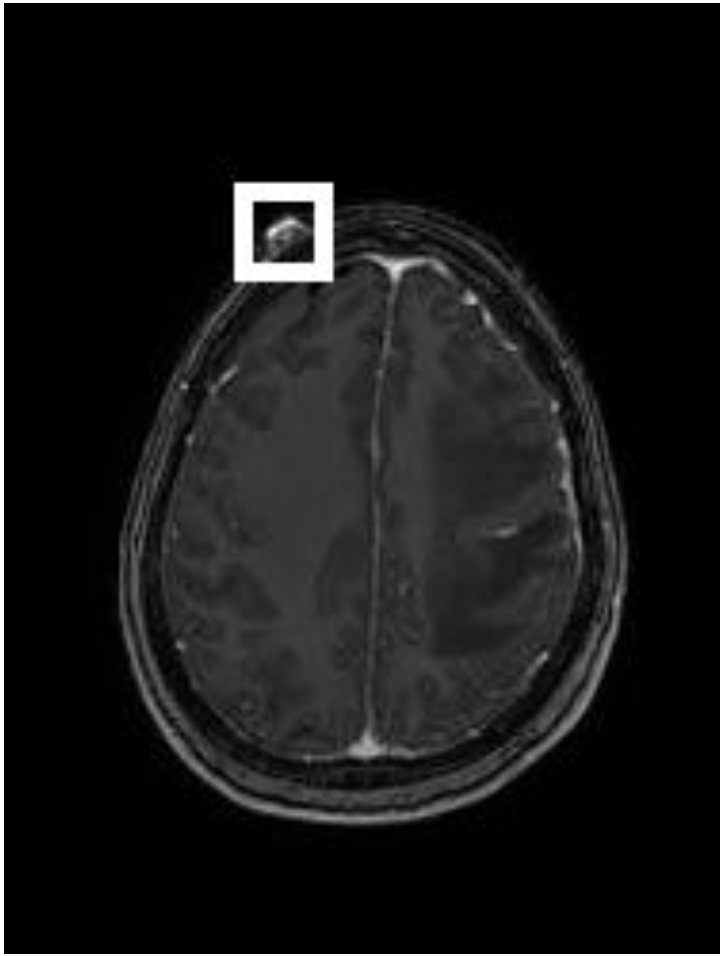
Fiducial Localization for Pre-Operative Planning in Neurosurgery

-Team Saboteur

Problem Statement

1. Detection and Localization of fiducial marker in a preoperative medical scan. (MRI Scan)

2. Estimation of 3D coordinates of the center of Fiducials w.r.t. Image Coordinate System.



TERMINOLOGIES USED:

1. DICOM:Digital Imaging and Communications in Medicine.

2. IGNS:Image Guided NeuroSurgery

3. Fiducial (IZI Medical Products):Markers affixed on skull.

4. IPP:Image Position Patient:Coordinates of reference pixel in Image Coordinate System.

5. IOP:Image Orientation Patient:Direction Cosines of Vector aligned along row and column vector matrix of image.

6. Aspect:The pixel spacing in all 3 directions.

ABSTRACT

1. Our algorithm proposes two approaches for automatic fiducial localization and detection.

   1.1 Designing Template of fiducials from processed images and then matching it with our outline test data using OPEN_CV.

   1.2 Preparing a dataset of annotated fiducial images and training the same with Deep Learning models, which will then identify fiducials on test images accordingly.

