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Revisiting the Haken Lighthouse Model: Bridging Spiking and Non-Spiking Neural Networks

Simple spiking neural network models built from integrate-and-fire (IF) units display rich emergent behaviour but are difficult to analyse, especially in terms of pattern formation. Rate-based models and coupled phase oscillators are more tractable but miss important dynamical features of spiking systems. To bridge these paradigms, Hermann Haken introduced the Lighthouse model, a synergetic framework capturing synchronisation, travelling waves, and neural pattern formation. We revisit the Lighthouse model and develop new mathematical results that clarify self-organisation in spiking networks. We derive linear stability conditions for phase-locked spiking states in Lighthouse networks defined on graphs with realistic alpha-function synapses and axonal delays. Extending this graph-based analysis to spatially continuous (non-local) networks, we formulate a Turing-type instability criterion for emergent spiking patterns. We further show that localised spiking bump solutions — difficult to analyse in IF networks — arise naturally in the Lighthouse model and examine their stability against wandering dynamics. These results reinforce the Lighthouse model as a powerful framework for studying structured neural interactions and self-organisation, advancing the synergetic perspective on spiking neural dynamics.