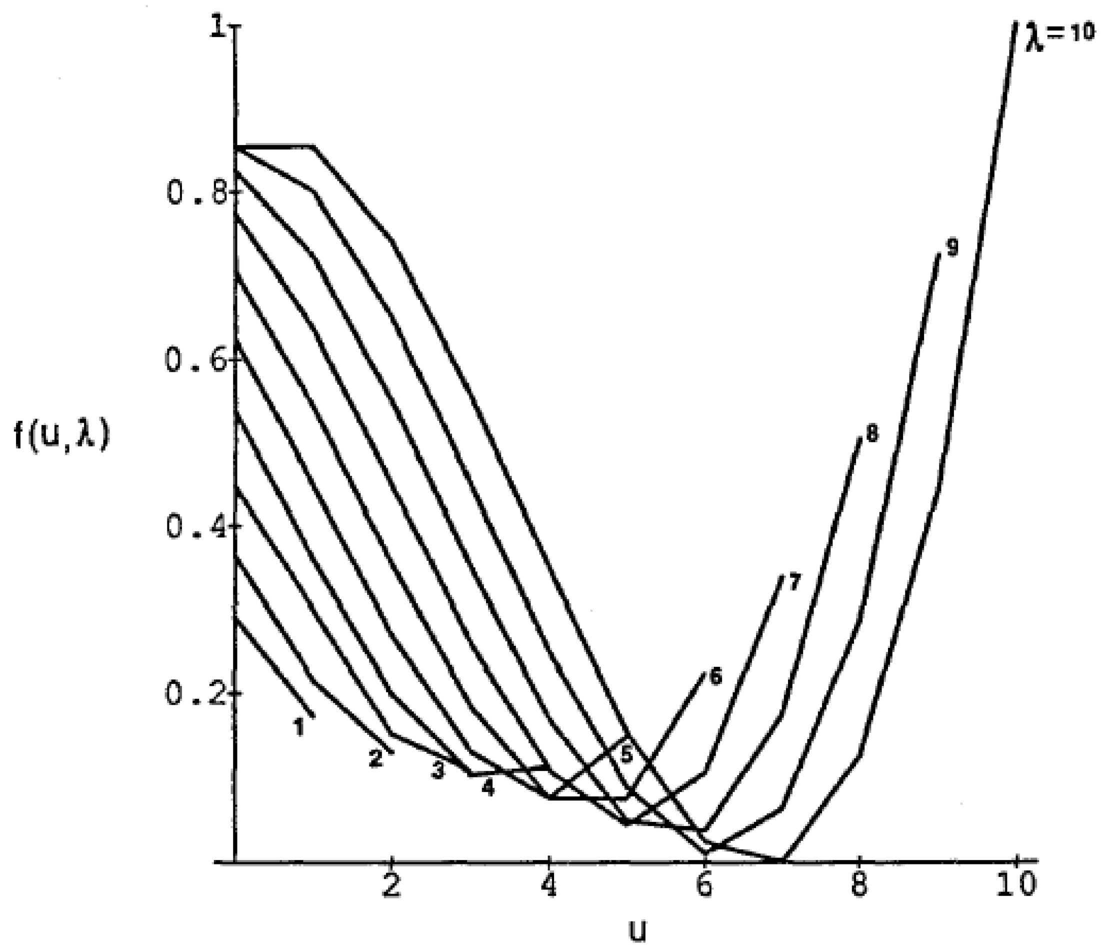
Using Walsh Coefficients to limit the effect of Deceptive Functions on Genetic Algorithms

by Eric Jiang, BSc Computer Science
supervised by Dr. Ilias Kotsireas
Wilfrid Laurier University
23rd April 2018

Abstract

This project takes Walsh Coefficients and applies to them to Genetic Algorithms (GAs) to minimize the impact that deceptive functions have on them.
Deceptive functions are functions that have a tendency to lead GA's toward a suboptimal solution, as shown below[3]



1 Genetic Algorithms and Deceptive Functions

First, a genetic algorithm must be created. In this case, a simple genetic algorithm (SGA) will be used. Then, a deceptive function will be fed into the SGA and the results will be shown and analyzed.

1.1 Creating the SGA

The starting point of this project is the SGA. This SGA will test a population of chromosomes (which are represented by a sequence of binary bits) for fitness and then adapt the population over generations. A random mutation rate will also be added to the algorithm as a way to introduce otherwise unexplored values to the population.