2. Finding center of Fiducials.
3. Hence, mapping the center coordinates of fiducials to 3D coordinates.

INTRODUCTION

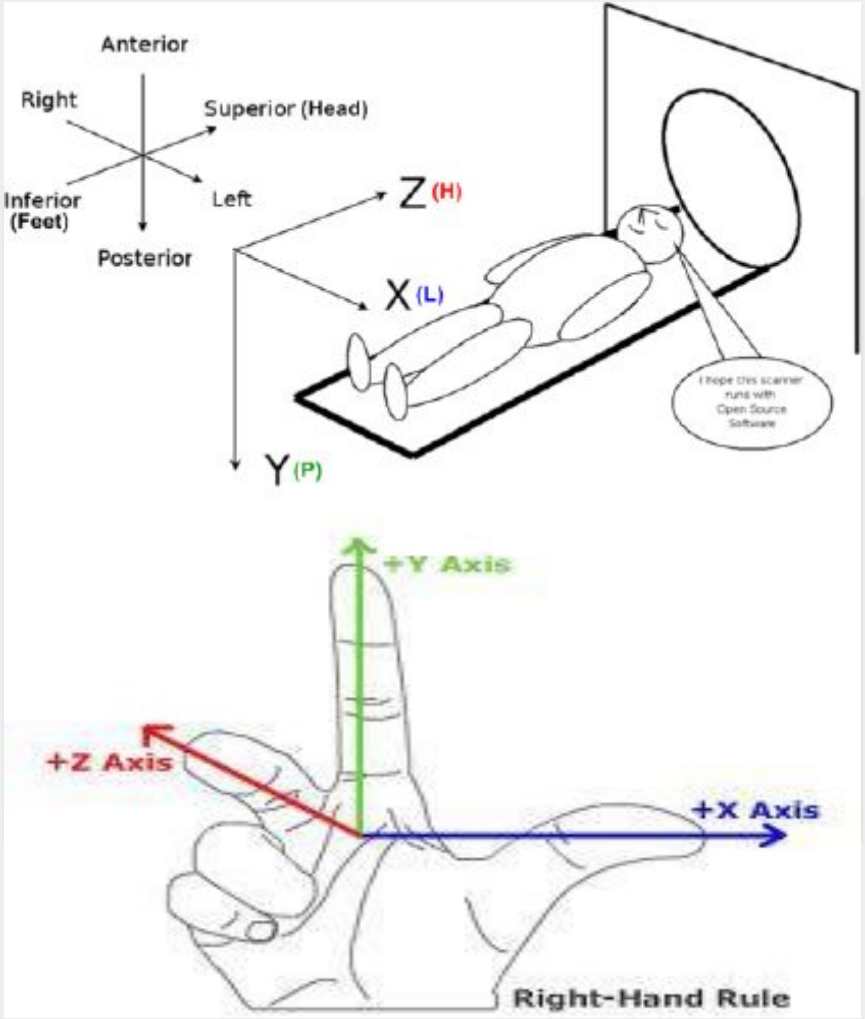
- Image Guided Neurosurgery System (IGNS) are playing a more and more important role in the field of minimally invasive surgery.
- Today, it is done by combining highly accurate localization of fiducial markers and guiding the surgical instruments efficiently.

- Registration, defined as the alignment of different coordinate systems, is an essential step in IGNS that determines the relationship between the patient space and the image space.
- Therefore our task is to finally do a registration process i.e., a mapping of coordinates of center of fiducials to 3D coordinate system.

Geometry Information in DICOM

DICOM uses a right handed LPH (=LPS) coordinate system.

DICOM provides public fields that relate a 2D image to 3D patient space.



LITERARY SURVEY

1. Maurer [1] proposed a hybrid registration technique that used a weighted combination of points and surfaces. **But the position of each marker was acquired by the probe, this need the user's intervention.**

2. Wang et al.[2] proposed an approach based on shape index and curvedness, experiments on clinical CT data showed that the center of the fiducial markers could be automatically localized with high precision. **But the results on MRI data were not as good as that with CT data.**

3. Zheng et al. [3] described a semiautomated solution for precise detection of fiducial screws. They solved it by iteratively matching a computer aided design (CAD) model of the fiducial screw to features extracted from the CT/DVT data. **But their solution called for a user-supplied initialization and the screws meant invasive to the patient.**

CURRENT SOLUTION:

1. The technique currently used for patient-to-image registration in IGNS is mostly based on **point-pair matching**.

2. At present, the user needs to select the points in images **manually**, **in this way the resulting error depends to a large degree on the user's personal experience and it is time consuming.**

ALGORITHM PLANNED:

1. APPROACH ONE: TEMPLATE MATCHING OF FIDUCIALS USING OPEN_CV.

APPROACH TWO: TRAINING CONVOLUTIONAL NEURAL NETWORK MODEL TO DETECT AND LOCALIZE FIDUCIAL MARKERS.

2.CONVERTING 2D COORDINATES OF FIDUCIALS TO PCS MAPPING.

PART A:
FIDUCIAL LOCALIZATION AND DETECTION

APPROACH 1:

- Parsing MRI(DICOM) images to JPG format.
- Binarizing image using Adaptive threshold technique.
- Using blurring techniques, such as Gaussian Blurring or Median Blurring to remove noise from image.
- Using Canny/Laplacian edge detection algorithms to detect edges of brain.
- Plotting Histogram for contrast adjustment.
- Further reducing noise by the use of Morphological Operators.

