

Deep Brain Stimulation in Parkinson's disease Workshop

Hamilton Institute

**National University of Ireland,
Maynooth Co. Kildare, Ireland.**



***August, 20th
2008***

General Information

Location:

Hamilton Institute, NUIM, Maynooth, County Kildare

Directions:

The Hamilton Institute is located on the North Campus of the National University of Ireland, Maynooth – for maps see www.hamilton.ie

Organisation, Information and Contacts:

The meeting is organised by Dr. Miriam Garcia. For further information contact Dr Miriam Garcia, at miriam.garcia@nuim.ie.

For travel arrangements, accommodation and general information contact Kate Moriarty at kate.m.moriarty@nuim.ie in the Hamilton Institute office.

DBS Agenda

20 th August		
14 : 00	<i>Pierre Jannin, Florent Lalys</i>	Post operative assessment of DBS based on multimodal images and clinical data
14 : 45	<i>Richard Bayford</i>	Development of Dynamic Structural models for Deep Brain Stimulation
15 : 30	Pause for coffee	
15 : 45	<i>Míriam R. García, Mark Vermoerd, Peter Wellstead.</i>	DBS in Parkinson disease: the desynchronisation hypothesis.
16 : 30	<i>Sabatino Santaniell, Giovanni Fiengo, Luigi Glielmo</i>	Identification and feedback control in deep brain stimulation: a simulation study
17 : 15	Coffee and round table	
19 : 00	Dinner	

Post operative assessment of DBS based on multimodal images and clinical data

Pierre Jannin and Florent Lalys

Context: Movement disorders in Parkinson disease patients may require functional surgery, when medical therapy isn't effective. In Deep Brain Stimulation (DBS) electrodes are implanted within the brain to stimulate deep structures such as SubThalamic Nucleus (STN). This presentation describes the successive steps we developed for constructing a digital Atlas gathering patient's location of electrodes and contacts along with clinical data for post operative assessment.

Materials and Method: 15 patients who had undergone bilateral STN DBS have participated to the study. Contacts on post-operative CT scans were automatically localized, based on black artefacts. For each patient, post operative CT images were rigidly registered to pre operative MR images. Then, pre operative MR images were registered to a MR template (super-resolution Collin27 average MRI template). This last registration was the combination of global affine, local affine and local non linear registrations, respectively. Four different studies were performed in order to validate the MR patient to template registration process, based on anatomical landmarks and clinical scores (i.e., Unified Parkinson's Disease rating Scale). Visualisation software was developed for displaying into the template images the stimulated contacts represented as cylinders with a color code related to the improvement of the UPDRS. Additionally, a data base was defined for gathering clinical data (neurological and neuropsychological) and contacts locations defined in a standard coordinate system.

Results: The automatic contact localization algorithm was successful for all the patients. Validation studies for the registration process gave a placement error of 1.4mm and coherence with UPDRS scores. We are currently implementing data mining tools for the joint analysis of imaging and clinical data.

Conclusion: The developed tools allow post-operative assessment. Correlation with clinical scores will certainly permit to learn more about DBS and to better understand clinical side-effects.

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- Jannin P, Grova C, Maurer C. Model for designing and reporting reference based validation procedures in medical image processing. *Int Journ. Comput. Assisted Radiol and Surg*. 2006 1(2)2:1001-115
- Paul P, Fleig O and Jannin P. Augmented Virtuality based on Stereoscopic Reconstruction in Multimodal Image-Guided Neurosurgery: Methods and Performance Evaluation, *IEEE Transactions on Medical Imaging, Special Issue on Image Processing for Intra-Operative Surgical Guidance*, November 2005,24-11, pp 1500-1511
- Jannin P, Raimbault M, Morandi X, Riffaud L and Gibaud B. Modeling Surgical Procedures for Multimodal Image-Guided Neurosurgery, *Journal of Computer Aided Surgery*, 2003;8(2):98-106.
- Jannin P, Fitzpatrick JM, Hawkes DJ, Pennec X, Shahidi R and Vannier MW. Editorial: Validation of Medical Image Processing in Image-Guided Therapy, *IEEE Transactions on Medical Imaging*, 2002;21(11):1445-1449.
- Jannin P, Morandi X, Fleig OJ, Le Rumeur E, Toulouse P, Gibaud B and Scarabin JM. Integration of sulcal and functional information for multimodal neuronavigation, *Journal of Neurosurgery*, 2002;96:713-723.

Development of Dynamic Structural models for Deep Brain Stimulation

Richard Bayford

Over the last decade various neurological disorders have been clinically treated using therapeutic deep brain stimulation (DBS). A fuller understanding of the role of modulating brain activity by electrical current will provide a rational basis for the optimisation of therapeutic effects. It remains unclear how the electrical current injected via the implanted depth electrodes is distributed locally or globally in the brain. This is largely because direct measurement of the distribution is difficult or almost impossible. A limited attempt has been made by some researchers to model the static conditions; however this does not include the dynamic features of the stimulation current. Additionally, the need for geometrically accurate finite element meshes of the adult human head is now becoming more acknowledged, and some investigations have been carried out to establish methodologies for their generation. A new dynamic model of the whole human head using a geometrically accurate forward model that includes scalp, skull, CSF and brain with the correct conductivity parameters has been produced. Results of 10 Hz sinusoidal stimulation, simulating the therapeutic frequency ranging from 10 to 200Hz, in a case of DBS of the subthalamic nucleus for Parkinson's disease have been obtained; we are hoping to extend this research to create multi-scale models and identify and focus the region stimulated by DBS.

