APPLICATION OF BPANN FOR MODELLING LOCAL GPS/LEVELLING GEOID UNDULATIONS

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INTRODUCTION

The geoid surface serves as a reference for most applications that require a datum for determining topographic heights or ocean depths.

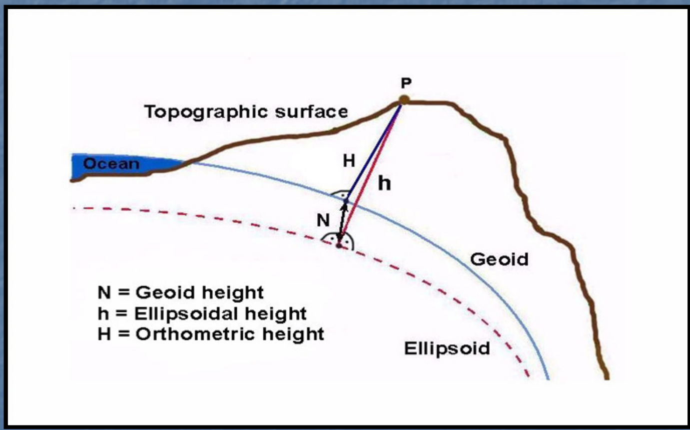
The increasing use of GPS techniques require the precise determination of local geoids, aiming at replacing the geometric levelling with GPS measurements.

INTRODUCTION

The objective of this study is to evaluate a back propagation artificial neural network (BPANN) for modelling local GPS/Levelling geoid undulations as an alternative method to the traditional interpolation methods.

The geoid undulation differences are compared over a study area, in terms of root mean square error (RMSE).

GPS/LEVELLING

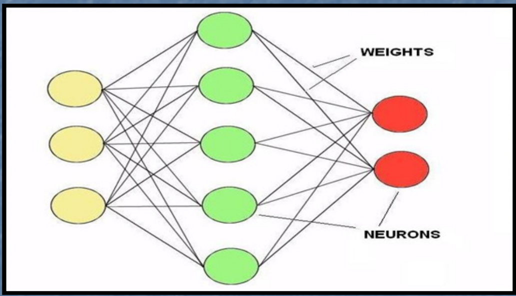


$$N = h - H$$

INTERPOLATION METHODS

- Kriging Method (KRIG)
- Inverse Distance Weighting Method (INDW)
- Modified Shepard's Method (MSHP)
- Radial Basis Function Method (RBAF)
- Local Polynomial Method (LPOL)
- Polynomial Method

ARTIFICIAL NEURAL NETWORKS



ANN is a highly simplified model of decision-making processes of a human brain and is formed by artificial neurons that are interconnected with weights.

ARTIFICIAL NEURAL NETWORKS

The sigmoid function is applied to the hidden and output layer neurons for generating the output information of ANN.

$$f(Z) = \frac{1}{1 + e^{-Z}}$$

The proposed ANN is trained using the back-propagation algorithm that has well-known ability as function approximators.

BACK PROPAGATION

BPANN has been more widely applied in engineering among all other ANN applications.

BPANN with one hidden layer using a sigmoid activation function can approximate any continuous function given a sufficient number of hidden neurons.

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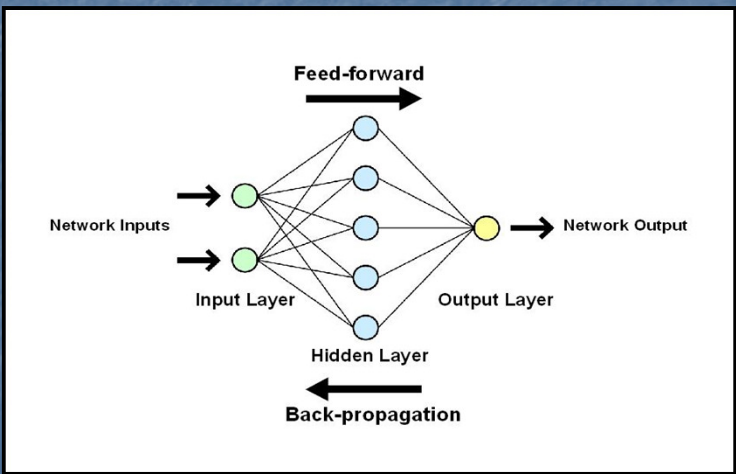
BACK PROPAGATION



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BACK PROPAGATION

BPANN training procedure corresponds to an adjustment of the weights between the hidden layer and the output layer for several thousand iterations.

