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Chimera state in a network of nonlocally coupled impact oscillators

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Chimera state

Chimera state:

- refers to the coexistence of coherent and incoherent domains in the network of coupled oscillators
- is associated with several natural phenomena
- has been investigated in a large number of researches with different oscillators
- Has also been observed experimentally

This paper → studies chimera in the network of coupled impact oscillators

The model

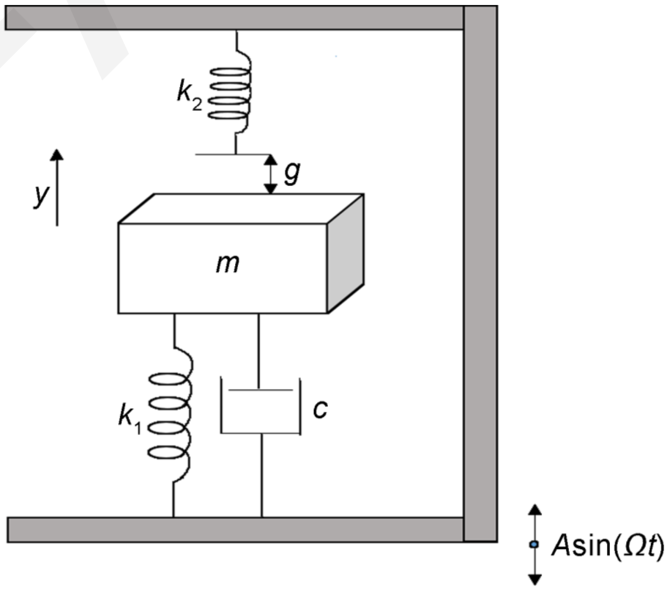
Motion of the mass:

$$m\ddot{y} + c\dot{y} + k_1 y = mA\Omega^2 sin(\Omega t), \quad y < g$$
$$m\ddot{y} + c\dot{y} + k_1 y + k_2(y-g) = mA\Omega^2 sin(\Omega t), \quad y \geq g$$

Non-dimensional

$$\dot{x} = v$$
$$\dot{v} = a\omega^2 \sin(\omega\tau) - 2\xi v - x - \beta(x-e)H(x-e)$$

A single impact oscillator

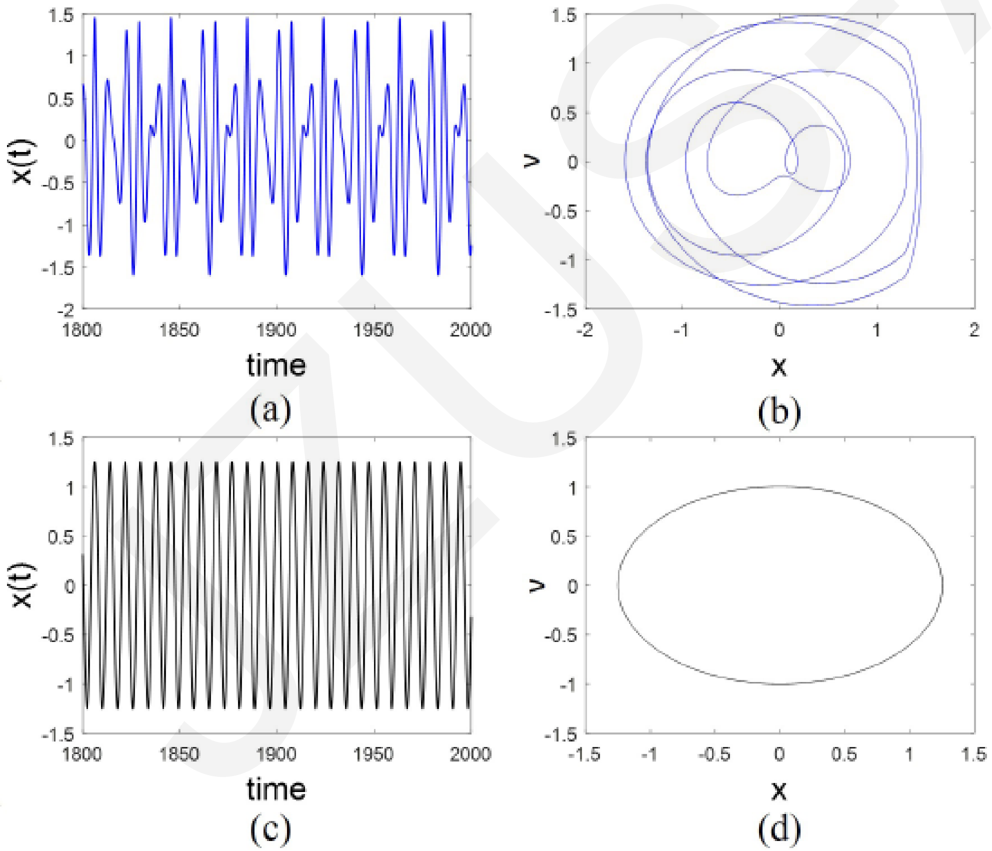


Pavlovskaia et al. (2010)

The model

Coexisting attractors of the oscillator by setting:

$$a = 0.7,\ \omega = 0.801,\ g = 1.26,\ \xi = 0.01,\ \beta = 29$$



The network

- A ring network of impact oscillators
- With nearest neighbor coupling

Equations of the network:

$$\dot{x}_i = v_i + \frac{\sigma}{2P} \sum_{j=i-P}^{i+P} (x_j - x_i)$$
$$\dot{v}_i = a\omega^2 \sin(\omega\tau) - 2\xi v_i - x_i - \beta(x_i - e) H(x_i - e) + \frac{\sigma}{2P} \sum_{j=i-P}^{i+P} (v_j - v_i)$$

