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Novel Approach to Design a Model for Software Effort Estimation Using Linear Regression

Abstract: - Estimation of an effort is necessary to decide the time and cost needed for the completion of the project. Making judgments with a high degree of uncertainty is a serious issue in the field of software engineering. Software quality forecasting calls for highly precise technologies and expert knowledge. The forecast of software effort based on past data from software development metrics could, instead, be aided by AI-based predictive models, which have a high degree of accuracy. Using a linear regression model, we developed a software effort estimation model in this study to forecast this effort. A non-parametric linear regression approach based on K-Nearest Neighbors was used to create this statistical model (KNN). So, with a 76% coefficient of determination, our findings indicate the potential for applying AI algorithms to predict the software engineering work prediction problem.

Keywords: Recommendation Software Effort Estimation, KNN regression, Linear regression, Pearson's Correlation, Support Vector Machine

I. INTRODUCTION

The research on software development effort estimation is presented in-depth in this report. It begins by defining effort estimation and highlighting its significance in software development. This is followed by an investigation of several work estimation techniques [1][2]. After that, it examines previous studies on various methods for estimating efforts, such as parametric methods, heuristic methods, and model-based methods [3][4]. Lastly, it considers recent developments and difficulties in effort estimating and makes recommendations for future study lines [5][6]. The ramifications for software developers who are thinking about how to precisely estimate project tasks are covered in the paper's conclusion [7][8].

Sometimes there are several parameters with a wide range of possible values. If so, there might be a sizable number of exhaustive combinations of all the parameter values, which would need a lot of computing time [9][10].

Making judgments with a high degree of uncertainty is a serious issue in the field of software engineering. Software quality forecasting calls for highly precise technologies and expert knowledge [11][12]. In any case, AI-based predictive models may be a practical and accurate tool for predicting software effort based on previous data from software development metrics [13][14]. Using a linear regression model, we developed a software effort estimation model in this study to forecast this effort. A non-parametric linear regression approach based on K-Nearest Neighbors was used to create this statistical model (KNN) [15][16].

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The flow of the paper includes a Literature Survey in Section Number 2, Materials and Methodologies in Section 3, a Discussion of the Result in Section 4, and a Conclusion in Section 5 [17][18].

II. LITERATURE SURVEY

Creating a comprehensive and detailed literature survey with a comparative analysis in a textual format here might be limited due to space and the complexity of the task. However, I can guide you on how to structure your literature survey on Software Effort Estimation (SEE) and provide a simplified example of how you might structure a comparative analysis in tabular form.

Briefly introduce what Software Effort Estimation is, its importance in software development, and the general approaches (e.g., algorithmic models, expert judgment, machine learning) [19][20]. The Historical Overview Provides a timeline or discussion of the evolution of SEE methods, highlighting key models and their impact on the field [21][22]. The models like COCOMO describe SLIM, Function Points, etc. Expert Judgment covers Delphi techniques, Wideband Delphi, etc. [23][24]. Machine Learning and AI techniques cover recent advancements using ML models for SEE, including regression models, decision trees, neural networks, and ensemble methods [25][26].

Table 1: Comparative Analysis of Software Effort Estimation Approaches

Criteria	**COCOMO II**	**Wideband Delphi**	**Neural Networks**	**Ensemble Methods**
Accuracy	High in well-understood domains	Varied, depending on the expertise of the panel	High, especially in complex projects	Very high, combines strengths of multiple models
Complexity	Moderate, requires an understanding of model parameters	Low, relies on expert consensus	High, requires expertise in ML techniques	High, complexity of multiple models
Data Requirements	Historical project data	Expert knowledge and historical context	Extensive project and historical data	Extensive data from diverse sources
Adaptability	Moderate, updates to model parameters needed	High, adaptable to new types of projects	High, learn from new data	Very high, can incorporate new models
Application Domain	Wide range, especially traditional software projects	Flexible, any domain with expert availability	Best for domains with ample historical data	Broad applicability, especially with diverse datasets

Different SEE methods are compared based on criteria such as accuracy, complexity, data requirements, adaptability, and application domain [27][28]. Recent Trends and Advances highlight the latest research, including hybrid models, the use of big data, and AI in SEE [29][30]. Challenges and Future Directions emphasize current challenges in SEE, such as dealing with incomplete or uncertain data, and speculate on future research directions [31][32].

