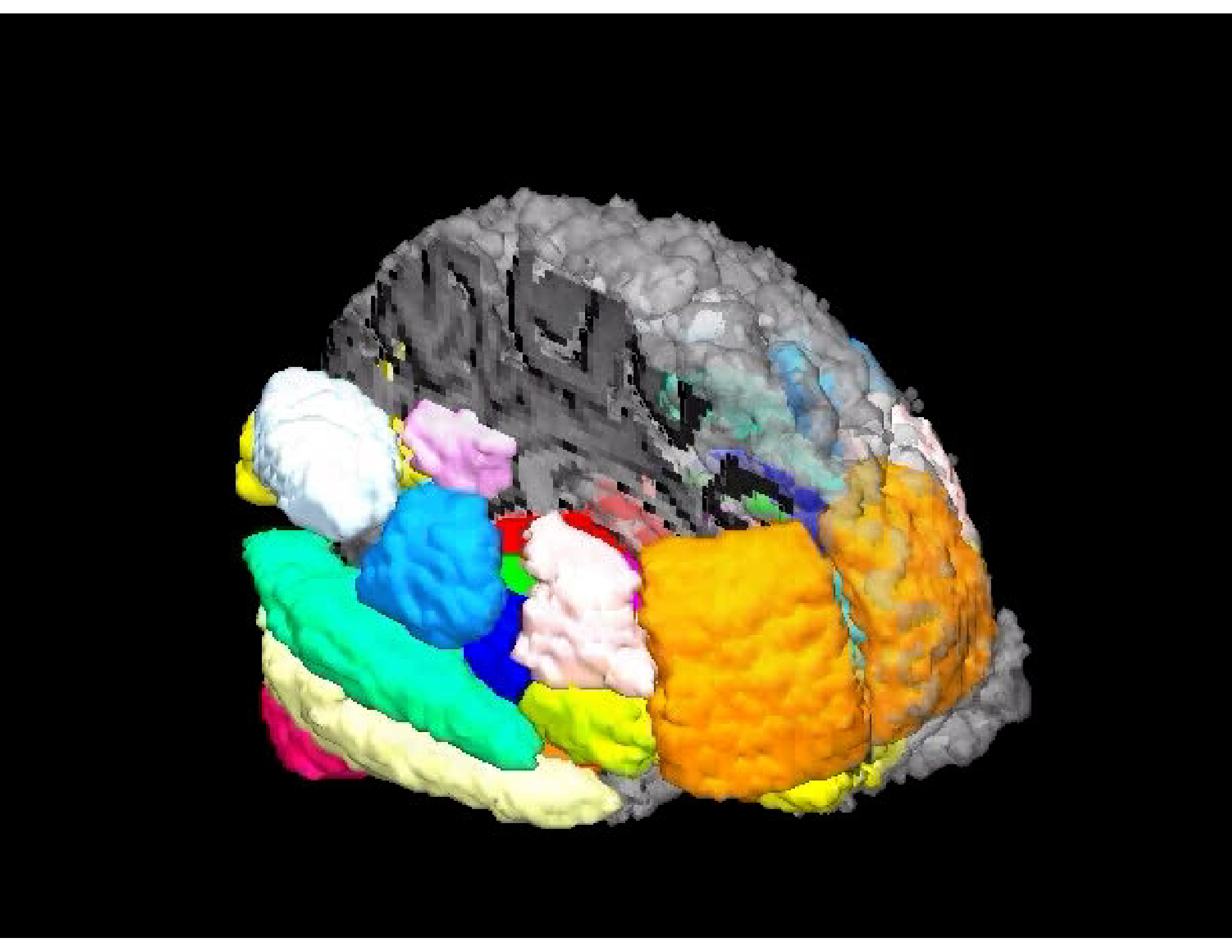


- Voxel overlap for the VOIs is not perfect (86%) even for 10 VOI sets in the training set, but though significantly higher than for 2 VOI sets in the training set (75%)
- Transferring only 1 VOI sets an overlap of only 62% is achieved

Conclusion 1

- Even with the common VOI set method and 10 VOI's sets transferred some variation in the created VOI's is present (86 % overlap between two VOI sets)

- Although this using more than one template set lowers the spatial variation in new subject space very much, overlap in generated VOI's is increased from 62% -> 86%