To characterize the network behavior → strength of incoherence (SI)

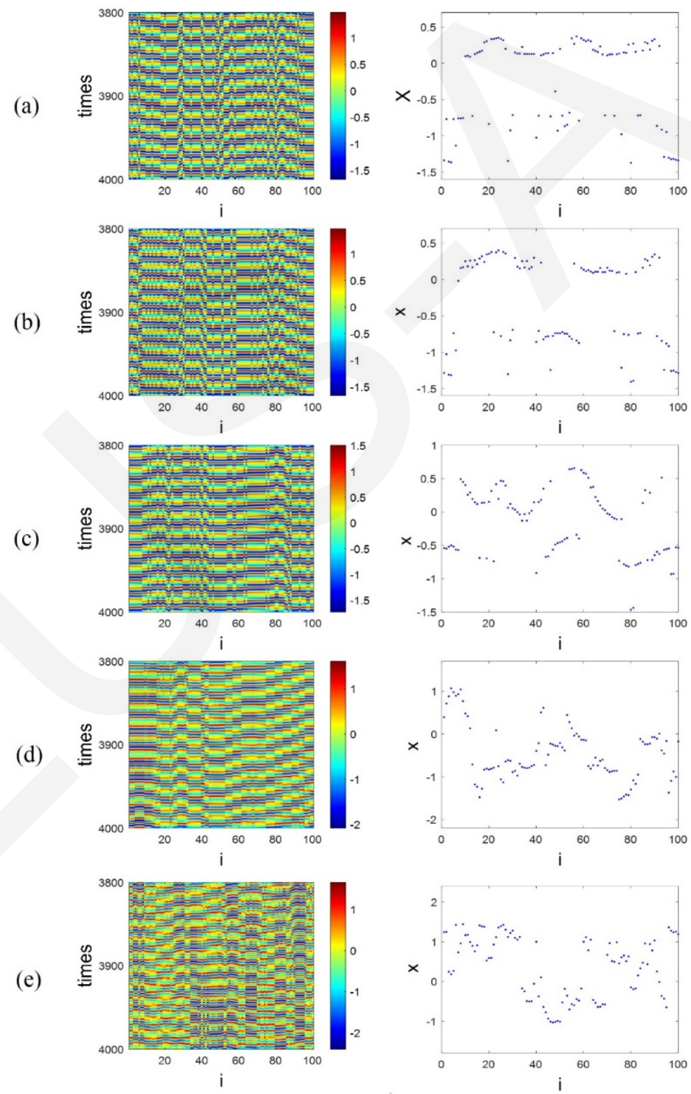
$$\sigma(m) = < \sqrt{\frac{1}{n} \sum_{j=n(m-1)+1}^{mn} [z_j - < z >]^2} >_t, m = 1, ..., M$$

$$SI = 1 - \frac{\sum_{m=1}^{M} s_m}{M},$$
$$s_m = H(\delta_0 - \sigma(m)),$$

Results

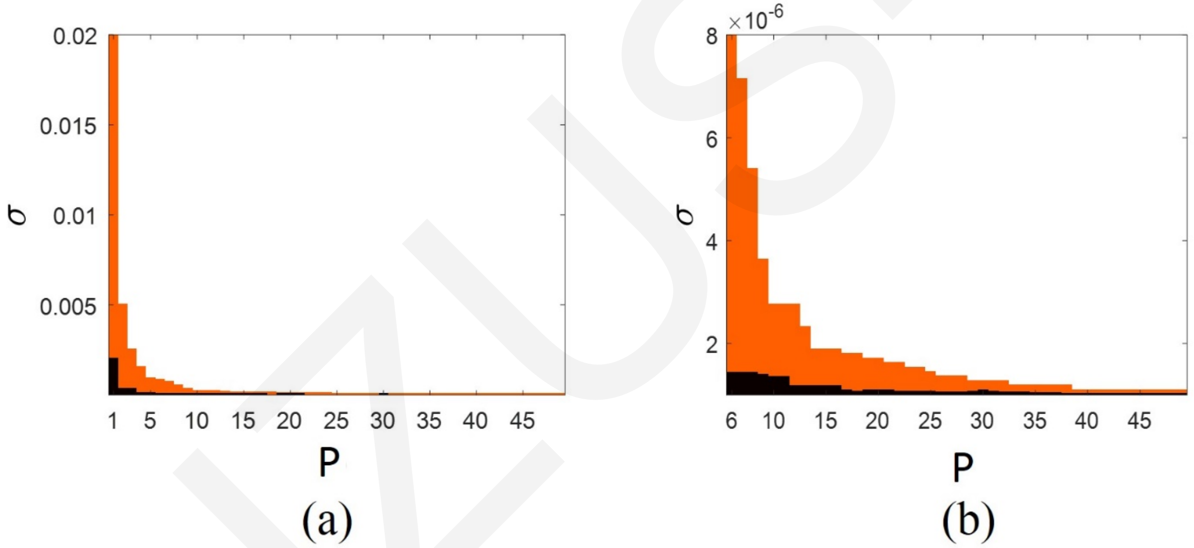
The behavior of the network by varying the coupling strength

The chimera emerges for specific parameters



Results

The regions of different observed states of the network in the (P,σ) parameter plane:



Black: *asynchronization,* ***Orange***: *chimera,* ***white***: *divergence*

Conclusions

- The coupled oscillators are asynchronous for significantly small coupling strengths.
- By increasing the coupling strength, the chimera state emerges in the network.
- Further increase of the coupling strength leads to the divergence of the oscillators.
- The complete synchronous state couldn't be obtained.
- With increasing the number of neighbors in the coupling, the region of chimera state is reduced considerably.
- The coupling has remarkable effects on the attractors of the coupled systems.
- The coupling can influence the motion of the failed oscillator.