Sample Exam

ECE 8485 Special Topics in BME Spring 2012

Student Name:____________________

GUID:___________________________

1. *What are the common characteristics of CT and 2D US and how do they differ from PET imaging?*

   CT and 2D US are both based on the principle of transmission imaging.
   CT and 2D US provide anatomical images.
   PET is based on the principle of emission imaging.
   PET provides functional images (metabolic activity).

2. *A patient is displaying symptoms associated with brain tumors. Which imaging modality, MR or CT, should we use for diagnosis? What if the patient has a cochlear implant (embedded metallic electrodes)? Explain your choices and indicate if there are cases when these may be sub-optimal.*

   As the brain is a soft tissue structure MR should be used as it has better differentiation capabilities between soft tissue types. MR cannot be used when the patient has a cochlear implant due to the magnetic fields which interact with the electrodes and may injure the patient (move the electrodes). In this case the only option is CT even though the electrodes may introduce streaking artifacts.

3. *What is the standard radiological approach to visualization of CT data? When using this form of visualization and a standard screen, is the original data modified in any manner, explain why this is required or why it is not?*

   The standard radiological visualization approach is to reformat the volume and display three orthogonal planes through it, axial, sagittal and coronal. The intensity values are modified as the CT has a high dynamic range which cannot be directly displayed on standard screens. The original intensity values are mapped to the range supported by the display.

4. *You are given the following convolution kernel* $\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$.

   What is the computational cost of convolving this kernel with an MxN image? Can we reduce the cost while still working in the spatial domain?

   The computational cost is 9MN, 9 multiplications and 8 additions per pixel. We can reduce the cost as this kernel is separable $\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \otimes \begin{bmatrix} 1 & 2 & 1 \end{bmatrix}$

   The computational cost is then 6MN, 6 multiplications and 4 additions per pixel.

5. *Compute the co-occurance matrix of displacement [1,1] for the following image:*

2	0	0	0	2
3	1	3	1	0
0	2	3	3	3
3	3	1	2	3
2	3	2	3	2

   What is the value of Haralick's energy feature?

   The co-occurance matrix of displacement [1,1] is:

$$\frac{1}{16}* \begin{matrix} 1 & 1 & 0 & 2 \\ 0 & 0 & 0 & 3 \\ 0 & 2 & 1 & 0 \\ 0 & 0 & 3 & 3 \end{matrix}$$

   The value of Haralick's energy feature(sum(p^2(i,j)) is $38/16^2$

6. *You are given an image containing an unknown number of circular markers. Assuming we know the circle radius, a circle is represented parametrically as:*

   $x = a + R\cos(\theta)$

   $y = b + R\sin(\theta)$

   what is the parameter space used for circle detection by the standard Hough transform? What is the shape of the curve generated by each point x,y in this space? Identify three issues associated with use of the standard Hough *transform?*

In our case the SHT uses a two dimensional parameter space, a x b. The shape of the curve generated by each point is a circle, as we have

$a = x - R\cos(\theta)$

$b = b - R\sin(\theta)$

and θ is in $[0,360^o]$.

The deficiencies of the SHT are:

a. Parameters are estimated with a predefined precision, due to discrete number of hypotheses.
b. The discrete accumulator can cause maxima to be spread across several cells or conversely aggregate data originating from several entities into one cell (over and under sampling of parameter space).
c. Excessive memory use, $\boldsymbol{n^d}$ sized accumulator. This limits the use of the transform to entities of low dimensionality.
d. High computational complexity due to the use of all the data and the one to many mapping.

7. *We attach four fiducials in a general configuration to a patient's abdomen. We then acquire a CT scan while the patient holds her breath. We then use these markers to rigidly register the image and physical space when the patient is holding her breath again. We use Horn's analytic solution to perform the paired point rigid registration. Finally, we compute the Fiducial Registration Error (FRE). Does FRE reflect the accuracy of our registration, explain why (give examples)? What else can we use FRE for?*

FRE does not reflect the accuracy of our registration. The quantity we are interested in is the Target Registration Error. Fiducial registration can over-estimate the TRE:

Two markers have a bias of 5mm in the +z direction and the other two have a bias of 5mm in the –z direction. As Horn's algorithm provides a least squares solution these biases will cancel out in the computation, yielding an accurate transformation but the FRE will be high.

FRE can also underestimate the TRE: All markers have a bias of 5mm in the +z direction. Horn's algorithm will yield a transformation that has an error of 5mm in the +z direction but the FRE will be zero.

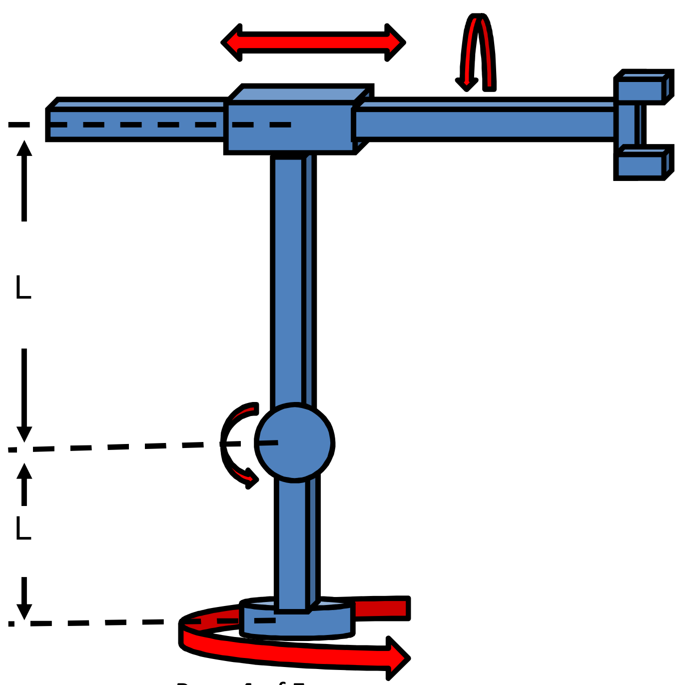
We can use FRE to check that the two breath-holds are similar, that is the relationships between the fiducials remained the same.

8. *What is the average rotation of the following two versors (quaternions representing rotations), explain why:*
[0.5332 0.5928 0.0831 0.5978]
[-0.5332 -0.5928 - 0.0831 -0.5978]

The average rotation is [0.5332 0.5928 0.0831 0.5978] or
[-0.5332 -0.5928 - 0.0831 -0.5978], as both v and –v represent the same rotation.

9. *Provide three reasons which explain why mechanical localizers not found in wide spread clinical use even though they are highly accurate?*
    a. When reasonably priced they only support tracking of a single tool (stereotactic frames, Faro Arm) and clinical practice often requires tracking of at least two objects, patient and tool.
    b. When they support tracking of multiple tools they become very expensive (for example the da-vinci robot).
    c. Extremely obtrusive, limiting access to the patient.
    d. They have relatively small workspaces, requiring that the system be positioned near the region of interest.

10. *Forward kinematics: you are given the following RRPR mechanism. Using the Denavit-Hartenberg convention, fill the DH parameter table:*



link	α_i	a_i	θ_i	d_i
1				
2				
3				
4				

You are given the transformation $^0T_2$ *, complete the forward kinematics calculations. That is, compute the matrix* $^2T_4$.