SOLVING MULTIDIMENSIONAL KNAPSACK PROBLEM BY USING SIMULATED ANNEALING WITH DIFFERENT RESTART TEMPERATURE

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INTRODUCTION

Multi-Dimensional knapsack problem (MKP) is a continuation of a basic concept for 0-1 knapsack problem (KP). 0-1 Knapsack is a problem where a subset of n item packed into the knapsack of capacity where the objective is to minimize the total profit of the selected item without going over the knapsack capacity.

MATHEMATICAL MODEL

Maximize,

$$Z = \sum_{j=1}^{n} p_j x_j \tag{1}$$

Subject to,

$$\sum_{j=1}^{n} w_{ij} x_j \leq c_i , \qquad i = 1, \dots , m \tag{2}$$

$$x_j \,\epsilon\, \{0, 1\} , \qquad j = 1, \dots , n \tag{3}$$

z = total profit
Pj = profit associated with item j
xj = decision variable with item j
wij = weight of resource i for item j
ci = capacity of the ith knapsack
n = number of items
m = number of knapsacks

Figure 1: Mathematical Model for MKP, Varnamkhasti (2012)

PROBLEM STATEMENT

Metaheuristic is found to be a reasonable method to solve MKP, such as SA. SA is one good metaheuristic method for solving MKP which can handle a large and unpredictable data. Nevertheless, SA is found to always possible to become stuck at local minima. Previous studies shows that a cooling schedule of SA plays important rules to reduce SA from being stuck at local minima. One of the approaches is to restart the temperature adaptively. However, previous studies are lacking in discussing on how to increase the temperature. Hence, this study proposed SA with various restart temperature for solving MKP.

RESEARCH OBJECTIVE

1. To identify the suitable restart temperature for SA in solving MKP
2. To evaluate the performance of different restart in SA to solving MKP

SIGNIFICANT OF STUDY

This study present a better algorithms for solving MKP and other real application.

LITERATURE REVIEW

Based on previous studies, there are various mechanism that use metaheuristics to solve MKP such as SA (*Fubin and Rui, 2007*), GA *(Hill and Hiremath, 2005*), hybrid approach (Hanafi et al, 2010). *Zhou, et al. (2008*) that depicts chaotic neural network combined with heuristic strategy. *Mian (2012)* present how to solve MKP by using a genetic algorithm and constraint handling technique by proposing three genetic algorithm. Besides that, some review on restart temperature for other domain,

Author	Domain	Technique
Salwani Abdullah,et al. (2011)	Rough set attribute reduction	By using linearly reduced
Michel et al. (2006)	Traveling Tournament Problem	By increasing the temperature to twice when the best solution was found
Warren et al. (2018)	Move acceptance in local search metaheuristic for cross- domain search	By periodically increasing the temperature of the system

