# Entrusting Selection Operation to Users in Interactive Genetic Algorithms: a Case Study of Designing Mineral Water Bottles

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## Abstract

How to solve the user fatigue problem is one of the most important challenges in Interactive Genetic Algorithms (IGA). There have been many different sorts of strategies for solving the problem. In this study we propose an interesting way, entrusting the selection operation to IGA users, to solve the fatigue problem. To verify the proposed model, a model which is proof against fatigue is served as a benchmark model. The results of a case study show that the proposed way is significantly helpful for solving the fatigue problem.

**Keywords**: Interactive genetic algorithms, Interactive evolutionary computation, fatigue problem.

## 1. Introduction

Since the first applications of the Interactive Genetic Algorithms (IGA) have been proposed [1], the researches on IGA have lasted for about fifteen years. One of the most important challenges in IGA is how to solve the user fatigue problem [7] and. lots of researchers have addressed many different sorts of strategies for solving the problem.

In this study we propose an interesting strategy, entrusting the selection operation to IGA users, to solve the fatigue problem. To verify the performance of the proposed strategy, we conduct a case study on designing a mineral water bottle and analysis the differences on efficiency and effectiveness between a benchmark system and our proposed system.

## 2. Background

Genetic algorithms (GA) need a fitness for measuring how good of individual chromosome in every generation to guide the evolution. Hence, we should carefully design a pertinent fitness function, and use the fitness function to generate the fitness. For the problems with difficulty in designing a fitness function, we could apply IGA in solving the problems and ask users serve as the fitness function. Hence, an effective fitness assignment way is needed. Conventional fitness assignment strategy is asking users to assign fitness to every individual chromosome of the population, i.e. the rating all strategy [1]. Some other assignment strategies, such as bias strategy; picking some up strategy [6]; have also addressed for improving the performance of IGA. The need of assigning fitness during the evolution process causes IGA users are forced to take on heavy loads in the interaction activities. The heavy loads result in a primary fatigue problem in IGA. Although many IGA-based systems have been proposed to apply at the real world cases, the underlying fatigue problem still remain unsolved.

The selection operation in GA is divided into three parts: 1. calculating the fitness of each individual chromosome according to a pre-designed fitness function, 2. deciding which chromosomes will be selected into the mating pool according to their fitness, and 3. choosing a pair of chromosomes for applying the genetic operations – crossover and mutation.

The execution of the first part of the selection operation is replaced by human in conventional IGA, and the 2 other parts remain executed by computer. In this study, we propose an interactive selection genetic algorithm (ISGA) which the first and second parts of the selection operation are executed by human while the third part of the selection operation remain still done by computer. Actually, users in ISGA need not to assign any fitness and they just need direct and carefully choose some of chromosomes into mating pool. It is expected that the proposed model is workable on solving the fatigue problem as well as improving the performance of the IGA.

## 3. Models

### 3.1. A Benchmark Model

For customer designs in IGA, Hsu and Huang [2] proposed a customer values-based IGA model to solve the fatigue problem. To assure the search space is a complete union set and will be suitable for different customers, they use the concept of Keeney's value-focused thinking [4] to build the search space. They conducted a case study and the results shown the model is significant helpful in reducing user burden.

Nishino et al. find that if the initial generation in IGA contains a few very likely good solutions, then the likely good solutions make the 7th to the 10th generations contains enough variations of expected solutions [5]. Accordingly, Hung and Hsu [3] proposed an over-sampling strategy allowing IGA users to involve in generating the first population. Because the over-sampling strategy could make sure a suitable proportion is prepared in the first generation, the results of a case study shown that the strategy performs as expected.

In this study, we introduce an over-sampling-based IGA model (OIGA) as a benchmark model for comparison with the proposed model of the paper. The procedure of the OIGA model is shown below.

*OIGA( )*
*{*
*Build a search space using the Keeney's value-focused thinking approach.*
*Generate a first generation of chromosome with over-sampling strategy.*
*Do*
*{*
*Phenotypes of the chromosomes in population are shown to the user.*
*The user assigns fitness to each chromosome.*
*IGA selects chromosomes into mating pool according to the fitness.*
*IGA generates new chromosomes of the next generation by applying crossover and/or mutation.*
*} until the user has found a satisfying chromosome or has reached other ending conditions*

## 3.2. Interactive Selection Genetic Algorithms Model(ISGA)

The fitness assignment process in IGA is boring and time consuming, moreover, an inaccurate rating will cause IGA to select improper chromosomes into the mating pool and will result in the fatigue problem.