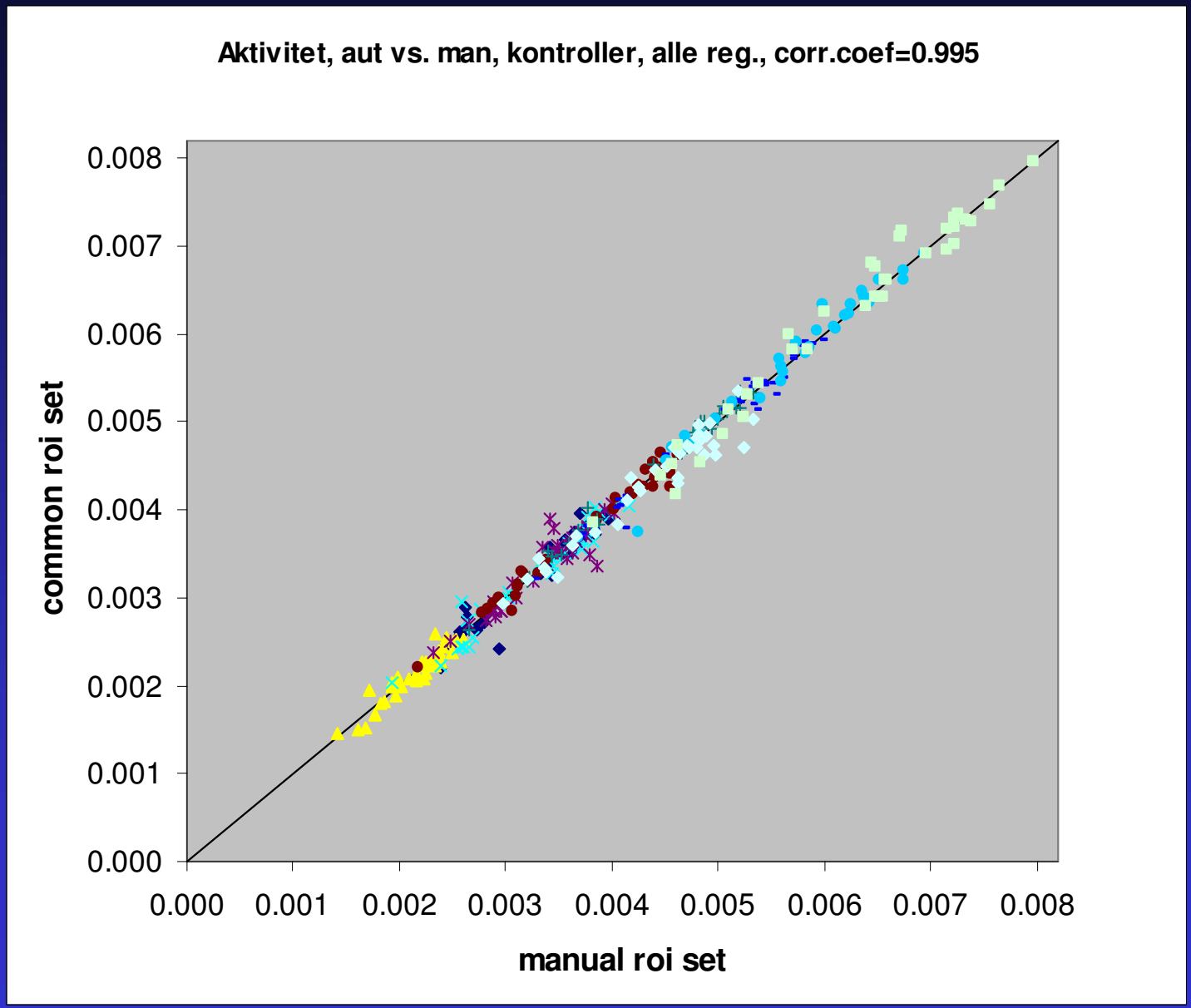
Using the VOIs for extracting values from the functional images

- 10 template VOI sets has been transferred to each new subject and a common VOI set has been generated
- Data has been extracted from the subject's functional PET altanserin image using the transferred VOI sets and a VOI set delineated manually at the subject's MR scan
- This is repeated for 10 different subject's

Scatter plots of VOI data

- Each box is average voxel data for one VOI (37 VOI's)
- Each color represents data for one of the 10 subject's

