NUMERICAL MODELING OF ROCK-FLUID INTERACTION

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1. Research Objectives

- Develop an efficient application to model a blocky rock mass
- Couple the rock mass model to an efficient fluid flow model

2. Rock-Fluid Interaction - Rock Scour

Rock scour of unlined spillways is a recurring problem at many dams. The erosion of the foundation of the spillway at Oroville dam shown in below is the most recent example of this phenomenon.

Rock erosion at Oroville Dam
Source: CADWR

2.1 Physical Modeling

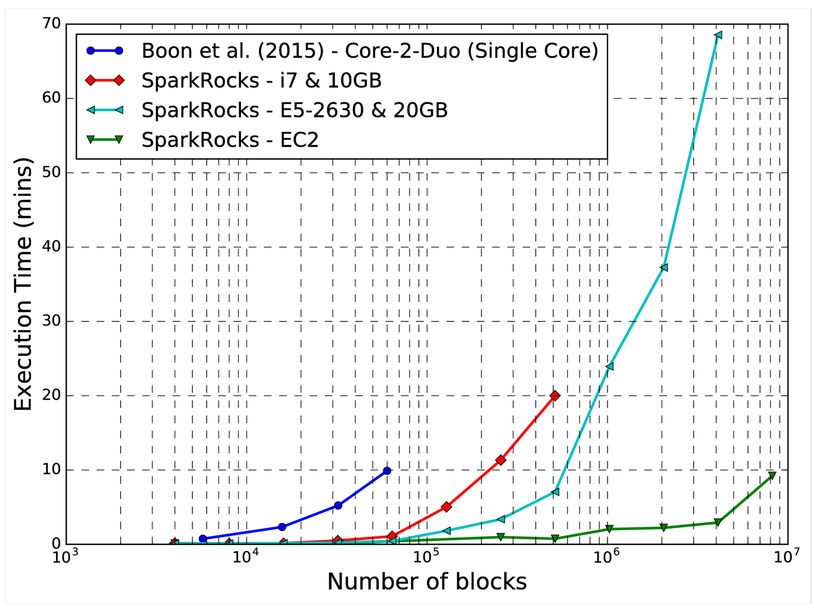
To explore this problem, George (2015) performed a series of flume experiments that investigate the mechanisms that govern scour of individual rocks in dam spillways. The figure below shows an individual block as it is being removed due to hydrodynamic loading. In addition two prototype blocks were instrumented in a spillway of a dam in the Sierra Nevada.

Model rock block "plucked" by flowing water. *George, Ph.D. Dissertation, 2015.*

3. Numerical Modeling

3.1 Fractured Rock Mass Representation – SparkRocks

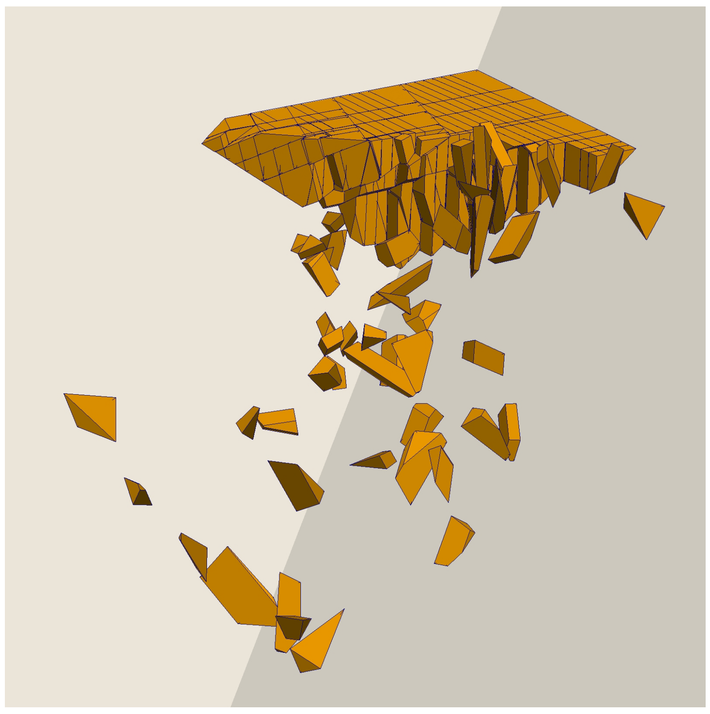
The first challenge is to generate a representative rock mass model. We developed a parallel open-source fractured rock mass generator capable of efficiently producing millions of blocks using Apache Spark. The software is platform independent and can run be on the Cloud.