In this study, we try to think over the real purpose of the fitness function in GA. Actually, a fitness function in GA is not for generating fitness values, but for helping select a set of suitable chromosomes into the mating pool. Without the fitness function the selection operation will not be functioned in GA. But in IGA the operations of selecting a set of suitable chromosomes into the mating pool are performed by users is naturally as well as effortlessly. In other words, selection operation will be well functioned without fitness function. Why don't we ask users bypass the fitness assignment process and direct select proper chromosomes into the mating pool?

Hence, we propose a model, ISGA (Interactive Selection Genetic Algorithms), in which the users are not necessary assigning fitness any more. The procedure of the ISGA is shown below.

*OIGA( )*
*{*
*Build a search space using the Keeney's value-focused thinking approach.*
*Generate a first generation of chromosome with over-sampling strategy.*
*Do*
*{*
*Phenotypes of the chromosomes in population are shown to the user.*
*The user selects k (0<= k <= n, n = population size) chromosomes into mating pool.*
*IGA randomly generates n-k chromosomes into mating pool.*
*IGA generates new chromosomes of the next generation by applying crossover and/or mutation.*
*} until the user has found a satisfying chromosome or has reached other ending conditions*

# 4. Case Study

Designing mineral water bottle is used as a case study to verify the performance of the purpose model.

The mineral water bottle is divided into cap, neck, label, body, and base; the cap attribute has 8 attribute levels and the other attributes take on 16 attribute levels. The chromosome structure and the phenotype of the encoded attribute levels, generated by following the value focused thinking approach, are shown in Fig 1. The size of the solution space is $2^{19}$ (= $2^3$ x $2^4$ x $2^4$ x $2^4$ x $2^4$).

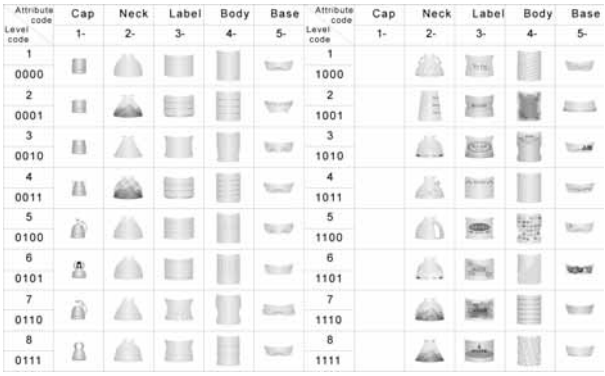


Fig 1 A chromosome structure and the phenotype of the encoded attribute levels

The benchmark system, OIGA, and the proposed system, ISGA, are developed in JAVA language and are available at http://210.60.9.57:8080. The subjects in the case study will search for their preferred bottle from 524,288 candidates with OIGA and ISGA systems separately. We invite 35 subjects taking part in an experiment to compare the difference on efficiency and effectiveness of two different systems. Each subject is asked to run both of the systems. Fig. 2 is the interface of ISGA system.

At the experiment, we recorded the numbers of generations were used in both systems as the efficiency index ($E_{i\text{-}OIGA}$ and $E_{i\text{-}ISGA}$). At the end of tests, both on OIGA and ISGA, subjects are asked to choose one satisfying bottles from the last generation, and rate the bottle on a 100-point scale to get a satisfaction score. Then, we use the scores as the effective index ($F_{i\text{-}OIGA}$ and $F_{i\text{-}ISGA}$).

For the experiment, the population size is set to 8, one-point crossover is used, one elitist individual in each generation is preserved in the next generation, the crossover rate and mutation rate are 0.8 and 0.01 respectively, and the over-sampling rate is 0.7.

