LOGICAL MODEL OF GEOLOGICAL STRUCTURE INCLUDING SLUMP BLOCK

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ABSTRACT

In recent years, GIS is used in landslide hazard mapping. Hazard mapping using landslide data is usually handled in two dimensions, because it is difficult to be treated in three dimensions on computers. For higher precision landslide hazard mapping and a better visualization and interpretation of the results, three-dimensional modeling of the landslide hazard mapping is promising.

In this research, an attempt has been made to formulate a law for logical modeling of landslide. Based on this model, a three dimensional geological modeling for geological structures including slump block can be realized and achieved in GIS. The proposed logical model is introduced, results with examples are explained, and conclusions are drawn.

1 INTRODUCTION

At present, hazard mapping is being serviced to a wide range of natural disasters. As for the field of landslide, many researchers have investigated landslide hazard mapping. Although, landslide hazard mapping is almost treated in two dimensions, geological modeling and analyzing of landslide data in three dimensions, will give a better results with a higher precision.

The way of modeling of the geological structures on computer is proposed by Shiono *et al*.(1994,1997,1998). This modeling is data analysis law that was based on the relation between the geologic unit and the geologic boundary surface that is called logical model of the geological structure. The distribution area on the stratum is some surfaces and logical model of the geological structure is expressed as the partial space that was done in the border. The geological structure becomes able to be modeled with the computer when geologic boundary surface is given from the arrangement of this space.

To build the three-dimensional geological model that contained a landslide on computer, logic model must be created. Therefore, in this research, for logical model representing the geological structure that is formed by landslide it extended logic model with the geological structure that is proposed by Shiono *et al*.(1994,1997,1998). Logic model that was created by this creating law becomes the theoretical basics of landslide model on computer.

2 LOGICAL MODEL OF GEOLOGICAL STRUCTURE

Logical model of geological structure proposed by Shiono *et al.*(1994,1997,1998) is a mathematical model in which geologic unit is expressed by the distribution of geologic boundary surface. By using this recursion formula, logical model can be mechanically created from event $V_k=(v_1,v_2,\cdots,v_k)(v_2,\cdots,v_k$ is c, r or c*).

Let Ω be a three-dimensional subspace. Also, let open space α be a upper part by surface S (earth surface) of Ω, and let filled space β be a lower part by surface S of Ω. Open space is an atmosphere and the area that consists of water and filled space is the area that is composed of bed and rock body. Assume β is b_1, then the relation between α and b_1 can be shown by the following type if being v_1 is the general term of event that results in the early stage condition, Being S_1 is geological space and the boundary of the open space and being geologic unit b_1 is filled space.

$\alpha = S^+$

$b_1 = S^-$

S^+: Upper part of surface S

S^-: Lower part of surface S

Assume that event$(v_1,v_2,\cdots,v_k)(v_2,\cdots,v_k$ is c, r or c*) progresses in the order from v_1. The condition immediately behind event k becomes like fig.1. But, Assume that surface A is earth surface.

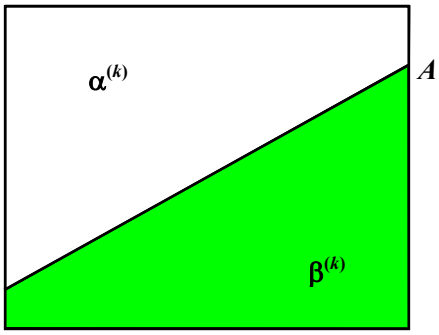

Figure 1: Geological structure of event k.

$\alpha^{(k)}$: Open space

$\beta^{(k)}$: Filled space

But, it is $\beta^{(k)} = b_1 \cup b_2 \cup, \cdots, \cup b_k$

3 LOGICAL MODEL OF GEOLOGICAL STRUCTURE INCLUDING SLUMP BLOCK

Assume event(d) be landslide. then it think that line of event is $V_{k+1}=(v_1,v_2,\cdots,v_k,$d). Landslide is the phenomenon that the block on the upper side than the slip surface moves to. Therefore, suppose that it is separates into the following three blocks by slip surface (fig. 2).

- The filled space γ (immobility region) is lower part the old earth surface and slip surface
- The open space α^* is upper part the old earth surface and Slip surface
- The block δ is upper part of slip surface and it is also lower part of old earth surface (slump block).

