Geodetic Monitoring Cable-Stayed Bridges Using GNSS

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SUMMARY

Bridges are important transport junctions and play a big role in the socio-economic development of cities and regions. This also applies to cable-stayed bridges, which are designed for a variety of transportation and everyday traffic [5]. It is known that to ensure the safety of engineering structures, particularly bridges, can monitoring as a continuous process of observing and recording the parameters of the object. Bridges in the course of their operation experience a different kind of load from moving traffic, wind, high or low temperatures, etc. So important is the process of continuous monitoring and recording of mixing in bridge structures.

Today there are a variety of devices and systems, of which we highlighted the global navigation satellite system (GNSS). To date, they have become an alternative to the classical methods of surveying accuracy, efficiency and reliability. The great advantage of GNSS monitoring is its continuous character in real time, as well as detailed signs long-term work. Several GNSS receivers installed on the observed structures, significantly increase the reliability of the results [3]. However, there are numerous sources of systematic measurement errors or displacements that affect the performance of the GNSS. However, the focus of this research is to show the differences between the use of Neural Network, Least square and regression models in GNSS data processing. The results of the neural networks give performance better than the results from others methods.

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1. INTRODUCTION

Method DGNSS work effectively within a local area, at distances up to 300 km with code measurements and 10-20 km by phase measurements (method RTK). Therefore, the standard method of local DGNSS can not provide sufficient accuracy for large areas. Moreover, from an economic point of view effectively use a large number of independent base stations to cover a wide area. Therefore, in recent years gained popularity wide network differential GNSS (WADGNSS Network RTK), which avoids the disadvantages, associated with the standard method DGNSS [9]. Network WADGNSS includes a number of widely dispersed base stations with base lines in the range of a few tens of kilometers; receivers at the base stations operate in 24-hour mode with communications equipment [6].
Location of the user can improve the carrier phase ambiguity resolution and improve the positional accuracy in real-time kinematic (RTK).
Efficient use of GNSS technology limits the following factors: the number of satellites, their spatial arrangement, and the length of the baselines of constructing mathematical models of the impact of the external environment [7]. An important result of the use of GNSS technology for monitoring various natural and technological systems is the ability to predict their behavior. Search reliable predictive models are often complicated by significant influence of various environmental factors not only for observation but the object itself. Thus, the search of an optimal variant of the geodetic network, observation conditions kinematics of engineering structures, cable-stayed bridges, in particular, as well as the development and improvement of mathematical methods, techniques and algorithms for processing data obtained by GNSS monitoring, are relevant.
The aim of the research is to develop methods of observation and data processing GNSS monitoring using alternative mathematical models for the prediction of the kinematics and dynamics of complex natural-technical systems on the example of cable-stayed bridges.

2 . MATHEMATICAL MODELS

There are several mathematical algorithms of the experimental data with a choice of approximating models.

2.1 Least squares method

In the first place is a method of least squares (LS) with possible modifications. We used the classical method of least squares algorithm. For example, if the reference was a power polynomial function, the coefficients of the matrix obtained [10].

$$A = \begin{bmatrix} (t_1 - t_0)^n & (t_1 - t_0)^{n-1} & \cdots & 1 \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \ddots & 1 \\ (t_i - t_0)^n & (t_i - t_0)^{n-1} & \cdots & 1 \end{bmatrix}$$

Where t_0, t_1, t_i - time observations and n - degree of the polynomial.

Giving almost the same estimates of the parameters of the Kalman filter is a device to determine the adequate predictive model of several models of applicants of different structures (Fig. 1).

