

Three-Dimensional Landslide Model For Predicting Affected Area With Particle Flow Simulation

Banphot Nobaew

School of Information Technology, Mae Fah Luang University, Chiang Rai, Thailand
Emails: banphot@mfu.ac.th

ABSTRACT – Landslides are a serious natural disaster in many countries around the world especially in highland areas during the rainy season. Therefore an early warning system which can predict the possibility of landslide in hazard areas is seriously required to prevent damage to life and assets. Three-dimensional models are also needed to simulate landslide areas for prediction of the overall effects. This paper describes a new three-dimensional landslide model by applying a methodology consisting of image processing, use of global positioning system, and risk factor interaction on programming. A landslide model is built by contouring the surveyed sites. In addition, a 3D Studio MAX script is employed based on existing risk factors to simulate the flow of land particles during the occurrence of a landslide. Based on observations of the landslide site, the proposed method shows acceptable accuracy on both the probability of landslide incident and its effects.

KEY WORDS – three-dimensional; landslide; particle flow; simulation

1. Introduction

Landslides are a serious natural disaster in Thailand's northern region especially in Chiang Rai province. Based on mostly hilly terrain, Chiang Rai is located in the storm route and close to the main fault line. In addition, Chiang Rai also has the highest national average rainfall. These factors make Chiang Rai most vulnerable to a landslide disaster mainly on hilly terrain. Prediction and warning systems are highly needed to decrease the amount of damage that might be caused without a warning system. Though the risk of landslides can be approximated by debris flows [1] and GIS classification [2], disaster simulation of landslides are also required to define the potential catastrophic caused by a landslide.

To define the risk area, the proposed warning system analyzes many risk factors using an algebraic equation. The landslide risk factor [3] divides landslide causes into external causes which result in an increase of the shearing stress and internal causes which result in a decrease of the shearing resistance. Consequently, International Institute for Geo-Information Science and Earth Observation [4] made a hazard map based on quantitatively defined weight-values. Many different methods exist for the calculation of weight-values. The method used in research is called the landslide index method. Carrara and others [5] recommended that geographical data processing is still a pioneering discipline that needs

major changes and advancements. Possible future research applications include object based models, 3D or even 4D data structures, integration of GIS with artificial intelligence, hypermedia and animation techniques.

Therefore, this paper presents a three-dimensional landslide simulation by applying a variety of methodologies. The affected areas are defined by using the landslide simulation which is analyzed by programming through factor values scripting.

2. Research Methodology

The landslide simulation process can be separated into five steps of implementation; factor analysis, image processing, Global Positioning System in landslide site, contouring the site and simulation. First, starting to analyze the risk factors and mapping these factors with a geographic map using a Geographic Information System to classify the risk area by landslide index formula and an image processing technique. Next, the site modelling is simulated in a three-dimensional model by a global positioning system with accuracy value in each position. After that, the landslide risk factors were conducted to the site modelling for simulating the landslide area compared with the result for a real situation.

2.1 Research Areas

The study site is situated on the north of Thailand; Ban Pha Mee village in Mae Sai district, Ban Santikiree village in Mae Fah Luang district and Ban Lao Fhu village in Mae Chan district, Chiang Rai province. They are the highest landslide risk area as defined by factor analysis with GIS technique. The selected site had frequently suffered from landslide and is still in danger.

2.2 Conceptual Framework

To define the risk factors, this involved the information about the landslide which is required for analysis. The landslide factors were mapped with the geographic map by the GIS to classify the risk area. Then, the landslide factors were input into the model for simulation which simulates site by contour value and simulation is calculated by scripting on programming software.

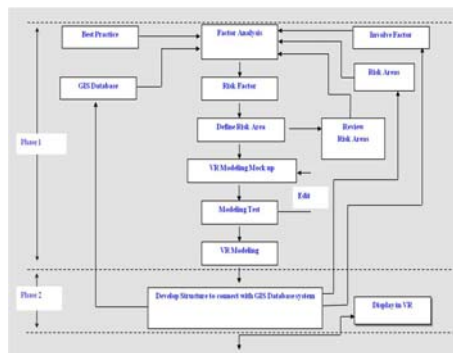


Figure 1. A research concept.

3. Experimental Results

The process of landslide simulation is showed step by step in the following subsections.

