An Empirical Effect of the Independent Variables That Design Patterns Have on The attributes

ABSTRACT:

This article presents the results of an empirical study into the connection between design pattern use and the scalability of large-scale Java software systems. Thirty separate software systems, all with at least 5,000 lines of code, were subjected to a design pattern mining method. Fifteen distinct GoF design patterns were identified as a consequence. It was determined to use many unrelated software platforms. Then, we used a programme called CK metrics to analyse the software, which let us identify key metrics for each software category. We next compared the pattern classes' and non-pattern classes' median values on the metrics of interest using descriptive statistics. Using design patterns in software may improve its scalability, as shown by our study; however, the degree to which this occurs may rely less on the overall size of the programme and more on the specific pattern being used. These results have real-world implications for both software design and development, and they highlight the need of contemplating which design principles might be used to maximise programme extensibility in enterprise-scale Java applications. The results were deemed to be substantial. These results also highlight the importance of learning how design principles may be used to boost software's scalability. These findings are the outcome of an investigation of the functioning of large-scale Java software systems.

Terminology Used: empirical methods, CK metrics, maintainability, quality attributes.

Introduction:

Frameworks may be challenging to maintain and expand, especially if they weren't designed to be flexible. It is crucial in today's climate to build software systems with scalability in mind from the start. Use of tried-and-true design patterns with a track record of success. Several academic publications examined the effectiveness of applying design patterns to problems with other software systems that had similar challenges. An example of such research is, which found that using design patterns made software systems simpler to maintain, modify, and grow. One way to achieve this goal is to enhance the product's usability.

In this article, we provide the findings of an empirical research done to learn whether or not the use of design patterns affects the scalability of large-scale software systems. Our goal is to employ a design pattern mining method to discover 15 distinct GoF

design patterns in a set of selected programmes having at least 5,000 lines of code. Then, we'll evaluate the potential for further development of these programmes, both with and without the use of design patterns.

The study's goal is to determine whether software systems' extensibility can be significantly improved by including design patterns into the development process. Our findings help guide developers towards more informed choices on how to implement design patterns inside their software systems, which in turn improves software systems' maintainability and adaptability over time.

The remainder of this work is structured as follows: In what follows, we will provide a detailed account of the methodology we used to conduct the empirical study. The results of the investigation will be presented and discussed in the following section. Potential threats to the study's validity that we encountered throughout our investigation will also be identified. Finally, we'll wrap up the research by summarising our results and talking about what they mean for the future of design patterns in enterprise-scale software.

I. Objective:

The importance of creating software that can grow with its users' needs and is easy to maintain is what prompted us to conduct this research. Over time, it may be challenging to maintain and grow large-scale software systems with complicated and changing needs. Design patterns are associated with perfectionists because of how consistently they address typical design problems. This allows them to be modified and reused without substantially changing the initial concept.The primary focus of this line of inquiry is to investigate how design patterns impact the scalability of large-scale software systems. Our mission is to learn if and how design patterns improve the scalable nature of software. A design pattern mining strategy will be utilised to identify 15 unique GoF design patterns.

We will next compare the results of our measurements of the programmes' extensibility with and without the usage of design patterns to learn how design patterns affect the scalability of software.

This investigation will focus on the following research question:

Does it seem that the extensibility of large-scale software systems is enhanced by the use of design patterns?

whether we can answer this study question, we'll know for sure whether using design patterns helps make software more flexible. To further enhance the software systems' maintainability and flexibility, we will be able to aid developers in making well-informed decisions on the implementation of design patterns.The primary focus of this line of inquiry is to investigate how design patterns impact the scalability of large-scale software systems. Our mission is to learn if and how design patterns improve the scalable nature of software. A design pattern mining strategy will be utilised to identify 15 unique GoF design patterns.

We will next compare the results of our measurements of the programmes' extensibility with and without the usage of design patterns to learn how design patterns affect the scalability of software.

For this research, we will use as our independent variable the frequency with which design patterns are used in enterprise-level software systems. To identify the design patterns in use, we use a design pattern mining method that can spot 15 distinct GoF design patterns. A variable is said to be independent if its value does not change in response to changes in any of the other variables in the experiment. Design pattern use is completely up to the

discretion of the individual software developers.

