Center for Quantum Science and Engineering (CQSE)

Weekly Seminar
Apr. 1, 2011 (Friday)

TIME	Apr.1, 14:30 ~ 15:30
TITLE	Landslide simulations with continuum hydrodynamic models
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PLACE	Rm716, CCMS & New Physics Building, NTU

Abstract

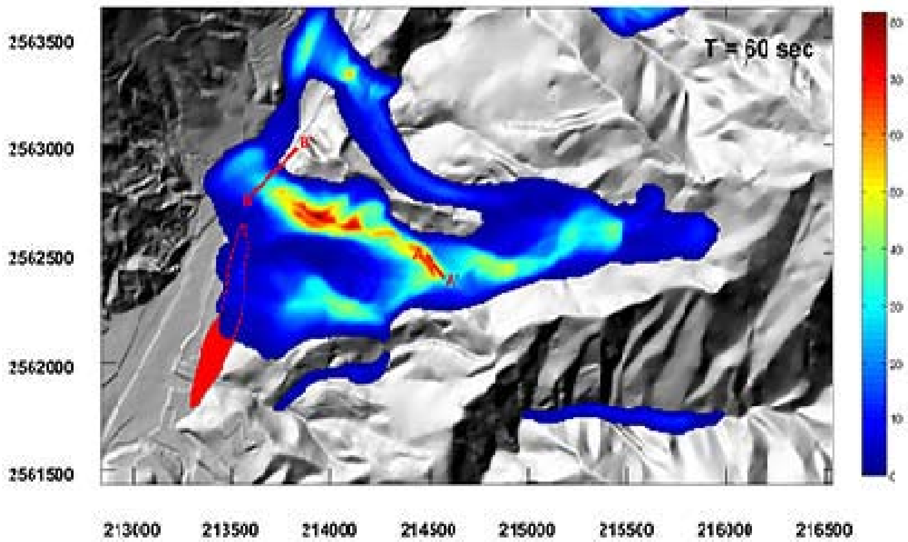
Recent advances in landslide/avalanche modeling [1,6,8,9] have been enabling us to investigate the kinematics of such catastrophic events with much more details. Taiwan is located in a region where seismic activities and extreme weather conditions frequently occur. One of their common consequences is the slope failure. In the past decodes, we witnessed at least three giant landslides: Tsaoling, Jiufenershan landslides, triggered by the Chi-Chi earthquake in 1999, and Shiaolin landslide, triggered by the heavy rainfall of Morakot typhoon in 2009. Their slid volumes are 125, 42, 24 million cubic meters, respectively. The common observations are that these landslides are rapid rock avalanches with velocities estimated higher than 40 m/sec and the deposit particles have sizes ranging from sub-millimeters up to a few tenths meters in diameters[2,3]. The excess amount of debris particles in these landslides suggests that their overall motion may follow the postulate of the continuum mechanics and, consequently, exhibit the characteristics of fluid flows. Indeed, it is common to find the flow morphology in the deposit areas.

The model equations are, therefore, derived from the differential forms of the equations of motion, namely, the mass and momentum conservation equations. For gravity driven flows, like landslides, the flow usually has a thickness much smaller than its extension along the topography directions and its velocity remains mainly tangential to the basal interface. Therefore, the depth should be defined in the direction normal to the topography. The velocity component is negligibly small along this depth-wise direction which leads to a hydrostatic pressure distribution. With the help of a terrain-fitted coordinate system and formulating with the contravariant velocity, we can carry out the depth integration with a prescribed velocity profile[1,8,9]. This yields a two-dimensional model which not only shares great similarities with the classical shallow water equations but also equips with capabilities to incorporate with the GIS

DEM seamlessly. Mathematically, the model equations are of hyperbolic type which supports discontinuous weak solutions, ie. the hydraulic jumps, and the topographical effects act as momentum sources. The model equations have to be solved numerically for arbitrary topography. We use a shock capturing non-oscillatory finite volume method to solve for the kinetic motion numerically.

The other important physical aspect arises from the theoretical derivation is the rheology laws of thematerials. They contribute to the flow field from two main categories: the friction/shear force at the basal interface and the flow internal dissipation. A hierarchy of the continuum more can be identified according to the fluid rheology via the scaling analysis and, within it, the most important influencing factor is the drag at the basal surface[7]. While more sophisticated laws have continuously been proposed and validated in the laboratories. e.g.[8], we can verify via numerical simulations with a few well-known friction laws, such as the Coulomb and the Voellmy [10] friction laws. The rheological parameters are determined by the best fit of the simulated deposits and the measurements.

(a)



(b)

Fig 1 (a) Shiaolin landslide at t = 60 sec, (b) Overview of Shialin Village prior to the landslide and the near-surface magnetic measurement.

The rainfall brought by Morakot typhoon triggered the Shiaolin landslide which buried about 500 people and extinguished the township of Shiaolin Village, Kaohsiung. The tragic event is composed of two sub-events: the landslide and the block dam breach. With the current hydrodynamic model and the laboratory measurement of the material friction, we can accurately reconstruct the landslide event. The simulation shows that one branch stream of the landslide debris is created as a result of the impact on the 590 Height and it swipes over the north part of the village, Fig. 1(a). Its destruction to the village is confirmed by the near-surface magnetic measurement, Fig. 1(b). The simulation deposit is further integrated with hydrology calculations to resolve into the second stage dam breach sub-event.

These landslides are all large scale geological failures and, especially, the Shiaolin landslide shows the topography can significantly affect the sliding courses. This urges us to initiate detail surveys to identify potential hazardous sites further beyond the shallow slope failures which must include the predicted pathways and deposits. The present application benchmarks demonstrate that the hydrodynamic model can be a valuable analysis tool for this purpose.