Experimental self organization in an array of coupled inverted pendula

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ABSTRACT
This case study, analyzed during the lab activities linked to the Nonlinear Systems Control course, highlights particular emergent behavior found in an array of eight inverted pendula linked through semi-rigid links. The generation of complex traveling waves is characterized in different scenarios, including external perturbation and noise. When specific conditions are met, the interplay between imperfections, irregularities and sinusoidal inputs drives the system to a nontrivial coordinated behavior.

OBJECTIVE
The goal of this experiment is to assess the self-organizing properties on the array of inverted pendula in different scenarios. In particular, the scenarios involve the introduction of parametric uncertainty in the pendula model, by acting on the suspended mass position over the rods of the inverted pendula. Moreover, the effects of the introduction of an external mechanical sinusoidal input is investigated. According to literature, the interplay between order (the sinusoidal input) and disorder (masses position) should lead to unexpected regular oscillation, as shown in [1] with extensive numerical simulations. Our case study aims at recovering experimentally this emergent behavior in a physical system.

$$G_{pend}(s) = \frac{\theta(s)}{\phi(s)} = \frac{\omega_r{}^2 s^2}{s^2 + {}^{\omega_g}/_{Q}\, s - \omega_g{}^2}$$

Fig 1: Transfer function single pendulum

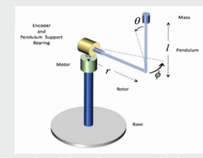


Fig 2: Single pendulum

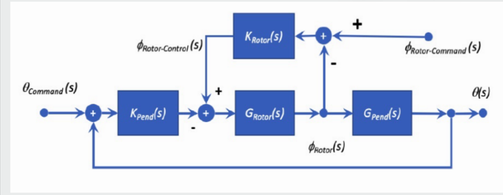
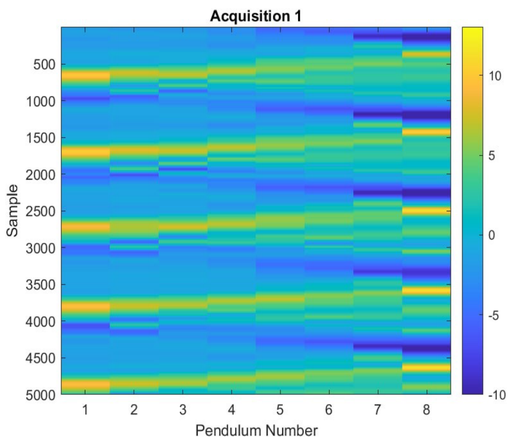
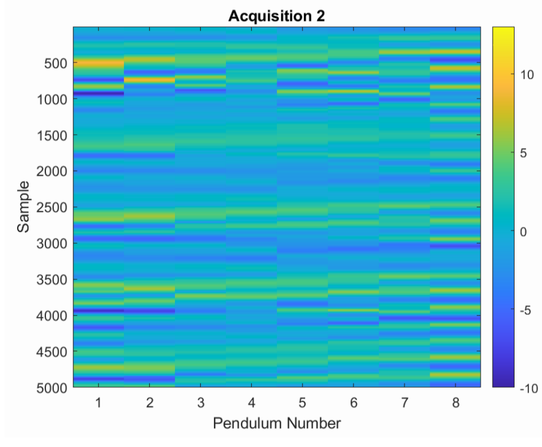
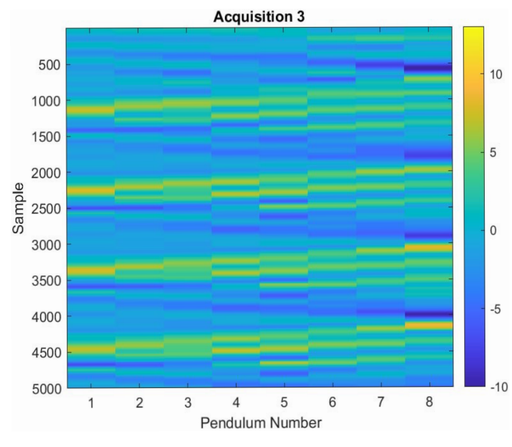


Fig 3: Block diagram single pendulum with control action to stabilize the inverted position

The experimental campaign was conducted considering the different scenarios. In particular, two series of tests with or without the presence of the external signal are conducted and
- all the masses equally positioned near the top of the rods,
- masses put in random positions,
- masses put in descending positions.







Our tests achieved a fundamental outcome: when the clips are placed in random positions, the introduction of an external input elicits the self-organizing properties on the considered complex nonlinear system. These preliminary results represent the starting point for a more structured investigation of self-organizing behavior in physical systems.

[1] *Taming spatiotemporal chaos with disorder: Y. Braiman, John F. Lindner & William L. Ditto*