The mean square error (MSE) is used as a network performance indicator.

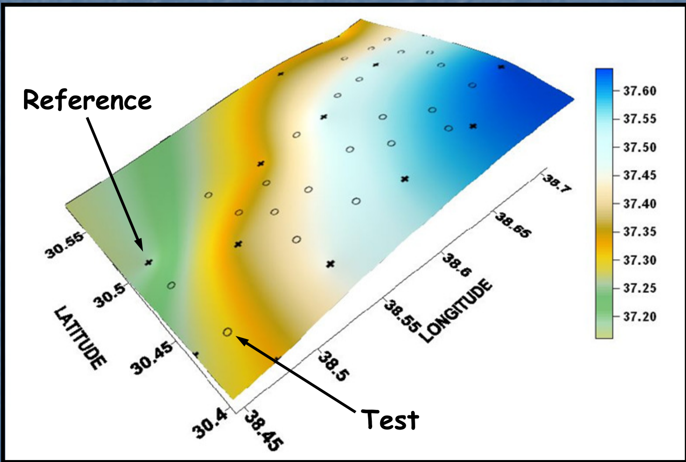
$$MSE = \sum_{i=1}^{K} \left(y_i^{actual} - y_i^{estimated} \right)^2 / K^2$$

COMPARATIVE STUDY

The comparative study refers to 38 points that are located in the province of Afyonkarahisar (Turkey).

14 points were selected as reference points in the study area and the remaining 24 points were used as test points.

COMPARATIVE STUDY



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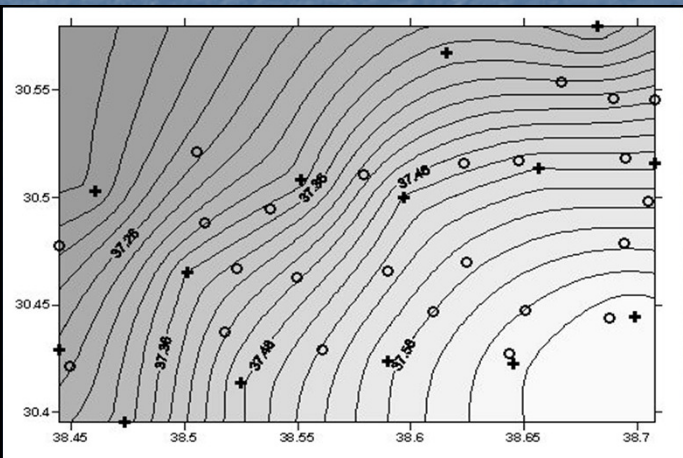
COMPARATIVE STUDY



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COMPARATIVE STUDY

The surface models of the study area are generated by reference points on the basis of the selected interpolation methods.

From these constructed models, the geoid undulation differences of reference and test points are computed.

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COMPARATIVE STUDY

BPANN with one hidden layer was used to compute the geoid undulations.

The input layer consists of three neurons: ϕ, λ and h.

N is selected as the output layer's single neuron.

The optimum BPANN structure was determined as [3:20:1] after a trial-and-error strategy.

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COMPARATIVE STUDY

The reference points are used for the training procedure of the proposed BPANN.

From the trained BPANN, the geoid undulation differences of test points are computed.