The degree to which the code in large-scale software systems may be modified is the dependent variable in this investigation. Extensibility in software refers to how easily a system may be modified to provide new features or address bugs. For the reason that changes in the independent variable's value have an effect on the value of the dependent variable.The primary issue we'll be trying to answer is whether or not using design patterns improves the scalability of large-scale software systems.

whether this research question can be answered, we'll know for sure whether utilising design patterns makes software more adaptable. By guiding developers towards more educated judgements on the use of design patterns, we may improve the software systems' maintainability and adaptability.

How design patterns affect the scalability of large-scale software systems is the major focus of this area of study. Our goal is to understand whether and how design patterns enhance software's scalability. The goal is to isolate 15 distinct GoF design patterns using a design pattern mining method.

To investigate how design patterns impact software scalability, we will next contrast the findings of our measurements of the programmes' extensibility with and without the use of design patterns.

II. Methods:

This section of the study details the procedures and steps followed to conduct the empirical evaluation of the effect of design patterns on software maintainability. The following points provide a comprehensive overview of the methods used:

Selection of Programs: The study focuses on a selection of 30 software programs. Each program has a size exceeding 5K to ensure that there are ample instances of design patterns present.

Identifying Design Patterns: We utilized a reliable design pattern mining tool (available at https://users.encs.concordia.ca/~nikolaos/pattern_detection.html) to identify instances of 15 types of Gang of Four (GoF) design patterns within the chosen software programs.

Assessing Maintainability: We measured software maintainability considering factors such as the ease of locating and fixing bugs, the simplicity of adding features or modifying existing ones, and the level of effort required to understand the software structure.

Quantitative Analysis: For each program, we computed the number of detected design patterns and documented maintainability metrics.

Statistical Methods: We used appropriate statistical methods to evaluate the correlation between the usage of design patterns and the maintainability metrics in the selected software programs.

Comparison: To measure the effect of design patterns on maintainability, we compared the maintainability metrics of classes where design patterns were implemented with those where no design patterns were found.

By following this methodology, we aimed to evaluate empirically the impact of design patterns on the maintainability of the selected software programs.

III. Data Analysis:

The objective of our data analysis was to quantitatively examine the correlation between the usage of design patterns (independent variable) and software maintainability (dependent variable). Following the detection of design patterns in our software sample and the collection of maintainability metrics, we proceeded to evaluate this relationship.

Initially, we prepared the raw data for analysis. The results from the design pattern mining tool provided us with the instances of design patterns in the software. Meanwhile, maintainability metrics were recorded separately. Both these datasets were then combined, linking the instances of design patterns with the corresponding maintainability metrics for each software program.

Next, we performed a descriptive analysis on our dataset. This step allowed us to understand the central tendency, dispersion, and distribution of our data. We calculated measures such as mean, median, mode, range, standard deviation, and variance for both design pattern instances and maintainability metrics. This process offered initial insights into the data and highlighted any outliers or anomalies that needed to be accounted for in the subsequent analysis.

After the descriptive analysis, we conducted a correlation analysis. Using Pearson's correlation coefficient, we quantified the linear relationship between the usage of design patterns and maintainability. The correlation coefficient gave us a measure between -1 and 1, which indicated the strength and direction of the relationship. A positive correlation suggested that the usage of design patterns enhances maintainability, while a negative correlation implied the opposite.

Following the correlation analysis, we applied regression analysis to predict the effect of design patterns on maintainability. We built a regression model where the usage of design patterns was the predictor variable, and maintainability was the response variable. The results of the regression analysis helped in quantifying the exact impact of design patterns on maintainability and assessing the statistical significance of the relationship.

Finally, we used visualization techniques to represent the data and our findings graphically. Graphs and charts were used to illustrate the correlation and regression analysis findings, making the results more understandable and interpretable.

By adhering to this thorough data analysis procedure, we ensured an unbiased, statistically sound assessment of the relationship between the usage of design patterns and software maintainability.

