Modeling Discrete-Event Systems Using DEVS (2012 fall)

Assignment 2: Simulation of 3D rock fall

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Part I

Rock fall is a quite normal phenomenon in the natural activities, which poses a threat to the mountain area all over the world. It is a hard work to predict when it will happen because different areas or regions have various rock properties. Once it happens, it has a huge damage to the humanity, animals and the nature.

A rock fall starts from a loose rock falling along vertical and sub-vertical paths together. Apparently, as for the vertical path, the velocity can reach a very high speed by accumulating stones. The much heavier rock is, the faster speed has. In terms of sub-vertical rock fall, it can only get a relatively small horizontal speed brought by the collision of near stones at first, while as they are rolling all the time and they can be fast as well finally before they reach the bottom of mountain.

In our simulation, we will develop a three-dimensional simulation program that simulates the process of rock fall in a mountain with a 45-degree slope, using cell-DEVS technology without considering other physical parameters which can affect the velocity of stones falling in reality, such as friction, air resistance and wind strength.

In our model, assume the point (0, 0, 0) is the first loose stone which will lead to a rock fall. As we can see from the YoZ platform, stones will be affected by the loose stone are listed in the Figure 2. So there are 7 neighbors, but the probability they will fall is ranging from 25% to 65% according to the reasonable circumstance. In addition, all of stones' initial values are set to 1. If the affected stone falls, the value will change from 1 to 0. If the value is 0 (which means it has already fallen), it will just keep its value (0).

(-1,-1,1)	(-1,0,0)	(-1,1,-1)
(0,-1,1)	(0,0,0)	(0,1,-1)
(1,-1,1)	(1,0,0)	(1,1,-1)

Table 1: From the (YoZ) dimension

In the figure 2, it is seen from the XoY platform, only 2 affected stones can be drawn.

				(0,1,-1)
			(0,0,0)	
		(0,-1,1)		

Table 2: From the (XoY) dimension

Part II

Introduction

We propose the 3D rock fall cell-DEVS model to simulate the rock-falls natural phenomenon using Cell-DEVS based on the paper “STONE: a computer program for the three-dimensional simulation of rock-falls” by Fausto Guzzetti, Giovanni Crosta, Riccardo Detti, Federico Agliardi.

3D rock fall system in nature

As we had learned from the paper [1], we know that there are several parameters which may affect the result of the simulation. For instance, it varies dramatically and is unpredictable once we take starting velocity and direction, the dynamic friction coefficient and the normal and the tangential energy restitution coefficient in to consideration. All these parameters are different and difficult to calculate in nature world. So a lot of simulators choose to use random components to test the rock fall situation due to local conditions. After reading these papers we decide to use different random probabilities to represent the combination of different parameters of nature geographic information. We know that one fall rock can cause different affects to different dimensions, which we use different probabilities to represent in this project. Here are some explains about the idea which is the foundation of this simulation.

First, we use 3D dimensional Geometry to depict the scenario of a falling rock. We use 8*8*8 cubes to implement the environment.

Secondly , we initial the whole cubes with the value 0,which represents the stones on the slope of the mountain are stable .Then , we initial a cube with the value 1 on a slope ,which indicts the stone on this slope begin falling.

Thirdly, we use random probability to show that a falling rock may cause its neighbour rocks to fall on different probabilities. Since these probabilities are different on different geography. We simplify the calculation with some basic sense to replace the complex calculation. It is obvious that the fall rock will have the biggest probability to cause the current lower neighbour rock to fall.

Finally, because the rock may have different velocity to different directions, so we use different delay time to represent this. And these delays are also depending on the comment sense .For instance, the shortest delay is also to the current low neighbour rock on the slope.

