Multiple Sensor Data Fusion-based Context Inference for Predicting Cause of Landslide Protection Wall Deformation

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Abstract. To prevent safety accidents of the landslide protection wall, it is necessary to devise measures for detecting the deformation of the landslide protection wall and for inferring the cause of the deformation. Context inference through multiple sensor data fusion can be used to analyze the influential factors of the problem among safety-threatening factors during generation of anomalous events in the landslide protection wall. This study presents the method for inferring decisive factors through multiple sensor data fusion based on the Dempster-Shafer evidence theory in an environment in which the deformation of the landslide protection wall is affected by earth pressure, water pressure and surcharge effect.

Keyword: Dempster-Shafer Evidence Theory, Multiple sensor data fusion, Context inference

1. Introduction

Context inference through multiple sensor data fusion is being used in various fields. To measure the deformation of the landslide protection wall, the degree of risk is analyzed through sensors. It is necessary to apply the multiple sensor data fusion-based context inference method in landslide protection wall construction. This study proposes the context inference method based on the Dempster-Shafer evidence theory that can be used to prevent accidents generated in landslide protection wall construction.

2. Related studies

2.1 Multiple-sensor Data Fusion and Context Inference Using Dempster-Shafer Theory(DST).

DST is a theory to calculate the basic probability assignment (BPA), when the independent BPA has been defined. Each sensor, S_i will contribute its observation by

assigning its beliefs over Θ. This assignment is called the "basic probability assignment" of the sensor S_i, denoted by m_i.

For each possible proposition, Dempster-Shafer theory gives a rule of combining sensor S_i's observation m_i and sensor S_j's observation m_j:

$$(m_i \oplus m_j)(A) = \frac{\sum_{E_k \cap E_{k'} = A} m_i(E_k) m_j(E_{k'})}{1 - \sum_{E_k \cap E_{k'} = \phi} m_i(E_k) m_j(E_{k'})} .$$

With the use of DST, the belief and uncertainty interval of each focal element that consists of an entire set mathematically can be computed. By comparing the belief and uncertainty of each estimation, it is possible to infer context or factors making up context.

2.2 Deformation factors of landslide protection wall

The external forces that influence timber sheeting in ground excavation may include earth pressure according to the backfill load, pressure according to groundwater and surcharge of surrounding ground. Other deformation factors of the landslide protection wall include the weight of heavy equipment placed on back suspension and the hydrodynamic pressure during earthquake that influences the rear side of the wall. This study selects the following 3 factors as the subjects for multiple sensor data fusion.

1) Lateral Earth Pressure
2) Earth Pressure At-Rest for Partially Submerged Soil
3) Backfill-Partially Submerged Cohesionless Soil Supporting a Surcharge

3. Multiple sensor data fusion-based context inference for predicting the cause of landslide protection wall deformation

The landslide protection wall is used to acquire construction capacity and create a safe construction environment. Thus, it is crucial to construct a system in which various sensors can be installed on the landslide protection wall structure, rear ground and surrounding structures to infer safety-threatening causes for deformation and to implement immediate countermeasures. To achieve this, this study applies the DST to achieve fusion of data measured by multiple sensors and to find the decisive cause of landslide protection wall deformation.

3.1 Inference of risk factors

  Three types of sensors were used to detect changes in Lateral Earth Pressure, Earth Pressure At-Rest for Partially Submerged Soil and Backfill-Partially Submerged Cohesionless Soil. Event situational reports from these sensors were estimated and adopted as h_1, h_2, h_3 to detect changes related with risk factors.

Table 3.1 Acquired *belief, plausibility*

	m	*bel*	*pl*
Ω	0.0839	1	1
$h_1 \cup h_2$	0.1469	0.7622	0.9580
$h_1 \cup h_3$	0.1119	0.6434	0.8741
h_1	0.4895	0.4895	0.8322
h_2	0.1259	0.1259	0.3566
h_3	0.0420	0.0420	0.2378

  The data recorded in Table 3.1 can be acquired by calculating the *belief* and *plausibility* of all calculated values and interest elements after normalizing the BPA function of each estimation.

  By observing the calculation results of Table 3.7, it can be verified that the estimations h_2 and h_3 have significantly lower belief and plausibility when compared with other estimations. This presents that it is difficult for these two estimations to be established independently. Estimation h_1 presented a relatively wide uncertainty interval (*pl-bel* = 0.34). On the other hand, it can be known that the uncertainty interval (*pl-bel* = 0.23) calculated from the combination of estimations h_1 and h_3 is narrower than the interval presented in the independent occurrence of estimation h_1. As h_1 and h_2 present a narrower uncertainty interval (*pl-bel* = 0.19) than h_1 and h_3, it can be concluded that the estimation achieved by the combination of h_1 and h_2 becomes the cause of the danger situation.

  Thus, the causes for the deformation of landslide protection wall can be deducted as Lateral Earth Pressure and Earth Pressure At-Rest for Partially Submerged Soil.

4. Conclusion

  To prevent safety accidents, landslide protection wall is measured to analyze the deformation of the landslide protection wall, analyze the cause of the deformation and establish relevant measures. Thus, it is necessary to apply the multiple sensor data fusion-based context inference method in landslide protection wall construction. This study proposed the context inference method that can be used to prevent safety accidents in landslide protection wall construction. In this study, we introduced the

data fusion method based on the Dempster-Shafer evidence theory. We selected factors that influence the context and calculated the BPA function based on factor assessment to implement multiple sensor data fusion. We calculated the belief and plausibility values of the factors that were expected to affect contexts by implementing multiple sensor data fusion based on Dempster-Shafer theory. Ultimately, we compared the belief and uncertainty intervals to deduct the cause of the context.

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