Questions and Answers

Chapter 4

Questions

(Q1) *What is image registration?*

(Q2) *How is the image registration used in retinal imaging?*

(Q3) *What are the characteristics of retinal image registration?*

(Q4) *What is mutual information?*

(Q5) *What is mutual information based registration?*

(Q6) *What is image interpolation? Why is it important in image registration process?*

(Q7) *Why is the exhaustive optimization not feasible in the mutual information registration process?*

(Q8) *What is a multiresolution optimization? Why is it needed? How is it applied in the registration process?*

(Q9) *Why is the mutual information registration algorithm written in Java?*

(Q10) *What is the MVC framework?*

Answers

(A1) Image registration is the process to determine a one-to-one mapping between the coordinates in one space and those in another such that points in the two spaces that correspond to the same point are mapped to each other. The simplest mappings are the rigid-body transformations, which are transformations in which the distances among all points are preserved. The rigid-body transformations are typically used to compensate for different imaging orientations of rigid objects. Other possible transformations include affine where parallel lines remain parallel, projective that is from 3D to 2D, and warping which is nonlinear in general.

(A2) Retinal or fundus photographs are standard diagnostic tools in ophthalmology. In the follow-up of age-related macular degeneration, drusen deposits need to be tracked and compared. Screening of diabetic retinopathy can involve a follow-up over many years. To determine the progression of glaucoma, a series of optic-nerve-head topographies are assessed and compared. Serial photographs of the flow of fluorescein dye are also used to determine areas of ischemia, hemorrhaging, neovascularization, and occlusions in diseases such as diabetic retinopathy. Averaging registered images of laser scanning ophthalmoscope can reduce the noise in images. Multimodality registration is also performed in retinal imaging. In glaucoma diagnosis, for example, the optic-nerve-head is assessed from color stereo images and the nerve fiber layer is assessed from red-free images. In retinal analysis, two types of images, fluorescein images and green images, are often used for the diagnosis of the gravity of diabetic retinopathy. Physicians often use more than one image to identify a lesion and assess its seriousness, or base their diagnosis on detection of various image features in different modality images.

(A3) Retinal image registration generally involves large x translation, due to changes between sittings and smaller y translation from changes in position of the chin cup. Rotation occurs due to tilting of the head and through ocular torsion, and scaling is caused by changes in the distance between the camera and the head, due to equipment changes or differing head positions. In most cases, a rigid-body transformation with uniform scaling is sufficient.

(A4) Mutual information is an information-theoretic measure. It measures the interdependence of two random variables. For two random variables A and B, the mutual information is defined as

$$I(A, B) = \sum_A \sum_B p_{AB}(a, b) \log \frac{p_{AB}(a, b)}{p_A(a) p_B(b)},$$

where $p_{AB}(a, b)$ is the joint probability density function, and $p_A(a)$ and $p_B(b)$ are marginal probability density functions.

(A5) In the mutual information based registration, the mutual information is used as a similarity measures and it is assumed that the mutual information will be maximized when images are registered (i.e., the uncertainty of one image given another image is minimized). In that context, one treats the voxel values a and b at corresponding points in two images that are to be registered as random variables A and B.

(A6) Image registration is to seek an optimal transformation to be applied to the floating image. After a transformation is applied, the grid point in the floating image will typically not coincide with another grid point in the transformed space. Since the pixel values of the reference image are known on grid, and under a transformation, only the pixel value of the transformed floating image on grid are of interest, the pixel values of the transformed floating image on grid have to be estimated. The technique is called interpolation, which is to estimate a pixel value based on the pixel values of its surrounding pixels. There are different kinds of interpolation methods and Tsao evaluated the interpolation effects on registration performance.

(A7) This brute-force search is very expensive. If one wants 0.1 pixels (1000 steps in both x and y directions), 0.1 degrees rotation (100 steps), and 0.001 scaling (100 steps) accuracy, one would have 10^{10} iterations.

(A8) The idea of multiresolution strategy is simple: Find the optimal registration on coarse images first. Then using the found solution as the starting point, find the optimal registration for the fine images. The coarse images are derived from the original images, by averaging several pixels in the original images. As a variation of this multiresolution, subsampling is also used sometimes. Instead of taking the average, a single pixel is picked to form a coarse image. In the subsampling scheme, the images are never scaled down. The original images are subsampled periodically, with a gradually increasing sampling frequency. The optimization result at the lower sampling frequency is used as the starting point for the higher sampling. The multiresolution optimization is intended to do a pseudo global optimization while reduce the chance that the optimization process is trapped to a local optimal. The multiresolution subsampling scheme is to combine the advantages of multiresolution and subsampling. That is, for each resolution, a subsampling is utilized. The pseudo code for this scheme follows:

```
For resolution r1 > r2 > ... > rn
Rescale the translation offsets (divided by the
   folding number)
Prepare the coarse images
      For sampling s1 > s2 ... > sm
         Do simplex optimization
      Rescale translation offsets to correct different
         resolution effect
```

(A9) The algorithm is written in Java due to the following reasons: (1) Java is an object-oriented programming language and the object-oriented software is easy to develop and maintain. (2) Java program is platform independent. The software "is written once, but runs everywhere". (3) Java 2D and Java Advanced Imaging provide graphics and image processing capabilities, which are highly desirable for this retinal image registration problem.

(A10) The MVC framework is developed in the object-oriented programming language, Smalltalk. Models represent the information, views present information, and controllers interpret user manipulation. The control and view can be combined, which is similar to the document-view pattern used in Microsoft Foundation Class Doc-View framework. In the retinal image registration case, the model has the information on the two images to be registered, i.e. the reference image and the floating image and the current registration parameters. The view object gets two images as well as the registration parameters from this model and displays the images properly. The registration object also gets two images from the model object and sets the registration parameters after a solution is found.