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Optimization and comparison of three spatial interpolation methods for electromagnetic levels in the AM band within an urban area

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ABSTRACT

A comparative study was made of three methods of interpolation – inverse distance weighting (IDW), spline and ordinary kriging – after optimization of their characteristic parameters. These interpolation methods were used to represent the electric field levels for three emission frequencies (774 kHz, 900 kHz, and 1107 kHz) and for the electrical stimulation quotient, Q_E, characteristic of complex electromagnetic environments. Measurements were made with a spectrum analyser in a village in the vicinity of medium-wave radio broadcasting antennas. The accuracy of the models was quantified by comparing their predictions with levels measured at the control points not used to generate the models. The results showed that optimizing the characteristic parameters of each interpolation method allows any of them to be used. However, the best results in terms of the regression coefficient between each model's predictions and the actual control point field measurements were for the IDW method.

1. Introduction

With the current growth of the world of communications, human exposure to electromagnetic radiation is increasing rapidly. This is raising public concern about the possible harmful effects of such radiation on health. Faced with this concern, the scientific community has responded by carrying out research determining the levels to which the general public is exposed in their daily life, and comparing these levels with the exposure limits published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2010, 1998), the Federal Communications Commission (FFC) (Cleveland and Ulcek, 1999), the Institute of Electrical and Electronics Engineers (IEEE Standard, 2005) the European Union (Recommendation, 1999) and the regulations adopted by some individual countries.

Some recent studies have considered the total electric field levels in different towns (Calvente et al., 2015; Paniagua et al., 2013), and others the electromagnetic radiation to which the population is exposed depending on the frequency of that radiation (Rufo et al., 2011). There have been dosimetric studies of the electric field levels to which an inhabitant is exposed in their daily life, using personal exposimeters (Bhatt et al., 2016a, 2016b; Gajšek et al., 2013; Joseph et al., 2010).

However, the results of these investigations are not available to the general public. Instead, the recipients of this information are themselves scientists, so that the fears of the population remain unresolved. Not only is the information not readily accessible, but the results of these many research papers are difficult to extrapolate from one scenario to another. One way of overcoming these problems is to represent the electric field levels in a geographic information system (GIS) (Aerts et al., 2013). GIS's have been used for the representation of a variety of parameters, such as continuous wind speed surfaces (Luo et al., 2008), surface temperature (Tiengrod et al., 2013), water quality (Aminu et al., 2015), and electromagnetic field levels in different towns (Azpurua and dos Ramos, 2010; De Doncker et al., 2006; Paniagua et al., 2013). Some studies have compared different interpolation methods for such different variables as daily global solar radiation (Jeong et al., 2017), surface temperature (Tiengrod et al., 2013), and average electromagnetic field magnitude (Azpurua and dos Ramos, 2010). However, which method best reproduces the measured values can depend on such aspects as data density, spatial distribution of samples, and temporal variation, inter alia (Bennett et al., 2013; Li and Heap, 2014).

One of the most important factors in generating a spatial model is to be able to indicate its associated accuracy (Kirchner et al., 1996). For this, the results of the model need to be compared with a source of greater accuracy. In the present case, this source was quantification at control points, i.e., points at which field measurements were made but not used in the generation of the different models.

The main objective of this work was to optimize and compare three different models of the electric field levels in a given study area. The models were generated using the ArcGIS 9.2 program, considering three

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Fig. 1. The village of Valdesalor, with the locations of the medium-wave radio broadcasting antennas (774 kHz, 900 kHz, and 1107 kHz).

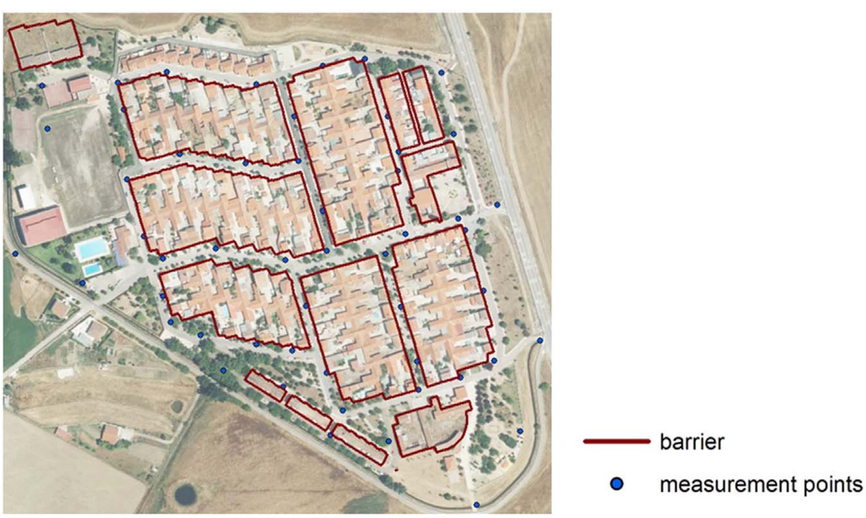

Fig. 2. Digital map of the village of Valdesalor with the measurement points distributed throughout the locality.

interpolation methods for study: inverse distance weighting (IDW), ordinary kriging and spline. The parameters defining these interpolation methods were analysed to maximize the accuracy of the corresponding models. We then used ArcGIS to compare the values measured in the field at a set of control points with the predictions of the different models at those points. (As noted above, the control point data were not used at any time for the computation of the various maps or models).

The analysis of the results was centred on calculating the mean absolute error (MAE), mean square error (MSE), and root-mean-square error (RMSE). In addition, linear fits were made of the values predicted by the different models to the measured values, quantifying the value of the regression coefficient, r. Finally, we studied the percentage error obtained with the three models for each of the emissions and the electrical stimulation quotient, Q_E.

2. Material and methods

2.1. Sampling procedure

The study was conducted in a village, Valdesalor, situated near the city of Cáceres, at 39.377938°N, 6.347946°W (Fig. 1). Its area is 0.16 km^2. The fundamental characteristic of this village is that, although it has only 600 inhabitants, it is just 3 km from a site of MW antennas. The site has two medium-wave radio broadcasting transmitters with effective radiated powers (ERP) of 60 and 25 kW, and frequencies of 774 and 1107 kHz, respectively. Farther away, at about 8.5 km from the village, there is another site with an antenna of 10 kW ERP and 900 kHz frequency (Royal Decree, 1993).

We selected 52 measurement points in the village, distributed in accordance with the communication routes (Maling, 1989) throughout the village. The electric field associated with each of the