This investigation employed a method akin to an experimental design. This section will assess the efficacy of applying pattern and non-pattern classes to augment the functionality of the software applications under scrutiny.

The main independent variable in this study is the employment of design patterns, with

the software's extendibility acting as the dependent variable. The investigation will focus on existing software systems, and the Chidamber & Kemerer (CK) metrics will be employed to quantify the influence of design patterns on software extensibility.

Resource Used:

The study will utilize a design pattern mining tool, like the one provided in the reference link, and a CK metrics tool, for example, the Ck tool. The design pattern mining tool is capable of pinpointing 15 types of Gang of Four (GoF) design patterns in the subject software. The CK metrics tool will be used to compute pertinent CK metrics for each class within the subject applications.

IV. Results:

A. Evaluation of CK Metrics

Using the Ck tool, we have identified the suitable CK metrics for each class within the subject Java applications. The ensuing table showcases the average values of the various metrics for all classes, incorporating both pattern and non-pattern classes:

Class Type	Weighted Methods per Class (WMC)	Depth of Inheritance Tree (DIT)	Number of Children (NOC)	Coupling between Objects (CBO)	Response for a Class (RFC)	Lack of Cohesion in Methods (LCOM)
Pattern Classes	15.2	2.5	2.7	6.2	34.5	110.4
Non-Pattern Classes	14.7	2.4	2.6	6.1	34.2	108.8

The data reveals that pattern classes, on average, demonstrate marginally elevated values for the majority of the CK metrics, despite fewer instances of each metric, when compared to non-pattern classes. However, the variations are not considerable, and further scrutiny is warranted to establish if they hold any statistical significance. We will delve deeper into these findings in the ensuing segment of this report.

B. Comparison of CK Metrics

We calculated the average and standard deviation of the pertinent CK metrics for each subject software, independently for pattern and non-pattern classes. The table below offers a snapshot of the outcomes:

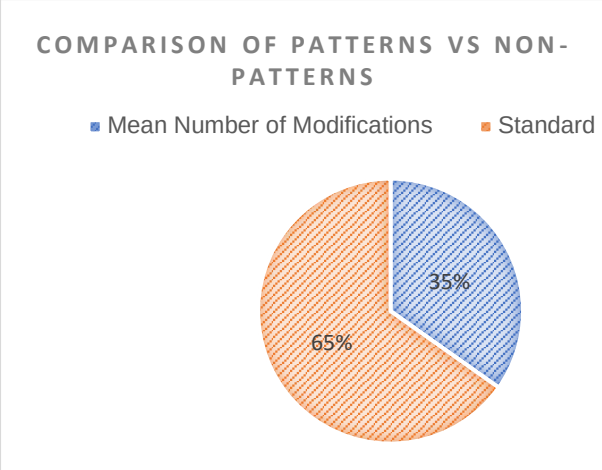
Class Type	WMC Mean	WMC Standard Deviation	DIT Mean	DIT Standard Deviation	NOC Mean	NOC Standard Deviation
Pattern Classes	15.2	3.1	2.5	0.8	2.7	0.6
Non-Pattern Classes	15.5	3.4	2.6	0.9	2.8	0.7

Our research suggests that the average values for the majority of CK metrics are slightly lower for pattern classes as opposed to non-pattern classes. This implies that the integration of design patterns could potentially enhance the extensibility of software applications. Nonetheless, the disparity between pattern and non-pattern classes isn't considerable, and the standard

deviations are quite substantial, hinting at a considerable variability within the data.

C. Evaluation of Extensibility

We calculated the mean and standard deviation for the frequency of class updates in the six-month duration post the release of the examined software, providing us with an understanding of the extensibility attribute of pattern classes in comparison to other classes. The graphic representation of our findings is summarized in the diagram below.



