Assignment VII

Biomedical Imaging & Analysis (ECE J1-791) - Fall 2014

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Instructions

Please show your solutions to each problem in full, writing explanations neatly along with mathematical justifications, as needed. For computer programs, please remember to turn in your code through the course's blackboard session, as well as any plots / figures that are requested. This assignment is due on **Thursday, 27 Nov 2014** via Blackboard, including an a Report with explanations associated with each question in the assignment, as well as any associated code and result files. If you have collaborated with another student on solving this homework assignment please state so (e.g. "I helped John with question 1" etc.).

LEARNING GOALS:

- *Landmark based deformable registration using Thin Plate Splines:*
  - Hands on experience for performing image registration.

1. **(50 points, total) In this assignment you will implement Landmark based image registration using Thin Plate Splines (TPSfor regional image warping.** This assignment has been designed as a **"fill in the blanks"** starter code scripting exercise which you will need to work out and complete using the definitions of matrices given on Page 322 of the following paper:
   Johnson, H. J., & Christensen, G. E. (2002). Consistent landmark and intensity-based image registration. *Medical Imaging, IEEE Transactions on*,*21*(5), 450-461.
   (available on Blackboard!)

   The overall goal of the exercise is to compute the TPS displacement field *u(x) that minimizes* the bending energy cost function, **C**, defined by at all points, *qi*, on an image, relative to landmarks with known movement, *pi*:

$$C = \int_{\Omega} ||\nabla^2 u(x)||^2 dx$$

   where, *u*(*pi*) is a displacement field defined by: *u(pi)* = *qi* − *pi* for *i* = 1, . . . ,*M* landmarks.

It is well known (from the literature) that the TPS displacement field u(x) that minimizes the bending energy, C, has the analytical form:

$$u(x) = \sum_{i=1}^{M} \xi_i \phi(x - p_i) + Ax + b$$

where, $\Phi(r) = r^2 \log r$ and ξi are 2×1 weighting vectors. The 2×2 matrix $A = [a1, a2]$ and the 2×1 vector b define the affine transformation (i.e. "rotation+scaling+skewing" and "translation", respectively) where a1 and a2 are 2×1 vectors.

Based on this knowledge, compute a TPS displacement field, u(x), which will warp an image of your face onto the image of your favorite animal, after selecting corresponding landmarks on the pair of images.

- ***[3]Code given:***
  - Matlab function to write compute Φ(r): *tps_rbf.m*
  - Starter code with "fill in the blanks" and hints to evaluate u(x): *tps_script_TODO.m*

Please submit a report including snapshots of your landmark selections and plots explaining the resulting transformation, including a visualization of the displacement field, u(x). Also submit your code along with the source and target images you use.

Scope for Bonus Points (50 to 100 points, each, depending on effort!):

Formulate the above problem to either:

a) Automatically identify landmark points (using SIFT or another feature selection method) and establish point correspondences which can be used to compute u(x). You may use internal Matlab functions but provide details of your image processing pipeline, justifying function choice in Matlab, in your reports!
b) Instead of computing the forward transformation, u(x), based on known or selected Landmarks, attempt to create an iterative framework to incrementally evolve and solve for u(x) which will minimize the "difference image" between the source and target images.

- [3]*This symbol means that "code" provided on Blackboard which requires to be used in this assignment.* ***NOTE:*** *You may use the code provided with this assignment or you may choose to ignore it if you find it confusing. The starter code does not apply to the suggestions for Bonus Points listed above.*