3.1 Factor Analysis

From the field survey and data collection that involves research, we could collect meteorology data, landslide data and GIS primary information to find the landslide factors. So, the physical characteristics, such as rainfall, rock unit, slope, forest, buffer fault, windward, altitude and satellite information, all used to classify the spatial characteristic.

3.2 Image Processing

After determining the landslide factor, we had to merge these factors with the geographical map by the Geographic Information System to classify the risk area. To classify the high risk level, we need to determine the weighting rate for each factor within one to six. The weighting rates are dependent on an importance value for of each factor.

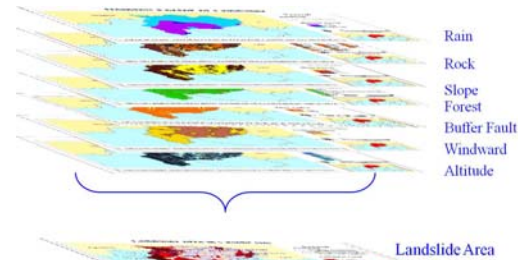


Figure 2. Factors intersection.

To find landslide risk area and villages of the landslide risk areas, this research uses Landslide Index, which refers to those factors.

$$\text{Landslide Index} = \{(RrRw) + (RUrRUw) + (SrSw) + (FrFw) + BFrBFw) + (WrWw)\} * (Hr)$$

Where: R = Rainfall, RU = Rock Unit, S = Slope, F = Forest, BF = Buffer Fault, W = Windward, H = High, r = Rating, and w = Weighting

The result of landslide area is classified by the image processing technique dividing areas into 3 types; high risk, risk, and no risk area as shown in figure (3).

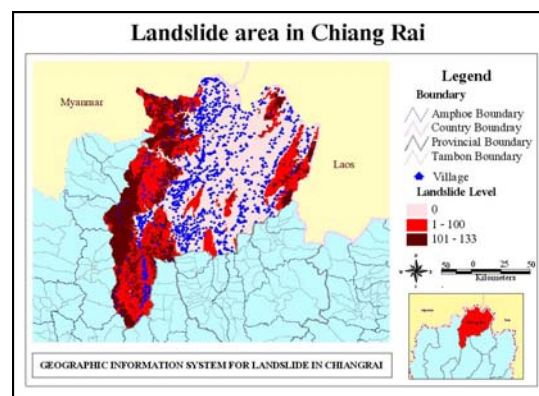


Figure 3. Landslide area of Chiang Rai.

3.3 Global Positioning System in landslide site

Measuring the positioning value using GPS in the site, and then it was transferred to model a landslide shape in three-dimensions with the contour value in CAD. The global positioning system in the research areas is starting from setting a squares grid on the satellite map in subdivide-size 10X10 meters and also mixing with the real situation on site which is measurement along with the ridge of hills. The total measurements taken included 478 points at Ban Pha Mee village in Mae Sai district (Figure 3.), 307 points at Ban Santikiree village in Mae Fah Luang district (Figure 4.), and Ban Lao Phu village in Mae Chan district (Figure 5.) with 216 points. Next, all points' values are employed to create the contour map in CAD. Then the contour map is taken to simulate the three dimension models in 3D Studio Max software.

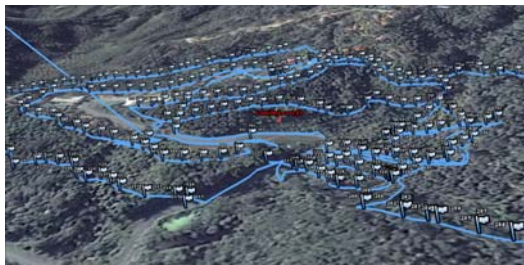


Figure 3. Site Positioning by gridding system.

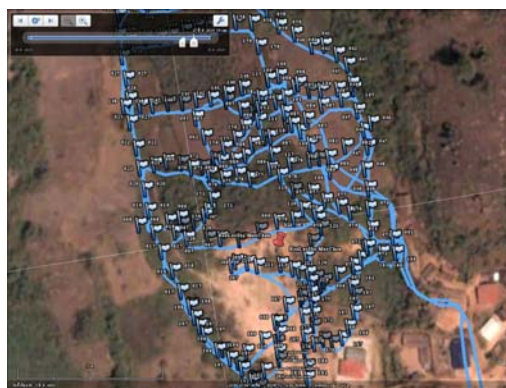


Figure 4. Site Positioning by gridding system.