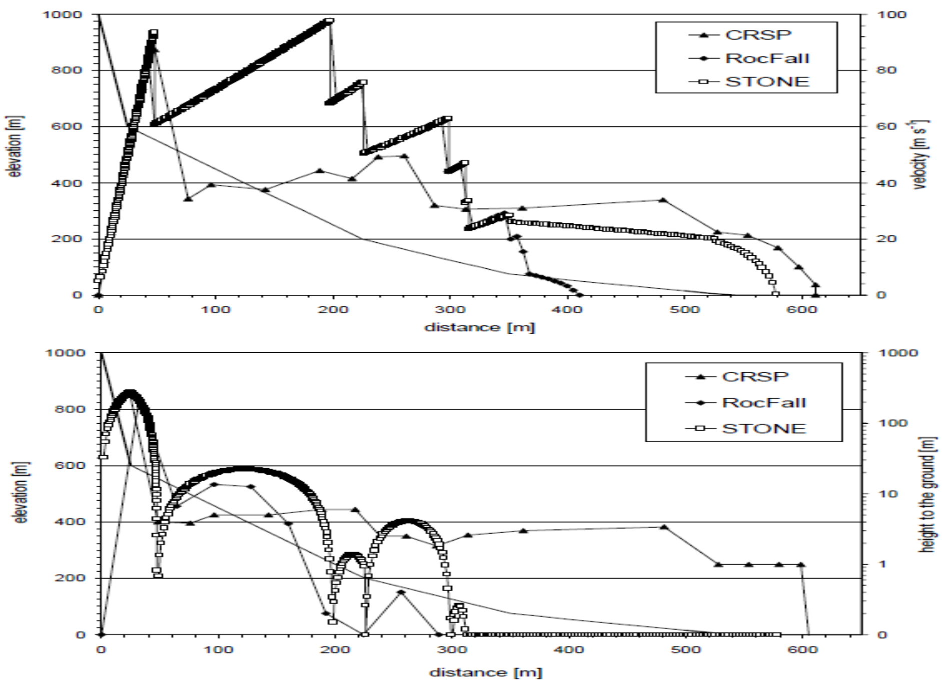

Figure 1[1]

This picture mainly shows that on different heights, the rock fall has different speed. The more higher height , the faster speed .Then ,we change this height to relative height and relative distance .For instance , because the relative height between the upper stone with under below neighbour is the biggest , so we can assume the speed is the fastest and the momentum is the biggest . So, to this direction, it has the shortest delay time and biggest probability to cause the below one to fall.

Implementation in Cell-DEVS model

Cell-DEVS formal specification

M = < Xlist, Ylist, I, X, Y, η, N, {r, c}, C, B, Z, select >

Xlist = { Φ}

Ylist = { Φ}

X = Φ

Y = Φ

η = 8

N = {(-1,-1,1), (0, -1, 1), (1,-1,1), (-1,0,0), (0,0,0) (1,0,0), (-1,-1,1), (0,1,-1), (1,-1,1) }

r= 8

c = 8

S= {0,1}

B = Φ(nowrapped)

C = {C_{ij} / i ∈ [0, 7], j ∈ [0, 7]}

Based on the specification to build the model using CD++

The rules should be set depending on the different probabilities that a falling stone will affect other stones in different directions.

Also, according to the fact that different affected stones should fall down after various periods when the collision happens between 2 stones, delays are set differently in order to be close to the real situation.

Direction	Inclined top (0, -1, 1)	Oblique below (0, 1, -1)	45 degree of Inclined top (-1,-1,1) and(1,-1,1)	45 degree of Oblique below (-1,1,-1) and(1,1,-1)	Horizontal (-1,0,0) and (1,0,0)
Probability	0.65	0.5	0.05	0.15	0.25
Delay(ms)	15.21	11.1	26.4321	23.54321	21.321

Table 3

State of Stones

If the stone is not affected by near stones, its value will keep 0.

If the stone is affected and falls down, its value will change to 1.

Test strategy

Using CD++ modeler

In order to make it clear, we use Cell-DEVS animation to view the results in a direct way.

As we can see in the Figure 2, the initial value is assigned to 1 is (4, 2, 3) which means the first stone triggers rock fall.

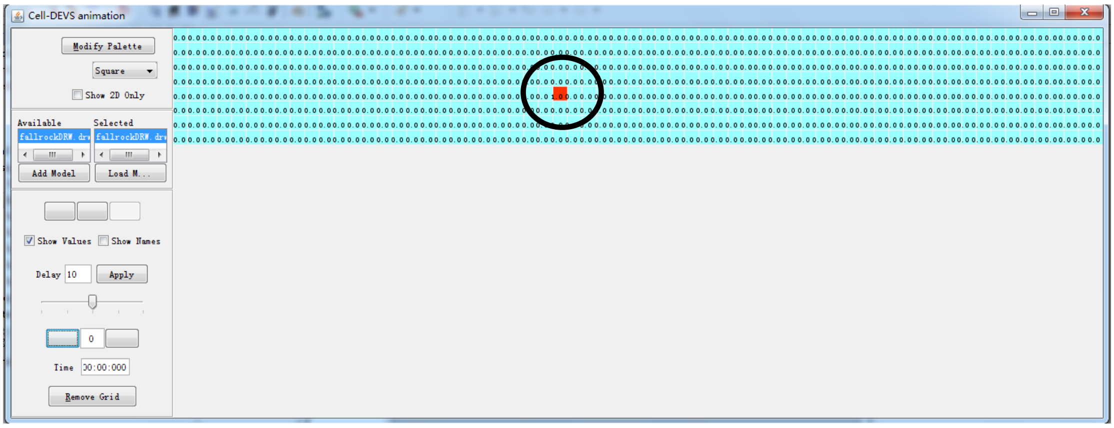

Figure 2

In figure 3, it shows that one stone in the last plane is triggered which means the rock fall has reached the hill bottom. Also, it indicates that the rock fall has reached the bottom after the first stone had been triggered.