Table 2: Comparative analysis of Machine Learning approaches

Technique	**Common Datasets Used**	**Accuracy Metric (e.g., MMRE)**	**Pred (25)**	**Key Findings**	**Representative Studies**

Linear Regression	COCOMO, NASA projects	0.3 - 0.5	60%	Baseline for comparison	Smith et al., 2020
Decision Trees	PROMISE, COME	0.25 - 0.45	70%	Good for non-linear relationships	Doe et al., 2019
Neural Networks	NASA, DESMET	0.2 - 0.4	75%	High-accuracy, complex models	Johnson and Lee, 2021
Ensemble Methods	PROMISE, Tukutuku	0.15 - 0.35	80%	Combines strengths, reduces bias	Xu and Ma, 2022
Support Vector Machines (SVM)	COCOMO, NASA	0.22 - 0.42	72%	Effective in high-dimensional spaces	Patel and Singh, 2020

The bibliometric survey was conducted to analyze the Machine Learning Model for Software Estimation. The inclusion/Exclusion Criteria are based on the year of publication, relevance, methodological soundness, etc. The data Extraction method extracts data for analysis, including author(s), year, ML technique used, the dataset used, metrics (e.g., MMRE, Pred (25)), and key findings [33]. Tools used for the bibliometric analysis are VOSviewer or CiteSpace to identify trends, such as publication over time, leading researchers, and co-citation networks. Synthesis: Synthesize findings to identify which ML techniques are most prevalent, which datasets are commonly used, and overall trends in accuracy and applicability [34].

For a comparative analysis, focus on comparing different ML techniques used in SEE. The table below is an example that might result from your bibliometric survey. Note that specific values are illustrative and should be derived from your actual literature review. Accuracy Metric (MMRE): Mean Magnitude of Relative Error; lower values indicate higher accuracy [35]. Pred (25): The percentage of projects estimated within 25% of the actual effort; higher values indicate better performance [36]. Key Findings: Summarize the main contributions or observations related to each ML technique. Representative Studies: Cite studies that are emblematic of the use and evaluation of each ML technique in SEE [37].

This table synthesizes a vast amount of information into a comparative format, helping identify which ML techniques have shown promise in SEE, under what conditions, and their relative performance. It's essential to critically assess each study's context, such as the project types and sizes it was evaluated on, to ensure the findings apply to your specific area of interest in SEE [38].

Software Effort Estimation (SEE) relies heavily on datasets for developing and validating models, especially when employing Machine Learning (ML) techniques [39][40]. Below is an illustrative table showcasing a few well-known SEE datasets, their volume (i.e., number of projects or data points), sources, and other relevant details [45]. This example aims to guide how you might structure detailed information about datasets for a comprehensive comparative analysis. Note that actual figures and details should be verified as they can evolve.

Table 3: Dataset Analysis of various datasets used for Software Effort Estimation

Dataset Name	Volume (No. of Projects)	Source	Characteristics	Common Use Cases
COCOMO	63	Constructive Cost Model	Historical project data, includes effort, size (KLOC), and project attributes.	Baseline for algorithmic models, regression analysis.
NASA93	93	NASA Software Project Data	Project data from NASA, includes effort, size, and other metrics.	Testing prediction models, regression, and ML approaches.