Table 1: Review on Restart Temperature for Other Domain

METHODOLOGY

RESEARCH FRAMEWORK

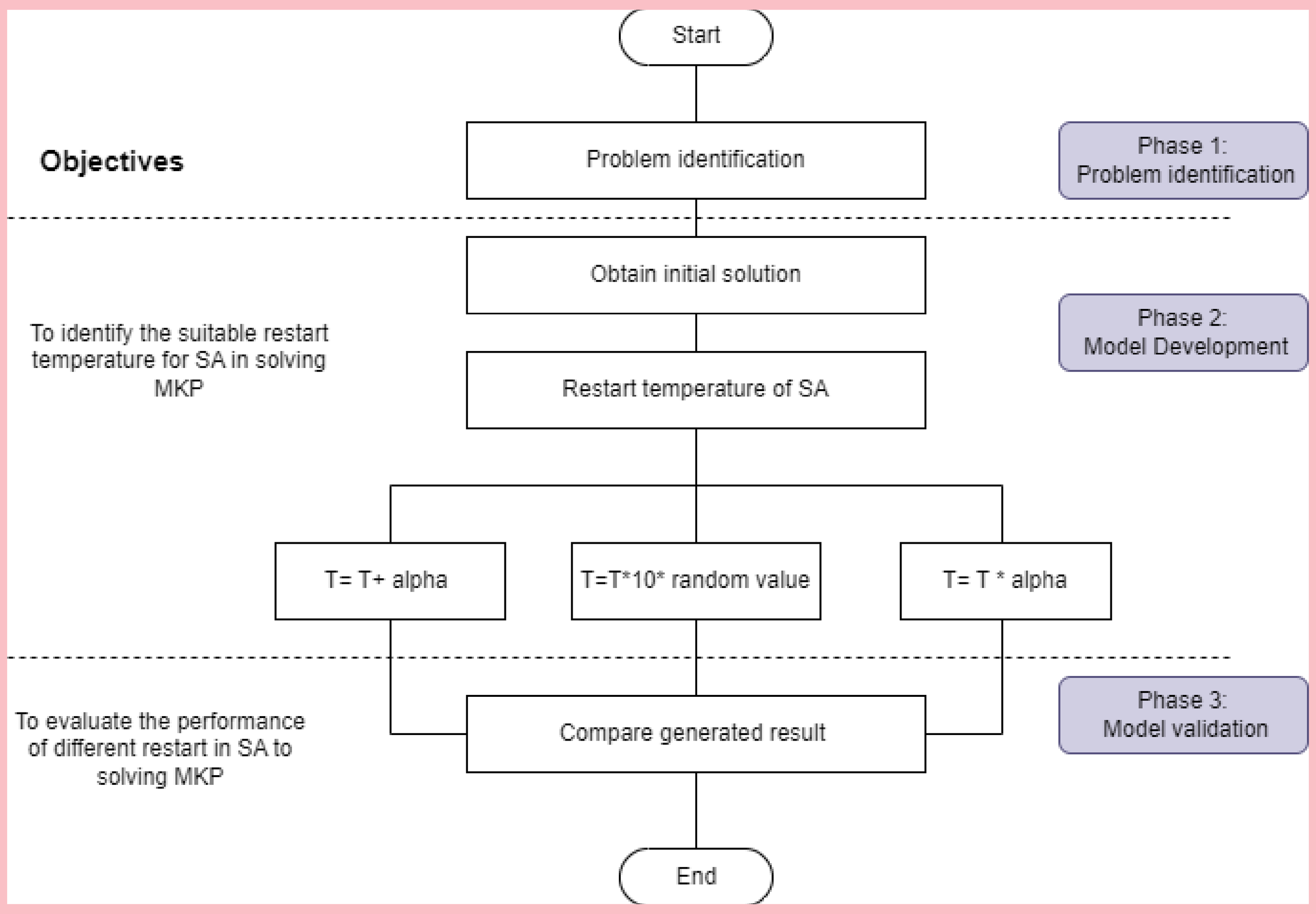

Figure 2: Research Framework

MODEL DEVELOPMENT

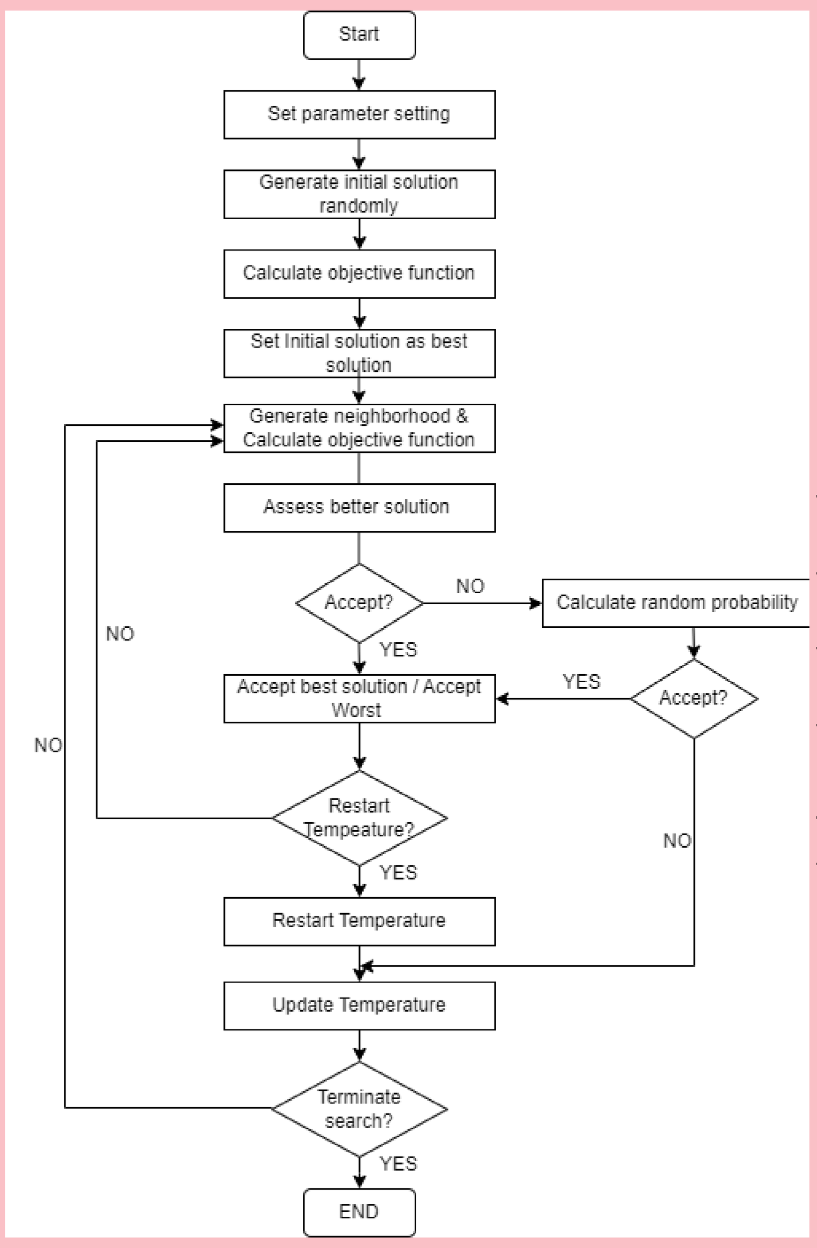

Figure 3: Flow Chart for SA Restart Temperature

PARAMETER SETTING

Parameters	Value
1. Starting Temperature	$T_0 = 10$
2. Temperature Decrement	$T_i+1 = 0.9\ T_i$
3. Ending Temperature	0.1
4. Number of Iterations for each Temperature	Based on the problem size
5. Number of runs	Each dataset processes 10 runs.

Table 2: Parameter Settings

RESULT & ANALYSIS

Comparison between the Best Solution of General SA and SA Restart Temperature

Dataset	General SA	T=T+alpha			T=T*alpha			T=T*10*random value
		α=10	α=50	α=100	α=2	α=4	α=5	
		Best			Best			Best
1	19833	21741	21694	21417	21531	21237	21724	21830
2	21165	21130	21706	21422	21342	21895	22125	21708
3	20404	20282	20684	20984	21359	21572	20877	20430
4	20629	21553	21039	21530	21120	2116	21092	21704
5	20804	21229	22124	21298	21807	21689	21568	21675
6	21772	21322	21724	21747	22171	21497	21696	22102
7	21690	23342	22410	22990	22695	23132	23379	22757
8	19500	20319	20409	20649	21105	20375	20543	20787
9	18916	21517	21939	22342	21053	21412	21663	20944
10	20522	21225	21796	21354	21200	21329	21597	21404

Table 3: Comparison between the Best Solution of General SA and SA Restart Temperature

- Based on the table 2, we found that the Best solution among 10 dataset with three different temperature settings is **geometric restart temperature (GRT)** .
- **The number of the best solution** for GRT is higher than T+alpha and random number.
- **The higher value of alpha**, the higher chances of best solution will found.
- The higher the value of alpha the longer it will take to decrement the temperature.

