Selectively stimulating neural populations in the subthalamic region using a novel deep brain stimulation lead design

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Background

Deep brain stimulation (DBS) of the subthalamic nucleus (STN) is widely used in advanced stages of Parkinson's disease (PD) and has proven to be an effective treatment of various motor symptoms. The therapy involves implanting a DBS lead in the STN through which continuous high frequency electric pulses are delivered. The clinical outcome highly depends on the location of stimulation within the STN. Unfortunately, despite careful planning and precise stereotactic surgery, a placement error of the lead may occur. The state of the art DBS lead containing four cylindrical electrode contacts is only able to correct a placement error in dorsal-ventral direction. A new high resolution (HR) lead is developed which enables spatial steering of the stimulation field in multiple directions [1].

Objective

The goal of the study was to evaluate stimulation effects in the subthalamic region evoked by the HR DBS lead using multiple stimulation modes, and compare this with stimulation effects evoked by the state of the art DBS lead.

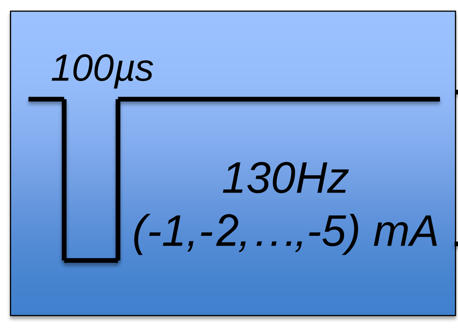
Methods

Computational model:

The anatomic model consists of two parts [2]:

1. Finite element method (FEM) model to calculate the evoked potential field in the subthalamic region.
2. Multi compartment neuron models to calculate stimulation effects of the evoked potential field on three neural populations in the subthalamic region (STN projection neurons, globus pallidus internus (GPi) fibers, and internal capsule (IC) fibers).

Two virtual DBS leads are included in the model:



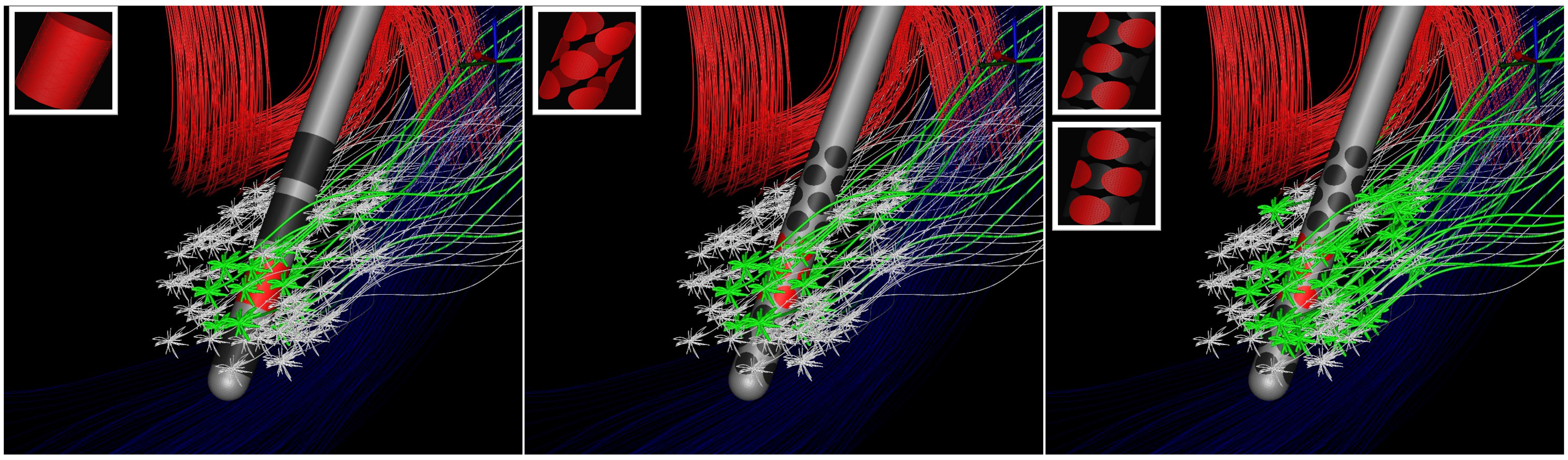
The Medtronic 3389 DBS lead

The Sapiens HR DBS lead.

Configuration optimization:

To find the optimal stimulation setting, we maximized the number of activated STN cells without stimulating the internal capsule fibers, by adjusting the stimulation amplitude and contact configuration.

Results



Medtronic		Sapiens (ring)		Sapiens (steering)	
STN	STN + GPI	STN	STN + GPI	STN	STN + GPI
15%±1%	55%±5%	16%±1%	58%±5%	43%±5%	66%±3%

Conclusion

Our results showed the Sapiens HR lead was able to mimic the stimulation effect of the Medtronic lead. In addition, the spatial steering modes enabled -without activation of the IC fibers- higher coverage of neural activation, and increased ability to selectively stimulate the projection neurons in the STN. The clinical effect of the increased coverage and selective stimulation of the STN and GPi fibers needs further investigation. Furthermore, we believe that the model can be used as a tool for the neurosurgeons in further research to optimize patient specific stimulation settings.

References

1. H.C.F. Martens, E. Toader, M.M.J. Decré, D.J. Anderson, R. Vetter, D.R. Kipke, K.B. Baker, M.D. Johnson, J.L. Vitek, Spatial steering of deep brain stimulation volumes using a novel lead design, Clinical Neurophysiology, 122(2011) ; 558-566.
2. A. Chaturvedi, C. R. Butson, S.F. Lempka, S.E. Cooper, C.C. McIntyre, Patient-specific models of deep brain stimulation: Influence of field model complexity on neural activation predictions, Brain Stimulation (2010) ; 3(2):65-77.

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