A Minimal Test Suite Generation Method Based on Quotient Space Theory

Lei Wu[1,2] and Longshu Li[1]

[1] College of Computer Science and Technology, AnHui University, Hefei, Anhui, China
[2] Department of Computer Teaching, Anhui University, Hefei Anhui, China
wuleijsj@ahu.edu.cn

Abstract. The cost and effectiveness of software testing is determined by the quantity and quality of the test suite. In order to select the most efficient and least subset from the test suite, a minimal test suite generation method based on quotient space theory is proposed. Based on the testing requirements, decomposition method and synthesis technology of the quotient space theory are applied to give a partition of the test suite, and a set of effective algorithm of the minimal test suite generation is concluded..

Keywords: testing requirement, test case, test suite reduction, quotient space, attribute function.

1 Introduction

When the software is tested, test goals must be determined according to the requirements analysis, design introduction, coding etc. which is also called the testing requirements set. To realize a full test of the testing requirements, a group of related test suites should be produced to each testing requirement. Test suites generated in this way usually is numerous and very probably has a quite big redundancy. The cost of software testing will be too high because of much time, labor and material resources consumed in running and maintaining the test suite. How to design a group of test suite which is efficient, with a small number and fully meet the testing requirements has always being under research.

The test suite which satisfying the whole testing goals should be reduced in order to meet the testing requirements with the least test cases. Traditional reduction methods are heuristic method, integer programming algorithm and so on. [1]-[4] Now the relatively commonly used method of test suite reduction is proceeded by testing requirement. [5]-[6] So it is to divide the whole suite of test cases which meet the test goals into equivalence classes according to the relationship of each testing requirement that totally optimize the testing requirements among the test goals, and each equivalence class is the subset that consist of the test cases which satisfy one or some testing requirements. In view of this mind, there is a testing requirements reduction method based on greedy

J.T. Yao et al. (Eds): RSKT 2011, LNCS 6954, pp. 579–584, 2011.

and linear search algorithm[7], but this method can not get rid of the restraints of the traditional method. A method using the granular computing of quotient space theory is provided to instruct the division of test suite, and this method of producing the minimal test suite has the very good theoretical basis and operability.

2 The Granular Analysis Method of Quotient Space

Quotient Space theory[8] indicates the different granularity of the material world by mathematical concept of quotient set. It uses a triple (X, f, T) to describe a question, where X denotes the universe of discourse, $f(\cdot)$ denotes the attribute on X and denotes the structure of X. The equivalence relation R can be introduce to X , and the quotient set according to R is $[X]$. A new triple $([X], [f], [T])$ must be constructed on $[X]$ is called quotient space of the original granular world. The question can be described as different granular world by analysis and research the quotient space mentioned above, in order to simplify the question or reduce the complexity of solving the problem.

The Attribute projection method denotes: assume $f{:}X \to Y$ is the attribute function, the attribute function of element $x \in X$ is multi-dimensional, for example, attribute function f have n components as $f_1, f_2, \ldots, f_n$, if only attribute f_1 is extracted from each element x without considering the attribute $f_2, \ldots, f_i, f_{i+1}, \ldots, f_n$ at one time, and then extract every attribute f_i in order, coarsen granular quotient space of different attribute can be get. Just as an object observed from different angle can obtain descriptions on different sides of the object.

The attribute synthesis method denotes: quotient spaces(X_1, f_1, T_1) and (X_2, f_2, T_2) are known, and the synthesis space (X_3, f_3, T_3) is wanted. The ideal synthesis principle of attribute asks for the attribute function to satisfy the following conditions:

(1) $p_i f_3 = f_i, p_i(X_3, f_3, T_3) \to (X_i, f_i, T_i)$ (i=1,2) is the natural projection

(2) $D(f_3, f_1, f_2) \to minD(f, f_1, f_2)$, $D(f, f_1, f_2)$ mentioned left is a given most optimal criterion$f$ is the attribute function for X_3.

The semi-ordered structure synthesis, assume X_1, X_2 are two quotient spaces of X, and T_1, T_2 are semi-ordered structure on X_1 , X_2, the semi-ordered space (X_1, f_1, T_1) and (X_2, f_2, T_2) can be get, the desired synthesis semi-ordered space must satisfy the synthesis principle: X_3 is the supremum of X_1, X_2, and $T_1(T_2)$ is the semi-ordered quotient structure T_3 on $X_1(X_2)$. The available methods to obtain T3 are the topological method and the direct method.

3 Test Suite Model of Quotient Space

Firstly the related conception will be introduced, assume the testing requirements set R is made up of n testing requirements, as shown by the following $r_1, r_2, \ldots, r_n$, there is a test suite C_i for any testing requirement $r_i \in R(1 \leq i \leq n)$, make all the test cases c can satisfy test requirement r_i. So for any given $r_i \in R(1 \leq i \leq n)$, there must be one or many test cases satisfy r_i in the universe $X = C_1 \bigcup C_2 \bigcup \ldots \bigcup C_n$, thus X can cover all of the testing requirements. $f(\cdot)$ is the attribute function of universe, and f is multi-dimensional, as $f = (f_1, f_2, \ldots, f_n)$, f_i :$X \rightarrow f_i(X)$, $f_i(X) = 0$ indicates the test cases can meet test requirements while $f_i(X) = 1$ indicates the opposite case, T is the semi-ordered structure of X.

