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A Survey of the Application of Combinatorial Testing

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***Abstract*—After more than 30 years of development, combinatorial testing has become an essential method in the field of software testing, which has always been an active field. Through combined coverage, combinatorial testing can detect faults caused by various parameters and their interactions in a software under test. This paper aims to review the development of combinatorial testing and briefly introduce its basic applications. We classify today's combinatorial testing applications, including those of traditional industry and those of the IT industry. The research and application progress of combinatorial testing was investigated with respect to various fields of application, and potential application directions for the future were proposed to provide ideas for the extensive application.**

Keywords—software testing, combinatorial testing, combination coverage, practical application

I. INTRODUCTION

With the speedy development of information technology and the rise of a wide variety of application software, people today focus on the quality of the software more than ever. With the development of the Internet era, the functional requirements of computer software in daily production and life grow higher and higher, such that software structure is becoming more and more complex, the operating environment and methods of development grow increasingly diversified, and the factors which affect software quality are increasing. Input parameters, configurations, internal events, and their possible interactions are the factors that trigger software failure. In view of these factors, corresponding test cases must be designed to detect them and their interactions. However, there are some problems in the design and generation of traditional test cases. For example, many factors may affect the quality of software, and the value of these factors is complex. When these factors are combined, the situation to be considered is exceptionally complex, and the one method cannot cover all of them.

Today, combinatorial testing is developing rapidly in the field of software testing. It is a scientific testing method that fully considers various parameters and their interactions. This method overcomes the defects of traditional orthogonal experimental design and uniform design. It reduces the number of test cases, and it directly detects the influence of various parameters and interactions on software. In recent years, people have performed in-depth, systematic studies on test cases generation and the application of combinatorial testing. Based on existing re-search, we analyzed and studied more than 160 articles in various mainstream journals and conference papers[1], and we divided the application fields of combinatorial testing into two categories, traditional industry and the IT industry. The IT industry is divided into web network, games and application software.

- We analyzed 21 articles on traditional industry. In solving industrial problems, combinatorial testing uses advanced test-case-generation technology to process test data, so as to achieve the effective and extensive coverage of test cases.
- We analyzed 65 articles on the Web. Combinatorial-Testing applies to the traditional web-test field, usually by using A combinatorial test generation tool(ACTS) or AETG system as test-case generation tools, which greatly improve relative to traditional test technology.
- We analyzed 42 articles about games. These papers applies the design-and-analysis method of combination-test experiment to the test process of manual games, and it proves that combination testing is an effective way to generate test cases. Combined tests generate far fewer test cases than full game tests and can find bugs that developers miss[2].
- We analyzed 34 articles about application software. General-application software includes computer-terminal software and mobile-device-terminal software. The structure of general-application software is generally complex, as the system state varies, so that traditional testing methods are not able to play an effective role[3].

After 30 years of effort, combinatorial testing has been adopted in the latest software testing standards and is listed as an important black-box testing method. Today, research on the application of composite testing is ongoing. We describe several common combinatorial testing tools and their application areas below.

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II. Introduction to Common Testing Tool

Combinatorial testing is typically performed with the help of overriding arrays. Selecting the algorithms or tools available to generate a combinatorial testing suite can greatly improve the efficiency of testing. We briefly introduce several common testing tools and their application areas below.

- The AETG system was proposed by Cohen and Dalal of bell LABS in 1994. It generates tests for a set of relations by combining tests for the individual relations[4]. This method is commonly used both in software- system testing and in industrial processing of test-case generation. It is an ideal testing tool in the field of combinatorial testing.
- ACTS is a combination test tool based on the greedy algorithm, which supports t-way combination-test generation and can achieve six-way coverage[5]. We have studied the current application fields of ACTS, as shown in Figure 1.

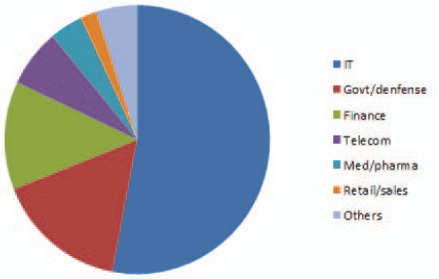

Figure.1. distribution of ACTS in various fields

We can see that ACTS combination test tools are still mostly applied in the IT field.

- Pairwise independent combinatorial testing(PICT) is a testing tool developed by Microsoft which is based on the pairwise algorithm and the combination principle (the pairwise paired principle).

The following table summarizes six tools which are commonly used in the combinatorial testing area[6].

TOOLS	algorithm policy	Supported selection criteria	Maximum coverage intensity/number of parameters and values		Expression of constraint
AETG	greedy algorithm	Uniform strength	2	MCA(N,t,4^1,3^{39},2^{35})	Forbidden Tuples using if else expressions
ACTS	greedy algorithm	Base choice Variable strength Uniform strength	6	MCA(N,t,10^2,4^1,3^2,2^7)	Full constraint support using Boolean relational and arithmetic operators Based expressions
Cascade	greedy algorithm	Variable strength Uniform strength	2	Information not available	Full constraint support using Boolean relational and arithmetic operators Based expressions
PICT	greedy algorithm	Base choice Variable strength Uniform strength	6	VSCA(N,3,3^{15}{CA(6,3^9)})	Full constraint support using Logical Expressions are used to define
ATGT	greedy algorithm	Uniform strength	2	MCA(N,t,4^1,3^{39},2^{35})	Full constraint support using Prepositional logic
CASA	Meta-heuristic techniques	Variable strength Uniform strength	3	CCA(N,t,3^1,2^4,F)	Forbidden tuples converted into Boolean Formula

III. Conclusion and Future Prospects

Today's combinatorial testing is an important area of software testing and is gaining more and more attention. We investigated a large number of articles and have found that the field of application of combinatorial testing is mostly biased towards the IT industry. Although it is used in the industrial and medical fields, most fields use combinatorial-testing ideas, and have not thoroughly studied their testing efficiency and improvement measures. In the IT field, combined testing has been fully studied and developed. From this point of view, the future development of combinatorial testing is still driven by the IT industry, and then promoted in other fields. This paper covers only the general tools and the scope of application of combinatorial testing. For this reason, our future work will include expanding our database, studying more practical examples of combined testing, and analyzing its potential application to non-IT industries.

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