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«Information Control Systems and
Technologies»
(ICST- ODESA – 2024)
23th – 25th September, 2024**

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Наведені матеріали конференції охоплюють основні напрямки розвитку в області інформаційних систем управління; інтелектуальних систем і аналізу даних; моделювання та розробки програм.

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**Materials of the XII International Scientific Conference
«Information-Management Systems and Technologies»
23th – 25th September, 2024, Odesa**



The collection contains materials accepted by the organizing committee for participation in the International Scientific and Practical Conference "INFORMATION CONTROL SYSTEMS AND TECHNOLOGIES" (ICST-ODESSA-2024).

The materials of the conference cover the main directions of development in the field of artificial intelligence, development and analysis of big data, blockchain and crypto technologies, control systems in robotic systems, data security and cryptography, ICT in the network and administration, information systems and technologies in Data Mining, intelligent technologies management, mathematical modeling, methodology and didactics of teaching and using ICT, application development, project management, system analysis, software development. Conference materials are presented in the following sections:

- Information control systems
- Intelligent systems and data analysis
- Modeling and software engineering

The conference materials were reproduced from the author's originals. The organizing committee of the conference expresses gratitude to all the participants of the conference and hopes for further fruitful cooperation

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EARLY KLOC ESTIMATION OF JAVA-APPLICATIONS BY THE THREE-FACTOR NONLINEAR REGRESSION MODEL

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РАННЯ ОЦІНКА KLOC JAVA-ЗАСТОСУНКІВ ЗА ДОПОМОГОЮ ТРЬОХФАКТОРНОЇ НЕЛІНІЙНОЇ РЕГРЕСІЙНОЇ МОДЕЛІ

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Abstract. The aim of the research is to build the three-factor nonlinear regression model for early lines of code size estimation of Java-applications on the basis of multivariate Johnson SB family normalizing transformations using Cross-Validation technique. The obtained nonlinear regression model is verified with quality criteria for regression models.

Keywords: software size estimation, nonlinear regression model, normalizing transformation, Java.

Анотація. Метою дослідження є побудова трьохфакторної нелінійної регресійної моделі для оцінки розміру рядків коду Java-застосунків на основі багатовимірних нормалізуючих перетворень Джонсона сімейства SB з використанням методу перехресного-затвердження. Отриману нелінійну регресійну модель перевірено за допомогою критеріїв якості регресійних моделей.

Ключові слова: оцінка розміру програмного забезпечення, нелінійна регресійна модель, нормалізуюче перетворення, Java.

The software size estimation plays a key planning role at the early stages of software project planning for the successful implementation of software projects. Software development effort estimation (SDEE) is one of the significant indicators of budget, resources and duration planning of any project for software development business. Software size in the total number of code lines (KLOC) is widely used in SDEE parametric models such as COCOMO, COCOMO II, etc. It leads to the necessity to construct an

appropriate model for Java KLOC estimation at the early stages of project planning.

The aim of the research is to build the three-factor nonlinear regression model for early KLOC estimation of Java-applications on the basis of multivariate Johnson SB family normalizing transformations to increase the accuracy of the Java-applications size estimation at the early stage of software project planning using UML class diagram metrics.

The authors collected code metrics dataset of 571 open-source Java-applications hosted on the GitHub platform using the CK tool (<https://github.com/mauricioaniche/ck>). The obtained dataset was randomly separated into training and testing samples with sizes of 286 and 285 rows. The following metrics were selected to build the model: total quantity of classes (CLASS) X_1 , total number of unique method calls (RFC) X_2 and average value of visible methods per class of the application (aVMQ) X_3 . Variance inflation factors (VIFs) technique indicates the absence of multicollinearity between the factors of the regression model. For factors X_1 , X_2 , and X_3 , the VIFs are equal to 6.09, 6.09 and 1.0 respectively.

