APPLICATION OF BPANN FOR MODELLING LOCAL GPS/LEVELLING GEOID UNDULATIONS

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- GPS/LEVELLING
- INTERPOLATION METHODS
- ARTIFICIAL NEURAL NETWORKS
- BACK PROPAGATION
- COMPARATIVE STUDY
- RESULTS
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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.

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.

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.
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.
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.

\[
MSE = \frac{1}{K} \sum_{i=1}^{K} (y_i^{\text{actual}} - y_i^{\text{estimated}})^2
\]

**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

TS07C - Geoid and GNSS Heighting

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.

BPANN with one hidden layer was used to compute the geoid undulations. The input layer consists of three neurons: $\phi$, $\lambda$ 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.
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.

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

\[
\text{RMSE} = \sqrt{\frac{1}{K} \sum_{i=1}^{K} (N_{i}^{\text{GPS/Lev}} - N_{i}^{\text{estimated}})^2}
\]
### COMPARATIVE STUDY

#### INTERPOLATION

<table>
<thead>
<tr>
<th>Method</th>
<th>KRIG</th>
<th>INDW</th>
<th>MSHP</th>
<th>RBAF</th>
<th>LPOL</th>
<th>POLYNOMIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min (m)</td>
<td>-0.0528</td>
<td>-0.0427</td>
<td>-0.0381</td>
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<tr>
<td>Mean (m)</td>
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<td>-0.0004</td>
<td>0.0034</td>
<td>0.0024</td>
<td>-0.0067</td>
<td>0.0023</td>
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<tr>
<td>RMSE (m)</td>
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<td>0.0244</td>
<td>0.0242</td>
<td>0.0239</td>
<td>0.0245</td>
<td><strong>0.0236</strong></td>
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</table>

#### TEST

<table>
<thead>
<tr>
<th>Method</th>
<th>KRIG</th>
<th>INDW</th>
<th>MSHP</th>
<th>RBAF</th>
<th>LPOL</th>
<th>POLYNOMIAL</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-0.0020</td>
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<tr>
<td>RMSE (m)</td>
<td>0.0489</td>
<td>0.0269</td>
<td>0.0266</td>
<td>0.0261</td>
<td>0.0246</td>
<td><strong>0.0243</strong></td>
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</tbody>
</table>

**TS07C - Geoid and GNSS Heighting**

#### COMPARATIVE STUDY

#### ITERATION NUMBERS

<table>
<thead>
<tr>
<th>Iterations</th>
<th>50000</th>
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<th>150000</th>
<th>200000</th>
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<th>300000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min (m)</td>
<td>-0.0427</td>
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<td>Max (m)</td>
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<td>0.0026</td>
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<td>-0.0063</td>
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<tr>
<td>MSE (m)</td>
<td>0.0004</td>
<td>0.0004</td>
<td>0.0004</td>
<td>0.0004</td>
<td><strong>0.0003</strong></td>
<td>0.0004</td>
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<td>0.0196</td>
<td>0.0191</td>
<td><strong>0.0185</strong></td>
<td>0.0190</td>
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</tbody>
</table>

**TS07C - Geoid and GNSS Heighting**

#### ITERATION NUMBERS

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</thead>
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<tr>
<td>Min (m)</td>
<td>-0.0427</td>
<td>-0.0435</td>
<td>-0.0430</td>
<td>-0.0459</td>
<td>-0.0416</td>
<td>-0.0499</td>
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<tr>
<td>Max (m)</td>
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<td>0.0376</td>
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<td>0.0324</td>
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<tr>
<td>Mean (m)</td>
<td>0.0077</td>
<td>0.0089</td>
<td>0.0094</td>
<td>0.0060</td>
<td><strong>0.0010</strong></td>
<td>0.0015</td>
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<tr>
<td>RMSE (m)</td>
<td>0.0229</td>
<td>0.0221</td>
<td>0.0222</td>
<td>0.0211</td>
<td><strong>0.0202</strong></td>
<td>0.0204</td>
</tr>
</tbody>
</table>
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).

TS07C - Geoid and GNSS Heighting

RESULTS
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.
THANK YOU FOR YOUR ATTENTION

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