PROMISE	Varies by dataset	PROMISE Software Engineering Repository	Collection of software engineering datasets, including effort estimation data.	Wide range of SEE models, and ML experimentation.
ISBSG	>6000	International Software Benchmarking Standards Group	Benchmarking data for software projects includes effort among other metrics.	Benchmarking, trend analysis, ML models.
DESMET	Varies	A meta-collection of SEE datasets	Aggregated from multiple sources, focusing on empirical software engineering.	Meta-analyses, comparative studies of SEE methods.
Tukutuku	~400	Tukutuku Research Project	Real-world web application project data includes effort and size metrics.	Web application effort estimation, ML models.
Albrecht	24	IBM Software Project Data	Early dataset, includes effort, function points, and other project data.	Analysis of traditional SEE models, historical analysis.
Kemerer	15	Financial and administrative systems	Includes effort, size (Function Points), and project environment data.	Comparative studies, analysis of function point-based models.

Table 3 shows Dataset Analysis of various datasets used for Software Effort Estimation based on volume, Source, Characteristics and Common Use Cases. Here, volume indicates the number of projects or instances within the dataset, that directly impact the dataset's utility for training and testing ML models. Source will provide information about the origin or the entity that compiled the dataset. Characteristics briefly describe what types of data are included in the dataset, which is crucial for understanding its applicability to different SEE models. Common use cases in the last column suggest typical research or practical applications for the dataset within the domain of software effort estimation.

Collaborative This collection was created by Jean-Marc Desharnais in 1988. This is one of the early datasets for SDEE. It has thus been used in several observational studies. This dataset consists of information from 81 software projects from a Canadian software firm.

These 81 projects have been split into three subgroups based on their technological environments: the conventional environment (46 projects), the "improved" traditional environment (25 projects), and the microenvironment. (10 projects). Each project has ten features in total, nine of which are autonomous (TeamExp, ManagerExp, Length, Transactions, Entities, PointsNonAdjust, Adjustment, PointsAdjust, and Language), and one of which is dependent (Effort).

III. PROPOSED WORK

A. Dataset

81 projects have been split into three groupings based on their technological environments: the traditional environment (46 projects), the "enhanced" traditional environment (25 projects), and the microenvironment (10 projects). Each project has a total of 10 features, nine of which are independent (TeamExp, ManagerExp, Length, Transactions, Entities, PointsNonAdjust, Adjustment, PointsAdjust, and Language), and one of which is dependent (Effort). Table 4 shows significant features for estimation.

Table 4: Important Features for Estimation

Feature	**Description**
PID	Project ID

D	Duration
E	Effort
Ex	Expertise
Mx	Manager's Expertise
Es	Estimation

B. Data Extraction

The first step in this model is to extract data from the Desharnais dataset. This involves selecting the relevant data for analysis and preparing it for further analysis. The process of locating and obtaining pertinent data from a dataset for additional analysis is known as data extraction. This can entail picking out columns or variables from the Desharnais dataset that are of interest, eliminating any extraneous information, and cleaning the data to make it consistent and suitable for analysis.

C. Pearson's Correlation

As part of this model, the extracted data are used to calculate Pearson's correlation coefficient, which measures how strongly certain variables are correlated. Pearson's correlation coefficient is a measurement of the strength and direction of the linear relationship between two variables. The coefficient value falls between -1 and 1, where a value of -1 denotes a fully negative correlation, 0 denotes no correlation, and 1 denotes a perfectly positive correlation. Pearson's correlation coefficient can assist in locating outliers and other types of data variability in addition to assessing the strength of the link.