Secondly according to the attribute projection method, f_i a component of the attribute function f can be used to define a equivalence division, that decompose the original space X into a coarser quotient space which represented by $[X_i]$. Using n components $f_1, f_2, \ldots, f_n$ of the attribute function, n different divisions of universe can be get, as n quotient spaces $[X_1], [X_2], \ldots, [X_n]$ which are all coarser than original space.

Thirdly according to the attribute synthesis method, considering the meet condition for testing requirements r_i and r_j, the quotient space $[X_i]$, $[X_j]$ can be synthesized into $[X_{ij}]$ by attribute f_i, f_j, $[X_{ij}] = [X_i] \bigwedge [X_j]$, among this "$\bigwedge$" means asking for supremum. In addition, assume $([X_i], f_i, T_i)$ is a semi-ordered space, that construct the following relationship on the elements of $[X_i]$ satisfying: (1) $f_i(x) = 0$and $f_i(y) = 1 \Rightarrow x \prec y$; (2) $x \prec y$ and $y \prec x \Rightarrow x = y$; (3) $x \prec y$ and $y \prec z \Rightarrow x \prec z$. Among them, x, y$\in [X_i]$, using this semi-ordered structure T_i, all of the test cases which satisfy the testing requirement r_i can be guaranteed in the first item of $[X_i]$.

Assume $([X_i], f_i, T_i)$, $([X_j], f_j, T_j)$ are the semi-ordered space defined above, on the basis of getting the synthesis quotient space $[X_{ij}]$ from $[X_i]$, $[X_j]$ by the method of attribute synthesis, the direct method can be used to synthesize the semi-ordered structure T_i, T_j, and the direct method is as following: take $\forall$ x_i, $x_j \in [X_{ij}]$, let $x_i = a_i \bigcap b_i, x_j = a_j \bigcap b_j$, where $a_i, a_j \in [X_i], b_i, b_j \in [X_j]$, define $x_i \prec x_j \Leftrightarrow a_i \prec a_j$ and $b_i \prec b_j$, especially if $b_i = b_j$, then $x_i \prec x_j \Leftrightarrow a_i \prec a_j$, it is recorded as T_{ij} that the relationship acquired by this means. It has been proved that T_{ij} is the semi-ordered structure on $[X_{ij}]$ by the method of direct synthesis structure in reference [8], and $p_i : \rightarrow ([X_{ij}], f_{ij}, T_{ij})$ $([X_m], f_m, T_m)$, $m = i, j$ is order-preserving, thus the set of test cases which satisfying the testing requirements r_i and r_j simultaneously is the first item of $[X_{ij}]$.

4 The Minimal Test Suite Generation Algorithm

Definition: Any true subset C of the test suite C' can not realize the full test to the testing requirements R, so call the test suite C as the minimal test suite. Assume given a original quotient space as mentioned in section 3. The steps using the attribute projection method, the attribute and the structure synthesis method to generate the minimal test suite are as following:

Step1: Separately using attribute function $f_1, f_2, \ldots, f_n$, the test suite can be divided into two parts as $f_i(X) = 0$ or $f_i(X) = 1$, thus n different quotient space $([X_1], f_1, T_1), ([X_2], f_2, T_2), \ldots, ([X_n], f_n, T_n)$ can be get;

Step2: Using the synthesis technology, synthesize f_1 and f_2 as well as T_1 and T_2 to get $([X_{12}], f_{12}, T_{12})$, if the first set of $[X_{12}]$ is not $\emptyset$, it should be followed by f_3, T_3, and so on, if the first set of $[X_{12\ldots i}]$ is not $\emptyset$, it should be followed by

f_{i+1}, T_{i+1}, on the contrary if the first set is $\emptyset$, then let $[X_i]$ enter the queue Q, and consider f_{i+1}, T_{i+1} on the basis of $[X_{12 \ldots i-1}]$, until f_n, T_n,enter a flag into Q, at this time finished once synthesis can be achieved, and a quotient space recorded as $[X_{\mathrm{I}}]$ can be get.

Step3: Pick up the first element from the queue Q to synthesize constantly, similar to the process of step2, Step 3 is repeated until the queue Q is null.

Step4: After Γ times synthesis process we get Γ quotient spaces as $[X_{\mathrm{I}}], [X_{\mathrm{II}}], \ldots, [X_\Gamma]$, then we select a test case from the first set of each $[X_\Phi] = (\Phi = \mathrm{I}$ to $\Gamma)$, the compositive suite of test cases is the desired minimal test suite.

