A shuffled complex evolution algorithm for the multidimensional knapsack problem

CIARP 2015
XX Iberoamerican Congress on Pattern Recognition

Marcos Baroni & Flávio Varejão
Universidade Federal do Esprito Santo - Departamento de Informática
marcos.baroni@aluno.ufes.br

Abstract

This work addresses the application of a population based evolutionary algorithm called shuffled complex evolution (SCE) in the multidimensional knapsack problem. The SCE regards a natural evolution happening simultaneously in independent communities. The performance of the SCE algorithm is verified through computational experiments using well-known problems from literature and randomly generated problems as well. The SCE proved to be very effective in finding good solutions demanding a very small amount of processing time.

Keywords: Multidimensional knapsack problem, Meta-heuristics, Artificial Intelligence

Introduction

The multidimensional knapsack problem (MKP) is a strongly NP-hard combinatorial optimization problem which can be viewed as a resource allocation problem and defined as follows:

$$\begin{aligned} \text{maximize} & \sum_{j=1}^{n} p_j x_j \\ \text{subject to} & \sum_{j=1}^{n} w_{ij} x_j \leqslant c_i \quad i \in \{1,\dots,m\} \\ & x_j \in \{0,1\}, \quad j \in \{1,\dots,n\}. \end{aligned}$$

The multidimensional knapsack problem can be applied on budget planning scenarios and project selections [5], cutting stock problems [4], loading problems [6], allocation of processors and databases in distributed computer programs [3].

The problem is a generalization of the well-known knapsack problem (KP) in which $m = 1$. However it is a NP-hard problem significantly harder to solve in practice than the KP. Due its simple definition but challenging difficulty of solving, the MKP is often used to to verify the efficiency of novel metaheuristics. A good review for the MKP is given by [2].

In this paper we address the application of a metaheuristic called shuffled complex evolution (SCE) to the multidimensional knapsack problem. The SCE is a metaheuristic, proposed by Duan in [1], which combines the ideas of a controlled random search with the concepts of competitive evolution and shuffling.

