The prospects of information technology using for the analysis of industrial buildings defects

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Abstract. The article discusses an approach to describing cracks using machine learning algorithms to simplify the issuance of defective statements for the reconstruction object. The presented approach makes it possible to describe the geometric characteristics of concrete structures and their defects by sets of equations in order to subsequently find the main characteristics of defects and enter them into the defect lists.

1. Introduction
The active development of information technologies [1-3] has led to the fact that their implementation is taking place in various industries and technology to achieve new results that improve the quality of people’s life, ensure the safety of their life and their stability, etc.

At the same time, the density of urban development in settlements leads to the need to repair vital facilities, their timely reconstruction or re-equipment. So, for example, in 2016 it became necessary to reconstruct the building of the substation located in Bryansk. Several structures were erected on the territory of the 220 kV substation under construction in the period from 2010 to 2012: a substation building; water tanks with a fire extinguishing pumping station; sump; entrance building (checkpoint); fencing of the territory. But the construction of this facility was suspended later.

It is worth that any task for the reconstruction of a construction object, as a rule, includes several stages, and begins with the stage of project research, which includes: analysis of the existing one, conducting visual and instrumental studies in order to determine the conformity of structures to the project, as well as carrying out verification (confirming) calculations.

At the same time, according to the survey results, the issued technical reports, provided the above information, as well as defective statements that reflect the current state of the object. A lot of research works have been devoted to the analysis of cracks and the choice of solutions for their restoration [4-9 and etc.]. This article discusses an approach to describing cracks using machine learning algorithms to simplify the issuance of defective statements for the reconstruction object.

2. Methods and methodology
At the research stage, surveys of the construction site were carried out according to a unified methodology in accordance with the developed program, which included:
- carrying out measurement work in order to determine the compliance of existing design solutions with project documentation;
- analysis of technical and design documentation for the construction of the building;
- identification of defects and damages of building structures and assessment of their impact on the technical condition of the weakened areas and the building as a whole;
- determination of the causes of defects and damage;
- determination of the characteristics of materials of structures according to the generally accepted method;
- determination of deviations of the horizontal and vertical position of the building frame elements;
- determination of the reinforcement of the building frame elements;
- analysis of the survey results with the issuance of an opinion on the technical condition of the building and deciding on the need to monitor (observe) the condition of the facility.

At the same time, the study [10] presented a methodology for storing information about various states of a building object. The use of the technique allows to analyze the change in the state of a building object and identify defects in building structures.

3. Results

The use of this technique made it possible to simplify the process of performing measurement work in order to determine the compliance of existing design solutions with design documentation and determine the deviations of the horizontal and vertical positions of the building frame elements. The detected defects and damage of the building structures of the surveyed building were systematized and listed in the summary list of defects, where the defects were given markings, as well as their location relative to the alignment axes. The list also contains descriptions of defects, assessment of the state of structures and general recommendations for eliminating defects. A fragment of the summary list of defects is presented in Table 1.

**Table 1. Fragment of the defective statement**

| Position | Position in axes | Description of defects | Technical condition | Recommendations to restore |
|----------|-----------------|------------------------|---------------------|--------------------------|
| T1-1     | 8хА-Б           | Inclined (in the A-8 axes) crack, turning into a horizontal crack in the reinforced concrete wall of the building (opening width acr = 0.6-0.8 mm, length Ltot=6 m) | Limited workable | To open the crack and mark it with a polymer-cement mortar |

Defects detected during the inspection of the building, depending on the characteristic features, are combined into several groups and marked on the sheets of the graphical part of the report as follows:

- **T1-** - cracks in load-bearing structures;
- **T2-** - cracks in load-bearing structures;
- **Д1-** - defects in load-bearing structures;
- **Д2-** - defects in supporting structures;
- **Тн-** - cracks in the bearing structures of water tanks with a fire extinguishing pumping station;
- **Дн-** - defects in the supporting structures of water tanks with a fire extinguishing pumping station.

Consider the procedure for describing a crack by a mathematical equation. The data responsible for cracks can be obtained by using laser scanning technologies, however, at this object, the scanning
procedure was not performed in all areas, therefore, the work of the technique will be illustrated on the data taken from the photograph.

Let us consider the application of the technique using the example of the crack shown in Fig. 1.

![Photo of cracked floor](image)

**Figure 1.** Photo of cracked floor

Due to the fact that information about cracks was presented in the photographs form, the article will describe a general processing approach. Figure 2 shows the processed points that are responsible for the analysed crack, as well as the dimensions of the slab for scaling and converting them into AutoCad software.