5 An Example

The effectiveness of the method presented in this paper will be illustrated in this section. Assume a set of testing requirements for the system under test is $R = \{r_1, r_2, r_3, r_4, r_5\}$, according to the test case satisfying the testing requirement or not, the related attribute function $f(\cdot)$ values as the following table:

Table 1. The attribute function value of the given test cases

X	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}
f_1	0	0	0	0	1	1	1	1	1	1
f_2	0	0	1	1	0	1	1	1	1	1
f_3	1	1	1	0	0	0	1	1	0	1
f_4	0	1	1	1	1	0	0	0	0	1
f_5	0	1	1	1	1	1	0	1	0	0

Step1:

(X_1, f_1, T_1): $\{c_1, c_2, c_3, c_4\} \rightarrow \{c_5, c_6, c_7, c_8, c_9, c_{10}\}$
(X_2, f_2, T_2): $\{c_1, c_2, c_5\} \rightarrow \{c_3, c_4, c_6, c_7, c_8, c_9, c_{10}\}$
(X_3, f_3, T_3): $\{c_4, c_5, c_6, c_9\} \rightarrow \{c_1, c_2, c_3, c_7, c_8, c_{10}\}$
(X_4, f_4, T_4): $\{c_1, c_6, c_7, c_8, c_9\} \rightarrow \{c_2, c_3, c_4, c_5, c_{10}\}$
(X_5, f_5, T_5): $\{c_7, c_9, c_{10}\} \rightarrow \{c_1, c_2, c_3, c_4, c_5, c_6, c_8\}$

Fig. 1. Using the attribute function to divide (X, f, T), five quotient sets can be get "→" illustrate the semi-ordered structure

Step2:

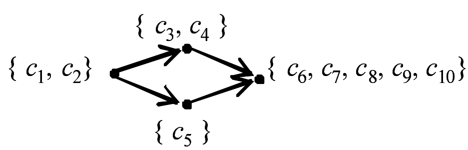

Fig. 2. Firstly,(X_1, f_1, T_1), (X_2, f_2, T_2) is synthesized into (X_{12}, f_{12}, T_{12}), this figure illustrates $\{c_1,c_2\}$ is the first element in X_{12}

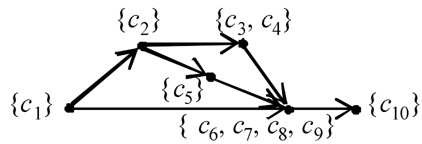

Fig. 3. $[X_{\mathrm{I}}] = (X_{124}, f_{124}, T_{124})$ is acquired and the queue Q is $\{(X_3, f_3, T_3), (X_5, f_5, T_5)\}$

Step3:

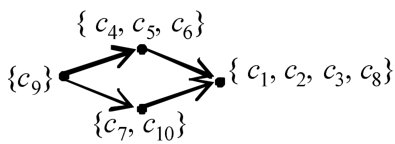

Fig. 4. $[X_{\mathrm{II}}] = (X_{35}, f_{35}, T_{35})$ is acquired and the queue Q is null, so the synthesis have finished

Step4: select a test case from the first set of $[X_{\mathrm{I}}]$ and $[X_{\mathrm{II}}]$ respectively, the minimal test suite c_1,c_9 can be get, obviously this minimal test suite can cover the whole test requirements r_1, r_2, r_3, r_4, r_5.

6 Conclusions

In this paper, the attribute projection method of the quotient space theory is used to decompose the test suite based on the test suite against the testing requirements satisfaction relationship. Next, the attribute synthesis method of the quotient space theory is used to synthesize the quotient sets of test suite after decomposition, meanwhile the semi-ordered structure is used to describe the relationship of the subsets of test suite, and therefore through the simple selection from the quotient spaces after synthesis the minimal test suite can be acquired later. Finally, the effectiveness of this method is validated with experiments. This method essentially simplify the test suite reduction problem, greatly improve the test efficiency, reduces the test cost.

References

1. Harrold, M.J., Gupta, R., Sofia, M.L.: A methodology for controlling the size of a test suite. ACM Transactions on Software Engineering and Methodology 2(3), 270–285 (1993)
2. Chen, T.Y., Lau, M.F.: A new heuristic for test suite reduction. Information and Software Technology 5(6), 347–354 (1998)

3. Zhong, H., Zhang, L., Me, H.: An experimental comparison of four test suite reduction techniques. In: Proceeding of the 28th International Conference on Software Engineering, pp. 636–640. ACM Press, New York (2006)
4. Chung, C.G., Lee, J.G.: An enhanced zero-one optimal path set selection method. Journal of Systems and Software 39, 145–164 (1997)
5. Marre, M., Bertolino, A.: Using spanning sets for coverage testing. IEEE Transactions on Software Engineering 29(11), 974–984 (2003)
6. Tallam, S., Gupta, N.: A concept analysis inspired Greedy algorithm for test suite minimization. In: Proceedings of the ACM SIGPLAN-S1GSOFY Workshop on Program Analysis for Software Tools and Engineering, pp. 35–42. ACM Press, New York (2005)
7. Nie, C.H., Xu, B.W.: A minimal test suite generation method. Chinese Journal of Computers 26(12), 1690–1696 (2003)
8. Zhang, L., Zhang, B.: The theory and applications of problem solving-quotient space based granular computing. The 2nd Version, pp. 1–188. Tsinghua University Press, Beijing (2007)