How function may abruptly emerge or disappear in physical and biological systems

November 6 2018, by Latina Emerson

Credit: CC0 Public Domain

In physical, biological and technological systems, the time that a system's components take to influence each other can affect the transition to synchronization, an important finding that improves understanding of how these systems function, according to a study led by Georgia State University.

The researchers developed analytical formulas that helped them arrive at these conclusions. Their findings are published in the journal *Scientific Reports*.

Synchronization is common in many natural and man-made oscillator systems, where considerable function emerges as a result of cooperative behaviors of many interacting elements in the systems. Examples of synchronizing systems include neurons in the brain, cardiac pacemaker cells, rhythmically chirping crickets, an audience's applause in concert halls and semiconductor lasers. In these systems, interacting elements, also called oscillators, have their own rhythms, but the interactions can lead to a common rhythm. The interaction delays, which are always there in any real system due to the finite speed of the movement of signals, processing times and other factors, can modify the ultimate rhythm. This study looks at how this happens.

"Interaction strength and time delays can change the way synchronization appears and develops," said Dr. Mukesh Dhamala, associate professor in the Department of Physics and Astronomy and Neuroscience Institute at Georgia State. "The system's history makes a difference in synchronization. This paper looks at the effects of time delays in critical interaction strength needed to achieve synchronization of coupled oscillators. The synchronization transitions remind us of the first-order and second-order phase transitions commonly studied in statistical physics.

"These findings can be helpful to make sense of experimentally observed network oscillations, for example, the neural oscillations in the brain where conduction time delay between two connected regions ranges from a few to tens of milliseconds. A smooth or abrupt transition to synchronization might be helpful in distinguishing a normal brain function (e.g. perceptual decision) from a dysfunction (e.g. epileptic seizure)."

In this study, the researchers introduced time delays and changed the coupling strength between oscillators to understand transitions to and out of abrupt synchronization. They found that time delay does not affect the transition point for abrupt synchronization when coupling strength is decreased from a synchronized state, but time delay can shift the transition point when coupling strength is increased from an unsynchronized state.

More information: Hui Wu et al. Dynamics of Kuramoto oscillators with time-delayed positive and negative couplings, *Physical Review E* (2018). DOI: 10.1103/PhysRevE.98.032221

Hui Wu et al. Exact explosive synchronization transitions in Kuramoto oscillators with time-delayed coupling, *Scientific Reports* (2018). DOI: 10.1038/s41598-018-33845-6

Provided by Georgia State University

Citation: How function may abruptly emerge or disappear in physical and biological systems (2018, November 6) retrieved 26 April 2024 from https://phys.org/news/2018-11-function-abruptly-emerge-physical-biological.html