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Comparative Analysis of Genetic Crossover Operators in Knapsack Problem

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ABSTRACT: The Genetic Algorithm (GA) is an evolutionary algorithms and technique based on natural selections of individuals called chromosomes. In this paper, a method for solving Knapsack problem via GA (Genetic Algorithm) is presented. We compared six different crossovers: Crossover single point, Crossover Two point, Crossover Scattered, Crossover Heuristic, Crossover Arithmetic and Crossover Intermediate. Three different dimensions of knapsack problems are used to test the convergence of knapsack problem. Based on our experimental results, two point crossovers (TP) emerged the best result to solve knapsack problem. ©JASEM
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The knapsack problem (KP) has been used in many real life problem such as investment decision making (Peeta, 2010), project selection (Mavrotas, 2008) and (Hartvigsen, 2006) applied it in vote-trading problem. The Knapsack problem can be defined as a set of items, each with a weight(w) and a profit(p), determine the number(n) of each item to include in a collection(j) so that the total weight is less than or equal to a given limit and the total profit(p) is as large as possible. Mathematically it can be represented as follows:

$$\max_x \sum_{j=1}^{n} p_j x_j \qquad (1)$$
$$s.t\ \sum_{j=1}^{n} w_j x_j \le C \qquad (2)$$
$$x_j = 0\ or\ 1, j = 1, \dots, n \qquad (3)$$

The difficulty of the problem is caused by the integrality requirement of equation (3).
Recently, different algorithms have been developed to solve optimization problem. (Li and Li, 2009) proposed a binary particle swarm optimization to solve knapsack problem. (Shi, 2006) proposed an improved ant colony algorithm to solve knapsack problem. GA is the most popular among them; it was due to the meta-heuristic nature of it.

(Huseyin *et al.* in 2015) proposed a chaotic crossover operator on Genetic Algorithm. He applied it into arithmetic crossover. In his paper, chaotic crossover yielded better results. (Kellegoz *et al.*, 2008) used GA for solving job scheduling problem and compare their performance of proposed algorithm with different crossover operators. A paper titled "performace comparison of genetic algorithms crossover operators on university course timetabling problem" by (Chinnasri, 2012) used GA with three different crossover operators on web classifier.

In this study, the role of different crossover operators (single point, two point, arithmetic, heuristic, intermediate and scattered) on Knapsack problem is investigated.

MATERIALS AND METHODS

In GA Crossover operators is used to divide a pair of selected chromosomes into two or more parts. It consists of combining the chromosomes of two parents to produce a new offspring (child). The reason behind using crossover is that the new chromosomes being formed (child) may be better than both of the parents, if it takes the best chromosomes from both parents. For the purpose of this work, the following Crossover will be use:
Single point Crossover (SP)

A single point crossover involves the two mating chromosomes (parent) are cut once at corresponding points and the selection after the cuts exchanged. Fig. 1 below shows the single point crossover (SP). The shaded area is the crossover point.

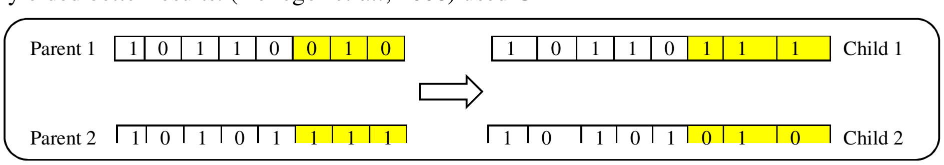

Fig 1: Single point crossover

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Two point crossovers (TP): Two point crossover often involving more than one cut point. The two mating chromosomes (parent) may cut in more than point end and the selection after the cut may exchange. Fig. 2 below show the two point crossover. The shaded area indicated the crossover point.