Speedup achieved in SparkRocks through parallelization. *Gardner et al., 2017*

3.2 3-D DEM Rock Mass Model Implementation

A new 3-D Discrete Element Method (DEM) application had to be developed in order to make the computations feasible by taking advantage of parallel computing.

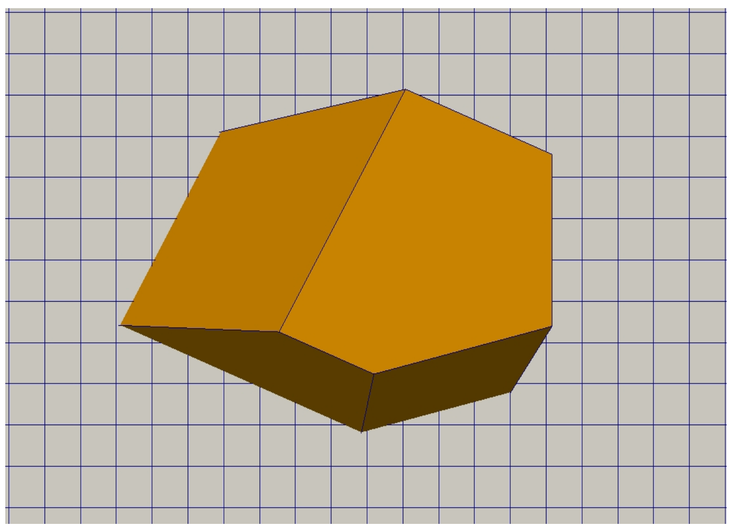


Rock slide modeled using DEM

3.3 Rock-Fluid Interaction Modeling

Modeling the interaction between the polyhedral rock blocks and the surrounding water requires coupling between the solid and fluid models. We chose to couple the DEM with the Lattice Boltzmann Method (LBM) for two particular reasons:

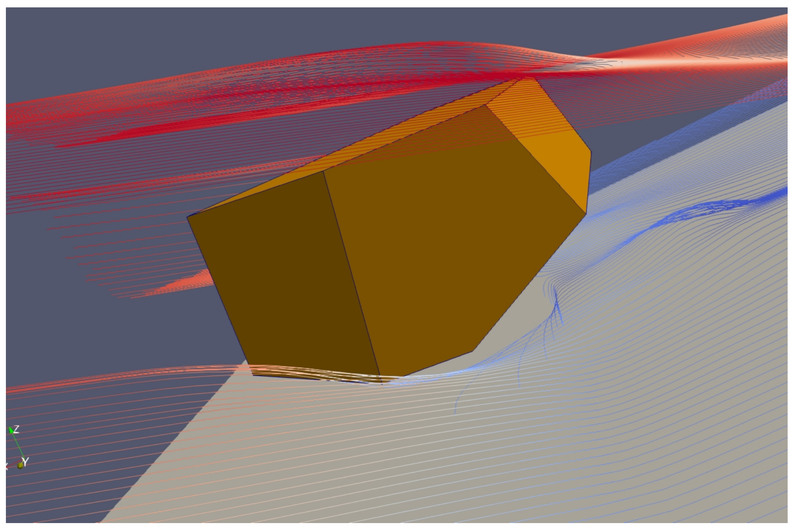
- LBM is inherently parallel
- Explicit control over resolution in model



Rock block (DEM) moving through fluid (LBM) mesh

Coupling is achieved through a momentum exchange between the rock block and the fluid nodes that are partially or completely covered by it.

The next step in our research is to parallelize the fluid portion of the coupled model. In order to adequately solve for the hydrodynamic forces acting on the block, a very high resolution fluid solution is required. This necessitates the use of high performance computing.



Streamlines bending round a polyhedral block moving through the fluid mesh

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