The nonlinear regression models building technique [1, 2] is used to build the three-factor nonlinear regression model. It includes detecting outliers in nonlinear regression analysis of non-Gaussian data, bijective normalizing transformations, Mahalanobis distance outliers detection, residuals distribution verification and prediction interval detection.

Typically, the software code metrics have non-Gaussian distribution. To normalize the training datasets we used Johnson normalizing translation of SB family that is given by [3]:

$$\psi(P) = Z = \hat{\gamma} + \hat{\eta} \ln \left(\frac{X - \hat{\varphi}}{\hat{\varphi} + \hat{\lambda} - X} \right) \quad (1)$$

where $\psi(P)$ is non-Gaussian random vector $P = \{Y, X_1, X_2, \dots, X_k\}^T$, γ, η, φ та λ – parameters of Johnson SB family normalizing transformation, $\varphi < X < \varphi + \lambda$, $\eta > 0$, $\lambda > 0$; X - non-Gaussian random variable which X equals to Y, X_1, X_2, X_3 , respectively.

Parameters of Johnson SB transformations (1) are estimated by the maximum likelihood method. The estimators for the parameter Y are: $\hat{\gamma}_Y = -4.0611$, $\hat{\eta}_Y = -0.5013$, $\hat{\varphi}_Y = -0.6082$, $\hat{\lambda}_Y = 82315.0766$; for X_1 : $\hat{\gamma}_{X_1} = -45.7011$, $\hat{\eta}_{X_1} = 48.6731$, $\hat{\varphi}_{X_1} = -32.7353$, $\hat{\lambda}_{X_1} = 163.5047 \cdot 10^{12}$; for X_2 : $\hat{\gamma}_{X_2} = -41.8031$, $\hat{\eta}_{X_2} = 47.0422$, $\hat{\varphi}_{X_2} = -110.3211$, $\hat{\lambda}_{X_2} = 627.4514 \cdot 10^{14}$; for X_3 : $\hat{\gamma}_{X_3} = -36.5209$, $\hat{\eta}_{X_3} = 37.5829$, $\hat{\varphi}_{X_3} = -0.8413$, $\hat{\lambda}_{X_3} = 952.1377 \cdot 10^9$ for the latest iteration.

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The linear regression model is built on the basis of the normalized multi dimensional sample.

$$Z_y = \hat{Z}_y + \varepsilon = \hat{b}_0 + \hat{b}_1 Z_1 + \hat{b}_2 Z_2 + \hat{b}_3 Z_3 + \varepsilon, \quad (2)$$

where ε is Gaussian random variable, $\varepsilon \sim \mathcal{N}(0, \sigma_\varepsilon^2)$; $\hat{b}_0, \hat{b}_1, \hat{b}_2, \hat{b}_3$ - estimators for parameters of the linear regression model (2). The estimators are calculated by the least square method: $\hat{b}_0 = -23.784722$, $\hat{b}_1 = -0.005724$, $\hat{b}_2 = -0.005062$, $\hat{b}_3 = -0.008718$.

The nonlinear regression models is built by applying inverse transformation to (1) to the linear regression models (2):

$$Y = \psi_Y^{-1}(\hat{Z}_y + \varepsilon) \quad (3)$$

where ψ_Y^{-1} is inverse Johnson SB transformation (4).

The obtained three-factor nonlinear regression model (3) is build in 19 iterations and it is tested on training and testing datasets using regression models quality criteria such as the coefficient of determination R^2 , a mean magnitude of relative error MMRE and percentage of prediction for magnitude of relative error level 0.25 PRED(0.25). The values of the quality criteria indicate good accuracy of the model, the high values of for the testing sample confirms the model is not overfitted that confirms robustness and reliability. R^2 , $MMRE$ and $PRED(0.25)$ values for the training dataset are 0.9073, 0.1645, 0.7692 and testing dataset are 0.9016, 0.1617, 0.8175 respectively. The obtained three-factor nonlinear regression model solves an important problem of Java-applications size estimation at the early stages of software development project planning.

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