Ain Shams University
Faculty of Computer and Information Sciences
Computer Science Department

Faculty of Computer and Information Sciences

Cost, Time and Quality Trade-off in Software Engineering

A Dissertation Submitted to the Department of Computer Science, Faculty of Computer and Information Sciences, Ain Shams University; in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Computer Science

By

Abdelelah Ghaleb Farhan Saif

Master of Computer Science, Faculty of Information Technology and Computer Science,

Yarmouk University, Jordan 2010

Supervised By

Prof. Dr. Zaki Taha Ahmed Fayed

Professor of Computer Science

Faculty of Computer and Information Sciences

Ain Shams University

Dr. Safia Abbas Mahmoud Abbas

Lecturer of Computer Science

Faculty of Computer and Information Sciences

Ain Shams University

Cairo- 2017

Ain Shams University

Faculty of Computer and Information Sciences
Computer Science Department

Faculty of Computer and Information Sciences

Cost, Time and Quality Trade-off in Software Engineering

A Dissertation Submitted to the Department of Computer Science, Faculty of Computer and Information Sciences, Ain Shams University; in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Computer Science

By

Abdelelah Ghaleb Farhan Saif

Signature of Author: _______________

Committee		**Signature & Date**
Prof. Dr. Zaki Taha Ahmed Fayed	**(Supervisor)**	_______________
Dr. Safia Abbas Mahmoud Abbas	**(Supervisor)**	_______________
Prof. Dr. Said Ghoniemy	**(Examiner)**	_______________
Prof .Dr. Atef Zaki Ghalwash	**(Examiner)**	_______________

Cairo- 2017

DECLARATION

This part declares that the work reported in this dissertation was done by author to certify that:

1. The dissertation comprises only my original work toward the PhD,
2. Due acknowledgement has been made in the text to all other materials used,
3. The dissertation consists of 130 pages, exclusive of references and appendices.

Abdulelah Al-Mikhlafi

2017
Cairo- Egypt

CERTIFICATE

This is certified that the dissertation, entitled "**Cost, Time and Quality Trade-off in Software Engineering"** submitted by Mr. **Abdelelah Ghaleb Farhan Saif;** in partial fulfillment of the requirements for the degree of Doctor of Philosophy in computer science**,** faculty of computer and information sciences at Ain Shams University is a bonafide record of research work carried out by the candidate under our supervision and guidance. The work involved in this dissertation has not been previously submitted to this or other university for PhD. or any other degree. We further declare that the materials obtained from other sources have been duly acknowledged in the dissertation**.**

Prof. Dr. Zaki Taha Ahmed Fayed
Professor of Computer Science
Faculty of Computer and Information Sciences
Ain Shams University
Date: 17/ 01/2017

Signature:

Dr. Safia Abbas
Lecturer of Computer Science
Faculty of Computer and Information Sciences
Ain Shams University
Date: 17/ 01/2017

Signature:

ACKNOWLEDGMENT

First of all, I must glorify **Allah** the Almighty who gave me courage and patience to carry out this work successfully.

I would like to express my sincere gratitude to my supervisors, **Prof. Dr. Zaki Taha Ahmed Fayed** and **Dr. Safia Abbas Mahmoud Abbas**. They were always receptive to the ideas that I came up with, and provided me great knowledge and continuous encouragements and they always taught me how to explain the idea and how to move toward the goal.

I would like to dedicate this work to my family in Yemen who courage me to continue in education. Many thanks to **my parents**, **my wife**, **my brothers** and **my sisters**.

Big thank to **Yemeni government** which provides me the funding support to perform this work.

Finally, I want to thank **my friends** in Ain Shams University for their help.

Abdulelah Al-Mikhlafi

Cairo- 2017

Abstract

Cost, schedule and quality are highly related factors (objectives) in software development. They constitute the three sides of the triangle. It is hard to raise the quality without raising either the cost or schedule or both for the software under development. Similarly, development schedule cannot be decreased without sacrificing software product quality and/or raising development cost.

The Discrete Time, Cost and Quality Trade-off Problem (DTCQTP) is special case of this problem in which there are number of execution modes for each activity (modes can be either bids offered by subcontractors to develop an activity where each bid has duration, cost and quality), and the best execution mode of every activity should be determined in order to optimize the total cost, time and quality of the software project.

