

# ESTIMATION OF UNKNOWN HEIGHT WITH ARTIFICIAL NEURAL NETWORK ON DIGITAL TERRAIN MODEL

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### ABSTRACT:

In Digital Terrain Models (DTM) interpolation is actually a surface fitting problem. For the estimation of heights of points with known X-Y coordinates there are many interpolation methods. Besides, there are various works about the determination of DTM accuracy. The aim of this study is to develop an Artificial Neural Network (ANN) method as an alternative to other common methods. The ANN model having Multi Layer Perception structure is programmed under Matlab. This ANN method and selected seven interpolation methods are tested in a test area and the result are compared. In terms of accuracy, the results show that ANN does not deliver the best results, but seems as an alternative interpolation method.

## 1. INTRODUCTION

3D visualization with its support for decision-making and flexible usage has been widely used in many branches such as industry engineering, surveying, civil engineering, architecture, and in many applications based on geographical information systems. The 3D visualization of terrain surface characteristics – slope, roughness, etc- is called Digital Surface Modeling (DSM) or Digital Terrain Modeling (DTM) in general (Yanalak 1997). A DTM is referred to as a “form of computer surface modelling which deals with the specific problems of numerically representing the surface of the earth” (Heesom and Mahdjobi 2001). DTM is created by using two methods: triangulation and gridding. Gridding is a method, in which the corners of regular rectangles or squares are calculated from the scattered control points. In triangulation, triangles are created based on the scattered control points. These triangles do not intersect each other and represent the terrain surface as a linear or nonlinear function. In both methods, the heights of grid points and triangular points with unknown heights in the model area, which is not match with control points, should be estimated by interpolation methods by using the control points (Yanalak, 2003).

There are many interpolation methods. Hardy published the multiquadric interpolation that is suitable for topography and uneven surfaces in 1971 (Hardy, 1971; Hardy, 1990; Larsson 2003). Yanalak (2003) reports the influence of gridding method – based on scattered points – to the digital terrain profile. Guler (1985) performed a study with multiquadric interpolation and least square interpolation, and gave results. Amidror (2002) classified the scattered data interpolation methods for electronic imaging systems into four categories: triangulation (or tetrahedrization), inverse distance weighted, radial bases function, natural neighbors. He also handles surface fitting with interpolated points instead of scattered points. Taskin et al (2002) implement least squares curve fitting via

High Dimensional Model Representation (HDMR) for DTM and compare this method with conventional methods such as nearest neighbors, weighted average, polynomial, minimum curvature, multiquadric and linear interpolation. Desmet (1997) discusses relevant interpolation methods for DTM, which is applicable for measured points, considering the distribution and accuracy of points. Rees (2000) reports a work about bilinear, cubic, kriging and random midpoint displacement interpolation methods. Kidner (2003), Shi (2005) and Zhu (2005) handle high-degree interpolation algorithms such as bilinear, biquadratic and bicubic. Yang et al (2004) analyses 12 different interpolation methods by using Surfer 8.0 considering applicability, the algorithm itself, accuracy, and practical usage. These methods are utilized to calculate the unknown parameters of points by using scattered point sets.

The aim of this study is to develop an Artificial Neural Network (ANN) method as an alternative to other common methods. Inverse distance to power method, local polynomial method, minimum curvature method, modified shepard's method, nearest neighbor method, polynomial regression method, radial basis function interpolation method (multiquadric), and artificial neural network (ANN) Method were tested in a test area. Each standard deviation was obtained from differences between ground truth and estimated height values. In terms of accuracy, the results show that ANN does not deliver the best results, but seems as an alternative interpolation method.

## 2. MATERIAL AND METHOD

For this study a test area located in the Selcuk University Campus is formed. It is situated out of the built-up area of campus. Its dimension is about 750x750 m<sup>2</sup> (Figure 1). Some facts about the test area are given in Table1.

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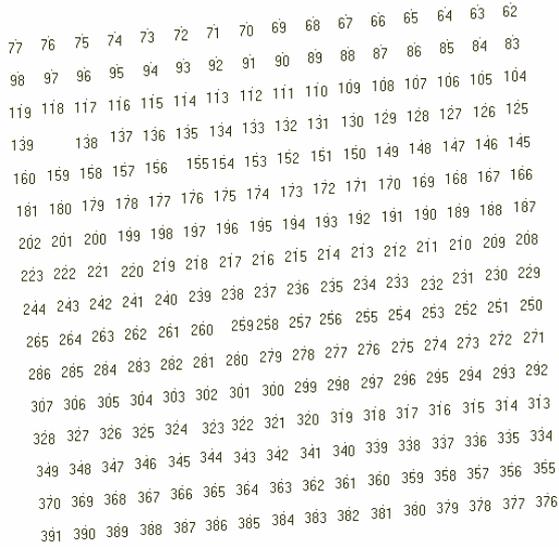