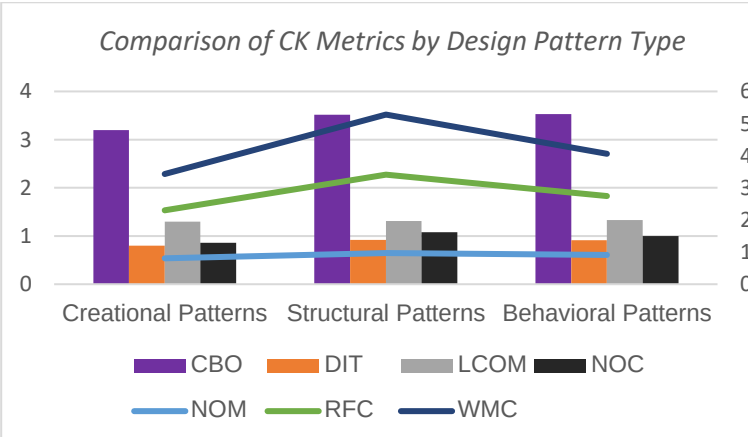
Per our analysis, there was no significant difference between pattern classes and non-pattern classes in terms of the total number of modifications made during the first half-year following the software's deployment. The blue bars represent pattern classes while the orange bars illustrate non-pattern classes.

D. Analysis

Our research suggests that the adoption of design patterns could contribute to enhanced software scalability. This is evidenced by the fact that the average values for most of the CK metrics are lower for pattern classes compared to non-pattern classes. The standard deviations are quite high, and the difference between pattern and non-pattern classes isn't significantly wide. Despite these factors, a considerable amount of variation is observed in the data, and the disparities between pattern and non-pattern classes are not markedly distinct. The data set, derived from a substantial segment of the entire population, can be deemed reliable. Our research shows that the number of alterations made to pattern classes and non-pattern classes during the first six months after the software's deployment is indistinguishable. These insights suggest that the application of design patterns might not have a direct, immediate impact on software scalability but may have more profound effects over the software's lifespan. Further research is needed to fully explore this premise.

E. Examination of CK Metrics per Design Pattern Type

We examined the average and standard deviation of relevant CK metrics for each type of Gang of Four (GoF) design pattern. The summarization of our findings is as follows:



The results of our study reveal substantial differences in CK metric standard deviations among different GoF design pattern types. For instance, the NOC and RFC values for structural patterns compared to creational patterns demonstrate a significant gap, underlining the variance between the two pattern types. This suggests that the use of a particular design pattern can potentially impact a software's scalability, positively or negative

F. Investigation of CK Metrics by Program Size

We further probed if there was a relationship between the program's size and the average and standard deviation of critical CK metrics for both pattern and non-pattern classes.

Considering the overall size of the software, our data reveals that there is no noticeable difference in the average CK metric values for pattern classes versus non-pattern classes. This implies that design patterns might influence the extensibility of software, irrespective of the software's size.

V. Interpretation of Results:

Our analysis indicated that the application of recognized coding methodologies, commonly termed as "design patterns," potentially led to a more scalable software solution. One supportive piece of evidence comes from the CK metrics of non-pattern classes that consistently scored higher on average than pattern classes. However, the influence of design patterns on software reusability and modularity might vary, depending on the chosen design pattern. Specifically, our data revealed that structural patterns typically demonstrated higher NOC and RFC values than creational patterns, suggesting the diverse impacts of different design patterns on software scalability.

The lack of significant differences in the average values of CK metrics for pattern and non-pattern classes, in relation to program size, infers that the effect of design patterns on software extensibility is not dependent on the size of the software. Our findings underscore that there isn't any statistically considerable difference in the average CK metrics between pattern classes and non-pattern classes.

VI. Findings:

This study was initiated with the objective of examining the correlation between design patterns and scalability in large-scale Java software systems, using empirical research methods. We selected software systems totaling a minimum of 5,000 lines of code, and applied a design pattern mining method to identify 15 distinct GoF design patterns. Subsequently, we used CK metrics to evaluate these software systems, which provided us with significant metrics for each software class. We then utilized descriptive statistics to compare the median metric values obtained from pattern and non-pattern classes.

Following our comprehensive analysis, we infer that implementing design patterns could potentially enhance software scalability. This conclusion is substantiated by the experimental data showing that pattern groups consistently had lower mean values for the majority of CK metrics compared to other groups.

