Utilization and analysis of digital mining dump models

A case study from German lignite mining

Natalie Merkel [1], André John [2]

Abstract: This extended abstract describes the main features of the planned activities to support decision-makers in the transformation process of converting mining areas into attractive post-mining landscapes.

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1 Introduction

The decision to phase out fossil energy production in Europe will ensure that most of the coal mines in Europe will go into the closure phase over the next two decades. This means that large areas that have previously been used for coal mining will have to be renewed and restored in the future, to successfully master the structural transformation from industrial to attractive post-mining landscapes in the European coal regions. The multi-partner research project 'Trim4Post-Mining' funded by EU Research Fund for Coal and Steel (RCFS / funding code 899278) addresses the challenges and possibilities associated with the coal phase-out. In one of the work packages in the project, data-driven spatio-temporal analysis and prediction methods for inside-dump deformations and geochemical processes in lignite or hard coal waste dumps will be developed to support decision making and planning during the transition from coal exploitation to a re-vitalized post-mining land. The following research work can be classified in this context.

2 Research Objectives

The current research regarding the decommissioning and renaturation of mining areas is focused on the analysis and utilization of digital mining waste dump models. The main objective is thereby to characterize the dynamical processes in overburden dumps related to timely dependent deformations and geochemical processes because of the inhomogeneous material composition in the dump. This can be used, for example, to

[1] TU Bergakademie Freiberg, Institute of Mine Surveying and Geodesy, Fuchsmuehlenweg 9 B, 09599 Freiberg, natalie.merkel1@mabb.tu-freiberg.de
[2] TU Bergakademie Freiberg, Institute of Mine Surveying and Geodesy, Fuchsmuehlenweg 9 B, 09599 Freiberg, andre.john@mabb.tu-freiberg.de, https://orcid.org/0000-0003-0187-5071

identify potential contamination areas or to plan new usage concepts for former mining areas in terms of residual risks, technical feasibility and environmental impact.

To estimate the potential post-use or development possibilities of a dump site a geotechnical hazard assessment is necessary. Settlement, slumping and liquefaction are considered as possible deformation scenarios in the following work. The first two damage mechanisms differ essentially in their cause. Whereas slumping can always occur as a result of a change in groundwater level, settlement occurs as a result of an external stress input or just due to the material's weight. Both damage scenarios are characterized in its occurrence as a vertical displacement, i.e. uplift or subsidence, at the surface. The third damage mechanism, liquefaction, is a complex process in which the soil spontaneously or also due to an initial event takes on characteristics of a liquid and results in large vertical and horizontal displacements.

3 Data and Methods

The central German lignite mining area is one of the example regions within the Trim4Post-Mining project and also provides the data basis for the current research. The primary data basis is an already available, operational digital dump model based on a long-term monitoring. This theoretical voxel model of the dump defined by the bounding box consists of approximately 740.5 million voxel cells (n_x=2057, n_y=2011, n_z=179) with a size of 1 m^3 (1m *x* 1m *x* 1m) each. However, not all cells actually contain information. A total of approximately 72.5 million voxels of the model contain information relating to the following attributes:

- Geometry (x, y, z - coordinates)
- Date and time of interstratification into the dump
- Allocation of the voxel volume to the 28 defined material classes (geological layers) of the model by specifying the percentage of the volume.

That means the present dump model of the Central German lignite company (Mibrag mbH) gives a statement about the locality and the percentage of the different materials in the dump, but not about their properties. In order to be able to make a soil mechanical estimation, further parameters are needed. A statement about the exact grain distribution of the materials as well as their coefficient of uniformity and grain shape can be determined in the laboratory. For other parameters such as compactness, water content and degree of saturation, field tests are required. With the help of these parameters, the materials can be then divided into hazard classes that represent the probability with which settlement, slumping or liquefaction can occur due to the position of the materials in the dump. For this purpose, methods from the area of machine learning, specifically, methods of cluster analysis, i.e. unsupervised learning, are to be used. Clustering is the task of grouping a set of objects in such a way, that objects in the same group are more similar to each other than to those in other groups. Whereby the groups are also referred to as clusters. Basically, clustering can be formulated as a multi-objective optimization problem. The selection of a specific algorithm and the associated parameters, such as the used distance function or the number of expected clusters, depend always on the individual data set and the intended objectives of the clustering. There is no single best clustering algorithm for all use cases, hence it is an iterative process to find an appropriate algorithm and its parameter. Due to the size of the model to be processed, the efficiency of an algorithm is a decisive selection criterion. The aim of the current work is to develop a cluster model that can independently create a hazard analysis for the damage scenarios mentioned on the basis of a dump model extended by geotechnical soil parameters. The representation of the clusters or respectively hazard classes could then be done for the respective damage scenario for example with the help of a geographic information system (GIS). A kind of traffic light map would be conceivable, in which the endangered areas are recognizable in the three-dimensional space and thus also clarify conclusions about their damage effect on the surface. And in a further development, an extension to design recommendations for structures subdivided according to different types of use would be conceivable.

Figure 1 shows a visualization of the described dump model. Exemplary the clustering of material groups in the dump model based only on the geometry, the date of the interstratification and the percentage material composition in each voxel, is presented. As a common pre-processing step all attributes were standardized to a value range of [0,1]. The number of clusters was defined using elbow method and silhouette analysis. The k-means algorithm was only used as an example to visualize the initial dump model. The choice of the cluster algorithm to achieve the objectives described will be part of the further work.

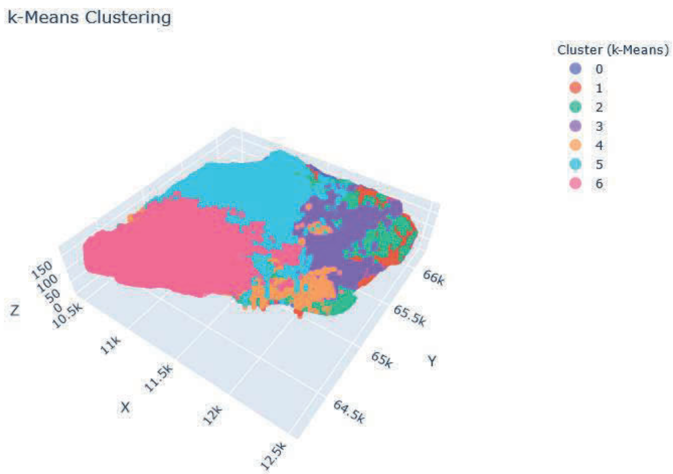

Figure 1: Example cluster result created by k-means clustering