Figure 5. Site Positioning by gridding system.

3.4 Contouring the site

Contour maps of Ban Pha Mee village in Mae Sai district were generated by CAD as shown in figure (6), Ban Santikiree village in Mae Fah Luang district in figure (7), and Ban Lao Phu village in Mae Chan district shown in figure (8) respectively.

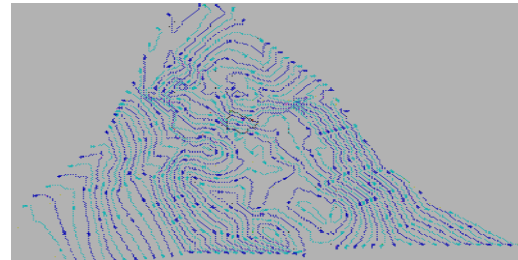


Figure 6. Ban Pha Mee Contour map.

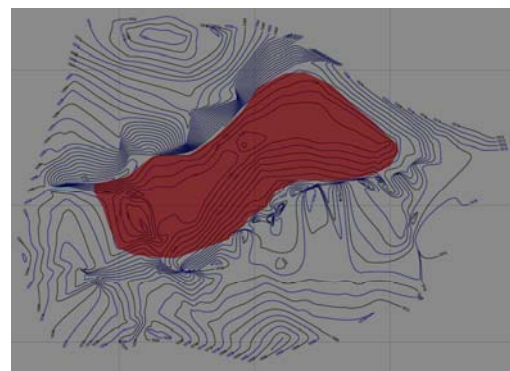


Figure 7. Ban Santikiree Contour map.

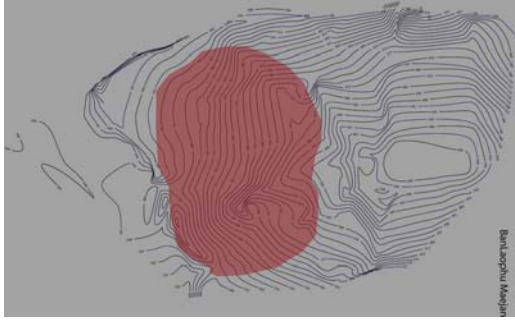


Figure 8. Ban Lao Phu Contour map.

3.5 Simulating the landslide model

The contour data, which is position from GPS, has been taken to simulate the landslide model in three-dimensional modeling (Figure 9.).

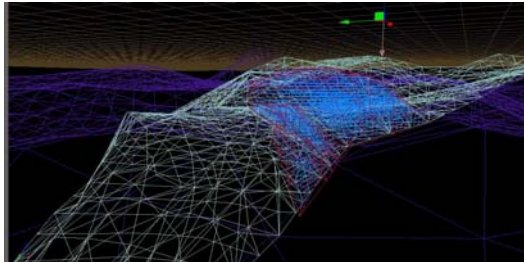


Figure 9. Landslide site 3D-model.

3.6 Landslide Simulation

Simulating the landslide movement requires the landslide risk factors and the interaction among factors which affect the landslide characteristic.

3.6.1 Soil particle analysis

Rainfall is a main key factor which induces a land movement which is a debris flow type. Soil cohesive strength between soil particles is decreased when water infiltrate to the soil. Simulating the landslide in site study, it applies the particle flow to analyze the process as a soil particle flow concept diagram (Figure 10).

Soil particle is simulated through programming by setting a soil particle source and naming the birth particle in the particle life span. The soil particle will interact with the water particle from the rainfall while other factors are set in an initial step such as high, slope, windward, etc.

Particle simulations are programmed and defined during the process by factoring values as soil particle shape, particle position, gravity, speed, rotation and spin, etc (Figure 11).