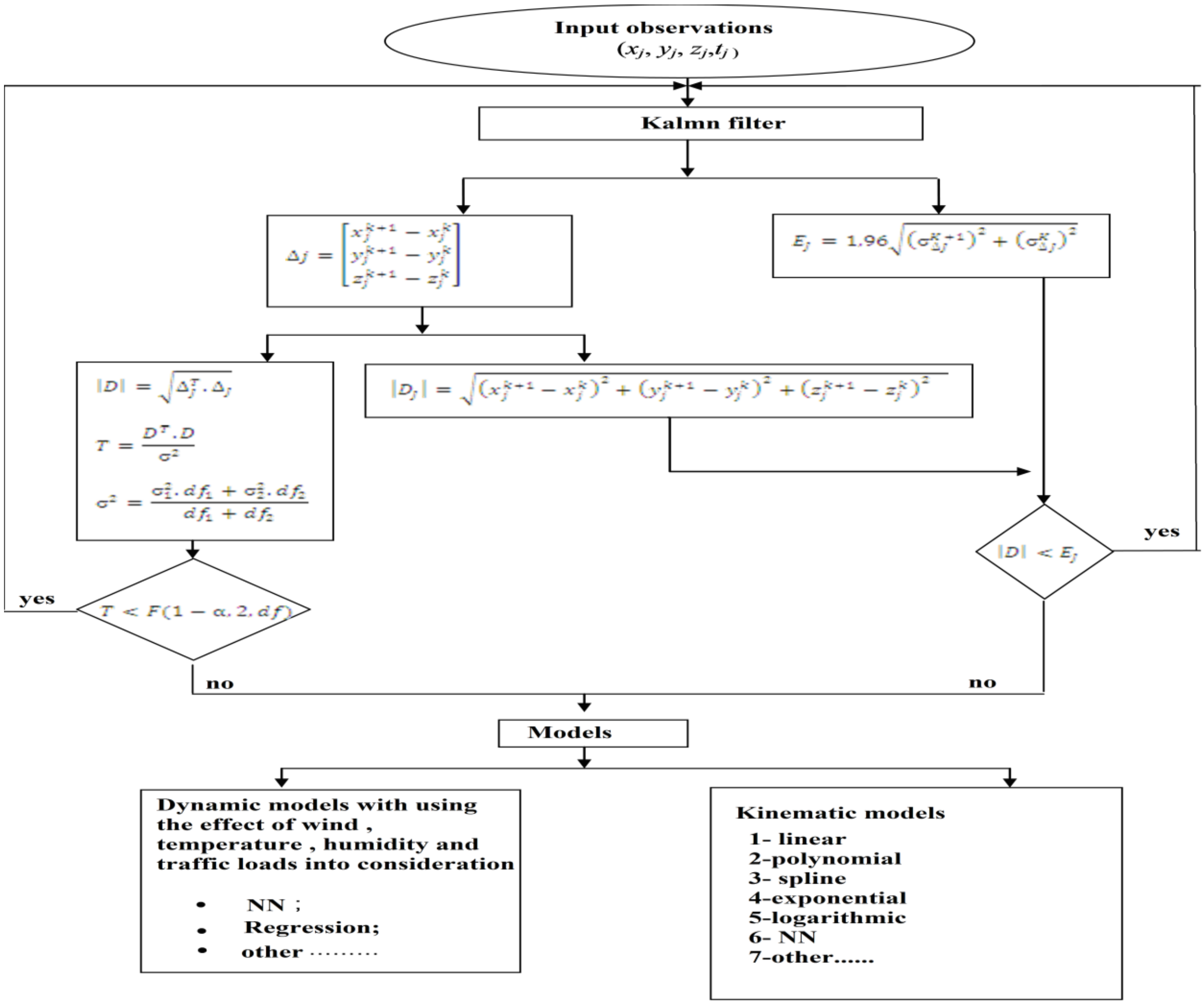

Figure 1: Prediction algorithm

2.2 Neural network

The behavior of NN depends on both the weights and the input-output function. This function typically falls into one of three categories: linear, threshold and sigmoid. Sigmoid units bear a greater resemblance to real neurons than do linear or threshold units, but all three must be considered rough approximations [1].

