Landslide Collapse Movement Simulation Using Savage-Hutter with a Staggered Grid Scheme

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Abstract. The avalanches can be simulated using the Savage-Hutter with Finite Volume Method (FVM) models as a numerical solution in one dimension. The scheme used in the Finite Volume Method here is the Staggered Grid Scheme. The purpose of this paper is to observe landslide movements based on different types of sediments on sloping inclines with the same initial sediment height. The results of the simulation are to produce landslide velocity and landslide height values. Each type of sediment has different velocity and height of landslides is affected by the shear angle and the internal angle of the soil. From the simulation that has been done, the average velocity of each sediment is obtained. Here are the average speeds for sediment *Yellow Sand* = 33.7216, *Rice* = 32.5029, *Quartz* = 21.8533 at $t = 1.0s$.

1. Introduction

Rainfall can trigger landslides and the high intensity of rainfall can add a heavy burden to the slopes and ground shifts [1, 2, 3]. There are several factors that can cause landslides such as, very heavy rainfall, shifting the earth's plates, poor surface structure, and others. Landslide can cause substantial losses from the destruction of houses to the loss of life in the worst. To find out the movement of land collapse or landslides, landslides can be simulated using numerical modeling. Numerical approach is a technique that can be widely applied in overcoming a complex geological problem. It uses computational simulation of geological scenarios. The results of the simulation can be used to predict the movement and velocity of the landslide which serves to anticipate a landslide disaster that will occur at another time.

The speed of landslides is greatly influenced by the shape of the land surface. During the direct shift simulation test there will be a change in the thickness of the soil sample due to solidification or expansion of the soil, especially in the shear plane area. If y is the change in thickness of the soil sample and x is the magnitude of the lateral shift, then the dilation angle is defined as $(\delta y/\delta x)$. Basically, the denser the soil volume, the greater the value of the internal friction angle [4]. The denser the volume of soil development in the soil sample produced during the direct shear test, the grater the angle of boundary. Based on these two things, there is a relationship between the angle of internal friction of the soil and the angle of dilation of the soil in the direct shear test.

The movement of land collapse can be described by the Savage-Hutter model. This model is a fluid dynamic model in conservation law form. Where in this model, the depth average is simplified by assumption of a hyperbolic partial differential equation. Savage-Hutter model can be used to describe the movement of some loose mass of granules without cohesion such as soil, seeds, rocks, and snow [5, 6]. Moreover, this model is designed to predict motion and deformation from initials so that it runs along the landslide path according to the topography that has been made.

In this paper, the numerical simulation of landslide using Savage-Hutter Model staggered grid scheme will be elaborated. The staggered scheme is one of the finite volume method schemes which is a robust method for approximating the conservation law form [7, 8]. Moreover, Savage-Hutter model is similar to the shallow water model, therefore staggered grid can be used to approximate the numerical solution. In order to show the ability of staggered grid in solving the Savage-Hutter model, three sediment types will be elaborated in the numerical simulation.

2. Research Methods

2.1. Savage-Hutter Model

The Savage-Hutter model is a model to describe the flow of shallow water driven by gravity in a sloping channel from modeling parabolic forms such as landslides that move in mountain valleys or landslide movements [9, 10]. The Savage-Hutter equation written in conservative form, as follows:

$$\frac{\partial h(x,t)}{\partial t} = -\frac{\partial (h^* u(x,t))}{\partial x} \tag{1}$$

$$\frac{\partial u(x,t)}{\partial t} = -u\frac{\partial p(x,t)}{\partial x} - \beta\frac{\partial h(x,t)}{\partial x} + S_x \tag{2}$$

In the savage-hutter model has 2 equations namely, Eqs. (1) is the equation for flux and Eqs. (2) is the equation for momentum. Where x is the place or position observed in one-dimensional space, and t represents time, $h(x,t)$ is a function of landslide height, $u(x,t)$ is a function of landslide velocity and S_x is a function of acceleration of a landslide in the momentum equation. Whereas S_x and β can be obtained using the following equation:

$$S_x = \sin(\zeta) - \frac{u}{|u|}\tan(\delta)\cos(\zeta) \tag{3}$$

$$\beta = \epsilon K_x \cos(\zeta) \tag{4}$$

In Eqs. (4) there is an ϵ, the value is obtained from $\epsilon = H/L < 1$, where H is the thickness of the landslide while L is the path length of the landslide, and for ζ is the angle formed from the slope surface on the topography, K_x is the value of the pressure coefficient the earth on the x-axis and δ is the angle of shift of land [5, 9]. Where K_x can be obtained using the following equation :

$$K_{x_{act/pass}} = 2\sec^2(\phi)\left(1 \mp \sqrt{1-\cos^2(\phi)\cos^2(\delta)}\right) - 1 \tag{5}$$

in which,

$$K_x = \begin{cases} K_{x_{act}}, & \partial u/\partial x \geq 0 \\ K_{x_{pass}}, & \partial u/\partial x < 0 \end{cases} \tag{6}$$

for ϕ is the internal angle of the land, while the values for ϕ and δ will be explained in detail in the discussion of topology and sediments.