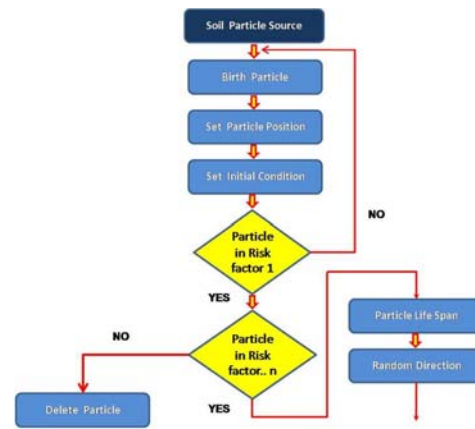


Figure 10. Particle simulation process.

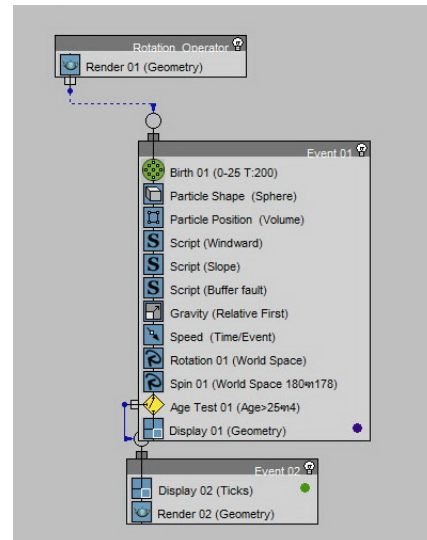


Figure 11. Particle simulation programming.

3.6.2 Soil particle strength and characteristic

To consider the soil strength and characteristic on soil particle flow, it can define as landslide force (Figure 12).

$$\mu = Fc/R \quad (1)$$

$$\mu = Fc/R = W \sin \phi / W \cos \phi \quad (2)$$

$$= \tan \phi \quad (3)$$

$$\text{or } Fc = R \tan \phi = \mu R \quad (4)$$

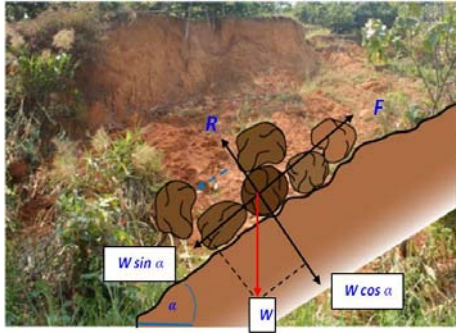


Figure 12. Force in the land movement.

W = particle of soil weight, F = frictional force between sand particle and plane surface, θ = critical angle, μ = the static coefficient of friction and F_c = critical limit value of F

Moreover classifying the soil structure for re-modeling simulation as the previous (Figure 9), needs to analyze the soil sampling by applying a boring technique to collect soil sampling in depth 20 m. which is depend on soil type. The result shows in 6 different soil levels (Figure 13.). It includes:

- Soil level 1, size 17 - 100
- Soil level 2, size 6 - 84
- Soil level 3, size 11 - 73
- Soil level 4, size 13 - 55
- Soil level 5, size 11 - 77
- Soil level 6, size 22 - 77

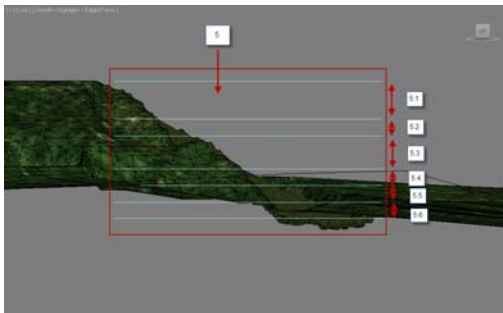


Figure 13. Soil level analysis.

3.6.3 Landslide Simulation modeling and particle forces

The first result of landslide simulation experiment shows affected area and coverage in ground level when applies the input factor values at 90% of water content (Figure 14, 15).

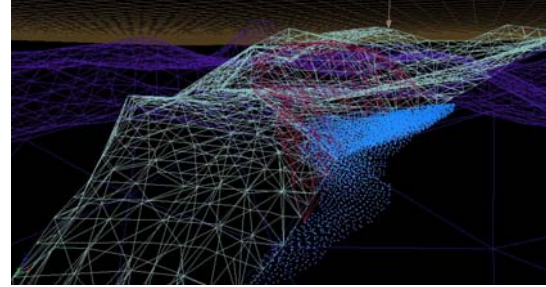


Figure 14. Landslide simulation result.

