A PVA-C Brain Phantom Derived from a High Quality 3D MR Data Set

Kathleen J.M. Surry[1] and Terry M. Peters[1,2]

[1] Imaging Research Laboratories, Robarts Research Institute, London Canada
[2] Department of Medical Biophysics, University of Western Ontario, London Canada
kath@irus.rri.on.ca

Abstract. A brain mould was constructed by converting the digital surface of a high quality 3D magnetic resonance (MR) data set to a real model, using a stereo lithography apparatus (SLA). The tissue mimicking material (TMM) poly(vinyl alcohol) cryogel (PVA-C) was used to form a homogeneous phantom in the mould. 3D images of this phantom were then acquired in MR, CT and ultrasound. The surface contours of the phantom were compared between each modality and the source image. This phantom is employed in our laboratory as a model of a deformable brain.

1 Introduction

The neurosurgical image guidance tools that are being developed in our lab often make use of a high quality brain image [1] for testing and development. This reference brain image was created by averaging 27 magnetic resonance (MR) 3D images of the same brain to achieve a very high signal-to-noise ratio. To validate our research in ultrasound-MR integration to correct for brain shift, we required a deformable brain model which we based on this 3D MR image. We have developed a realistic, physical brain model, or phantom, from poly(vinyl alcohol) cryogel (PVA-C) [2], based on the surface of this human brain using a mould created from the reference brain data set.

2 Methods

Internal structures of the reference brain were masked and removed before a marching cubes algorithm extracted the surface. This surface was then cut at the cantho-meatal plane and appropriately formatted for input to a stereo lithography apparatus (SLA). The SLA built the mould by plastic deposition, with a layer resolution of 0.1 mm.

PVA-C liquid, 10% by weight in water, was poured into the mould and degassed. PVA-C is gelled by freezing to –20^{o}C and thawing it back to room temperature in a standard chest freezer, with an internal fan to ensure air circulation.

MR, US and CT volumes were acquired of this phantom. These volumes were compared to the original reference brain volume using Register (3).

W. Niessen and M. Viergever (Eds.): MICCAI 2001, LNCS 2208, pp. 1149-1150, 2001.

3 Results

A photograph of the mould can be seen in Figure 1. Registered slices of the reference brain and the phantom in MR and CT are shown in Figure 2. Registration of the phantom's MR scan with the original reference MRI demonstrated a fit accurate to ± 0.7 mm for homologous points on the cortical surface. The overall scaling factor for the fit was 1.044.

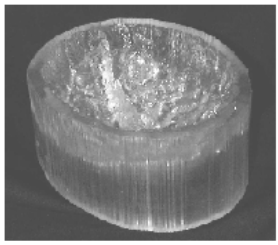

Fig. 1. Brain Mould

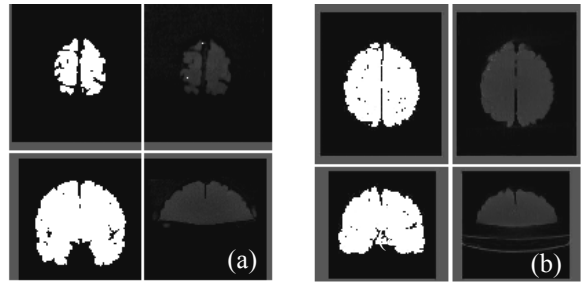

Fig. 2. Registered slices of the reference brain (white) and the phantom (grey) in (a) MR and in (b) CT.

4 Conclusions

We are satisfied with the external surface of this brain mould, and we are now adding internal structure to this phantom. While grey/white matter distinction is currently outside of our ability, we can produce water or PVA-C filled ventricles, or suspend fiducial markers (beads, wires etc) into the volume.

This "anatomically correct", deformable phantom can be manufactured with realistic tissue mechanical properties, and with imaging characteristics appropriate for MR, CT and US. It has application in the validation of stereotactic targeting procedures, multi-modality image registration studies and validation of 3D image warping algorithms.

5 References and Acknowledgements

We gratefully acknowledge Bill Wells and the NRC IMTI for building the SLA mould, and also David Gobbi, Sean Deoni, Chris Norley and Hua Qian for help in various stages of this project. This work was funded by the CIHR.

1 Holmes CJ, Hoge R, Collins L, Woods R, Toga AW and Evans AC 1998 Enhancement of MR images using registration for signal averaging *J Comput Assist Tomogr* **22** 324-333.
2 Nagura M, Nagura M and Ishikawa H 1984 State of water in highly elastic poly(vinyl alcohol) hydrogens prepared by repeated freezing and melting *Polym Comm* **25** 313-314.
3 Custom software from the McConnell Brain Institute, Montreal Neurological Institute, Montreal Canada.