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COMPARATIVE STUDY

The differences between the geoid undulations based on GPS/Levelling and the geoid undulations estimated by BPANN and interpolation methods are investigated by RMSE.

$$RMSE = \sqrt{\frac{1}{K}\sum_{i=1}^{K}\left(N_i^{GPS/Lev} - N_i^{estimated}\right)^2}$$

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COMPARATIVE STUDY

REF

INTERPOLATION	KRIG	INDW	MSHP	RBAF	LPOL	POLYNOMIAL
Min (m)	-0.0528	-0.0427	-0.0381	-0.0389	-0.0485	-0.0410
Max (m)	0.0559	0.0447	0.0464	0.0443	0.0337	0.0397
Mean (m)	-0.0009	-0.0004	0.0034	0.0024	-0.0067	0.0023
RMSE (m)	0.0388	0.0244	0.0242	0.0239	0.0245	0.0236

TEST

INTERPOLATION	KRIG	INDW	MSHP	RBAF	LPOL	POLYNOMIAL
Min (m)	-0.0431	-0.0427	-0.0424	-0.0435	-0.0516	-0.0466
Max (m)	0.0967	0.0450	0.0415	0.0402	0.0312	0.0470
Mean (m)	0.0195	0.0077	0.0099	0.0089	-0.0001	-0.0020
RMSE (m)	0.0489	0.0269	0.0266	0.0261	0.0246	0.0243

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COMPARATIVE STUDY

REF

ITERATION NUMBERS	50000	100000	150000	200000	250000	300000
Min (m)	-0.0427	-0.0389	-0.0383	-0.0417	-0.0368	-0.0468
Max (m)	0.0447	0.0443	0.0427	0.0372	0.0403	0.0287
Mean (m)	-0.0004	0.0024	0.0026	-0.0010	0.0033	-0.0063
MSE (m)	0.0004	0.0004	0.0004	0.0004	0.0003	0.0004
RMSE (m)	0.0204	0.0199	0.0196	0.0191	0.0185	0.0190

TEST

ITERATION NUMBERS	50000	10000	150000	200000	250000	300000
Min (m)	-0.0427	-0.0435	-0.0430	-0.0459	-0.0416	-0.0499
Max (m)	0.0450	0.0402	0.0411	0.0376	0.0426	0.0324
Mean (m)	0.0077	0.0089	0.0094	0.0060	0.0010	0.0015
RMSE (m)	0.0229	0.0221	0.0222	0.0211	0.0202	0.0204

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RESULTS

The results of the polynomial method are better than the other interpolation methods.

The lowest MSE and RMSE values based on BPANN method are obtained when the iteration number is 250000.

BPANN method's undulation estimation accuracy is better than the other interpolation methods, in terms of RMSE (Reference: ± 1.85 cm, Test: ± 2.02 cm).

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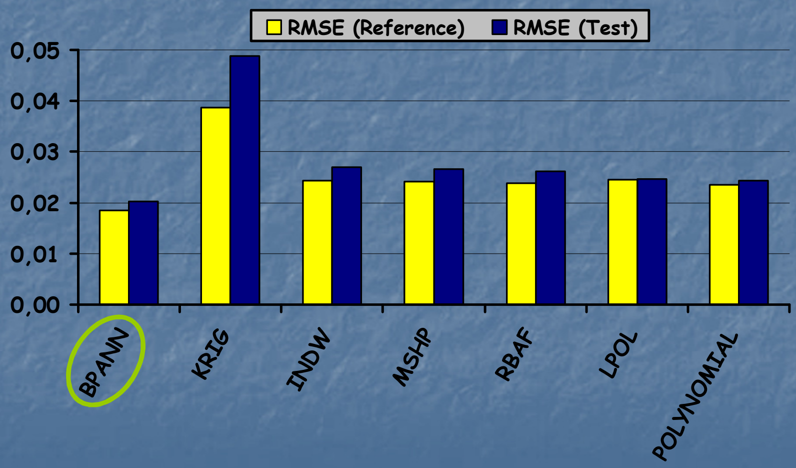
RESULTS



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CONCLUSIONS

The data are not assumed to have normal distribution when applying BPANN to geodetic problems.

BPANN method performs easy and flexible modelling with decreased and increased number of reference points when generating a local GPS/Levelling geoid.

CONCLUSIONS

BPANN method can be concluded as better than interpolation methods for modelling local geoid, on account of accuracy.

The combining of BPANN as a trend surface approximator with other techniques like LSC will provide a significant refinement for the modelling local geoid undulations, in terms of accuracy for future studies.


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