Empirical Validation of Object-Oriented Metrics on NASA for Fault Prediction

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Abstract. In this study, empirical analysis is carried out to validate Chidamber and Kemerer metrics suite for predicting fault proneness when taking fault severity levels into account. The results, based on KC1 data set from the public NASA repository, indicate that 1) WMC, NOC, LCOM and CBO are reliable metrics for fault-proneness of classes across fault severity in the prediction models built by decision tree method, and 2) only CBO is reliable metrics for fault-proneness of classes across fault severity in the prediction models built by binary logistic regression method.

Keywords: Chidamber and Kemerer metrics suite, Fault proneness, Empirical analysis, Prediction.

1 Introduction

Since Morris Kenneth L. proposed object-oriented design measure in year 1989 [1], its research and applications have been developed more than two decades. Till now, researchers have got great achievements in it. For example, Chidamber S. and Kemerer C. proposed CK metrics suite [2] in year 1994, which contains WMC (Weighted Methods per Class), DIT (Depth of Inheritance), NOC (Number of Children), CBO (Coupling between Objects), RFC (Response for a Class), and LCOM (Lack of Cohesion). Bieman J. proposed TCC (Tight class cohesion) and LCC (Loose class cohesion) [3]. Lee Y. S. proposed DAC (Data abstraction coupling), MPC (Message passing coupling), ICP (Information flow-based coupling), IHICP (Information flow-based inheritance coupling) and NIHICP (Information flow-based non-inheritance coupling) [4]. Fernando Brito e Abreu proposed MOOD (Metrics for Object Oriented Design) metrics suite [5] in year 1996, which contains MHF (Method Hiding Factor), AHF (Attribute Hiding Factor), MIF (Method Inheritance Factor), AIF (Attribute Inheritance Factor), PF (Polymorphism Factor), CF (Couple Factor). Henderson B. proposed DAC(Data Abstraction Coupling), MPC(Message Passing Coupling), NOA(Number of Attributes per Class), NOM(Number of Methods per Class), NMO(Number of Methods Overridden by a subclass) and AID(Average inheritance depth of a class)[6]. Kim E. proposed CBI (coupling based on inheritance) [7]. Benlarbi S. proposed SPA (static polymorphism in ancestors), SPD (static polymorphism in descendants), SP (static polymorphism in inheritance relations), DPA
Empirical Validation of Object-Oriented Metrics on NASA for Fault Prediction

(dynamic polymorphism in ancestors), DPD (dynamic polymorphism in descendants) and DP (dynamic polymorphism in inheritance relations) [8]. Bansiya J. and Davis C. G. proposed QMOOD (Quality Model for Object-Oriented Design) metrics suite [9] in year 2002, which contains NOH, DCC, DSC, ANA, DAM, CAM, MOA, MFA, NOP, CIS and NOM. Counsell S. proposed NHD (normalized Hamming distance based cohesion), SNHD(scaled NHD) and CAMC[10].

The rest sections are organized as follows. Section 2 summarizes related work. Section 3 describes data source, data preprocessing. Section 4 presents in detail the analytical results. Finally, Section 5 draws main conclusions of this paper.

2 Related Work

According to the ISO/IEC9126-1 software quality model [11], one of research task of software measurement is to build relationship between software internal properties (such as cohesion and couple) and external attributes (such as functional, reliability, easy usefulness, efficiency, maintainability and portability). Researchers have applied object-oriented design measure to fault prediction [12-18], change detection, reliability testing, software design style, etc. Qing Wang [12] and Yunfeng Luo [13] survey software fault prediction, and pointed out that it involved not only the number of faults, but also fault distribution, remove and legacy, etc.

Yuming Zhou and Hareton Leung [14] validated Chidamber and Kemerer metrics suite on NASA KC1 data set to predict fault proneness models with respect to high and low severity faults. Logistic regression, random forests and Bayesian network methods were adopted. They claimed that WMC, CBO and RFC were significant while DIT was not significant regardless of severity levels. Moreover, they concluded that Chidamber and Kemerer metrics suite were able to predict low severity faults in fault-prone classes better than high severity faults in fault-prone classes.

Ganesh J. Pai and Joanne Bechta Dugan [15] related Chidamber and Kemerer metrics suite to fault content and fault proneness on NASA KC1 data set. They did not categorize faults at different severity levels. Logistic regression, Poisson regression and Bayesian network methods were adopted. They concluded that WMC, CBO, LOC and RFC have significant effect on fault detection.

Jie Xu, Danny Ho and Luiz Fernando Capretz empirically [16] analyzed Chidamber and Kemerer metrics suite for defects estimation on NASA KC1 data set. Statistical analysis and neuro-fuzzy approach were adopted. They drew a conclusion that WMC, CBO and RFC are reliable metrics for defect estimation.

Cagatay Catal and Banu Diri [17] investigated the effect of dataset size, metrics set, and feature selection techniques for software fault prediction on NASA data set. They claimed that random forests provided the best prediction performance for large datasets and Naive Byes was the best prediction algorithm for small datasets in terms of the Area under Receiver Operating Characteristics Curve (AUC) evaluation parameter.

Yogesh Singh, Arvinder Kaur and Ruchika Malhotra [18] validated Chidamber and Kemerer metrics suite on NASA KC1 data set to predict fault proneness models with respect to high, medium and low severity faults. Logistic regression, decision tree and artificial neural network were adopted. They claimed that WMC, CBO, LCOM and RFC have significant effect on fault detection. They concluded that the performance