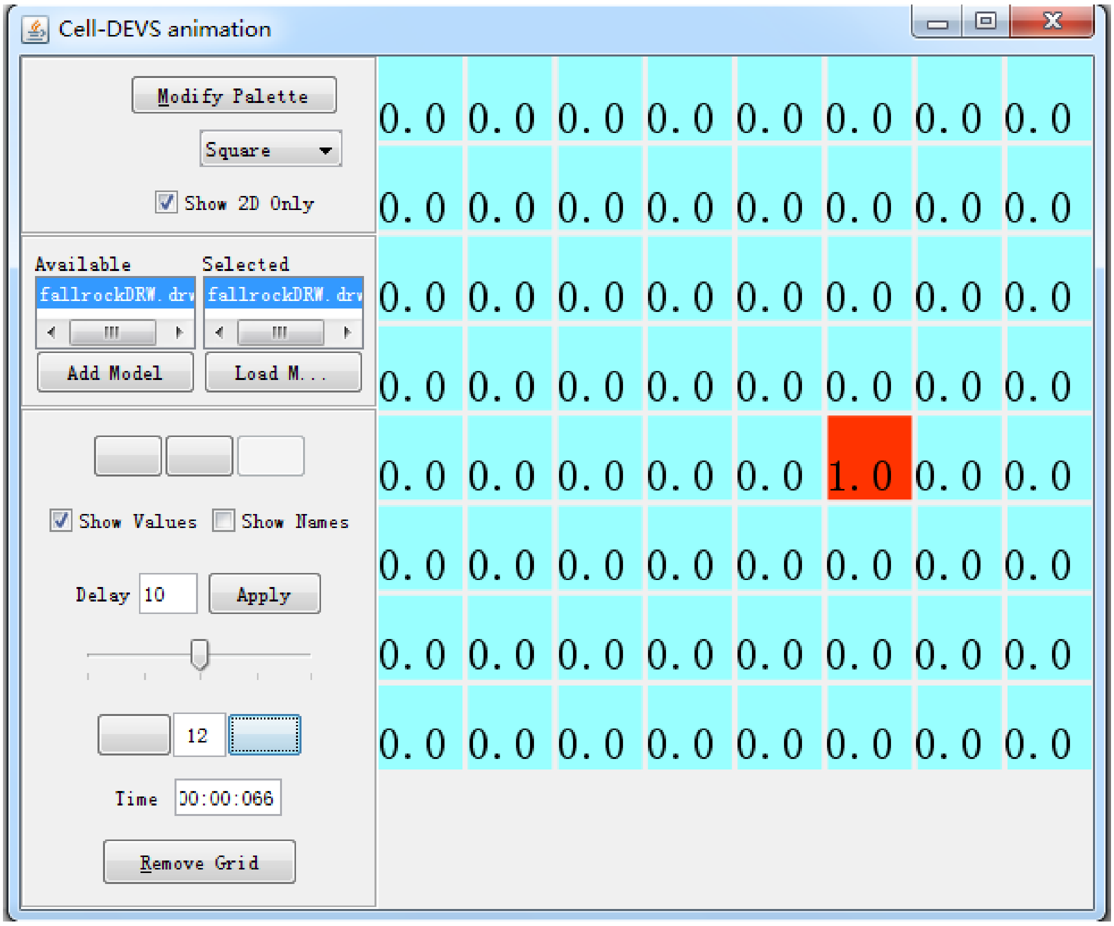

Figure 3

The figure 4 shows that the horizontal stones are triggered in the last plane but we do not know which stone triggers them to fall down because the upper top stone does probably affect them rather than the first triggered stone (horizontal stone).

