Using MATLAB for modeling of thermal processes in a mining dump

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Abstract: - Improvement of environmental quality in industrial areas is very important. The long-term measurement and monitoring variables of worsening environment is often desired. The work deals with the modeling of thermal processes occurring in the mining dumps and industrial waste dumps. This is an example how to use MATLAB for modeling of thermal processes.

Key-Words: - Thermal process, mining dump, Matlab, modeling, interpolation, measurement

1 Introduction
In the Ostrava region there are places that arose as a result of mining industry in the local region. In this article we will focus on mining dumps incurred by the systematic gathering of tailings from the Ostrava mines. We chose mining dump Hedvika, which is located between Ostrava and Petrvald. Hedvika was founded around 1910 and registered in the end of the 50th years, and since this time mining dump has been burning and some effort has been done in putting the fire out. Nowadays, Hedvika is still thermally active. Infrared photo of the studied area is shown in Fig. 1. Temperatures inside the mining dump can be generally very high and so regular monitoring of the mining dump is necessary.

In our project we concentrate on temperature measuring in some places in the mining dump and then modeling the distribution of heat in the mining dump. Measuring points are shown in Fig.2. The thermocouples of type K or PT 100 sensors are used. The sensors are located at a depth of 3m and 6m. There are 17 measuring points. Measurements were carried out once a month. Our goal was to obtain the temperature distribution throughout the mining dump Hedvika area. We used the Matlab interpolation functions.

2 Interpolation
The fundamental interpolation methods are presented in [1], [2], [7]. Interpolation is a method of constructing new data points within the range of a discrete set of known data points. It is important for applications such as signal processing, image processing and data visualization.

The measured data can be fitted by a broken line or a smoother curve. Interpolation is a specific case of curve fitting, in which the function must go exactly through the data points. Approximation function does not go exactly through the data points. Extrapolation is the process of constructing new data points outside a discrete set of known data points. It is similar to the process of interpolation, which constructs new points between known points, but the results of extrapolations are often less meaningful, and are subject to greater uncertainty.

In general, we use interpolation for many reasons. Plot line makes the data better legible, especially if we measure very variable quantity. Interpolation or extrapolation, but it may be our main goal and...
fitting curve represents our pattern of behavior of the measured variables. Sometimes we use a procedure that requires a regular step \( x \) in the value of \( y \). Equidistant data are obtained by interpolation. Gridding is expression for interpolation of measured data obtained in an irregular network into a regular rectangular grid.

![Fig.2 Measuring points](image)

### 3 Interpolation methods in MATLAB

Data interpolation is an application area based on underlying geometric algorithms. Data may be uniform, that is, sampling occurs over uniform intervals. Data may also be scattered, that is, sampling occurs over irregular intervals.

For uniform data Matlab applies functions interp1, interp2, interp3 in [5]. These functions use polynomial techniques, fitting the supplied data with polynomial functions between data points and evaluating the appropriate function at the desired interpolation points. When the sample data is scattered, the interpolation techniques use a triangulation-based approach as a basis for computing interpolated values. Matlab function griddata in [5] use the Delaunay triangulation for interpolation.

#### 3.1 One – dimensional data

The function interp1 performs one-dimensional interpolation. The basic syntax is

\[ YI = \text{interp1} \ (X, Y, XI, \text{method}) \]

\( Y \) is a vector containing the values of a function, and \( X \) is a vector of the same length containing the points for which the values in \( Y \) are given. \( XI \) is a vector containing the points at which to interpolate. Method is an optional string specifying an interpolation method:

- 'Nearest' - nearest neighbor
- 'linear' - linear interpolation
- 'spline' - cubic spline interpolation
- 'pchip' - piecewise cubic Hermite interpolation
- 'cubic' - the same method as 'pchip'

#### 3.2 Two – dimensional data

The function interp2 performs two-dimensional interpolation. The basic syntax is

\[ ZI = \text{interp2}(X, Y, Z, XI, YI, \text{method}) \]

Specification of interpolation method:

- 'Nearest' - nearest neighbor
- 'linear' - bilinear interpolation
- 'spline' – cubic spline interpolation
- 'cubic' – bicubic interpolation

The simplest and least accurate interpolation is again the nearest neighbor method, a piecewise constant surface. Another method is bilinear interpolation. Even this method does not meet the more complex areas of good results. The main advantage of cubic spline interpolation is that it produces the smoothest results of all the interpolation methods.