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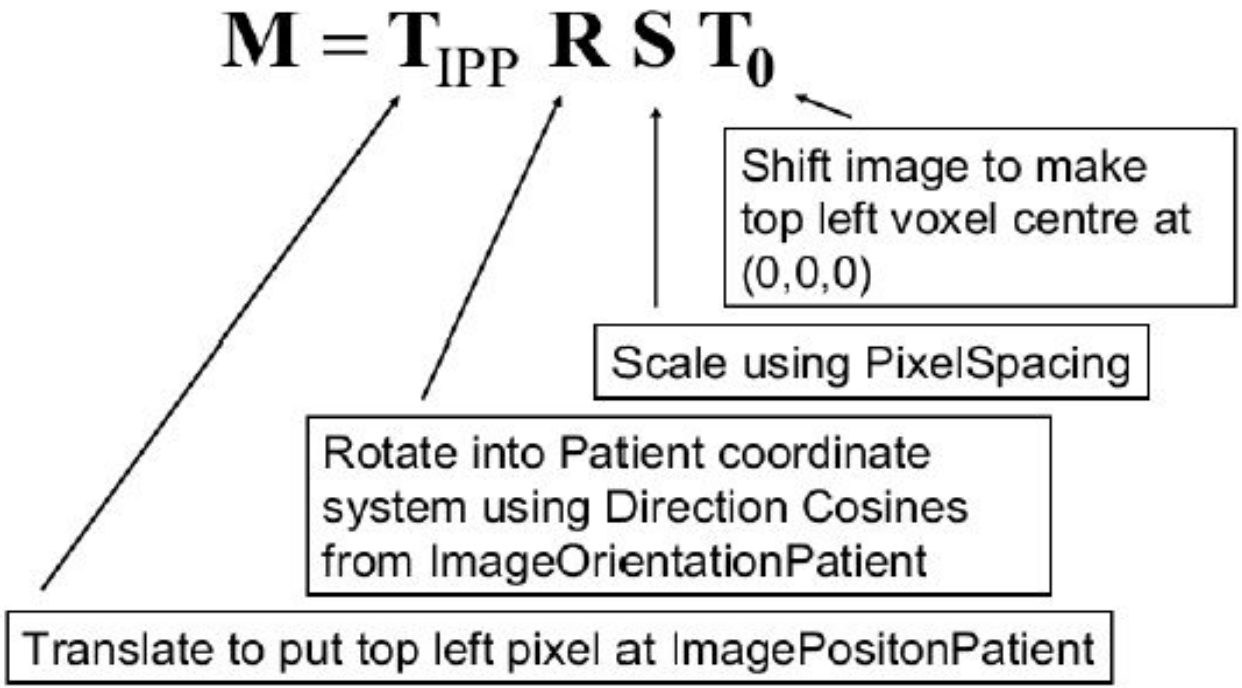
- Finding single contour that outlines brain using the largest contour area technique.
- Making Templates of fiducials from the resulting images.Grouping the templates into different classes.
- Finding outline from test dataset.
- Matching templates with outlines of datasets.

APPROACH 2

- Preparing a large dataset of MRI fiducials(Augmentation using scikit, Annotation using labelImg tool).
- Pre-Processing datasets to remove outliers.
- Feature extraction of fiducials.
- Through the concept of Transfer Learning, we will use the pre-trained model and weights of ResNet/DarkNet based on MSCOCO dataset, to train on our own datasets.
- Load the model to tweak on the validation dataset.
- Reducing loss using Empirical Risk Minimization and Hyperparameters tuning.
- Confirm results on test dataset(using accuracy,precision, recall and AUC curve).

PART B:
ESTIMATION OF 3D COORDINATE WITH RESPECT TO IMAGE COORDINATE SYSTEM

Composing the overall transform matrix (M):



‘AFFINE MATRIX’

$$\begin{bmatrix} P_x \\ P_y \\ P_z \\ 1 \end{bmatrix} = \begin{bmatrix} X_x\Delta i & Y_x\Delta j & 0 & S_x \\ X_y\Delta i & Y_y\Delta j & 0 & S_y \\ X_z\Delta i & Y_z\Delta j & 0 & S_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i \\ j \\ 0 \\ 1 \end{bmatrix} = \mathbf{M} \begin{bmatrix} i \\ j \\ 0 \\ 1 \end{bmatrix}$$

1. Pxyz: The coordinates of the desired voxel in 3D space.
2. Sxyz: The coordinates of Image Position Patient.
3. Xxyz: The value of direction cosines of row vector.
4. Yxyz: The value of direction cosines of column vector.
5. i,j: The value of row and column index,starting from zero.
6. del(i),del(j): Pixel Spacing in units of mm. along row and column respectively.

ALGORITHM:

1. Obtain a (i,j) pixel coordinate of center of fiducial from image from part A algorithm.
2. A transformation matrix(M) is calculated from the parameters present in patients dicom file.
3. Apply affine transformation matrix(M) over (i,j) pixel to get coordinates of desired voxel in form of Px,Py,Pz.

References

1. Maurer Jr, C.R., Maciunas, R.J., Fitzpatrick, J.M.: Registration of head ct images to physical space using a weighted combination of points and surfaces. IEEE Transactions on Medical Imaging 17(5), 753-761 (1998)
2. Wang, M., Song, Z.: Automatic detection of fiducial marker center based on shape index and curvedness. In: Dohi, T., Sakuma, I., Liao, H. (eds.) MIAR 2008. LNCS,vol. 5128, pp. 81-88. Springer, Heidelberg (2008).

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3. Zheng, G., Gerber, N., Widmer, D., Stieger, C., Caversaccio, M., Nolte, L.P., Weber, S.: Automated detection of fiducial screws from ct/dvt volume data for image-guided ent surgery. In: 2010 Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), pp. 2325-2328 (2010)
4. http://dicom.nema.org/

5.[2nd International and 17th National Conference on Machines and Mechanisms iNaCoMM2015-44]

Image based Data Preparation for Neuronavigation

[Abhishek Kaushik, Gaurav Bhutani, Venkata P P K, T A Dwarakanath, Aliasgar Moiyadi]

6.Automatic fiducial localization in brain images

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