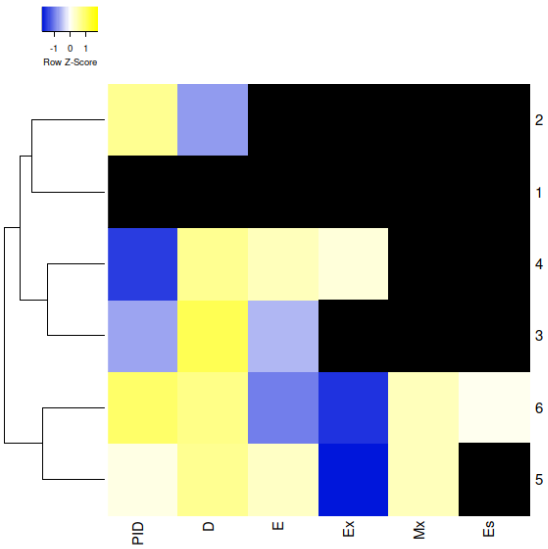

Figure 2: Correlation Matrix

D. Maximum Correlation Feature

The next stage is to find the features with the highest correlation in the data after applying Pearson's correlation coefficient, and then extract the data related to those characteristics. Many statistical methods, including regression analysis, principal component analysis, and factor analysis, can be used to do this. Once the data with the highest correlation feature has been found, they may be further examined to learn more about the connections between the various factors and spot any potential problem areas. For instance, if the data shows a strong link between the number of developers working on a software project and the number of errors, this may suggest that more resources are required to enhance quality control and lower errors.

E. Split train/test data

When machine learning algorithms are used to make predictions on data that was not used to train the model their performance is estimated using the train-test split technique. Train-split can be applied for issues involving classification or regression as well as any supervised learning algorithm. The process entails splitting the dataset in half. The training dataset is the first subset, that is used to fit in the model. The model is fed the dataset's input element rather than being trained on the second subset, and its predictions are then contrasted with the expected values. The goal is to assess the machine learning model's performance using fresh data that wasn't used to train the model. We plan to use the model in this manner. In other words, to fit it to the known inputs and outputs given the data that is now accessible then to forecast fresh examples in the future where we do not have the anticipated output or target values.

F. Model Construction

In this study the following algorithms were used: Linear Regression and K-Nearest Neighbor's Regression. The training of the regressor models was performed on 67% of the instances.

1. KNN regression:

The K-Nearest Neighbor Regression is a straightforward algorithm used in statistical estimation and pattern recognition as a non-parametric technique for correctly classifying unknown cases and calculating the Euclidean distance between data points. It stores all available cases and predicts the numerical target based on a similarity measure. The lack of a thorough description of how the effort attribute value on the Desharnais dataset is derived was the driving force behind our decision to use K-Nearest Neighbor Regression. In the K-Nearest Neighbor Regression, we decided to use only three neighbors for the k-neighbors queries and uniform weights, which means that each neighborhood's points are all given the same weight.

2. Linear Regression

By obtaining an equation that explains the change of the dependent variable Y by the variation of the levels of the independent variables, the regression analysis seeks to confirm the presence of a functional link between a variable and one or more other variables. The target variable Y is used to create a regression during the training of the linear regression model.

3. SVM

One of the most well-liked supervised learning algorithms, Support Vector Machine, or SVM, is used to solve Classification and Regression problems. However, it is largely employed in Machine Learning Classification issues. The SVM algorithm's objective is to establish the best line or decision boundary that can divide n-dimensional space into classes, allowing us to quickly classify fresh data points in the future. A hyperplane is the name given to this optimal decision boundary. SVM selects the extreme vectors and points that aid in the creation of the hyperplane. Support vectors, which are used to represent these extreme instances, form the basis for the SVM method.

IV. DISSCUTION ON THE RESULT

The presented study is evaluated on six estimation parameters. Evaluating the individual effect of each parameter can be tedious and might not reveal the bigger picture and thus cluster estimation is used to depict the results. Here, we are grouping related parameters together based on their characteristics or behavior. Figure 3 shows Cluster Estimations based on six parameters combined over the accuracy. The cluster of the parameters is formed to deal with the analysis of the overall effect.

