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OSCILLATIONS IN NEURONS COUPLED ELECTRICALLY VIA DENDRO-DENDRITIC GAP JUNCTIONS

Israel Ncube[1] and Manuel Rodríguez[2]

[1]College of Engineering, Technology, & Physical Sciences
Department of Mathematics, Alabama A & M University
4900 Meridian Street North, Huntsville, AL 35762, USA

[2]Universidad de Guadalajara, Av. Juárez No. 976 Colonia Centro
C.P. 44100, Guadalajara, Jalisco, México

Abstract. It is known that a large number of neurons in the inferior olive are coupled by gap-junctions. Such neurons exhibit spontaneous subthreshold oscillations in the frequency range 1-10 Hz, the specific causes of these oscillations remain unclear. Several studies have been conducted over the years, but none of them have considered the possible effect that time delays in signal transmission could have on the membrane potential dynamics. In this work, some novel and simple mathematical models of time-delayed artificial neuronal networks are studied. The models take into consideration discrete time delays in dendro-somatic signal transmission. The models are capable of generating subthreshold oscillations in the absence of any active currents or external input.

Keywords. subthreshold oscillations; inferior olive; linear delay differential equations; stability.

AMS (MOS) subject classification: 34K15, 58F36, 92C20.

1 Introduction

Rhythmic activity can be generated by populations of neurons in the central nervous system. However, the physiological mechanisms that underlie this activity are unclear. The inferior olive (IO) is a brain structure that contains neurons which produce spontaneous, subthreshold oscillations (STOs) [23]. Gap junctions (GJs) are well-known portals of electrical, intercellular communication channels between neurons. They consist of twelve connexin (Cx) proteins, six of which form hemichannels or connexons. Neuronal GJ proteins (Cx36) have been identified and Cx36 knockout (KO) mice have been created. Furthermore, GJs are known to interconnect IO neurons at dendritic sites, i.e. *not* at their cell bodies or somata. It has been hypothesized that electrical coupling is essential not only for mediating synchrony, but also for generating the subthreshold oscillations ([6], [13]). In particular, Manor et al. [13] suggested that neurons with heterogeneous channel densities could give rise to oscillations in electrically coupled IO neurons that did not oscillate on their own. They used one-compartment models for their neurons which precluded coupling at dendritic sites being considered. Loewenstein et al. [6] presented a dynamic mechanism in which electrical coupling could disrupt a negative