limitations that are often associated with redundancy found in the classical genetic algorithm scheme. Figure 1 illustrates the group representation scheme for the example above, which yields chromosome [A B C]

Items :	1,8	2,3,6	4,5,7
Groups:	A	B	C

Figure 1. Group encoding scheme for chromosome [A B C]

Having defined the group encoding scheme, the GGA procedure is iterated through a loop consisting of group crossover, mutation, and inversion operators.

4.2 Group Crossover

The crossover operator is the main procedure whose function is to facilitate guided information exchange between selected chromosomes. In so doing, its end goal is to generate new chromosomes while avoiding adverse disruptions of the crucial group structure of the selected chromosomes. We further explain the crossover operator based on an example of two parent chromosomes P1 = [A B C], and P2 = [D E F G]:

1. Randomly select two cross-points in any two randomly selected chromosomes, and select a crossing section from first parent, P1.
2. Inject the crossing section from first parent P1 into the second parent P2, which yields a new offspring likely to contain repeated item (or doubles).
3. Empty the groups with doubles.
4. Eliminate those groups that contain doubles and empty groups.
5. Re-insert missing items using problem-specific heuristic.
6. Interchange the roles of P and P2 and repeat steps 2 to 4
7. Repeat the process until the required number of offspring is obtained.

From the above illustration, we note that the crossover operation must be repeated until the desired population of new offspring is generated. To illustrate further, consider two randomly selected parent chromosomes, (i) chromosome [A B C], consisting of groups of items {1,8}, {2,3,6}, {4,5,7}, and (ii) chromosome [D E F G] comprising groups of items {2,4}, {1,7}, {3,8}, {5,6}. The crossover operation for the two chromosomes is presented in the figure (Fig. 2). By the group crossover operation, we obtain two final offspring, namely, O1 = [D A G] and O2 = [E F H I], as shown in Figure 2.

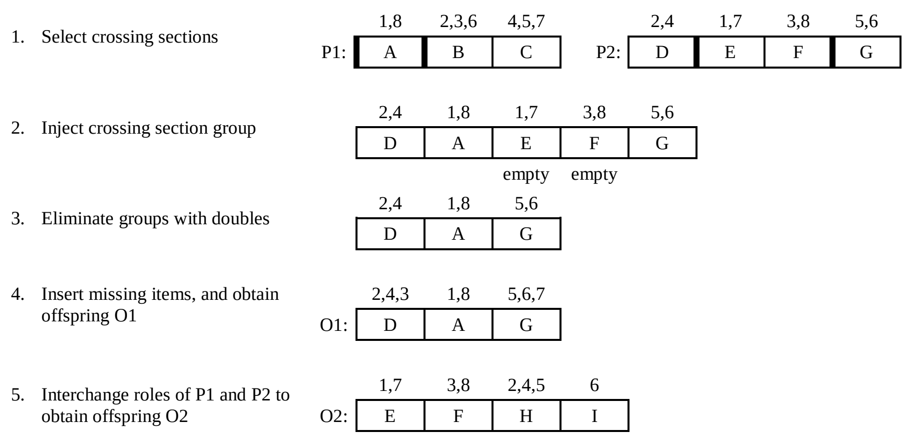

Fig. 2. An illustration of the group crossover operation

4.3 Group Mutation

As with the crossover operator, the group mutation should work with groups, and not individual items (Falkenauer, 1994; Mutingi and Mbohwa, 2016). There are three possible procedures for executing group mutation: (i) by creating new groups, (ii) by eliminating some selected groups, and (iii) by shuffling a few selected items among the groups. In practice, computational implementation depends on the problem domain that is to be solved. Domain specific constructive heuristics may also be utilized.

4.4 Inversion

The purpose of this operator is to facilitate transmission of good schemata from parents to offspring in order to ensure increased rate of sampling of better performing schemata (Mutingi and Mbohwa, 2016). The mutation operator works by overturning the order of groups between two points in a randomly selected chromosome. To illustrate, assume that we are given chromosome [A B C D] and two points are selected as shown below. Then the chromosome,

[A |B C D|]

could be inverted to:

[A D C B],

Assuming that it is known that it is more desirable to have A and D closer together, then this increases the probability of transmitting both groups (genes) A and D together into the next generation when the next crossover is performed.

5. Concluding Remarks and Further Research

The GGA approach has is the only evolutionary algorithm that has been refined to especially model grouping problems by taking advantage of the grouping structure of the problems. The algorithm can be adapted to a wide range of grouping problems (Mutingi and Mbohwa, 2016). In this paper, it was observed that the ABC inventory classification problem is a grouping problem whose grouping structure can be modelled using grouping algorithm approaches. As a result, we proposed and presented a GGA methodology for addressing the inventory classification problem with a wide range of possible groups, and from a multi-criteria perspective. In summary, the proposed approach has the following advantages:

1. GGA approach uses an efficient group encoding scheme which avoids time-consuming redundancies in the chromosomes, which helps to improve the efficiency of the algorithm;
2. GGA avoids adverse disruption of essential information encoded in the groups of each chromosome, thereby improving the effectiveness of the algorithm;
3. GGA can easily model and optimize the number of groups by searching over a wide range of possible group sizes, which gives the decision maker a wider search than is possible with previous approaches; and,
4. GGA can model inventory classification problems based on multiple criteria, including, number of groups; assignment of items, service level for each group; and budget allocation to groups of items.

Further research is envisaged to involve numerical experimentation based on benchmarks as well as case studies to be gathered from literature. Comparative analysis will be beneficial in proving the efficiency of the proposed GGA approach to inventory classification problem.

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