International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 9 Issue 6 Series I || June 2020 || PP 53-56

Method to Substitute Threshold-value Criterion of Monitoring and Early Warning in Geotechnical Applications

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Abstract
Geohazards, like landslides in soils and rocks, which are induced by rainfall, flooding, earthquakes and human activity, are dramatically increasing worldwide. Apart from socio-economic factors, like increasing population and concentrations of settlements on endangered areas, extreme weather conditions are the main reasons for this ascent.
Hence, an effective monitoring and early warning system and an appropriate safety evaluation method are needed in the management of geohazards.
Up today, criteria for alarms in geo-management focus on threshold-valueevaluation of a certain parameters.This method is unreliable as it does not allow precise evaluation of the safety status.
In this paper, an innovative method is described that allows precise evaluation of the safety status and the prediction of safety changes in time. Hence, an early warning system can be created in conjunction with a real-time monitoring device.

Date of Submission: 21-05-2020 Date of Acceptance: 08-06-2020

I. INTRODUCTION

Monitoring systems are used in the management of large constructions and to control geo-hazardous events such as landslides. Different types of monitoring systems can be applied. One modern real-time monitoring system has been introduced by the author (1) that is based on self-organized wireless sensor network (WSN). The system consists of sensor nodes and a gateway for data transfer (Figure 1). Each node allows the integration of many different sensors including their data processing. The system enables data transfer from the nodes to the spatial data infrastructure (SDI) bidirectionally. Hence, commands or software modifications can be transferred individually to a node or to a group of nodes. The open structure of the system enablesflexible adjustment to the changes in conditions and also permit a simple real-time linkage with other data sources (e.g. climate data) or other sensor networks.

Apart from the detection of direct deformations caused for example by landslide movements, the systems shall also allow the monitoring of indirect deformations on buildings and constructions, like bridge, dams, retaining walls etc.

With this system that allows the real-time monitoring of different parameters it is possible to improve the data quality by sensor and data fusion, to evaluate the safety status by FEM simulation and due to integration of smart software to predict its changes in near future.

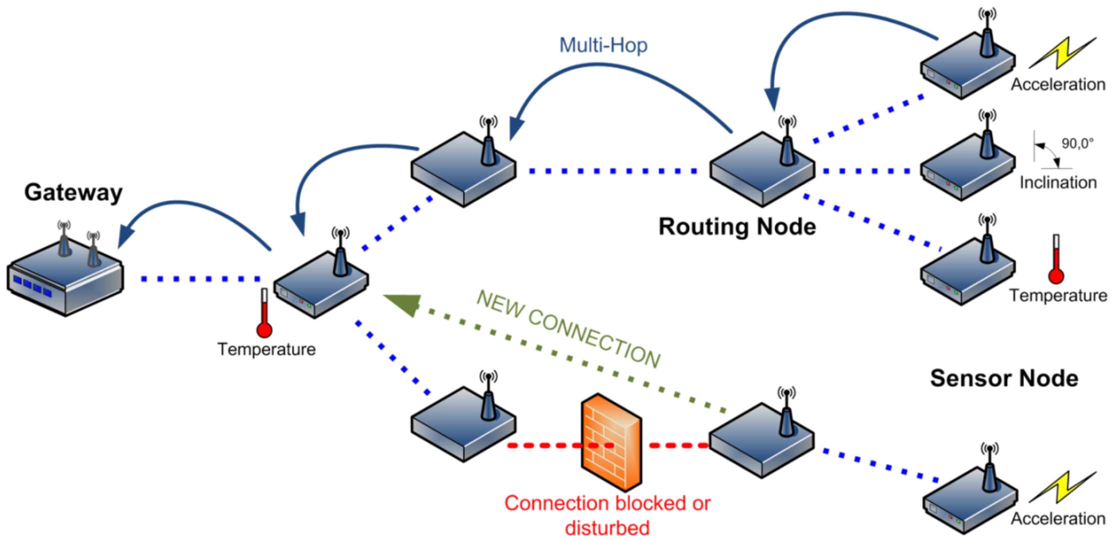

Figure 1:Spatial real-timesensornetworkmonitoring-*structure*

Proposed Method

Current monitoring systems focus on threshold-valueevaluation of a certain parameter.
But what does it mean if we measure a certain deformation?Does it mean that the slope will fail, and when it would fail?
How do we know that the measured deformation is dangerous?
If we give always false alarms, would the people trust us after a while?
Do we have other options to deal with this problem?
Now-a-days with the development of digital sensors, the MEMS and the associated hardware as well as smart software it is possible to develop sophisticated early warning systems based on self-organized sensor networks (1) in combination with sensor and data fusion to increase the reliability of such systems (2 and 4) as stated before. The data can be processed in real time to take a decision with regard to the safety status(3). In the following Figures (figure 2 and 3) two examples are given for the evaluation of the safety status of slopes considering different failure mechanisms.

