Single and Multi-objective Genetic Operators in Object-oriented Conceptual Software Design

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ABSTRACT
This poster paper investigates the potential of single and multi-objective genetic operators with an object-oriented conceptual design space. Using cohesion as an objective fitness function, genetic operators inspired by genetic algorithms and evolutionary programming are compared against a simple case study. Also, using both cohesion and coupling as objective fitness functions, multi-objective genetic operators inspired by a non-dominated sorting algorithm have been developed. Cohesion and coupling values achieved are similar to human performed designs and a large number and variety of optimal solutions are arrived at, which could not have been produced by the human software engineer. We conclude that this mass of optimal design variants offers significant potential for design support when integrated with user-centric, computationally intelligent tools.

Categories and Subject Descriptors
D.2.2 [Software Engineering]: Design tools and techniques.

I.2.8 [Artificial Intelligence]: Problem solving, control methods and search.

General Terms: Algorithms, Design.

Keywords
Object-oriented design, search, evolutionary algorithms.

1. INTRODUCTION
Empirical evidence suggests that the process of conceptual object-oriented software design is difficult for human designers to perform. Despite such difficulties, computerized tool support for conceptual software design is limited. However, search based approaches to design have received significant attention in the evolutionary computing (EC) domain, including engineering design [1]. In a cross-disciplinary transfer of technology, this poster paper proposes that the benefits of an engineering design search based approach may be applied to software engineering conceptual design.

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2. REPRESENTATION
Use cases are widely used in software engineering to denote the software problem domain. A use case describes a scenario of interaction in a chronological series of steps. According to Simons and Parmee [2], the verb in the step is designated the action of the step, while nouns are designated atomic data upon which the verb acts. We propose that the object-oriented software design search space comprises a set of methods and their parameters, (derived from the set of actions of the problem domain), and a set of attributes, (derived from the set of data of the problem domain). The notion of class is then applied to the search space as a grouping construct for methods and attributes; attributes and methods are partitioned among classes. The resulting representation is a scattered landscape of discrete class partitions.

3. FITNESS
The software engineering notions of coupling and cohesion have long been established as objective criterion to evaluate the fitness of class models within object-oriented software engineering designs. Of the many cohesion metrics proposed, COM [3] has been selected as it is straight-forward to compute, and values lie in the range 0..1. Of coupling metrics available, one derived from Briand [4] has been chosen based on the similarity of parameter types to attribute types. Also, coupling values lie in the range 0..1.

4. GENETIC OPERATORS
The single objective genetic operators investigated in this poster paper are inspired by genetic algorithms (GA) and evolutionary programming (EP). For genetic algorithm inspired operators, selection is performed by tournament and roulette-wheel, while recombination preserves the consistency of the sets of attributes and methods. For the evolutionary programming inspired operators, mutation is the sole variety promoting operator. The multi-objective optimization and diversity preservation operators investigated in this poster paper are inspired by the elitist Non-dominated Sorting Genetic Algorithm (NSGA-II) proposed by Deb [5].

5. CASE STUDY
The case study selected for investigation is a generalized cinema booking system. A specification of the classes, methods and attributes is available from [5]. Cohesion of the human-performed design has been manually calculated using the COM metric as

0.62975, while coupling of the human-performed metric has been manually calculated as 0.217.

6. EVOLUTIONARY SEARCH RESULTS

Figure 1 reveals the average population COM fitness results. obtained for GA tournament, GA roulette-wheel, and EP.

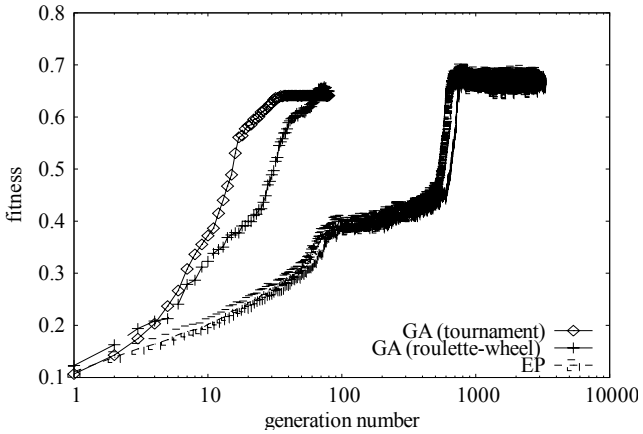

Figure 1. Average population COM fitness.