Suppose slip surface is *D*, then immobility region γ and Open space α^* are as follows.

$$\gamma = \beta^{(k)} \cap D^-$$
$$\alpha^* = \alpha^{(k)} \cup D^+$$

Slump Block δ gets on γ. Therefore, δ is the area of $\beta'^{(k)}$ (The one that the surface of $\beta^{(k)}$ was changed) in the open space.
Thus

$$\delta = \alpha^* \cap \beta'^{(k)}.$$

$\alpha'^{(k)}$: The relation between open space and the surface of event k
$\beta'^{(k)}$: The relation between the geological space and the surface of event k

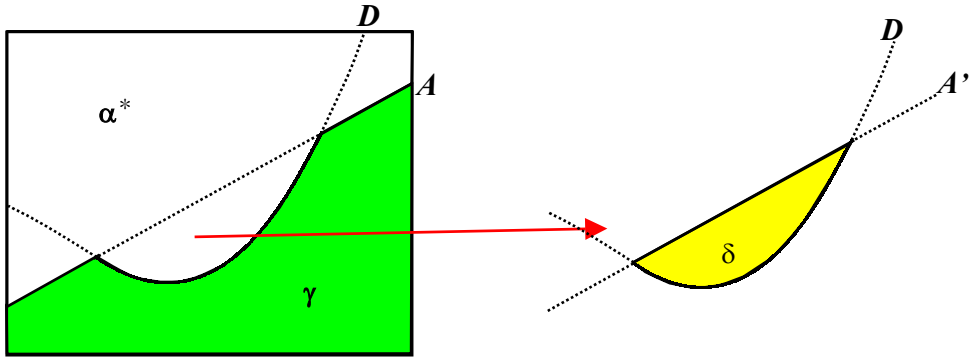

Figure 2: Three Blocks.

Open space $\alpha^{(k+1)}$ is the part which excluded slump block δ out of α^*.
Thus

$$\alpha^{(k+1)} = \alpha^* - \delta$$
$$= (\alpha^{(k)} \cap \alpha'^{(k)}) \cup (D^+ \cap \alpha'^{(k)}).$$

Filled space $\beta^{(k+1)}$ consists of immobility region γ and slump block δ, there are as follows (Fig.3).

$$\gamma = \beta^{(k)} \cap D^-$$
$$\delta = (\alpha^{(k)} \cup D^+) \cap \beta'^{(k)}$$
$$= (\alpha^{(k)} \cap \beta'^{(k)}) \cup (D^+ \cap \beta'^{(k)})$$

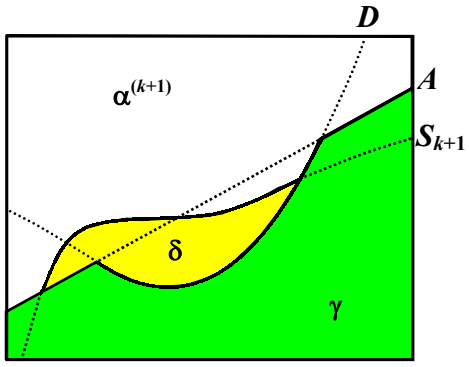

Figure 3: Landslide Model.

Let S_{k+1} be a slump block surface. If the above is summarized, the following change will occur by landslide.

- Open space set to $(\alpha^{(k)} \cap S_{k+1}{}^{+}) \cup (D^{+} \cap S_{k+1}{}^{+})$
- The geologic units of an immobility region $b_i{}^{(k+1)}$set to $b_i{}^{(k)} \cap D^{-}$
- Slump Block set to $(\alpha^{(k)} \cap S_{k+1}{}^{-}) \cup (D^{+} \cap S_{k+1}{}^{-})$

This is valid when geological structure isn't preserved in Slump Block. By landslide inside of Slump Block sometimes saves a geological structure. Let landslide of this case be an event(d *). Assume that geological structure in slump block be $\beta'^{(k)} = b_1' \cup b_2' \cup, \cdots, \cup b_k'$, then the following change will occur by landslide.

- Open space set to $(\alpha^{(k)} \cap \alpha'^{(k)}) \cup (D^{+} \cap \alpha'^{(k)})$
- The geologic units of an immobility region $b_i{}^{(k+1)}$set to $b_i{}^{(k)} \cap D^{-}$
- The geologic units of slump block set to $(\alpha^{(k)} \cap b_i'^{+}) \cup (D^{+} \cap b_i'^{+})$

4 THREE DIMENSIONAL MODEL INCLUDING SLUMP BLOCK

Here, the example of logical model of geological structure when landslide is actually caused is shown.

Assume that geological structure before landslide happens is $V_2=(v_1,c^{*})$ (Fig. 4), then logical model is as follows.

$$\alpha = S_2{}^{+}$$
$$b_1 = S_1{}^{-} \cap S_2{}^{-}$$
$$b_2 = S_1{}^{+} \cap S_2{}^{-}$$

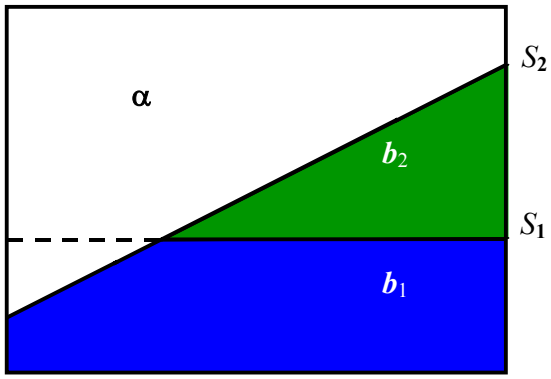

Figure 4 :The example of the geological structure at the time of V_2=(v_1,c*).