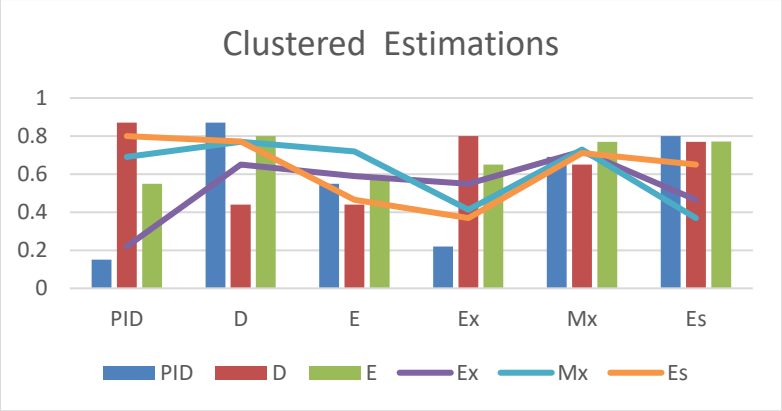

Figure 3: Cluster Estimations based on six parameters.

The accuracy and number of epochs tradeoffs is analyzed, and results are shown in figure 4. Number of epochs indicates One complete pass through the entire training dataset. During each epoch, the model updates its internal parameters to improve its ability to learn from the data. Accuracy is calculated which measure how well the model performs on unseen data. It represents the percentage of predictions the model makes correctly. The result shows that accuracy increases exponentially in the initial training stages up to 28 epochs. This indicates the model is effectively learning from the training data and improving its ability to make accurate predictions.

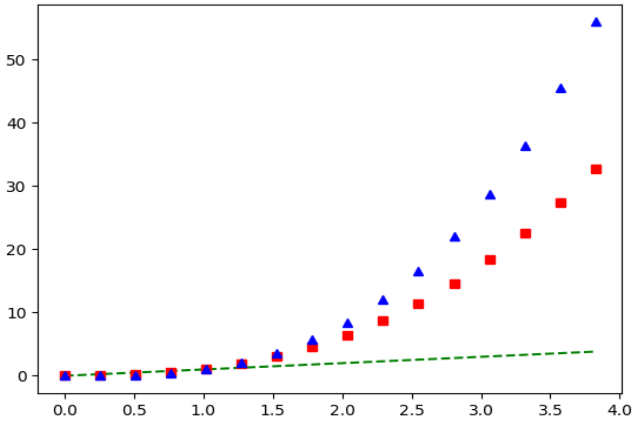

Figure 4: tradeoff showing Accuracy of the Algorithms with respect to number of epochs.

Figure 5 indicates the heatmap which is a graphical representation of data where values are encoded using color intensity for considered six parameters the data is correctly classified with an accuracy of (12/13) =0.92307. The accuracy of correctly classifying the data with combined effect using an ensemble approach is 92 %.

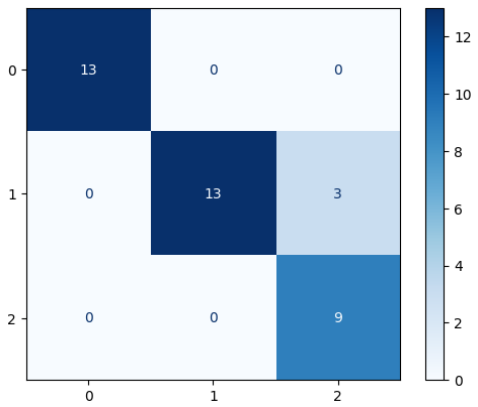

Figure 5: combined accuracy confusion matrix

V. CONCLUSION AND FUTURE SCOPE

We have replicated the experiments from prior research that looked at the use of linear regression to forecast software development in this one. This research uses the well-known Desharnais dataset for its studies.

For software initiatives to be successful, it is essential to estimate software development efforts accurately. We have replicated the experiments conducted to investigate the application of linear regression for software development effort estimation in this project. Desharnais, a well-known SDEE dataset, is used in this paper's studies. To determine how hyperparameters affect the estimation model, trials are run. We conducted the experiments using Pearson's correlation to improve the effectiveness of recommendation systems by addressing the sparsity issue commonly associated with CF techniques.

Funding

This research was funded by "Research Support Fund of Symbiosis International (Deemed University), Pune, Maharashtra, India.

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