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Title: YEARLY REPORT FOR THE PERIOD Jan. 2018 – Feb. 2019 IC Project: w17_faultprediction “Critical Stress in Earth”

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YEARLY REPORT FOR THE PERIOD Jan. 2018 – Feb. 2019

IC Project: w17_faultprediction "Critical Stress in Earth"

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Scientific and Programmatic Impact:

The consequence of earthquake is usually catastrophic. Currently, we cannot determine when a fault is approaching failure due to either anthropogenic activities or tectonic movement. In an anthropogenically perturbed setting, the rate of physical changes on faults far exceeds most natural processes with currently unpredictable and unmeasurable results. In a tectonic setting we generally do not know where a fault is in the earthquake cycle beyond noting how long has passed since the last rupture, which is itself sometimes unknown. The Laboratory has therefore funded a multi-million multi-year LDRD-DR program that comprises experiments, numerical modeling, and machine learning in order to develop and test a highly novel approach to probe the earthquake cycle and in particular, to detect and locate stressed faults that are approaching failure. For this program, modeling of a series of sheared granular layers undergoing stick-slip behavior using the EES-17's Combined Finite-Discrete Element Method (FDEM) based code HOSS (Hybrid Optimization Software Suite) plays a pivotal role since numerical simulations of granular fault gouge allow for analysis of the mechanical behavior of the system at a level of spatial and temporal resolution not accessible experimentally, and also offer the possibility of identifying the most important parameters governing earthquake dynamics. The simulated data also provide very detailed stress, strain and motion information for machine learning purpose to predict earthquake.

The code – HOSS – has been developed in Geophysics Group in LANL during the past ten years and is used to simulate the stick-slip behavior of granular fault gouge. One of the key feature of HOSS is that it is superior to pure finite element method and discrete element method and can provide very detailed evolvement information of granular fault gouge. Additionally, its parallel computing capability makes large scale earthquake gouge simulation possible. Taking these facts into account, and also because few other fully parallel FDEM code exists, this IC project allows LANL to stay at the forefront of earthquake gouge and granular material simulation in the world.

Financial Impacts:

Present Sponsors: LDRD Office

Future (potential) Sponsors: LDRD Office, Basic Energy Science Office, Office of Science.

Summary of Computational Effort Accomplished:

We have used ~4 M CPU hrs for earthquake gouge 2D simulation on Wolf and Grizzly, mainly focus on investigating the influence of different normal loads, shear velocity and plate stiffness on the stick-slip behavior of granular fault gouge. The simulated data show very good stick-slip phenomenon, which provide plenty of very useful information for us to further unveil the mystery of energy and stress evolution during the earthquake cycles. The data have been sent for machine learning purpose to predict earthquakes.

Publications/Presentations:

1. Gao K, Guyer RA, Rougier E, Johnson PA (2019) From stress chain to acoustics. *Physical Review Letters* (in review)
2. Gao K, Euser BJ, Rougier E, Guyer RA, Lei Z, Knight EE, Carmeliet J, & Johnson PA (2018) Modeling of Stick-Slip Behavior in Sheared Granular Fault Gouge Using the Combined Finite-Discrete Element Method. *Journal of Geophysical Research: Solid Earth* 123. doi: 10.1029/2018JB015668
3. Gao, K., Rougier, E., Guyer, R. A., & Johnson, P. A. (2019). *Ground vibration in simulated sheared granular fault gouge.* 53th US Rock Mechanics/Geomechnics Symposium, New York, USA.
4. Gao, K., Rougier, E., Guyer, R. A., & Johnson, P. A. (2019). *Simulation of source ground vibration in sheared granular fault.* Engineering Mechanics Institute Conference 2019, Pasadena, USA.
5. Gao, K., Rougier, E., Guyer, R. A., & Johnson, P. A. (2019). *Stick-slip induced source ground vibration in sheared granular fault.* Seismological Society of America 2019 Annual Meeting, Seattle, USA.
6. Gao K, Rougier E, Euser BJ, Guyer RA, & Johnson PA (2018) *Characterization of stick-slip dynamics in granular fault gouge using the combined Finite-Discrete Element Method*. 52th U.S. Rock Mechanics/Geomechanics Symposium, Seattle, USA.
7. Gao K, Rougier E, Euser BJ, Guyer RA, Johnson PA (2018) *Influence of normal pressure on the stick-slip behavior of sheared granular fault gouge using the combined finite-discrete element method*. In: SSA 2018 Annual Meeting, Miami, USA