Rigorous Approach to Demyelination Capacity

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Abstract

In this note, the authors study axon tracts with demyelination. It is observed that the ISI of action potentials gets modulated as the demyelinated segments are approached. By introduction of a function which maps the normal ISI to the demyelinated ISI, and finding the mutual information with respect to the demyelinated ISI, the authors are able to propose the use of a result by Ikeda and Manton so as to extend it to the diseased case.

Action potentials travel down myelinated axons maintaining a separation which is called the inter-spike interval (ISI). In [1], the authors base their capacity calculation on the ISI. In [2] (see Figures 5 and 6), the authors studied the case of demyelination and found that the ISI gets modulated downwards on approach to a demyelinated segment, and post-traversal the final ISI is somewhat longer than the pre-traversal ISI. Thus a function which captures this modulation of the ISI can be defined. The slope of the function will be proportional to the ISI. Thus initially say the slope is 45 degrees, upon hitting a demyelinated segment it becomes 30 degrees and post-traversal it stays at 55 degrees. We denote this function as $g(\cdot)$ which maps the normal ISI random variable to the demyelinated ISI random variable. Using Section 4.7 of [3], we know how the cumulative distribution function (c.d.f.) of the function of a random variable relates to the probability density function (p.d.f.) of the original random variable. Using this relation, we can determine the c.d.f. of the modified or demyelinated ISI random variable. Thereafter we can follow Section 2.3 of [1] and modify the first two and related equations to reflect this change. Continuing with that section, we should be able find the capacity of a neuron with a demyelinated axon. One of the limitations of this proposal includes the question whether the Ikeda-Manton approach is applicable to neurons with myelinated axons and to axon tracts with ephaptic coupling. In future work this should be addressed.

References

[1] Shiro Ikeda and Jonathan H Manton. Capacity of a single spiking neuron channel. *Neural Computation*, 21(6):1714–1748, 2009.

[2] Aman Chawla and Salvatore Domenic Morgera. On the geometry of interacting axon tracts in relation to their functional properties. *bioRxiv*, 2022.

[3] Geoffrey Grimmett and David Stirzaker. *Probability and random processes*. Oxford university press, 2020.