8.1 Introduction

The routine production of 3D imaging data from modern imaging systems has led to a rapid growth in image post-processing methods. As described in previous chapters, many of these can be applied to single 3D data sets to improve data interpretation by producing 3D visualizations of data content, or by allowing automatic identification of specific features using segmentation techniques. However, in many cases the data content of a single 3D image is inadequate to provide all the information required. Under these circumstances a combination of information from two or more separate data sets may be necessary. As practicing radiologists we subconsciously perform this type of data fusion when we use images from for example, CT and MRI sequences to attempt to better characterise an abnormality, or when we compare images from a single case taken at different times to allow monitoring of disease progression. For example, faced with a cystic mass at the base of the brain we would routinely request T1 and T2W MRI to determine the presence of free fluid in the cyst and the presence and extent of oedema, MR angiography to determine the spatial relationship of the lesion to the major vessels and CT scanning to determine the presence of any bony abnormality. When we perform this type of analysis we are instinctively increasing the information content of our data, using additional examinations to provide complementary information required for our analysis. When reporting this type of multi-modality imaging we also instinctively register the anatomical locations of features from the various examinations.

The increased data content of such multiparametric data sets can also be used to support a range of sophisticated image analysis techniques with a wide range of both clinical and research applications. It has been shown that image coregistration of different imaging modalities and interrogation of the fused images is diagnostically superior to side-by-side analysis of non-fused images (Amthauer et al. 2005). Analysis of data from multiple 3D images inevitably assumes spatial coregistration between the data sets. In practice it is extremely unusual to acquire images with these characteristics. Simultaneous collection of two or more data sets will ensure accurate coregistration. This can be exploited by the use of multiple echoes on MRI examinations to produce matched proton density and T2W images from the same series of excitations, or new echo planar...
imaging techniques which allow the simultaneous acquisition of predominantly T1 weighted and T2* weighted images in dynamic contrast-enhanced perfusion studies (Zaitsev et al. 2005). This approach is extremely restrictive and in most cases 3D images will be collected at different times and often on different modalities. In these circumstances separate 3D images must be co-registered in some way to provide absolute spatial coregistration.

8.2 Basic Theory of Image Coregistration

The aim of image coregistration techniques is to ensure that:

“Each pixel in the various data sets represents exactly the same volume of tissue in the patient.”

In practice there are many ways in which we can attempt to achieve this and the technique selection will depend on the imaging modalities involved, the reason for coregistering the images and the accuracy of coregistration required for the analysis technique to be employed.

The simplest approach to coregistration of data sets is to attempt to acquire subsequent images with a spatial geometry identical to that of the original base images. Image registration can be attempted by using a baseline set of images to guide the acquisition of the subsequent acquisitions. In practice this is relatively difficult except with MRI where the ability to produce rapid high-resolution anatomical survey images allows relatively accurate manual prescription of the slice positions. Using this approach allows matching of images with a typical accuracy of only 1–2 voxels, which is inadequate for the majority of applications (Hajnal and Bydder 1997).

An alternative and attractive solution has been applied to the problem of providing anatomical localization of isotope images from SPECT/PET and MRI scans. Besides the relatively low spatial resolution of these isotope modalities, they commonly aim to identify very specific physiological targets, such as inflammation, so that little or no anatomical information may be present in the image. This invalidates the use of most coregistration techniques except for the use of small spatial localization markers (fiducials) which can be seen on the isotope study and other imaging modalities such as fluoroscopy, CT or MRI. These fiducials may be used within the machine itself for calibration purposes as in the development of a hybrid X-ray/MRI system (XMR) where a calibration phase for coregistering the field of views of the MRI and fluoroscopy systems is performed using a 16 fiducial marker phantom. This enables the integration of both modalities and their use concurrent use during interventional procedures (Yu et al. 2005). Fiducial placement has also been applied to patient fixation devices, such as a novel moulded mattress, enabling coregistration of SPECT and CT images (Forster et al. 2003; Gabriel et al. 2005). Finally, the fiducials may be directly attached to the patient, although this is not entirely satisfactory since they may become dis-

Fig. 8.1a,b. A schematic (a) and product (b) photograph of a combined CT and gamma camera system. (Courtesy of GE Medical Systems)