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- Tizzard A and Bayford RH. (2007) Improving the Finite Element Forward Model of the Human Head by Warping using Elastic Deformation. *Physiol. Meas. Meas.* 28 S163-S182 doi:10.1088/0967-3334/28/7/S13.
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DBS in Parkinson disease: the de-synchronisation hypothesis.

Míriam R. García, Mark Verwoerd and Peter Wellstead.

The electrical stimulation of the brain for the treatment of neuropsychiatric disorders has a long history that goes back to the early 1950s. Specifically it was first used for the treatment of tremor in Parkinson's Disease (PD) in 1968 (Morten et al. 2007). However it was not until the work of (Limousin et al. 1995) that deep brain stimulation (DBS) was commonly accepted as a therapeutic procedure for PD. Since then, there have been significant advances in our understanding of DBS. Yet, some fundamental questions about the basic mechanisms remain (Erwin and Gale 2008).

A current hypothesis is that DBS acts via stimulation-induced modulation of pathological network activity. According to this hypothesis, DBS would modulate the pathological activity by interfering with the interneuronal communication, specifically by breaking the abnormal patterns of synchrony. This thesis is supported by experimental results (Beurrier et al 2001) and has inspired several computational studies (Tass 2001).

At the workshop, we will present a survey of recent experimental and theoretical work related to the desynchronization hypothesis. We will also present some preliminary results of a computational study based on the FitzHugh-Nagumo model.

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- P. Limousin, P. Pollak, A. Benazzouz, D. Hoffmann, J.F.L Bas, J.E. Perret, A.L. Benabid and E. Broussolle (1995). Effect on Parkinsonian signs and symptoms of bilateral subthalamic nucleus stimulation. *The Lancet*, 345(8942), 91-95.
- B.M.Jr. Erwin and J.T. Gale (2008). Mechanisms of action of deep brain stimulation (DBS). *Neuroscience and Biobehavioral Reviews* 32, 388-401.
- C. Beurrier, B. Bioulac, J. Audin and C. Hammond (2001). High-Frequency Stimulation Produces a Transient Blockade of Voltage-Gated Currents in Subthalamic Neurons. *Journal of Neurophysiology* 85:1351-1356.
- P.A. Tass (2001). Desynchronizing double-pulse phase resetting and application to deep brain stimulation. *Biological Cybernetics*, 85, 343-354.

Identification and feedback control in deep brain stimulation: a simulation study

Sabatino Santaniello, Giovanni Fiengo and Luigi Glielmo

Deep brain stimulation (DBS) is an effective electric therapy introduced to treat movement disorders associated with chronic neural degenerative diseases like essential tremor, dystonia and Parkinson's disease. In spite of a long clinical experience and detailed studies, the cellular effects of the DBS are still partially unknown because of the lack of information about the target sites. Recent studies, however, have proposed the local field potentials (LFPs) generated by the simultaneous electric activity of several neurons in the target sites as a useful tool to investigate the behavior before and after stimulation.

Our work investigates the relationship occurring between DBS settings (i.e., frequency and amplitude of the stimulus) and LFPs in a 3D simulation environment reproducing the activity of the Vim (a thalamic nucleus, one of the main surgical targets) in tremor conditions. A least-square identification approach is adopted to define a functional, input-output autoregressive model of the Vim and evaluate the effects of the stimulation on its electric patterns. Starting from that model, a minimum variance control scheme is then proposed to restore the auto-spectrum of the Vim LFPs to reference values, derived from subjects not affected by movement disorders. The control law works by updating the amplitude of the stimulus while the frequency is fixed at an aliasing-free value. Results indicate good performances in tracking the healthy spectral features through selective changes in the low (2-7 Hz), alpha (7-13 Hz) and beta (13-35 Hz) ranges.

- S. Santaniello, "Modeling and Control of the Neural Activity in the Extrapiramidal System for the Treatment of Movement Disorders Associated with Parkinson's Disease", Ph.D. Dissertation, University of Sannio, June 2007.
- S. Santaniello, G. Fiengo, L. Glielmo, and W.M.Grill, "DBS Feedback Controlled Tremor Suppression in Parkinson's Disease", in preparation, 2008.
- S. Santaniello, G. Fiengo, and L. Glielmo, "Adaptive feedback control in deep brain stimulation: a simulation study", 17th IFAC World Conference, July 6-11, 2008. Seoul, Korea.
- S. Santaniello, G. Fiengo, and L. Glielmo, "DBS Feedback Controlled Tremor Suppression in Parkinson's Disease", IEEE Multi-conference on Systems and Control, September 3-5, 2008. San Antonio, Texas (USA).