Suppose that landslide happened in this condition $V_3=(v_1, c^*, d)$, then logical model is as follows(Fig. 5).

$$\alpha = (S_2^{+} \cap S_2'^{+}) \cup (D^{+} \cap S_2'^{+})$$
$$b_1 = S_1^{-} \cap S_2^{-} \cap D^{-}$$
$$b_2 = S_1^{+} \cap S_2^{-} \cap D^{-}$$
$$b_1' = (D^{+} \cap S_1'^{-} \cap S_2'^{-}) \cup (S_2^{+} \cap S_1'^{-} \cap S_2'^{-})$$
$$b_2' = (D^{+} \cap S_1'^{+} \cap S_2'^{-}) \cup (S_2^{+} \cap S_1'^{+} \cap S_2'^{-})$$

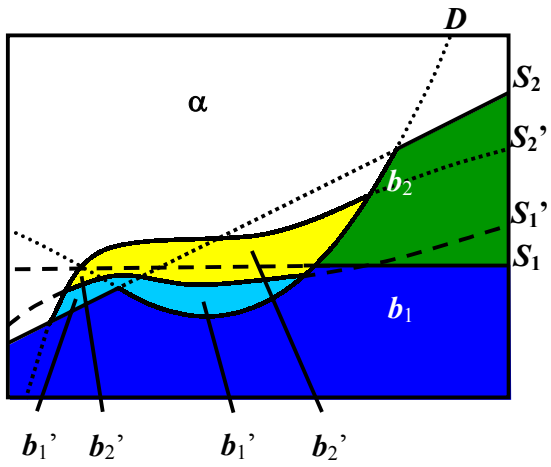

Figure 5 :The example of the geological structure at the time of V_3=(v_1,c*,d).

To display the geological structure that contains landslide, boundary surface, landform surface and slip surface must be estimated. By using these boundary surfaces and logical model, the three-dimensional geological model that contains landslide can be built.

Fig. 5 shows the proposed logical model urban which a three dimensional geological model was built (fig. 6) using Nviz visualization tool implemented in GRASS GIS based on a work done by Masumoto *et al*.(2000).

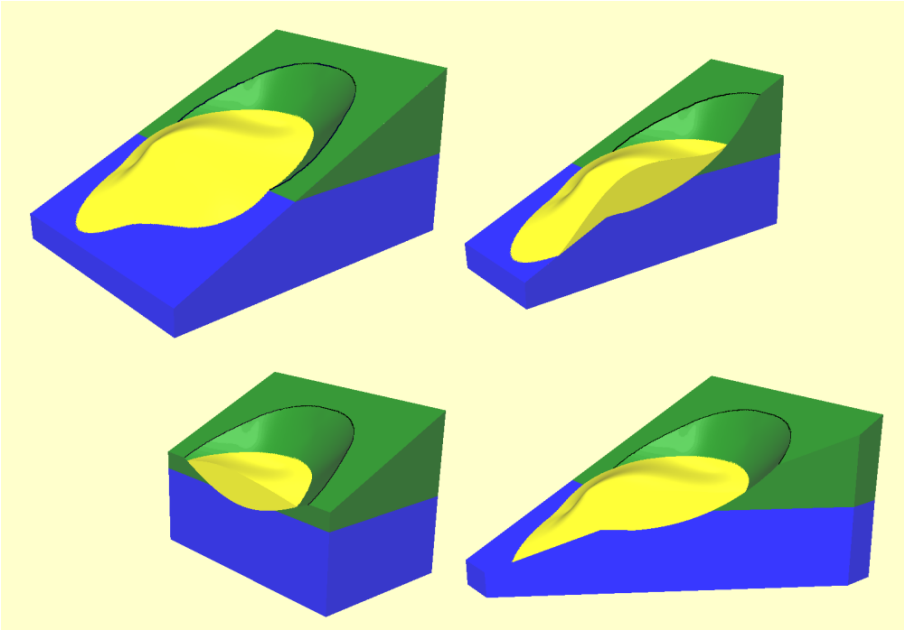

Figure 6 : Three Dimensional Geological Model

5 CONCLUSIONS

In this research, we proposed the recursion formula that builds logical model to have supported landslide. Also we built the three-dimensional geological model of geological structure that contains landslide in GIS in using logical model that created recursion formula by using it. This three-dimensional geological model is the multivariate analysis to have considered landform and geological and the basic model that can use for the stable analysis. Therefore, it thinks that logical model that is created by recursion formula that was created by this research accomplishes the theoretical basics to handle landslide in the three dimensions on the computer.

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