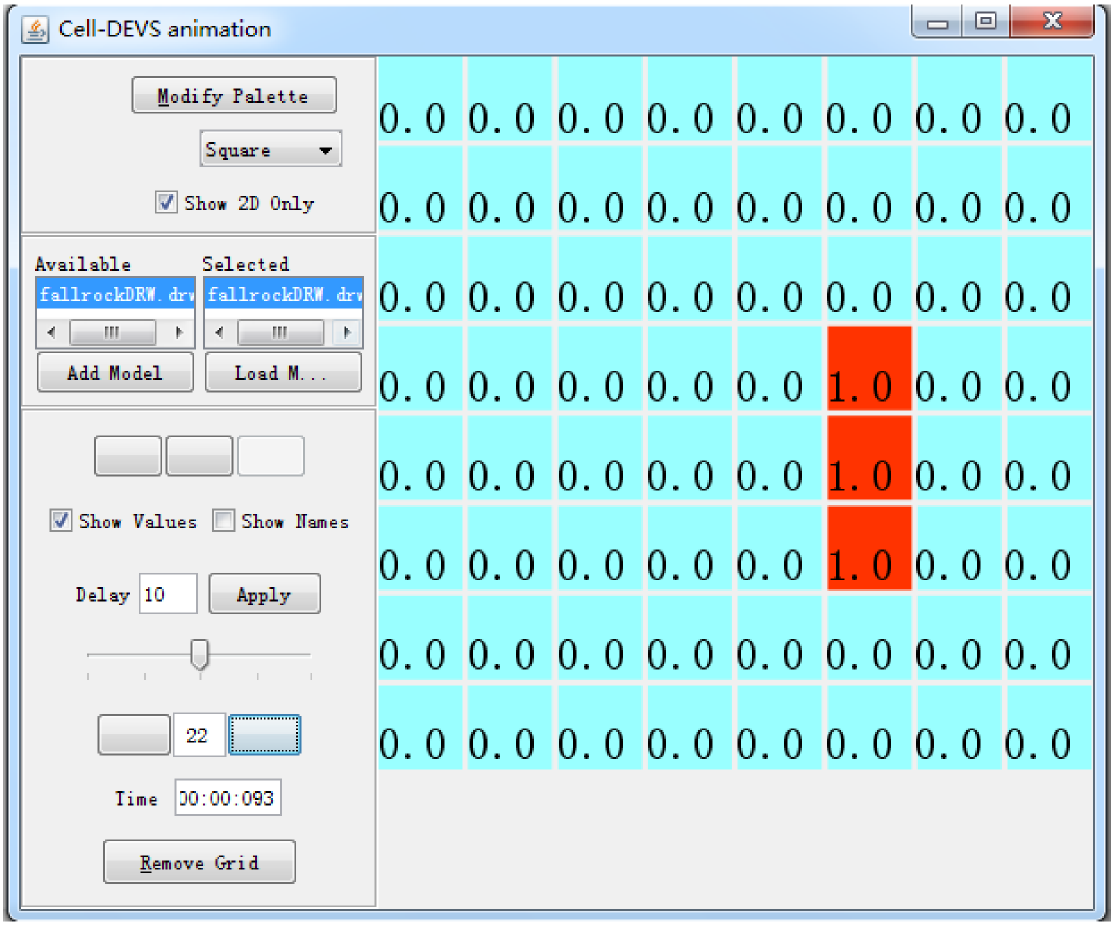

Figure 4

In figure 5, the result shows that 6 stones are triggered except for 2 remain stones (with 0.0).