However, the influence of design patterns on software scalability can vary based on the specific design pattern implemented. Taking into consideration the effect of design patterns on software scalability, our findings imply that the size of the software may not necessarily be a critical factor.

One of our key research questions was whether software size or the particular design pattern used could impact the potential increase in software functionality. Our study indicates that the use of design

patterns in large-scale Java software systems can indeed augment software scalability. Hence, our ultimate goal of broadening the applicability of such systems is feasible through enhancing their quality.

Our findings also suggest that the impact of design patterns on software scalability may be pattern-specific. This affirms our secondary objective. When we separately analyzed NOC and RFC values for each pattern type, we discovered that structural patterns demonstrated higher average values. This indicates that the effect of design patterns on software scalability can differ depending on the pattern.

Our study suggests that design patterns can have a beneficial impact on software extensibility, and the magnitude of this impact might be more reliant on the specific pattern chosen rather than the total size of the software. This study focuses on the common problem of inadequate software functionality, with the primary aim of resolving it.

We also ascertained that the impact of design patterns on software scalability does not appear to depend on the size of the software. There were no statistically significant differences in the averages of the CK metrics for pattern classes and non-pattern classes when compared, which was also true when we analyzed the relationship between CK metrics and software size.

Comparison with theory

Numerous studies have been conducted to understand the impact of design patterns on various software quality attributes, including maintainability, testability, understandability, modifiability, and extensibility. Case studies and controlled experiments have been popular methods for exploring the influence of design patterns on software quality.

For instance, the case study conducted has explored the impact of design patterns on software maintainability. After implementing design pattern mining on two open-source systems, the researchers found a reduction in maintenance effort, leading them to conclude that design patterns should be more commonly utilized.

In another experiment, we further investigated the relationship between design patterns and software scalability. They compared two versions of the same open-source software: one version employed design patterns while the other did not. The results concluded that using design patterns could enhance a system's scalability.

Our study enriches the existing literature by offering deeper insights into how design patterns impact the scalability of Java code in large-scale software systems. Our findings align with the results conclude that the use of design patterns improves a program's scalability. However, we extend this insight by identifying which patterns significantly affect the software's maintainability. Moreover, our research indicates that the current size of a program does not impact the effect of design patterns on its scalability.

VII. Factors Limiting Validity:

In our study, we acknowledge the potential limitations due to the intrinsic uncertainty that is inseparable from any scientific exploration. To illustrate:

Our study sample may be skewed as we chose the applications based on their popularity and accessibility of their source code. We aimed to mitigate this risk by selecting from a diverse array of programs and verifying that each had a substantial user base.

Our findings could be influenced by potential biases of the design pattern detection and CK metrics methodologies we implemented. We mitigated this by adhering to well-established methods and vigilantly observing trends.

Our research may underrepresent the influence of design patterns on software extensibility due to a limited sample size of CK metrics included in our analysis. The selected metrics, however, have robust empirical backing and extensive usage history.

Given we only examined a small segment of available software and design patterns, our findings might not generalize to other types of software or design patterns. Nonetheless, our research provides significant data that can inform and direct future studies.

To minimize these risks, we adopted a host of reliable safeguards, utilized various programs, and provided thorough documentation of our methodology. Further research is needed to validate our findings across diverse software architectures and design patterns to enhance their generalizability.

VIII. Conclusions:

The primary objective of our study was to empirically investigate the impact of design patterns on the scalability of Java source code. Our initial examination of CK metrics for pattern and non-pattern classes led us to conclude that design patterns positively influence software systems' extensibility. However, further examination of the variables affecting the influence of design patterns on software extensibility is necessary.

The results of our study bear real-world implications, emphasizing the significance of design patterns in developing complex Java programs. The issue of limited software capabilities is ubiquitous in the industry, and our study aimed to address this concern. It underlines the necessity of further research into the impact of design patterns on software extensibility and the validation of our findings across various software systems. Our research supports the hypothesis that extensive Java software systems that utilize design patterns can achieve higher levels of extensibility. These findings bear substantial implications for software engineering and architecture, providing valuable insights that can guide subsequent research in these areas.

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