Fig.2 The interface of ISGA system

## 5. Experiment and Result

The results of the efficiency test are shown in Fig. 2. It shows that most of the subjects finish their design works within 10 generations when using both of the systems. The results of the Wilcoxon signed ranks test on system's efficiency index are shown in Table 1. The results of Table 1 indicate that the efficiency index of the OIGA is not significant different from ISGA (p =0.748).

Fig. 3 and Table 2 are experiment results of effective test and the results of Wilcoxon signed-ranked test on effective index. The results indicate that ISGA models performed more effective than OIGA, and the effective index of the ISGA is significant different from OIGA (p =0.007).

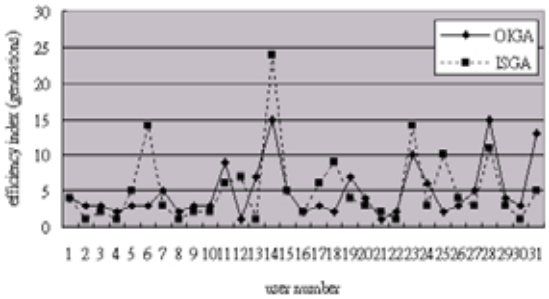


Fig 2. Result of the efficiency test

Table 1 Results of the Wilcoxon Signed-Ranked Test on efficiency index

Ranks

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| $E_{i\text{-}ISGA}$ - $E_{i\text{-}OIGA}$ | Negative Ranks | 18[a] | 12.06 | 217.00 |
| | Positive Ranks | 10[b] | 18.90 | 189.00 |
| | Ties | 3[c] | | |
| | Total | 31 | | |

[a] $E_{i\text{-}ISGA} < E_{i\text{-}OIGA}$ [b] $E_{i\text{-}ISGA} > E_{i\text{-}OIGA}$ [c] $E_{i\text{-}ISGA} = E_{i\text{-}OIGA}$

Test Statistics[b]

| | $E_{i\text{-}ISGA}$ - $E_{i\text{-}OIGA}$ |
|---|---|
| Z | -.321[a] |
| Asymp. Sig. (2-tailed) | .748 |

[a.] Based on positive ranks.
[b.] Wilcoxon Signed Ranks Test

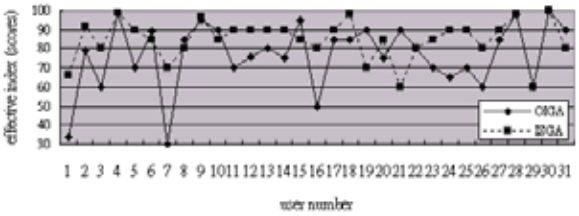


Fig 3. Result of the effective test

Table 2 Results of the Wilcoxon Signed-Ranked Test on effective index

Ranks

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| $F_{i\text{-}ISGA}$ - $F_{i\text{-}OIGA}$ | Negative Ranks | 7[a] | 10.00 | 70.00 |
| | Positive Ranks | 19[b] | 14.79 | 281.00 |
| | Ties | 5[c] | | |
| | Total | 31 | | |

[a] $F_{i\text{-}ISGA} < F_{i\text{-}OIGA}$ [b] $F_{i\text{-}ISGA} > F_{i\text{-}OIGA}$ [c] $F_{i\text{-}ISGA} = F_{i\text{-}OIGA}$

Test Statistics[b]

| | $F_{i\text{-}ISGA}$ - $F_{i\text{-}OIGA}$ |
|---|---|
| Z | -2.686[a] |
| Asymp. Sig. (2-tailed) | .007 |

[a.] Based on negative ranks.
[b.] Wilcoxon Signed Ranks Test

## 6. Concluding Remarks

In this paper, we propose the ISGA model which entrusting more activities of selection operation to IGA users. To verify the proposed model, an OIGA which is proof against fatigue is served as the benchmark model. The results of the case study, designing mineral water bottles, show that there is no significance difference between the proposed model and the benchmark model. It means that the proposed model is proved against fatigue. Actually, most of the subjects finished their design works within 10 generations when using both of the systems.

In the effective side, the proposed model performs significantly better than the benchmark model. It means the propose model performs better than the benchmark model in finding satisfied solution and without suffer from fatigue. Except that we also find that when using the propose ISGA system the performance, efficiency and effectiveness, of the users with knowledge of IGA seems to be better than the novice users

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