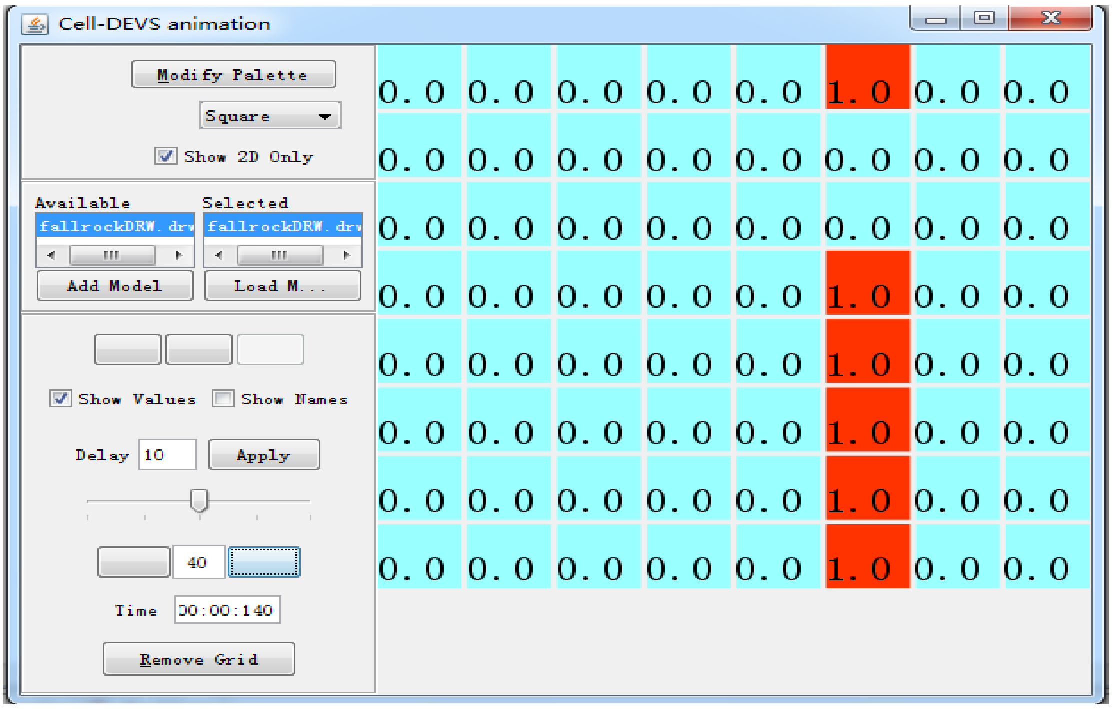

Figure 5

As we can see from the figure 6, it shows rock fall has spread 4 planes.

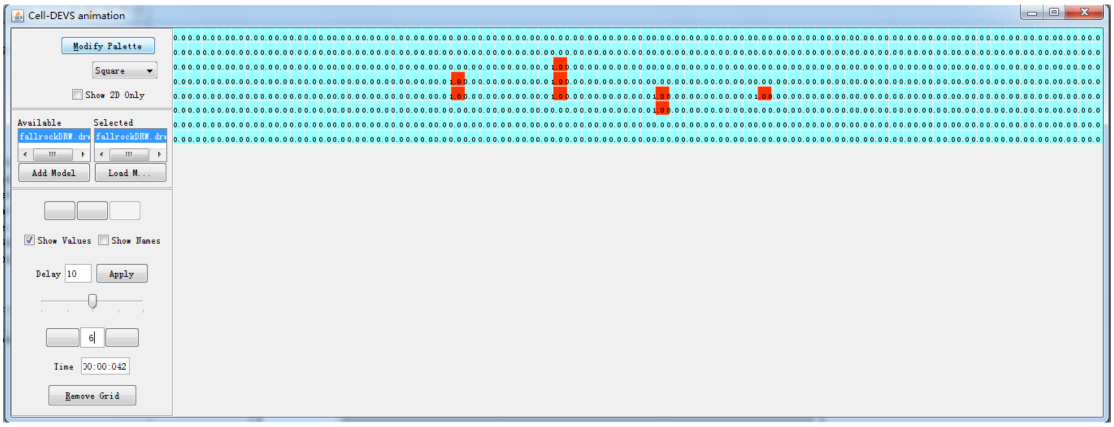

Figure 6

As the time goes on, the rock fall will trigger more stones fall down from the hill as shown in the figure 7.

Figure 7

We use figure 8 and figure 9 to explain that the stone in the black circle is not affected at first but it has fallen down at last due to the fact that stones from different directions will give it a aggregately high probabilities to move.