The SCE for the MKP

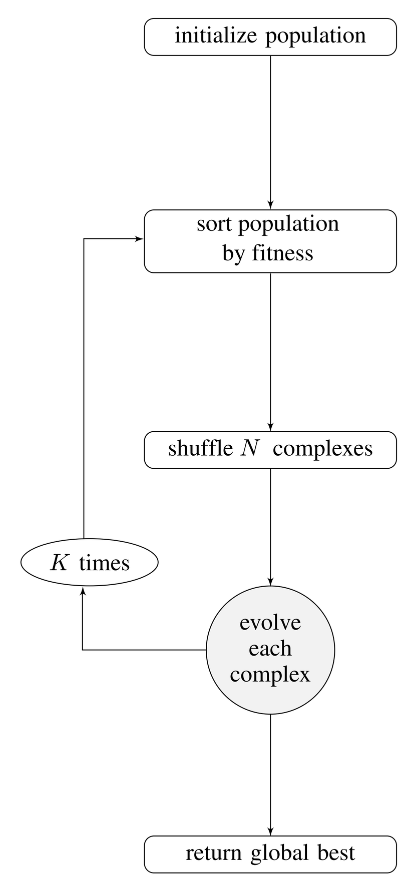

Figure 1: figure caption

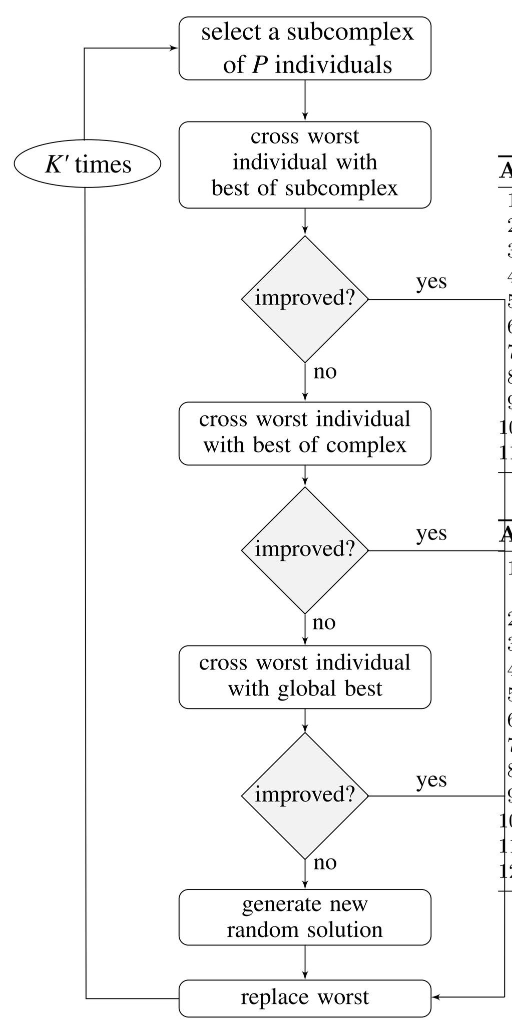

Figure 2: figure caption

Algorithm 1 Generation of a new random solution.

```
procedure NEW RANDOM SOLUTION
    v ← shuffle(1, 2, ..., n)
    s ← ∅                                  ▷ empty solution
    for i ← 1 : n do
        s ← s ∪ {v_i}                      ▷ adding item
        if s is not feasible then          ▷ checking feasibility
            s ← s − {v_i}
        end if
    end for
    return s
end procedure
```

Algorithm 2 Crossing procedure used on SCE algorithm.

```
procedure CROSSING(x^w : worst individual,
        x^b : better individual, c : n. of genes to be carried)
    v ← shuffle(1, 2, ..., n)
    for i ← 1 : c do
        j ← v_i
        x^w_j ← x^b_j                      ▷ gene carriage
    end for
    if s^w is not feasible then
        repair s^w
    end if
    update s^w fitness
    return s^w
end procedure
```

Figure 3: figure caption

Computational experiments

	Value	Description
N	20	# of complexes
M	20	# of individuals in each complex
P	5	# of individuals in each subcomplex
K	300	# of algorithm iterations
K'	20	# of iterations of evolving process
c	$n/5$	# of genes carried from parent in crossing

Table 1: Parameters used in SCE algorithm.

n	m	SCE t (s)	gap (%)
100	5	0.81	97.6
	10	0.86	97.0
	30	1.02	96.7
	average gap		**97.1**
250	5	1.75	95.3
	10	1.83	95.0
	30	2.24	94.7
	average gap		**95.0**
500	5	3.23	93.7
	10	3.40	93.7
	30	3.91	93.3
	average gap		**93.6**

Table 2: SCE performance on Chu-Beasley problems.

n	m	α	SCIP t (s)	SCE t (s)	gap (%)
500	10	0.25	278.85	2.23	96.1
		0.50	177.32	2.14	98.4
		0.75	8.47	1.87	99.6
				average gap	**98.0**
	20	0.25	284.11	2.30	96.7
		0.50	275.68	2.16	98.6
		0.75	33.67	1.90	99.7
				average gap	**98.3**
	30	0.25	283.78	2.50	96.9
		0.50	283.54	2.32	98.7
		0.75	71.66	1.96	99.7
				average gap	**98.3**

Table 3: SCE performance on random generated problems.

Conclusions

In this work we addressed the application of the shuffled complex evolution (SCE) to the multidimensional knapsack problem and investigated it performance through several computational experiments. The SCE algorithm, which combines the ideas of a controlled random search with the concepts of competitive evolution proved to be very effective in finding good solution for hard instances of MKP, demanding a very small amount of processing time to reach high quality solutions for MKP.

Future remarks

- Application of problem reduction procedures for the MKP;
- Investigation of different crossing procedures;
- Use of local search in the process of evolving complexes.

References

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Acknowledgements

Research supported by Fundação de Amparo à Pesquisa do Espírito Santo.