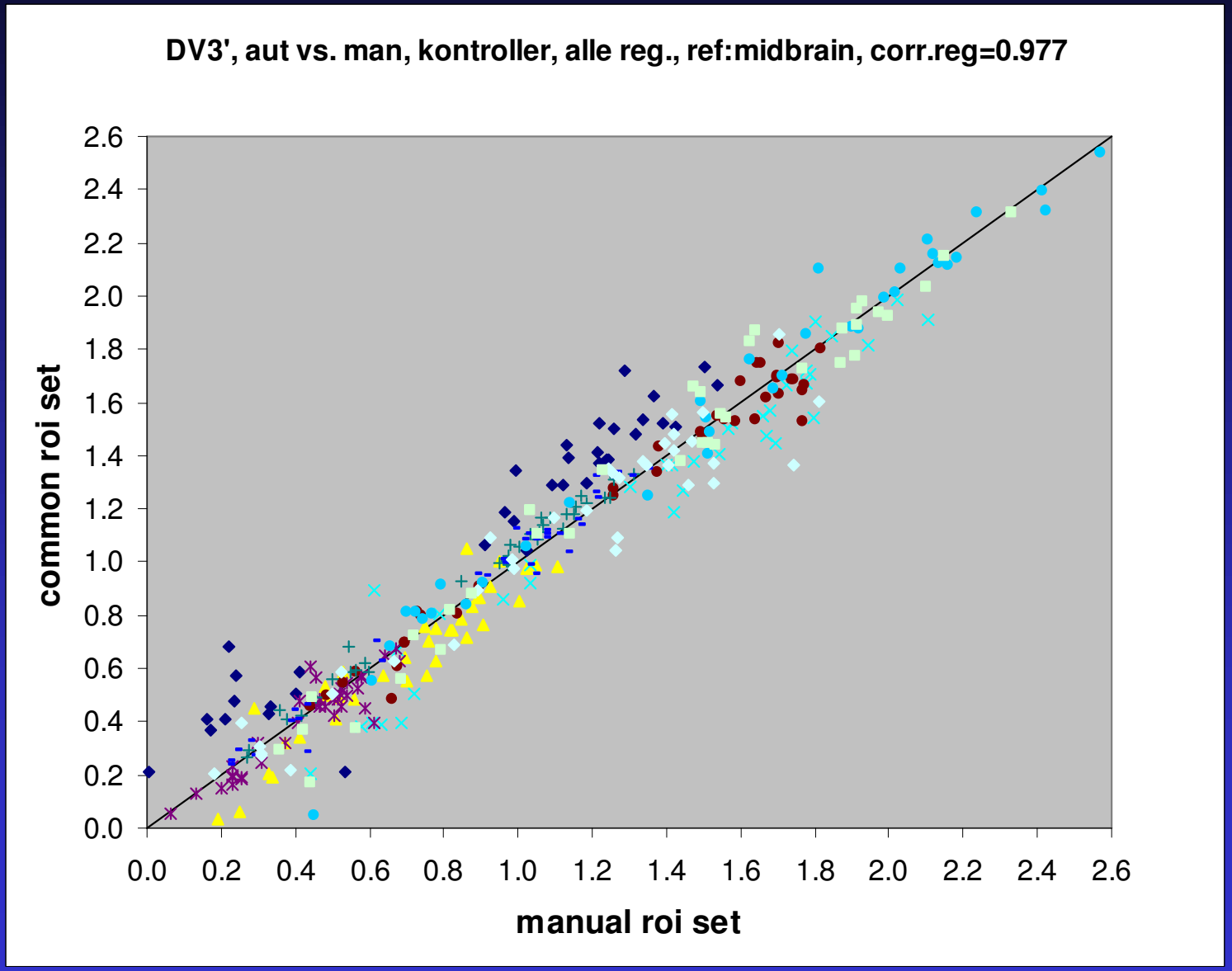
- Corr. Coef =0.995
- Partially because differences in injected dose



Scatter plots of VOI data

- Data has been normalized to $DV3'=(C_{voi}-C_{ref})/C_{plasma}$
- Each box is average voxel data for one VOI (37 VOI's)
- Each color represents data for one of the 10 subject's

- Corr. Coef.=0.977



Conclusion 2

- Even though some spatial variation in transferred VOI's is present the variation in extracted functional values are low

- It is therefor concluded that the method can be used for extracting average VOI values leading to:
  - reproducible and unbiased results (no operator dependency)
  - saving of time (automatic approach takes less than half an hour and are fully automatic)
  - VOI sets with fewer errors (no risk of do errors when labeling VOI's)

Program download

- Program can be downloaded from: http://mci.nru.dk/internal/downloads/ (username: nci-mci, password: hippocamp..)
  - applyrois_lib_20040331.tar.gz — matlab routines
  - applyrois.doc — documentation (not too detailed)
  - mriwarp-1.03.tar.gz — warping algorithm
- Other requirements:
  - Matlab 6.5
  - Linux computer (or other UNIX)
  - AIR (Automatic Image Registration)