The population is first initialized with random chromosomes filled in.

```
for(i=0; i!=maxpop; i++)
{
   for(j=0; j!=maxstring; j++)
   {
      if (probtype==3){
          pop[i].chrom[j] = rnd(0,7);
      }
      else{
          pop[i].chrom[j] = flip(0.5);
      }
      pop[i].parent1 = -1;
      pop[i].parent2 = -1;
      pop[i].xsite = -1;
      }
   }
}
```

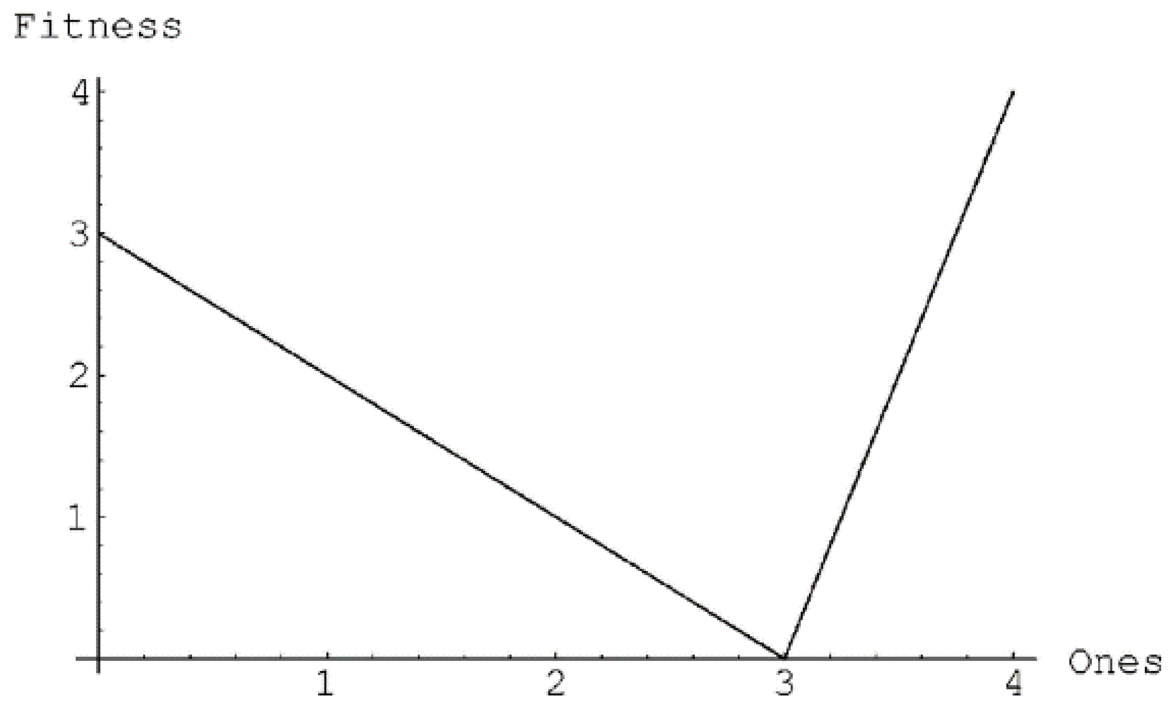
Next, the population is tested for fitness, and the max, min, and average is taken. Then, two mates are selected from the population, based on fitness, and then the next generation is created from these mates. This process is continued for a predefined number of generations.
Now, given certain starting populations, certain evolutions or areas of evolution may be missed and the GA may pigeonhole itself into a certain solution. Thus, an aspect of random mutation is inserted into the algorithm to potentially introduce a more optimal solution. At a predetermined rate, a member of the population will randomly mutate a part of its final chromosome.

1.2 Deceptive Functions

To demonstrate a deceptive function, a simple trap function is used to start. This particular function is one whose global maxima is next to the global minima. This means, that the optimal solution is isolated and it is unlikely the GA will evolve to this optimal solution.