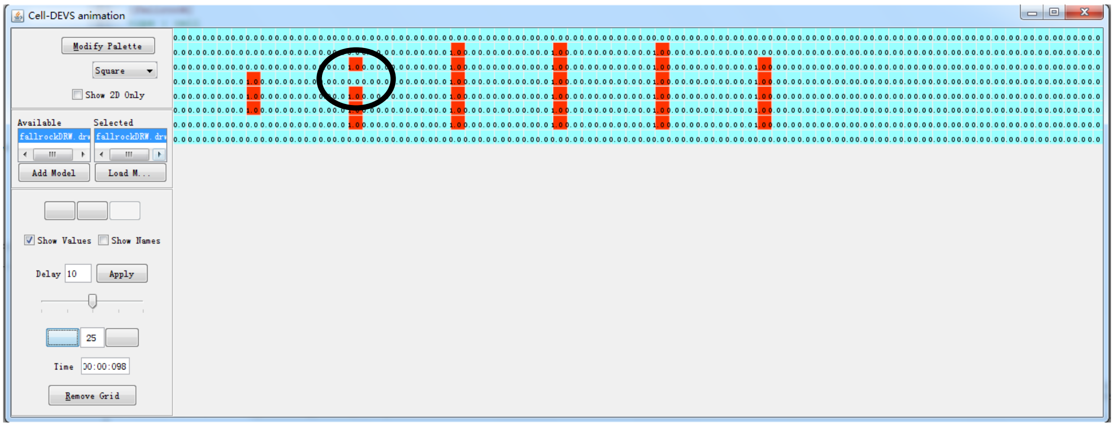

Figure 8

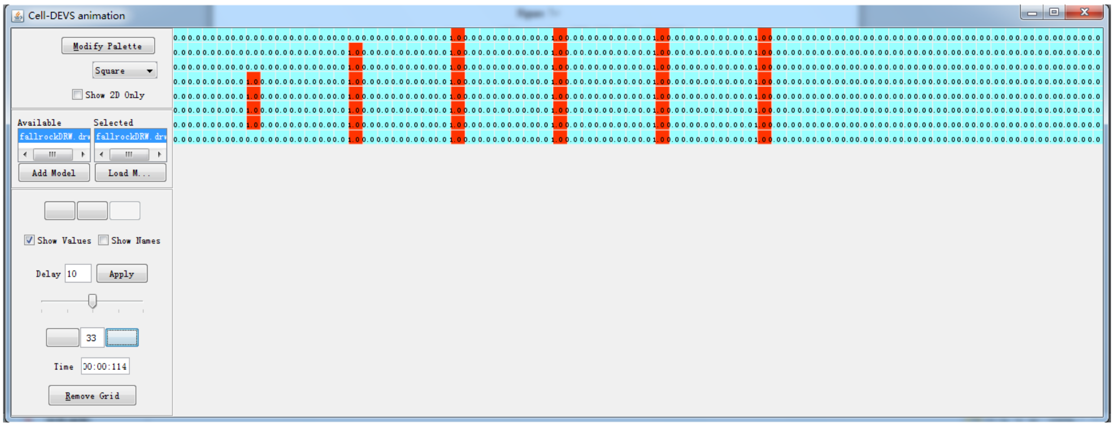

Figure 9

In figure 10, it shows the end of simulation with only 2 stones in the last plane remain immobile.

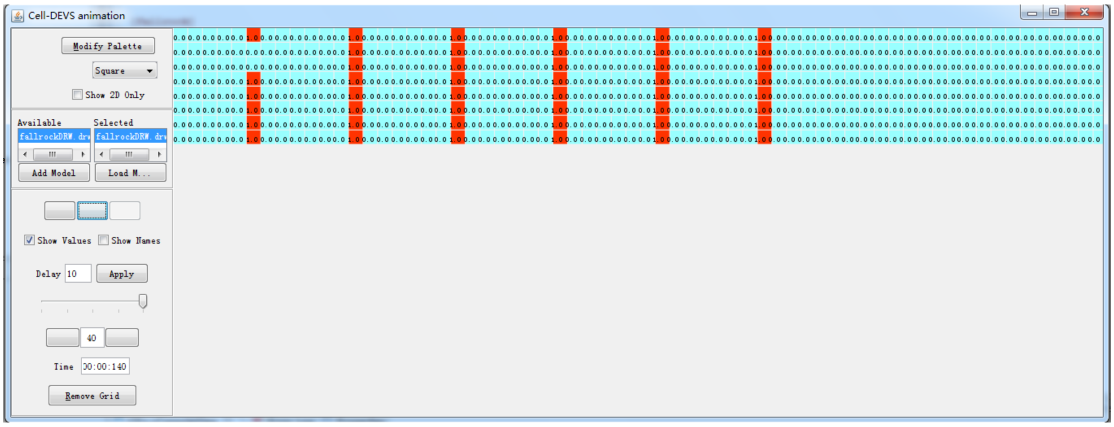

Figure 10

Bonus Mark

DEVSView tool

We use the results obtained with the Drawlog tool, and visualize them in the DEVSView tool. This application lets us visualize the results of the simulation in 3D. Compared with 2D view, it is more clear and easy to explain our results.

As can be seen from figure 10, the first stone assigned to the initial value (1) changes from red to green noted by the blue circle. And the first affected stone is the one noted by the green circle.

