Performance Requirements of MEMS based Vestibular Prosthesis

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Introduction: Hearing, vision, and balance are supported by the vestibular system. Dysfunction of the vestibular organs results in losing balance, consequently dizziness, gaze, and images instability. While MEMS-based vestibular prosthesis (VP) have the potential to restore the balance function of patients with instability problem, the analysis of sensor performances and long term drift underlying this rehabilitation is lacking. This paper presents the detailed analysis of sensors performance and derive the requirements for development of vestibular prosthesis.

Materials and Methods: The transfer function involved in the vestibular organ of squirrel monkey has been modeled by [1] relating head rotation to neural firing rate. In a VP, the rotational movement is captured by a gyroscope sensor. This sensor suffers from bias (B) and scale factor (SF) drifts (<10% for the rate grade class). Allan variance method is used for noise analysis, and the variation in the delivered pulses are used to demonstrate the effect of sensor drift.

Results and Discussion: Vestibular losses significantly increase the detection threshold from 0.5 °/sec to 5.8 °/sec [2]. Under no input rotation, the baseline activity of the electrical stimulation deviates from 125 Hz to 275 Hz under 10% changes in B & SF (Fig.1). As a result of long term drift for the prosthetic device, a normal human sensitivity will fall into vestibular dysfunction (Fig.2), therefore continuous sensor calibration is required.

Conclusions: We analyzed the challenges involved in the implementation of vestibular prosthesis based on MEMS vibratory gyroscope. We considered the drift of MEMS sensors and calibration algorithms to reduce sensors drifts under varying dynamic and environmental conditions. We concluded a MEMS gyroscope with a minimum bias instability of 100°/hr would satisfy the design requirements for a VP. These analyses are essential since they determine the ultimate feasibility of the prosthesis.

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