1.2.1 The Basic Deceptive Function

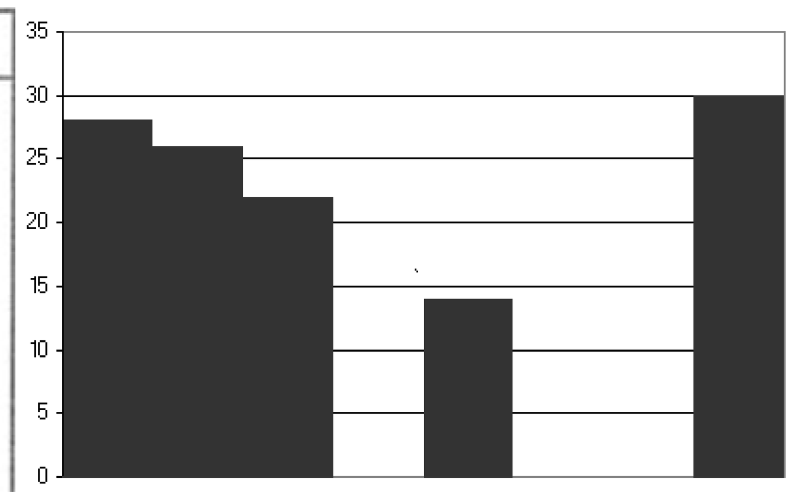
This basic deceptive function will determine fitness based on number of 1's in the chromosome, where higher is better. The trap/deception aspect of this that the chromosome containing only 0's is actually the optimal solution. Clearly, the algorithm would evolve towards the solution containing all 1's, and thus away from the truly optimal solution containing all 0's.



1.2.2 The Deceptive Function to Use

The deceptive function that will be applied in this experiment is a bit more complex than the basic deceptive function. This function from Goldberg's paper[1] uses 3 binary bits as its input and results in:

j	x	w_j	f_j
0	000	15	28
1	001	1	26
2	010	2	22
3	011	3	0
4	100	4	14
5	101	5	0
6	110	6	0
7	111	-8	30



However, with previous knowledge of algorithm itself, it should be noted that 111 is not the optimal solution. This will be demonstrated later.

2 Walsh Functions

Walsh functions are functions that contain a series of pulses between the states -1 and 1 at fixed intervals that can represent any discrete function, such as the ones involving the binary chromosomes.

2.1 Analysis

The concept here is to take the total set, and throughout each generation of the GA, study the near-optimal set (N) and then determine an
extended range (N+) where it is increased by a shift value, denoted *s*.
Then, Walsh coefficients are calculated using:

$$w_j = \frac{1}{2^l} \sum_{x=0}^{2^l-1} f(x)\psi_j(x)$$

Where:

$$\psi_j(y) = \prod_{i=1}^{l} y_i^{j_i}, \quad y_i \in \{-1, 1\}.$$

Finally, as the GA runs, an Analysis of Deception (ANODE) algorithm is performed on the population. ANODE in this case follows a number of steps and yields Walsh coefficients and

j	x	w_j	f_j	$-p_c\frac{\delta(j)}{l-1}$	$\Delta w_j'$	$\Delta f_j'$	f_j'
0	000	15	28	0.0	0.0	-1.5	26.5
1	001	1	26	0.0	0.0	-4.5	21.5
2	010	2	22	0.0	0.0	-8.5	11.5
3	011	3	0	-0.5	-1.5	14.5	14.5
4	100	4	14	0.0	0.0	-1.5	12.5
5	101	5	0	-1.0	-5.0	7.5	7.5
6	110	6	0	-0.5	-3.0	11.5	11.5
7	111	-8	30	-1.0	8.0	-17.5	11.5

It is easy to see that there has been a significant change between the adjusted fitness values and the original fitness values. Most importantly, the value 000 has jumped ahead of the former global optima of 111 and is now the clear optimal solution.

Conclusion

This project has looked into a key problem with GAs and offered a solution to minimize these concerns.
Problem:
Deceptive Functions will lead GAs to suboptimal solutions without their ability to identify this.
Solution:
Apply Walsh transformations and ANODE to identify adjusted fitness values and identify true optimal solutions within deceptive functions.

References

[1] D.E. Goldberg, *Genetic Algorithms and Walsh Functions: Part I, A Gentle Introduction*
[2] D.E. Goldberg, *Genetic Algorithms and Walsh Functions: Part II, Deception and Its Analysis*
[3] D.E. Goldberg, *Construction of high-order deceptive functions using low-order Walsh coefficients.*