While all three genetic operators achieve a COM cohesion fitness comparable with the human-performed design, there are differences in the characteristics of each operator. GA tournament achieves maximum fitness in the least number of generations, followed closely by GA roulette-wheel, with EP last. However, it was observed that EP did produce a greater variety of solutions of maximal fitness, suggesting that exploration pressure was greater for EP while exploitation pressure was greater for GA. Figure 2 reveals the average population COM cohesion and coupling fitness results obtained for the NSGA-II inspired genetic operators. As the evolutionary search proceeds, the population converges as optimality is achieved with respect to maximization of cohesion and minimization of coupling. Both cohesion and coupling values achieved are comparable to the human-performed design. Figure 3 reveals the optimal fronts achieved after the population is allowed to evolve for 200 generations.

7. CONCLUSIONS

The cohesion and coupling values produced by the genetic operators are comparable with the human performed design. For the single objective operators, a greater variety of designs is evident in the EP inspired operators. Based on this, mutation is used as the variety promoting mechanism for the NSGA-II inspired multi-objective operators. The characteristics of the results achieved by the multi-objective genetic operators suggest they provide a good balance between optimality of design solutions on the one hand, and diversity of solutions on the other. We conclude that it is highly unlikely that the large number and variety of optimal design solutions could have been achieved by a human designer manually, and so suggest that a search based approach using multi-objective genetic operators has significant potential when integrated with computationally intelligent tools for ueer-centric, interactive object-oriented software design.

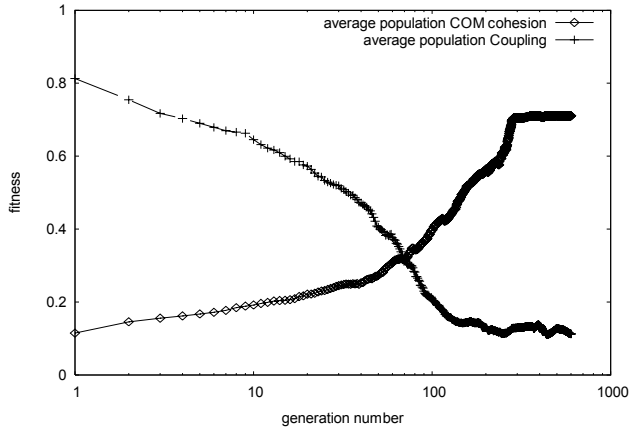

Figure 2. Cohesion and coupling fitness values.

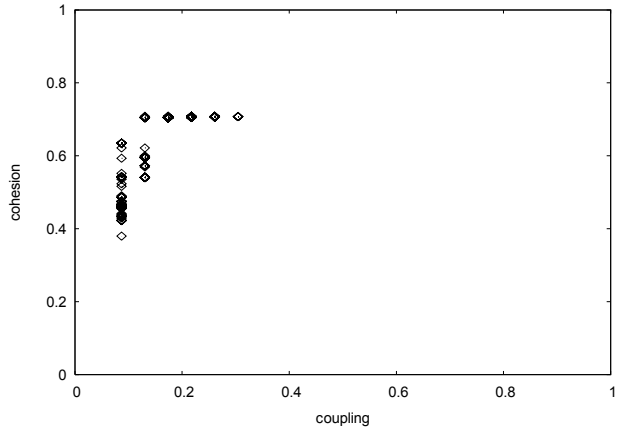

Figure 3. Optimal fronts at 200 generations.

8. REFERENCES

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