![Fragment of Autocad drawing containing information about the defect in the form of a point field](image)

**Figure 2.** Fragment of Autocad drawing containing information about the defect in the form of a point field

The data obtained as a result of extraction from the * dwg drawing are presented in table 2.

| Table 2. Fracture data |
|------------------------|
| Position X | Position Y | Position Z |
| 305,1325   | 172,2009   | 0          |
| 305,1325   | 171,9678   | 0          |
| 305,4929   | 172,2009   | 0          |
| 305,6626   | 172,328    | 0          |
| 305,7262   | 172,2433   | 0          |
| 305,7262   | 172,0102   | 0          |
| 305,8322   | 172,3068   | 0          |
Position Z is 0 because it is a 2D problem. The next step is to select a function that describes the received data. For this we will use Jupyter Notebook, an interactive web computing platform. At the first step, the basic libraries are imported, as well as the loading and splitting of data (Fig. 3):

```
In [1]: import numpy as np
    :   import matplotlib.pyplot as plt
    :   import pandas as pd

In [2]: df=pd.read_excel('data2.xlsx')
    :   x = df[['Position X']]   
    :   y = df[['Position Y']]  
```

**Figure 3.** A code snippet that demonstrates the step of importing base libraries and loading and parsing data

At the second step, the module is imported from the sklearn library - the module responsible for regression analysis (linearRegression), as well as a set of metrics (metrics) to analyze the correspondence of the obtained equation to the initial data, then the desired function is selected and drawn on the screen (Fig. 4).

```
In [3]: from sklearn.linear_model import LinearRegression
    :   from sklearn.metrics import mean_squared_error, r2_score
    :   model = LinearRegression()
    :   model.fit(x, y)
    :   y_pred = model.predict(x)
    :   r2=r2_score(y, y_pred)
    :   r2= r2_score(y, y_pred)
    :   print(r2)
    :   plt.figure(figsize=(10,6))
    :   plt.scatter(x, y, s=3)
    :   plt.plot(x, y_pred, color='r')
    :   plt.xlabel('x')
    :   plt.ylabel('y')
    :   plt.axis('equal')
    :   plt.show()

2.187655264454211
```

**Figure 4.** A code snippet demonstrating selection of a function and drawing it on the screen

Figure 5 shows the data obtained from the analysis described by linear regression.

![Data visualization](image.png)

**Figure 5.** The visualization of the description of the initial data by the linear regression equation
As can be seen from Fig. 5, simple linear regression does not describe the data well enough; this is also evidenced by the coefficient rmse = 2.18, the root of the root mean square error.

At the same time, a linear model of the form (1):
\[ y = \theta_0 + \theta_1 \cdot x \]

(1)

can be transformed to (2):
\[ y = \theta_0 + \theta_1 \cdot x + \theta_2 \cdot x^2 \]

(2)

The presented expression (2) is also considered a linear model, since the coefficients associated with the characteristics remain linear, and \( x^2 \) is just a function. However, the curve we fit is quadratic, which is a polynomial regression. The higher-level curve fitting will use the PolynomialFeatures class provided by scikit-learn. For example, with degree = 5.

![Figure 6](image)

**Figure 6.** A code snippet demonstrating the selection of a function and drawing it on the screen for the case of polynomial regression.

The fig. 7 shows the data obtained as a result of the analysis, described by polynomial regression. The RMSE = 0.90 of the second case is less than the RMSE = 2.18 of the first case, which tells us that the polynomial model describes the dataset better.

![Figure 7](image)

**Figure 7.** The visualization of the description of the initial data by the linear regression equation (the case of polynomial regression).
Already at the 5th degree the rmse indices describe the analysed defect more accurately than in the previous case, which will be considered sufficient for the example under consideration. However, for cases where greater accuracy is required, the data taken as an example can be split into sections, and on each of them a regression equation can be fitted that perfectly describes the data. This approach is called an ensemble of models. Meanwhile, knowing the function that describes the desired crack, you can get its length. In this way, any defect can be described, and its main characteristics obtained.

4. Conclusion
The article presents an approach to processing data on defects at a substation in Bryansk using Data Science technologies.

It should be noted that the presented approach makes it possible to describe the geometric characteristics of concrete structures and their defects by sets of equations in order to subsequently find the main characteristics of defects and enter them into the defect lists.

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