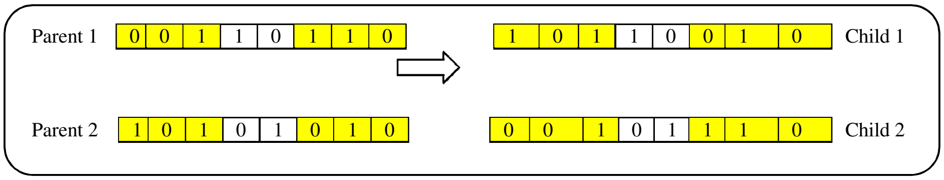

Fig 2: Two point crossover

Intermediate Crossover (IT): Intermediate creates offsprings (child) by a weighted average of the two mating parents. If parent 1 and parent 2 are the two mating chromosomes and Ratio is in the range [0, 1], then the returns the child (*offspring*). The equation is given below:

$offspring(child) = Parent\ 1 + rand \times Ratio \times (Parent2 - Parent\ 1)$ (4)

Heuristic Crossover (HE)

Heuristic crossover (HE), produces an offspring of the two parents which lies a small distance away from the parent with better fitness value in the direction away from the parent with the worse fitness value. $offspring(child) = Parent2 + Ratio \times (Parent\ 1 - Parent\ 2)$ (5) Where defaults value of $Ratio$ is 1.2

Arithmetic Crossover (AM): In Arithmetic crossover (AC), it produces an offspring (child) that are weighted arithmetic mean of two parents, α is random value between [0,1]. If parent 1 and parent 2 are the Parents, and parent 1 has the better fitness value, the function returns a child (offspring) $offspring = \alpha \times Parent\ 1 + (1 - \alpha) \times Parent2$ (6)

Crossover Scattered (SC): Crossover scattered (SC) creates a random binary chromosomes and selects the genes where the chromosome is 1 from the first parent, and the genes where the chromosome is 0 from the second parent and later combines the genes to form a child. Figure 3 below shows the scattered crossover.

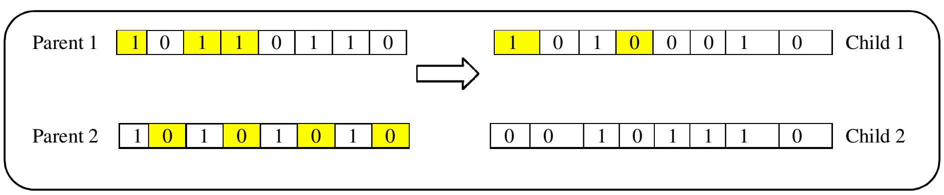

Fig 3: Crossover Scattered

RESULTS AND DISCUSION

In this study, we shall be using three different dimensions (5, 10, 15) of Knapsack problem that were used by (kaushik Kumar, 2014). All parameters used in this study are given Table 1 below:

Table I: Parameters of Genetic Algorithm

Parameter	Value
Population Size	200
Crossover Fraction	0.9
Generation	200
Elite count	3
Selection Function	Roulette Wheel
Crossover Function	Crossover single point
	Crossover two point
	Crossover intermediate
	Crossover Scattered
	Crossover Arithmetic
	Crossover heuristic
Mutation Function	Mutation Adaptive feasible

Genetic Algorithm was run 20 times for each of the problem and on six different crossovers used in this paper. Table II shows the comparative results of the entire six crossovers.

From Table II below heuristic crossover (HE), arithmetic crossover (AM) and intermediate crossover always stuck on local maximums in most cases especially in all the three dimensions used in this paper. Moreover, two point crossover, single point crossover and scattered crossover never stuck on local maximums and they all reach the global maximum point in all the three dimensions. Overall, two point crossover (TP) ranks the best among all other crossover in terms of the averages of mean and standard deviation, followed by scattered (SC) and single point (SP).

