PhD Thesis

Controlling earthQuakes (CoQuake) in the laboratory
using pertinent fault stimulating techniques

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Abstract

Anthropogenic seismicity has been increased since the last decades due to the intense human activity for energy production. However, despite the fact that merely injection of fluids can induce/trigger earthquakes, in this thesis, we show that the strategic interplay between fluid extractions and injections can control such seismic events and eventually prevent them. More specifically, a novel mathematical framework of robust earthquake control is built which in turn is exploited in numerical simulations of strike-slip faults and gas reservoirs, as well as in new laboratory experiments of decimetric scale.

First, the key parameters which constitute a conventional earthquake mitigation strategy are identified. Surrogate experiments on absorbent porous paper show that without the precise knowledge of the fault properties, fluid injections risk to nucleate faster a large seismic event.

In order to tackle such uncertainties, rigorous mathematical tools are developed using modern control theory. These tools require minimal information of fault's properties and frictional characteristics to assure robustness. Numerical simulations on strike-slip faults verify that earthquake prevention is possible, even in the presence of diffusion processes and the absence of sufficient measurements both in time and space. Going a step further, the developed control techniques can also be applied in large gas reservoirs, where the desired gas production can be achieved assuring acceptable seismicity levels.

Finally, during this thesis, a novel triplet apparatus of decimetric scale has been designed, constructed and calibrated accordingly. Pressure control can be achieved, in this machine, in real-time, through a fast response electro-pneumatic pressure regulator. As a proof of concept, the developed controller is plugged in this apparatus and by using sand-based 3D-printed specimens (to promote experimental repeatability), we manage, for the first time, to prevent laboratory earthquakes and drive the system aseismically to an equilibrium point of lower energy.

Keywords: Controlling earthQuakes (CoQuake); Fault Mechanics; Robust Control; Surrogate Experiments; Double-Direct Shear Apparatus; Induced Seismicity.

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