#### 3.3 Interpolation methods using Delaunay triangulation

\[ ZI=\text{griddata}(X,Y,Z,XI,YI,\text{method}) \]

fits a surface of the form \( Z = f(X,Y) \) to the data in the usually no uniformly spaced vectors \((X,Y,Z)\). griddata interpolates this surface at the points specified by \((XI,YI)\) to produce \( ZI \). The surface always passes through the data points. \( XI \) and \( YI \) usually form a uniform grid. Specification of interpolation method:

- 'linear' – Triangle – based linear interpolation (default)
- 'cubic' – Triangle – based cubic interpolation
- 'Nearest' - nearest neighbor interpolation
- 'v4' - MATLAB 4 griddata method

All the methods except 'v4' are based on a Delaunay triangulation(DT) of the data.

#### 3.3.1 Delaunay triangulation

Delaunay triangulation \( DT \) defined on the set of points \( V \in \mathbb{R}^2 \) is the set of triangles such that

- point \( p \in \mathbb{R}^2 \) is the top of the triangle in \( DT \) (V), \( p \in V \)
• the intersection of two triangles in DT (V) is either empty or is it a common edge, or joint top
• the circumcircles of all triangles have empty interiors.

Properties of Delaunay triangulation
• DT is optimal given the max-min angular criterion.
• DT is clear, if no four points lie on a circle.
• Boundary DT (V) is convex hull CH (V).
• The interior triangles DT (V) contains no points p∈V.
• Minor changes in the network point lead only to local changes in the triangle mesh around a point, in adverse event may trigger this change avalanche change across the network.
• DT is a planar graph dual to Voronoi chart.

Fig. 3A Delaunay triangulation with circles and their centers (red) [6]

Fig. 3B Delaunay triangulation and Voronoi diagram [6]

Fig. 4 The temperature distribution on the mining dump Hedvika a) March 2010 b) July 2010 C) December 2010 d) February 2011 at a depth of 3m

Many algorithms for the construction of Delaunay triangulation on the set of points have been developed [6]:
• Flipping
• Divide and conquer
• Incremental construction
• Sweepline
Sweephull
Matlab offers use of Delaunay triangulation related to Voronoi diagram, see Fig. 3. Delaunay triangulation is a set of lines connecting each point with its nearest neighbor. Delaunay circle has its center at the top of the Voronoi polygon.

4 Results
Matlab 7.10.0. was used for modeling of thermal processes in a mining dump. For measured data we applied functions griddata, surf, pcolor, contour. Results are shown in Fig. 4 and Fig. 5.

![Graph A](image)

**A)**

![Graph B](image)

**B)**

Fig. 5 Border areas with temperatures A) 180 °C, depth 3m, B) 150 °C, depth 6m

Conclusion
Matlab showed great capabilities for proved successful modeling the dynamics of temperature in the mining dump. The simulated results in Fig. 5 show that there is mining dump to burn. The highest measured temperature of the mining dump was 568°C in March 2010 and currently it is 185°C. This situation has, however, occurred earlier. It was assumed that the mining dump burns down, and then there was a spontaneous combustion. Therefore, regular monitoring is needed.

The project was set in a time when high temperatures began to threaten the adjacent buildings. Since it was not clear whether the temperature will decrease or increase, or lead to expansion or moving the burning waste rock was scheduled automated measurement of temperature on the mining dump, remote data transmission and storage in the database, calculating the rate of change of temperature, etc. The database is almost finished, now working on the remote transmission of data.

The work is certainly useful for other places where it is necessary to monitor the temperature of a particular territory.

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References