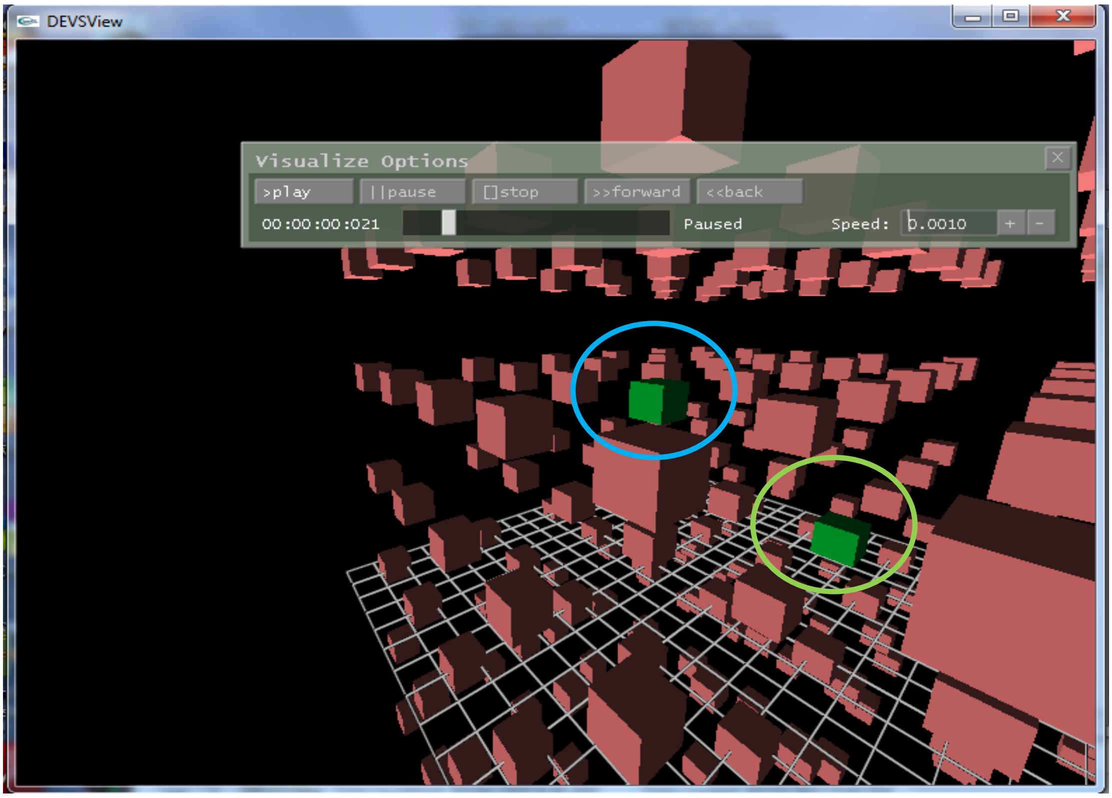

Figure 11

As time goes on, more stones are triggered by near stones. In terms of spread angle, it slants down markedly.