Soil strength value calculates in the soil particle surface follow the formula.

$$\begin{aligned} n F_c / A &= (n R / A) \tan \theta \\ \text{or } S &= Q \tan \theta \end{aligned} \quad (5)$$

F_c = shearing force, A = area of surface, R = normal reaction, Q = normal stress in overburden pressure

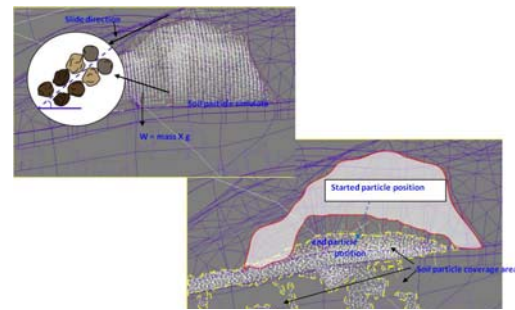


Figure 15. Soil particle coverage area.

Simulating the soil particle of landslide simulation, 7 risk factor values are employed in a program to calculate the prediction of the landslide following rain fall levels of 150, 180 and 200 mm. These are the critical points in particular areas. The soil particles are generated from the rain values which simulate in area 100 x 100 meters of each sample case, therefore the amount of soil particle is calculated as follows:

Landslide = amount of rain is 150,180,200 mm/12 hours

1 hour = 60 minutes, 1 minute = 60 seconds, so 1 second = 0.0046 mm of rain (1x1m)

This plane rain of scene is 100x100 m.

This scene is 25 frames/1 second; amount of particle is 4800/1 second

1 second = 25 frames

4,800 particles/25 frames = 100x100 m.

4,800/100 = 1x1m

48 particles = 1 second

So 48 particles = 0.0046 mm

$$0.0046 \text{ mm} \times 43,478 = 200 \text{ mm}$$

So 48 particles x 43,478 = 200 mm

Then the program script calculates all risk factor values and generates the simulation and interaction between the risk factors (Figure 16.).

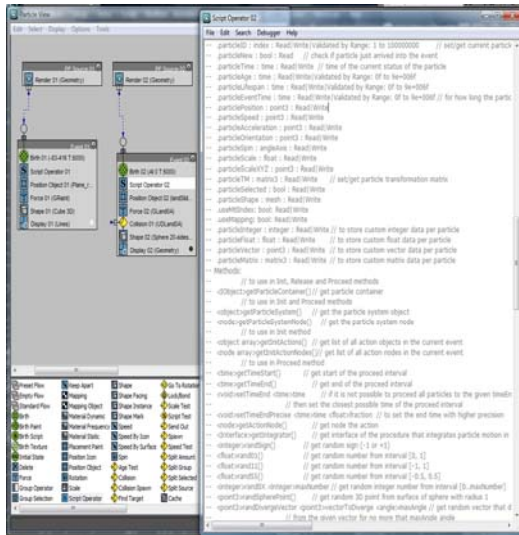


Figure 16. Script generates the soil particles.

As the final result (Figure 17.), the landslide simulation is rendered using the scripting in 3D Studio Max software which shows the coverage area.

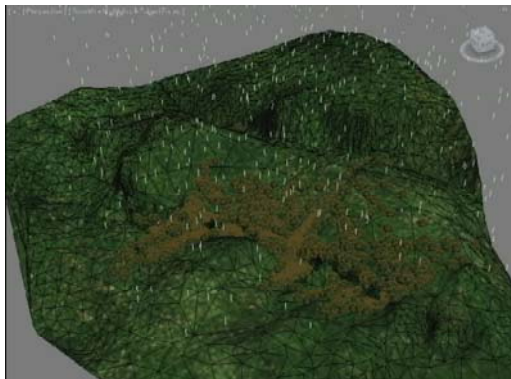


Figure 17. Landslide simulation when programs script.

4. Conclusion

Three-dimensional landslide modeling process simulating the characteristic of soil particle movement and affected area is introduced. Risk factors are initially applied in the program to be calculated in simulation model to generate parameters of soil particles which are fed to the 3D Studio MAX script to simulate interaction of particles that affect the size of the disaster area. The result shows satisfying accuracy on both the risk of landslide and its effects.

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