Figure.1 The point distribution in the test area

Test Area	Description	Height Range (m)
Selcuk University (Konya-TURKIYE)	Rough Terrain	1126 to 1180

Table.1 The definition and location of the test area

The test area includes 237 points with known X,Y,Z coordinates. All the point heights are measured with an electronic total station. It is modeled by a number of interpolation methods, which include inverse distance to power, local polynomial, minimum curvature, modified shepard's, nearest neighbor, polynomial regression, radial basis function (multiquadric) and artificial neural network (ANN). 81 of the 237 points are used for surface modeling. The heights of the other points are estimated with the models above. All the interpolation methods except ANN are applied in the Surfer 8.0 software package. ANN is programmed under Matlab software environment by using Multi Layer Perception (MLP) structure (Figure 2). MLP neural network is trained with a back-propagation algorithm. The dimensions of the data set, which is normalized ranging from 0 to 1, are 237x3. The dimensions of training data set are 81x3. X and Y coordinates are used as training input, where the Z coordinates is used as training output. The dimensions of test data set are 156x3. X and Y coordinates are used as test input, Z as test output. The best result is obtained in the 2x10x4x1 network structure, in which tansig transfer function is used for the first hidden layer, logsig function for the second hidden layer, and for output layer. The network is trained with 10000 iteration.

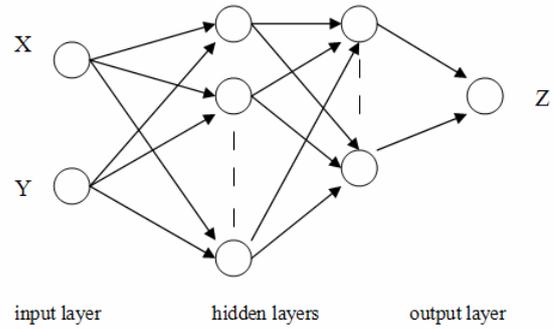


Figure.2 Developed ANN structure

### 3. RESULTS

By using inverse distance to power method, local polynomial method, minimum curvature method, modified shepard's method, nearest neighbor method, polynomial regression method, radial basis function interpolation method (multiquadric) and artificial neural network Model, different DTMs are created based on 81 points (control points). The heights of 156 points (test points) are estimated with these DTMs. Minimum, maximum and average errors (Table 2) and standard deviations (Figure 3) are calculated by using the differences between ground truth and interpolated heights. For ANN learning rate is 0.1, momentum coefficient is 0.8, and training accuracy %99.

	Errors(m)		
	Min.	Max.	Mean
<b>Inverse Distance to Power</b>	-5.40	8.15	0.34
<b>Local Polynomial</b>	-4.32	3.16	0.08
<b>Minimum Curvature</b>	-8.84	4.79	-0.07
<b>Modified Shepard's Method</b>	-3.13	1.61	-0.04
<b>Nearest Neighbor</b>	-3.81	5.87	0.18
<b>Polynomial Regression</b>	-8.71	5.97	0.21
<b>Radial Basis Function</b>	-3.44	1.59	0.05
<b>Artificial Neural Network</b>	-3.62	2.93	-0.05

Table.2 Minimum, maximum and average errors obtained with interpolation methods.

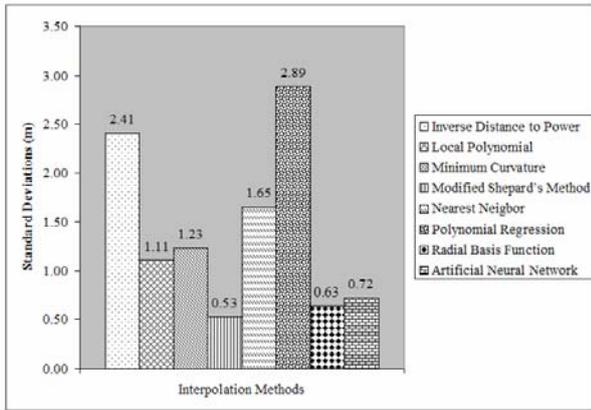


Figure.3 Standards deviations obtained with interpolation methods.

#### 4. DISCUSSION

Several interpolation methods, which has been widely accepted and used for a variety of applications, have been employed for years. In this work, our aim is to show how accurate the ANN method with respect to other conventional methods is. Considering the standard deviations modified shepard's method and radial basis function methods (multiquadric) seem to be more accurate than the others. Yanalak 2002 and Yanalak 2003 suggest that the DTM accuracies obtained by minimum curvature and multiquadric interpolation methods are better for scattered data in comparison to others. Yang et al 2004 obtained the best standard deviation with radial basis function and modified shepard's method. After this study the accuracy of ANN is not the best, but a little worse than those of radial basis function and modified shepard's method, and better than those of the other interpolation methods used here. As a result, the authors suggest the ANN method as an alternative interpolation method that can be employed for DTM applications.

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