SEQUENCE AND SEQUENCE-LESS *T*-WAY TEST SUITE GENERATION STRATEGY BASED ON THE ELITIST FLOWER POLLINATION ALGORITHM

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Doctor of Philosophy

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SUPERVISOR'S DECLARATION

We hereby declare that I have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy (Computer Science).

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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LIST OF ABBREVIATIONS

ACA	Ant Colony Algorithm
AETG	Automatic Efficient Test Generator
ASP	Answer Set Programing
BA	Bees Algorithm
BFPA	Binary Flower Pollination Algorithm
CPU	Central Processing Unit
CS	Cuckoo Search
CTEXL	Classification-Tree Editor eXtended Logics
DC	Direct Construction
DDA	Deterministic Density Algorithm
EDIST-SA	Event Driven Input Sequence Testing based on Simulated Annealing
eFPA	Elitism Flower Pollination Algorithm
FPA	Flower Pollination Algorithm
G_MIPOG	Grid_MIPOG
GA	Genetic Algorithm
HC	Hill Climbing
HSS	Harmony Search strategy
IEGA	Interaction Elements Generation Algorithm
IPO	Input Parameter Order
IPOG	Input Parameter Order Generalized
ITCH	IBM's Intelligent Test Case Handler
JDK	Java Development Kit
LAHC	Late Acceptance Hill-Climbing
mAETG	Modified Automatic Efficient Test Generator
MC_MIPOG	Multi_Core MIPOG
MIPOG	Modified Input Parameter Order Generalized
MOFPA	Multi-objective Flower Algorithm for Optimization
MPI	Message Passing Interface
PC	Personal Computer
PICT	Pairwise Independent Combinatorial Testing
RAM	Random Access Memory
SBSE	Search based software engineering

SA	Simulated Annealing
SCAT	Sequence Covering Array Generator
SPL	Software product line
STLC	Software Testing Life Cycle
SUT	System Under Test
TConfig	Test Configuration
T-SEQ	*T*-SEQ Algorithm
TSGA	Test Suite Generation Algorithm
TVG	Test Vector Generator
U	Upper bound Strategy
Ur	Upper bound reversal Strategy

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ABSTRAK

Pengujian interaksi (*t*-hala) (di mana *t* menunjukkan kekuatan interaksi) adalah pendekatan untuk menghasilkan sut ujian bagi mengesan kesalahan disebabkan oleh interaksi. Seiring dengan bidang baru yang dipanggil Kejuruteraan Perisian berasaskan Carian (SBSE), banyak strategi *t*-hala yang baru dibangunkan telah mengadopsi algoritma meta-heuristik sebagai asas pelaksanaannya (misalnya Simulasi Penyepuhlindapan (SA), Algoritma Genetik (GA), Algorithma Koloni Anai-anai (ACO), Algorithma Kumpulan Zarah (PSO), Pencarian Harmoni (HS) dan pencarian Burung Cuckoo (CS) kerana prestasi unggul mereka dari segi pengurangan saiz ujian berbanding dengan strategi berasaskan pengkomputeran umum (contohnya strategi *t*-hala umum (GTWay), Penjana Vektor Ujian (TVG), Parameter Dalaman Umum (IPOG), Jenny, dan Penjana Ujian Cekap Automatik (AETG)). Walaupun berguna, semua strategi *t*-hala yang telah disebutkan tidak mengambil kira interaksi tanpa urutan di antara parameter masukan. Dalam kes sistem reaktif, andaian ini tidak sah kerana beberapa operasi parameter (atau peristiwa) berlaku dalam urutan dan oleh itu, mewujudkan kemungkinan pepijat atau kesalahan yang dicetuskan oleh urutan (atau urutan) parameter masukan. Sekiranya strategi *t*-hala digunakan dalam sistem sedemikian, terdapat juga keperluan untuk menyokong penjanaan data ujian berdasarkan urutan interaksi. Bagi menangani isu-isu tersebut dan melengkapi strategi berasaskan urutan yang sedia ada (contohnya *t*-SEQ, Pelengkap Jujukan Penjana Urutan (SCAT) dan Algorithma Lebah (BA)), tesis ini membentangkan strategi berintegrasi berdasarkan algoritma meta-heuristik baru yang dipanggil Algoritma Elit Penyelarasan Bunga (eFPA). Tidak seperti strategi sedia ada, eFPA mempersembahkan pendekatan baru untuk mengintegrasikan penjanaan ujian *t*-hala berturutan dan tanpa turutan dalam satu strategi. Berdasarkan eksperimen penanda aras berturutan, eFPA mempunyai prestasi terbaik berbanding strategi berasaskan urutan sedia ada (dengan 100% penolakan hipotesis nul). Bagi eksperimen penanda aras tidak berurutan, eFPA mengatasi kebanyakan strategi sedia ada (dengan 92.85% penolakan hipotesis nul). Selain itu, penyelidikan ini menyimpulkan bahawa eFPA menjana hasil yang lebih baik dibandingkan dengan FPA yang asal disebabkan oleh keupayaan penerokaan yang dipertingkatkan melalui mekanisma elit tambahan. Malah, reka bentuk eFPA menyumbang kepada domain pengujian perisian kerana ia merupakan strategi t-hala pertama yang mengadaptasi elit FPA sebagai pelaksanaan utamanya.

ABSTRACT

Interaction, or *t*-way, testing, where *t* indicates the interaction strength, is an approach to generate test suite for detecting fault due to interaction. In line with the emerging field called Search based Software Engineering, many recently developed *t*-way strategies have adopted meta-heuristic algorithms as the basis of their implementations such as Simulated Annealing, Genetic Algorithm, Ant Colony Optimization Algorithm, Particle Swarm Optimization, Harmony Search and Cuckoo Search, owing their superior performance in term of test size reduction as compared to general computational based strategies, such as General *t*-way, Test Vector Generator, In Parameter Order General, Jenny, and Automatic Efficient Test Generator. Although useful, all aforementioned *t*-way strategies have assumed sequence-less interactions amongst input parameters. In the case of reactive systems, such an assumption is invalid as some parameter operations, or events, occur in sequence and hence, creating a possibility of bugs or faults triggered by the order, or sequence, of input parameters. If *t*-way strategies are to be adopted in such a system, there is also a need to support test data generation based on sequence of interactions. Addressing these aforementioned issues and complementing the existing sequence based strategies such as *t*-SEQ, Sequence Covering Array Generator and Bee Algorithm, this thesis presents a unified strategy based on the new meta-heuristic algorithm, called the Elitist Flower Pollination Algorithm (eFPA). Unlike existing work, eFPA presents the novel approach of integrating both sequence and sequence-less *t*-way test suite generation within a single strategy. Concerning the sequence benchmark experiments, eFPA has superior performance when compared with the existing sequence based strategies (with 100% rejection of the null hypothesis). As for sequence-less benchmark experiments, eFPA outperforms most existing strategies (with 92.85% rejection of the null hypothesis). Additionally, we also conclude that eFPA generates better results as compared to the original FPA owing to its enhanced exploration capability through the additional elitism mechanism. In fact, the design of eFPA adds new value into the domain software testing as it is the first *t*-way strategy that adopts elitism-FPA as its core implementation.

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