This work includes:

1. Introducing an optimized cost-quality model based on dataset in Constructive Cost Model (COCOMO) format by adapting Intelligent Water Drops (IWD) algorithm for optimizing COCOMO II Post Architecture (PA) and Constructive Quality Model (COQUAMO/COQUALMO) models to achieve more accurate estimation/prediction of software development effort and hence cost, time and quality on the project level and to allow making trade-off analysis. For this model, the prediction accuracy of IWD is compared with the original models, genetic algorithm (GA) and Problem Data Based Optimization for Continuous Optimization (PDBO-CO) which is developed for this purpose to enable project manager selects the suitable model. The experiment has been conducted on NASA 93 dataset.
2. Introducing a cost-quality model that optimizes effort and hence cost, time and quality (making trade-off analysis) by finding the best project options on the project level. For this model, a comparison is done among IWD, GA and Problem Data Based Optimization (PDBO) in terms of the stability of selecting the best project options, quality of solution and Processing Time (PT) to enable project manager selects the best one. The experiments are conducted on an imaginary software project with size of 25 Thousand Source Lines of Code (25KSLOC) and on Jet Propulsion Laboratory (JPL) flight software project.
3. Developing an application (solving DTCQTP). The algorithms that are used to solve such problem (DTCQTP) are IWD, GA, Ant Colony Optimization (ACO), Egyptian Vulture Optimization (EVO) and PDBO which is developed for this purpose. By using some

examples from the literature, the results of these algorithms are compared in terms of quality of solution and efficiency to enable project manager selects the best one.

4. Finally, comparing the proposed PDBO-CO with Intelligent Water Drops for Continuous Optimization (IWD-CO) for function optimization.

The results are as follow:

For **the optimized cost-quality based on NASA 93 dataset**, we conclude: Effort and time obtained by PDBO-CO, IWD, and GA are closer to the actual ones than that obtained by the original COCOMO II PA model. By doing a comparison among PDBO-CO, IWD, GA and the original COCOMO II PA model regarding prediction accuracy, the Mean Magnitude of Relative Error (*MMRE*) of PDBO-CO, and IWD for effort is equal and the best, and for the time, the *MMRE* of IWD is the smallest. The *MMRE* of GA for effort and time is larger than that of both PDBO-CO and IWD. Prediction (0.25) (PRED(0.25)) of PDBO-CO and of GA for effort and time is almost equal and the best. PRED(0.25) of IWD for effort and time is smaller than that of PDBO-CO and GA. The MMRE and PRED(0.25) of COCOMO II PA for effort and time is the worst among all. Requirements (Req), Design (Des), Coding (Code) and total defects obtained by IWD algorithm and the original COQUAMO model are closer to the actual ones. By doing a comparison among PDBO-CO, IWD, GA and the original COQUAMO model regarding prediction accuracy, the MMRE and PRED(0.10) of IWD, PDBO-CO and GA are somewhat comparable. The MMRE and PRED(0.10) of original COQUAMO model is the worst, except for Code defects is somewhat better. PT of PDBO-CO is the lowest and PT of GA is the second lowest whereas PT of IWD is the largest.

For **the cost-quality model which doesn't depend on dataset**, we conclude: The results for all goals (Faster Better Cheaper FBC, Better Cheaper BC, Better Faster BF and Cheaper Faster CF) are stable for 10 runs of PDBO and are satisfactory, whereas for IWD and GA are unstable. For the two projects, PDBO results generally are the best, whereas IWD results are the worst. GA results generally are the second best. For all goals, PT is recorded in ascending order as follow: PDBO, GA and IWD.

For solving the **DTCQTP**, we conclude: The results regarding minimum total cost, EVO, GA, PDBO are comparable. ACO is better than IWD in some quality bounds but fails to reach some large quality bounds. The results regarding minimum total time and maximum quality are different; in some quality bounds, one algorithm is the best and in others is the worst. The results regarding success rate (SR) for all bounds, IWD, ACO and PBDO have 100% SR whereas GA and EVO SR are different from quality bound to another. The results regarding processing time for all quality bounds are recorded in ascending order as follow: GA, ACO, PDBO, EVO and IWD.

For **function optimization**, we conclude: PDBO-CO reached the optimum values of the selected first four functions. For the last function, IWD-CO reaches the optimum value whereas PDBO-CO reached the value that is much near the optimal value. Processing time of PDBO-CO for *the selected five functions* is smaller than that of IWD-CO.

Table of Contents

List of Tables

List of Figures