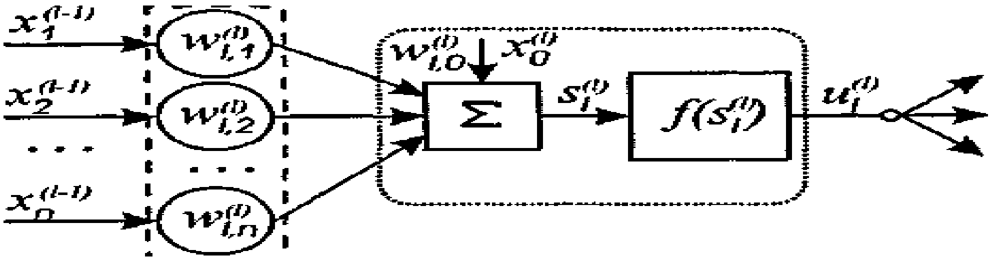

Figure 2: Neural network

2.3 Regression method

A convenient way to describe the dynamical system is the use of mathematical models. These models can be represented in continuous time as a differential equation system in the discrete-time, or as a system of differential equations [2]. There are two ways to construct mathematical models: physical modeling and system identification. The most common type of regression method. Consider this model:

$y = a + b_1x_{i1} + b_2x_{i2} + \dots\dots\dots\dots + b_kx_{ik} + e_i \; (i = 1,2,\dots\dots\dots,n)$

$F(x) = a_1 + a_2F + a_3W + a_4T + a_5H$

$F(x) = a_1 + a_2F + a_3W + a_4T + a_5H + a_6F\,W + a_7F\,T + a_8F\,H + a_9W\,T + a_{10}W\,H + a_{11}H\,T + a_{12}F^2 + a_{13}W^2 + a_{14}T^2 + a_{15}H^2$

where F- load cars on the bridge at a given time (ton); W- wind speed (m/s); T-temperature (C^0); H-humidity (%). Regression model are well positioned to display the relationship between the effects of applied loads and displacements of the bridge.

3. OBSERVATIONS METHODOLOGY

Huangpu Bridge was opened in 2008. It was at that time the third longest suspension bridge in China. The bridge has a total length of 2.27 km. The distance between the base station and the point 107 is 1.00 km and 1.50 km from the point 101 on Figure 3 [8].

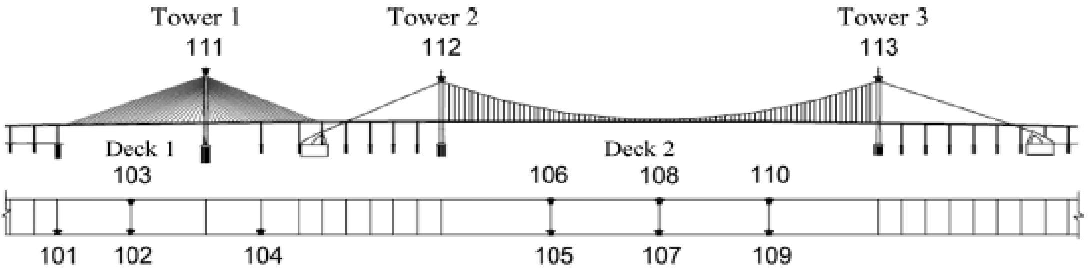

Figure 3: Numbering GNSS critical points of the bridge

4. MONITORING AND PREDICTION MODEL

With MATLAB, we have developed a program that can be used to calculate the coefficient equations. The algorithm of the main program consists of several steps:

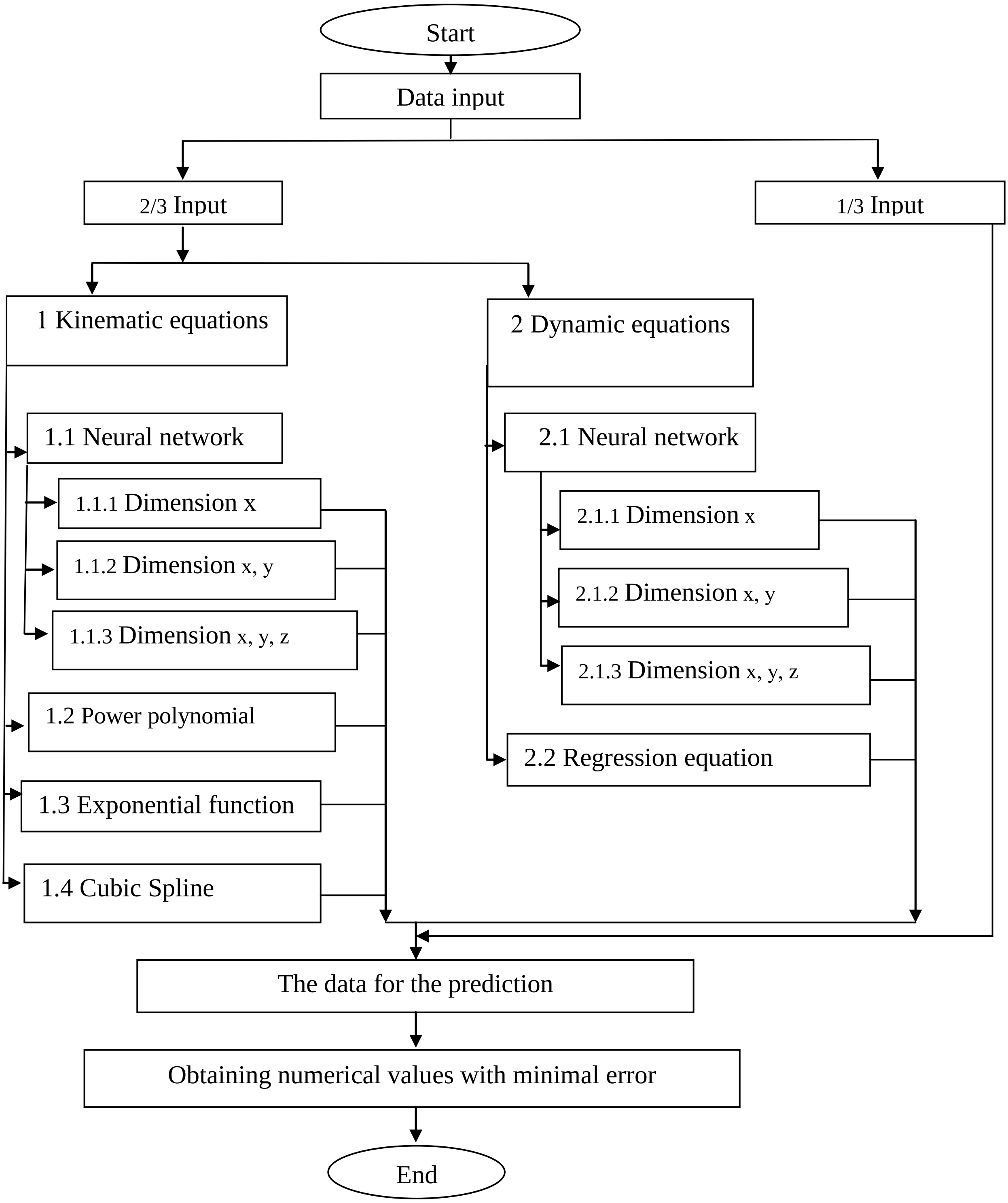

Figure 4 Algorithm main program prediction

5. RESULTS X- COORDINATES FOR EXAMPLE

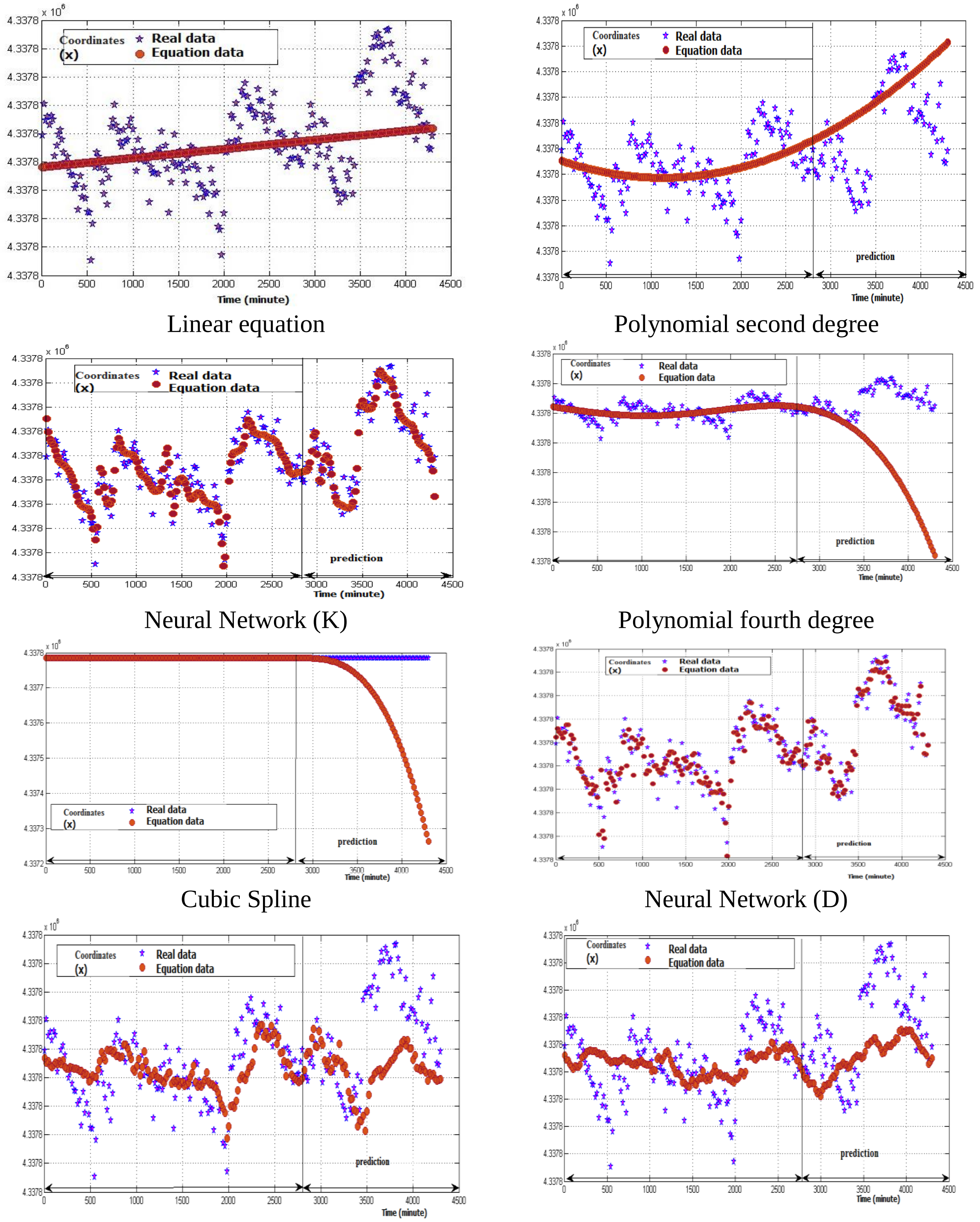

Figure 5 The results of prediction for x- displacements

The regression formula to predict the empirically derived mathematical equations relating the displacement in cm some meteorological factors (wind, temperature, humidity) and the traffic load in accordance with (1) and (2).

$XReg_1(H,F,T,W,X)$= 0,120(W)-0,131 (T)-0,0003(F)-0,021(H)+3,235
$XReg_2(H,F,T,W,X)$ = 0,03 (W^2)-0,003 (T^2)+0,008 (H^2) +0,00(F^2)-0,002 (F W)-0,005 (F T)+0,040 (T W)+0,160 (H W)-0,016(H T)+0,001 (H F)+0,774 W-0,043 T-0,015 F-0,352 H+2,640

This formula was obtained as part of a new technique of GNSS monitoring of critical points bridges experiencing variable traffic load and the influence of meteorological factors. Information blocks defined neural networks for each receiver used in the monitoring cable-stayed bridges. The technique of data processing GNSS monitoring in order to obtain predictive models that take into account the impact on the dynamics of natural systems and technical changes in the wind, temperature, humidity, traffic loads, and others.

CONCLUSION

1. The analysis of mathematical and algorithmic support for monitoring the use of GNSS technologies. Method RTK, using which it is possible to accurately estimate the degree of deformation of the structural elements of engineering structures. The possibility of predictting the dynamics of the situation structures depending on the time, place, and value of loads.
3. We consider separately the method of information neural network (NN), which proved to be the most promising for the prediction. Neural network not only give a good results in the case of kinematics but also, in the dynamic case.
4. An algorithm choice of predictive models in the software MATLAB. Empirically derived mathematical equations, which explain the relation between the displacements and some weather factors (wind, temperature, humidity).

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