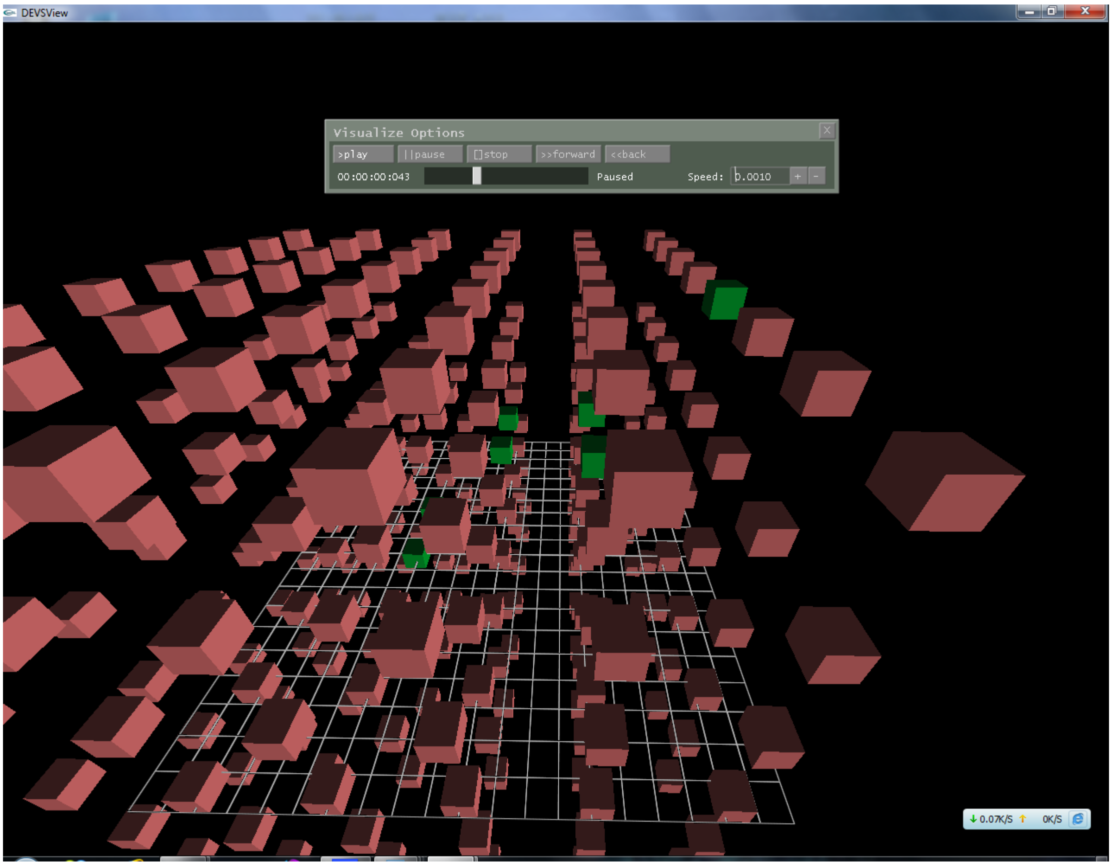

Figure 12

As for figure 12, the end of simulation, most of stones are fallen down from the hill. And the overall trend is along the mountain slope which meets our formal specification for the Cell-DEVS model well.

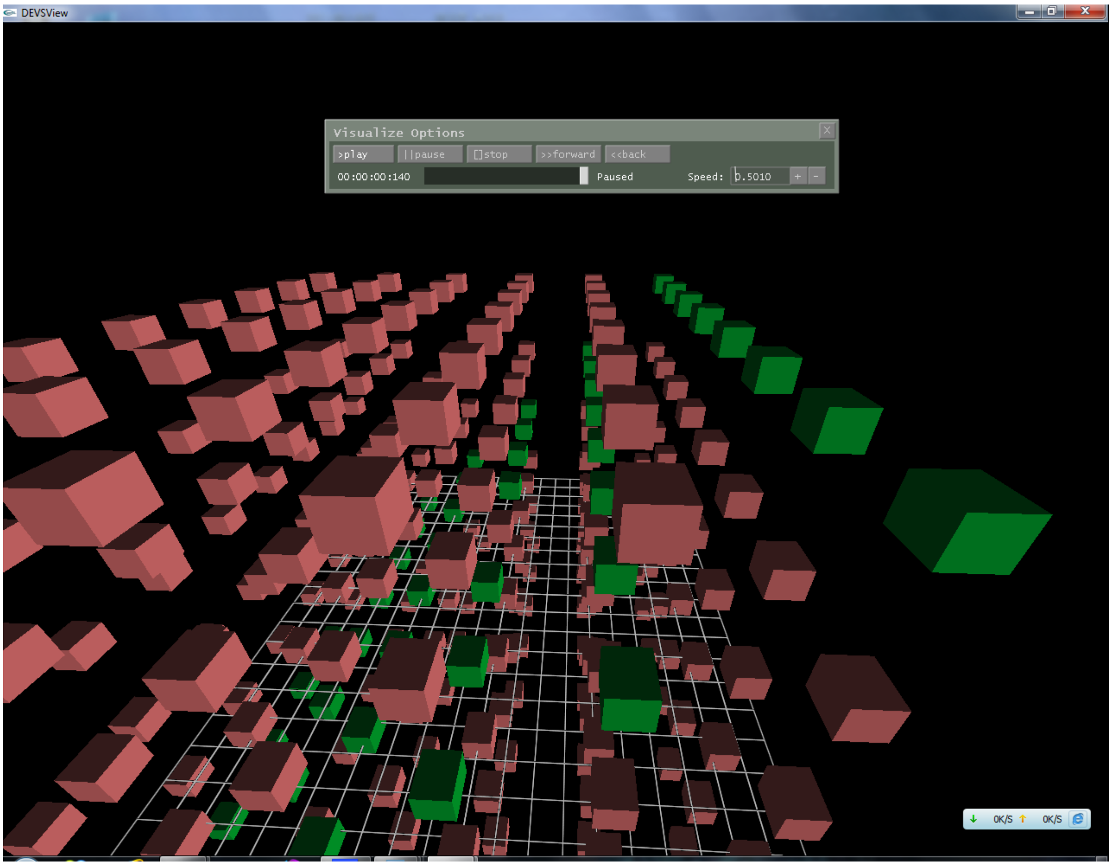

Figure 13

Reference

[1] Fausto Guzzetti, Giovanni Crosta, Riccardo Detti, Federico Agliardi. *STONE: a computer program for the three-dimensional simulation of rock-falls.* Computers & Geosciences, Volume 28, Issue 9, Pages 1079-1093, November 2002