Table 2: Results of SP, TP, HE,SC, IT and AM

Dimension(*d*)	SP Mean (std)	TP Mean (std)	AM Mean (std)	IT Mean (std)	SC Mean (std)	HE Mean (std)
5	129.48 (0.3723)	129.733 (0.2316)	3.49276 (1.4227)	6.8932 (3.8182)	129.666 (0.3644)	117.8912 (8.8273)
10	48.3360 (3.44651)	48.8 (2.0011)	6.396 (11.2968)	12.74716 (5.8230)	49.725 (2.9512)	32.9984 (11.1097)
15	472.73664 (5.5738)	469.8762 (3.4510)	29.01758 (33.5865)	92.01656 (28.0432)	471.71598 (5.5602)	89.49522 (129.4170)

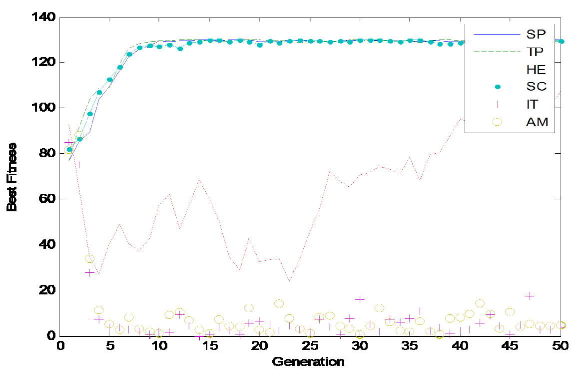

Fig 4: SP, TP, HE, SC, IT and AM *d* = 5

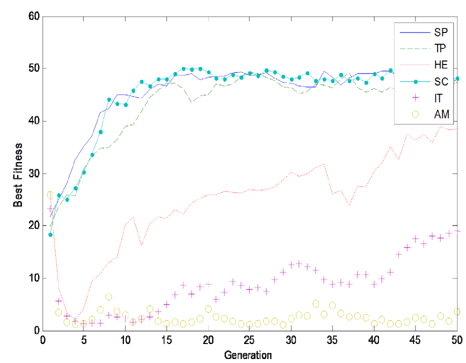

Fig 5: SP, TP, HE, SC, IT and AM *d* = 10

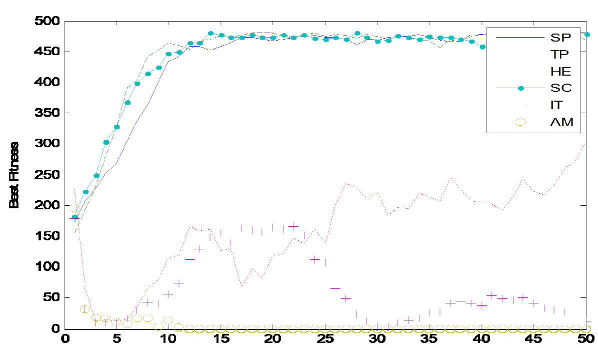

Fig 6: SP, TP, HE, SC, IT and AM *d* =15

The convergence process of two point crossover (TP), Single point crossover (SP), Scaterred crossover (SC), Arithmetic crossover (AM), Heuristic crossover (HE) and Intermediate crossover (IT) are shown above in Fig. 4-6 which illustrates the relationship between fitness and generation. As can be seen, the global optimum solution was achieved for two point (TP), Single Point (SP) and Scattered (SC) while Arithmetic (AM), Heuristic (HE) and Intermediate (IT) failed to achieve the same result.

*Conclusion***:** In this paper, we have presented Two point crossover (TP), Single point crossover (SP), Scaterred crossover (SC), Arithmetic crossover (AM), Heuristic crossover (HE) and Intermediate crossover (IT) to solve Knapsack problem. Based on our experimental results and analysis, Two point crossover (TP) emerged the best result compared to SP, SC, AM, HE and IT. The results indicated that two point crossover (TP) could be employed to solve Knapsack problem.

Furthermore, three different dimensions of knapsack problems are used to test the convergence of knapsack problem and the result shows that two point crossover (TP) is very effective to solve small and large sized knapsack problems Two point crossover (TP) could be recommended as a profitable solution method for
Knapsack problems.

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