Comparison between the Standard Deviation of General SA and SA Restart Temperature

Dataset	St dev for General SA	T=T+alpha			T=T*alpha			T=T*10*random value
		α=10	α=50	α=100	α=2	α=4	α=5	
		St dev	St dev	St dev	St dev	St dev	St dev	St dev
1	509.26	414.25	403.16	270.61	467.22	414.97	388.15	364.76
2	423.30	372.69	562.85	435.95	453.93	377.72	509.88	425.85
3	553.97	309.22	472.57	583.00	590.65	636.28	350.99	372.47
4	420.00	475.39	373.81	384.88	481.03	341.78	260.24	449.45
5	475.21	314.65	783.52	253.05	533.70	477.90	412.89	349.84
6	608.41	463.86	402.63	445.38	558.75	343.34	475.39	519.01
7	206.54	744.63	461.27	461.21	368.52	512.90	529.21	379.19
8	343.04	351.50	346.85	352.34	561.98	262.23	1111.41	187.36
9	527.53	586.70	478.09	749.83	426.20	379.70	426.42	320.78
10	669.22	317.87	552.87	220.65	512.67	570.93	315.20	339.00

Table 4: Comparison between the Standard Deviation of General SA and SA Restart Temperature

- Based on the result of standard deviation, we found that the **highest number** of standard deviation among 10 dataset with three different temperature settings is Linear increment.
- **In T=T+alpha** the lowest standard deviation is 220.65 at alpha=100 which is dataset 10.
- The smaller result STD, it shows that this dataset is a good.
- Based on comparison between STD general SA and SA restart temperature, we found that SA restart temperature is beter than general SA.

Acceptance value through the iterations

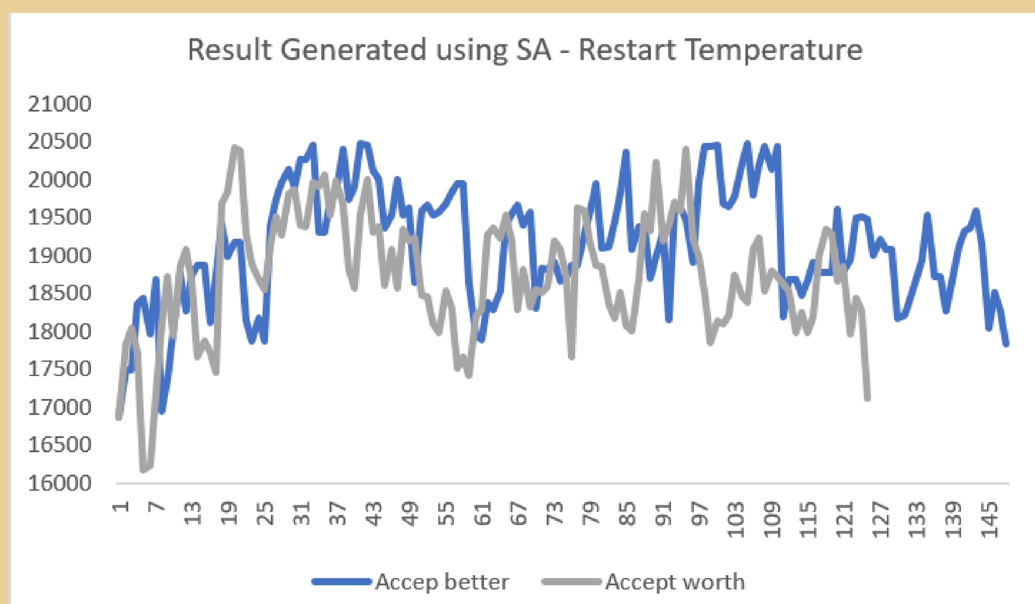

Figure 4:Result generated using SA- Restart Temperature

Figure 4 shows a fluctuated graph of the acceptance value through the iteration

References

- Hill, R.R. & Hiremath, C.S. (2007). Generation Method for Mutidimensional Knapsack Problem and their Implications. https://doi.org/10.1186/s12888-017-1275-5
- Mian, Z. (2012). Meta-heuristics for Multidimensional Knapsack Problems. IPCSIT vol.39. http://www.ipcsit.com/vol39/007-D00039.pdf
- Fubin.Q., & Rui.D. (2007). Simulated Annealing for the 0/1 Multidimensional Knapsack Problem. Global Science Press, 16(4). https://global-sci.org/intro/article_detail/nm/8060.html

CONCLUSION

- The result has successful produce 0-1 solution which can maximize the total profit while considering multi-dimensional of capacity constraints for MKP.
- The risk of SA being stuck in local optima is reduced using SA with different restart temperature.
- For future research, this problems can be solve using hybrid SA - TS.