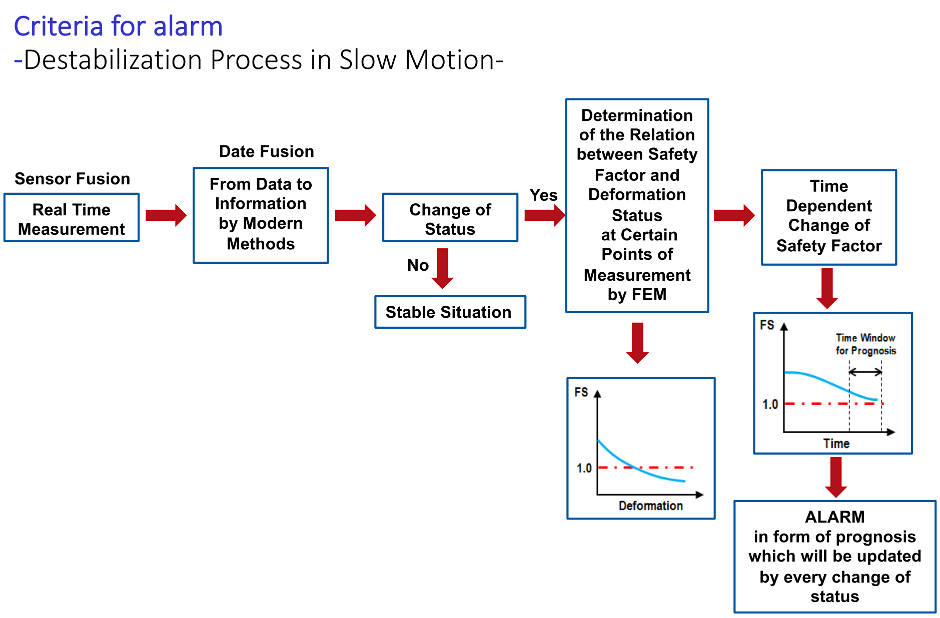

Figure 2: Flow chart of the process for the evaluation of the safety status of landslides in slow-motion destabilization mechanism.

To enhance the quality and reliability of data, sensor and data fusion can be applied as part of the data processing. The real-time data can be then evaluated with regard to changes as a criterion for further processing. A traditional numerical computer program for the calculation of the safety factor of the slope is integrated in the evaluation software. Also, a FEM-simulation by parameter reduction to establish the relationship between the deformation status of the measuring points and the safety factor of the slope is integrated. For every measuring point the relationship is then established. The safety factor is then depicted as time-dependent graph. By using time-series analysis the curve progression is analyzed every time new measurement is performed and the prediction is corrected. Once the predicted progression for the safety factor approaches in a certain time window e. g. in the next 12-24 hours the value 1, alarm can be issued.

The second example shows the method for another failure mechanism. If the destabilization occurs by rainfalls the failure mechanism is different and thus a different approach is needed. The Data fusion and processing is the same as in the first example. Only an additional sensor to measure the water content in the soil is needed. Also, for this case a traditional numerical computer program for the calculation of the safety factor of the slope is integrated in the evaluation software. A FEM-simulation should establish the relationship between water content, deformation and safety factor. The calculation of the safety factor can then be depicted as time-dependent graph.

By using time-series analysis the curve progression is analyzed every time new measurement is performed and the prediction is corrected. Once the predicted progression for the safety factor approaches in a certain time window e. g. in the next 12-24 hours the value 1, alarm can be issued.

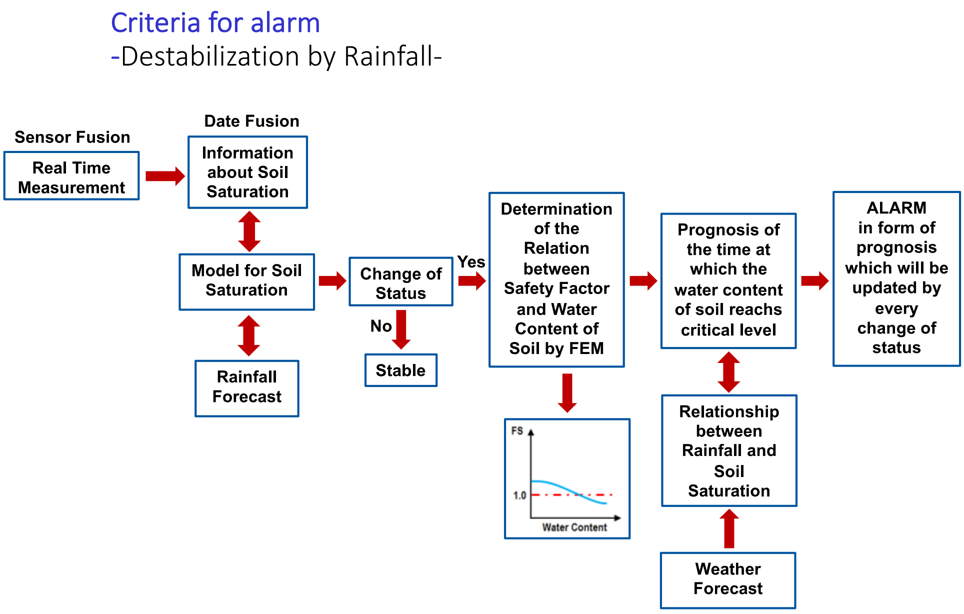

Figure 3: Flow chart of the process for the evaluation of the safety status of landslides in destabilization mechanism by rainfall.

The combination of self-organized sensor networks, sensor and data fusion, data infrastructure and processing in real time, numerical simulation and expert knowledge, and time series analyses allows us to develop an early warning system for landslides, but also for engineering constructions such as bridges etc. at high reliability.

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Prof. Dr. Dr. h. c. Rafig Azzam, et. al. "Method to Substitute Threshold-value Criterion of Monitoring and Early Warning in Geotechnical Applications."*International Journal of Engineering Science Invention (IJESI)*, Vol. 09(06), 2020, PP 53-56.