MRI Image Alignment Experiment

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1 Introduction

In this report, we will perform a simulation experiment for aligning MRI images acquired with different settings. We will use MATLAB to rotate and align the images, then evaluate the alignment using three different measures: Normalized Cross-Correlation (NCC), Joint Entropy (JE), and Quadratic Mutual Information (QMI).

2 Methodology

2.1 Image Loading and Rotation

We start by loading the images `T1.jpg` and `T2.jpg` and converting them to double precision. These images represent the same anatomical structures and are aligned. We rotate `T2.jpg` by 28.5 degrees anti-clockwise and assign a value of 0 to unoccupied pixels, creating `J3`.

```
% Load images T1.jpg and T2.jpg and convert them to
   double precision
J1 = im2double(imread('T1.jpg'));
J2 = im2double(imread('T2.jpg'));

% Rotate image J2 by 28.5 degrees anticlockwise and
   crop
J3 = imrotate(J2, 28.5, 'crop');
```

2.2 Alignment Measures

Next, we perform a brute-force search over angles ranging from -45 to $+45$ degrees in 1-degree steps. For each angle, we rotate `J3` to create `J4` and compute the following alignment measures:

1. Normalized Cross-Correlation (NCC)
2. Joint Entropy (JE)

3. Quadratic Mutual Information (QMI)

```
%% Loop through Different Rotation Angles

for i = 1:length(angles)
    % Rotate the cropped J2 image by the current angle
    J4 = imrotate(J3 + 1, angles(i), 'crop');  %
       Adding 1 to remember valid pixels
    J4 = J4 - 1; % Subtracting 1 to revert to original
        values

    % Find pixels that are valid in both images after
       rotation
    valid_pixels = J4 ~= -1;

    % Extract valid pixel values from the original and
        rotated images
    image1_valid = J1(valid_pixels);
    rotated_image_valid = J4(valid_pixels);

    % Compute joint histogram and alignment scores
    joint_histogram = compute_joint_histogram(
       image1_valid, rotated_image_valid, bin_width);
    NCC(i) = compute_normalized_cross_correlation(
       image1_valid, rotated_image_valid);
    JE(i) = compute_joint_entropy(joint_histogram);
    QMI(i) = compute_quadrature_mutual_information(
       joint_histogram);
end
```

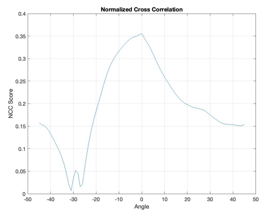
3 Results

3.1 Alignment Measures vs. Angle

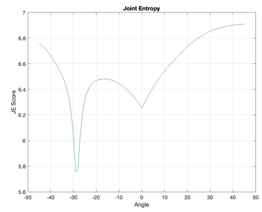
Figure 1 shows the values of NCC, JE, and QMI plotted against the rotation angle.

3.2 Optimal Rotation

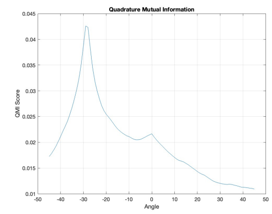
The optimal rotation angle for alignment is determined using JE, where the minimum JE score is achieved. The joint histogram for the optimized alignment is shown in Figure 2.



(a) Normalized Cross-Correlation (NCC)



(b) Joint Entropy (JE)



(c) Quadratic Mutual Information (QMI)

Figure 1: Alignment Measures vs. Angle

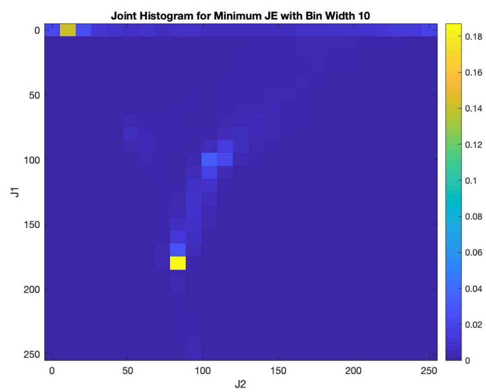


Figure 2: Joint Histogram for Optimized JE Alignment

4 Discussion

4.1 Observations

From the plots in Figure 1, we observe that JE provides a clear minimum, indicating the optimal rotation angle for alignment. NCC and QMI do not exhibit such distinct minima.

4.2 Quadratic Mutual Information (QMI) (part f)

QMI is a measure of statistical dependence between two random variables, here, the pixel intensities from the two images. Two random variables, I_1 and I_2, are considered statistically independent when their joint histogram is separable, meaning that $p_{I_1 I_2}(i_1, i_2) = p_{I_1}(i_1) \cdot p_{I_2}(i_2)$. In our case, if I_1 and I_2 were statistically independent, QMI would be zero. Higher QMI values indicate a stronger statistical dependence.

5 Conclusion

In this experiment, we successfully aligned MRI images using different measures. JE provided a clear minimum, indicating the optimal rotation angle for alignment. QMI can help quantify statistical dependence between images.