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A GENETIC ALGORITHM METAHEURISTIC FOR THE WEAPON-TARGET BASED MEDIA ALLOCATION PROBLEM

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Abstract

This effort is to solve the media allocation model using metaheuristic genetic algorithm. The NP-complete model which is an integer nonlinear programming is originated from the weapon-target assignment problem of military operations research. We solve the hypothetical example is previously given and solved by MS Excel's Solver using genetic algorithm in this paper. We obtain better solutions than found in the previous published study.

Keywords: Advertising campaign, integer nonlinear programming, genetic algorithm, metaheuristics

Jel Code: C02, M31, M37

SİLAH-HEDEF TEMELLİ MEDYA PLANLAMA PROBLEMİ İÇİN GENETİK ALGORİTMA METASEZGİSELİ

Özet

Çalışmanın amacı medya planlama problemini genetik algoritma metasezgiseli ile çözmektir. Problem askeri yöneylem araştırması alanındaki silah-hedef atama probleminden modifiye edilerek, NP-complete model olan tamsayılı doğrusal olmayan programlama problemi olarak modellenmiştir. Çalışmada, daha önce MS Excel Çözücü ile çözülen bir hipotetik problem genetik algoritma kullanılarak çözülmüştür. Daha önce raporlanan sonuçtan daha iyi bir sonuç bulunmuştur.

Anahtar Kelimeler : Reklam kampanyası, tamsayılı doğrusal olmayan programlama, genetik algoritma, metasezgiseller

Jel Kodu : C02, M31, M37

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1. INTRODUCTION

In various media for advertising, media planning is the process of selecting time and space, in order to maximize the effectiveness of advertising effort (Hairong, 2005). The best media plans provide the target audience with an optimum level of coverage and opportunities to see the campaign (Fox Media Company, 2005). Media allocation is to apportion the information to appropriate media vehicles and in determining the number of ads in each vehicle (Locander, Scamell, Sparkman and Burton, 1978). An advertising campaign should be more than just the sum of its parts (Fox Media Company, 2005). A synergistic media mix should be obtained and implemented. One of the most important issues in media allocation is how to allocate the media budget; that is, making decisions in which markets to advertise and how much to spend in each of these markets in order to match media audiences with the target audience (Hairong, 2005). In this study, we propose a metaheuristic solution technique based on genetic algorithm for the media allocation model developed by the second author Çetin and Esen (2006).

2. THE MODEL

In Çetin and Esen (2006), the authors employed the weapon-target allocation model which in the class of NP-complete models, for developing the media allocation model. The development of the model and the data of the hypothetical problem are quoted from Çetin and Esen (2006) as follows: By an analogy that the weapons can be determined as media vehicles to be advertised when the military targets as target audiences (segments) to be planned to reach. In that study, TV, radio, Internet, newspaper, billboard, printings, e-mail and etc. are given as media vehicles. People exposed by media vehicles in different times of the day are given as target audiences. The number of weapons (x_{ij}) is determined as the number of ads.

The number of ads (frequency) refers to the number of times within a given period of time an audience is exposed to a media schedule. Effective frequency is defined as the level of frequency that is essential to achieve the desired communication goals of marketing strategy (Hairong, 2005).

The mathematical programming model is as follows under the assumption that the target audience is constant to be exposed by such media vehicles (as in military targets) in a given time period.

Let $i = 1, 2, .., t, .., r, .., w, .., n, .., W$ be the number of kinds of advertisements,

w be the number of renewable (can be updated during the day) media type,

t be the number of TV appropriate to be advertised,

$r - t$ be the number of radio appropriate to be advertised,

$w - r$ be the number of renewable media types other than TV and radio (such as Internet),

$n - w$ be the number of newspaper appropriate to be advertised,

$W - w$ be the number of unrenewable media type,

$W - n$ be the number of press (unrenewable) media type other than newspaper (such as billboards, printing etc.),

$j = 1,2,...,T$ be the number of segments,

W_i be the number of advertisements type *i* available,

T_j be the minimum number of ads required for target audience *j*,

U_j be the relative segment weights,

p_{ij} be the probability of reaching the target audience *j* by a single ad type *i*,

c_{ij} be the unit variable cost of an ad *i* to the target audience *j*,

x_{ij} be the number of advertisements of type *i* assigned to target audience *j*,

B be the total advertising campaign budget,

ρ_1 be the upper limit for percentage of total budget invested to TV,

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ρ_2 be the upper limit for percentage of total budget invested to radio,

ρ_3 be the upper limit for percentage of total budget invested to newspaper.

The objective is to maximize the total percentage (probability) of reaching (exposure) the target audiences,

$$\max \sum_{j=1}^{T} U_j \left(1 - \prod_{i=1}^{W} (1 - p_{ij})^{x_{ij}} \right) \tag{1}$$

Total assignment cost must not exceed the total ad campaign budget. The expression enclosed in parenthesis denotes the sum of costs of each media vehicle,

$$\sum_{j=1}^{T} \left(\sum_{i=1}^{w} c_{ij} x_{ij} + \sum_{i=w+1}^{W} \frac{1}{T} c_{ij} x_{ij} \right) \le B \tag{2}$$

The total budget allocation to TV, radio and newspapers is restricted by desired proportions respectively,

$$\sum_{j=1}^{T} \sum_{i=1}^{t} c_{ij} x_{ij} \le B\rho_1 \tag{3}$$

$$\sum_{j=1}^{T} \sum_{i=t+1}^{r} c_{ij} x_{ij} \le B\rho_2 \tag{4}$$

$$\sum_{j=1}^{T} \sum_{i=w+1}^{n} \frac{1}{T} c_{ij} x_{ij} \le B\rho_3 \tag{5}$$

There are specific numbers of advertisements available for different advertisement vehicles,

$$\sum_{j=1}^{T} x_{ij} \le W_i \tag{6}$$

where $\forall i = w+1,...,W,\ W_i = Tk$ and In fact, Tk refers to k ads for those due to the stability nature of press media during the day.

Each target audience requires at least some number of advertisements, due to the fact that there is a threshold (effective frequency) for a media vehicle, which the total volume of this medium exceeds. The probability of arising the persons intention to buy the product or service under the influence of this kind of advertisements does not increase after this point (Belenky and Nistraman Consulting, 2001). We take the limits of each media vehicle as a whole. The model imposes the assignment to be as close as possible to the lower bounds and thus,

$$\sum_{i=1}^{W} x_{ij} \ge T_j \tag{7}$$

For press media vehicles, it is compulsory to be the same advertisement number (weapon) through different target audiences,

$\forall i = w+1,...,W,\ x_{ij} = x_{i(j+1)}, \forall j = 1,2,...,T-1,$

Finally, non-negativity and integer constraints complete the mathematical model,

$x_{ij} \ge 0$ and *integer*,

$\forall i = 1,2,...,W, \forall j = 1,2,...,T.$

The model is an integer nonlinear programming model which can be solved by any appropriate software. On the other hand, the proposed model is NP-hard (NP-complete). As in WTA problem, there is no exact algorithm to solve this model. Therefore, heuristic approaches can be employed for near optimal solutions (Çetin and Esen, 2006).

3. GENETIC ALGORITHM

Genetic algorithms (developed by Holland (Goldberg, 1989; Reeves, 1995) and a meta-heuristic that mimic the process of evolution in order to solve complex combinatorial problems), have been applied successfully to a wide variety of problems. Genetic Algorithms (GAs) updates a population of solutions via genetic operators such as crossover, mutation and selection to achieve offsprings with better quality until convergence criteria are met. At each generation, a genetic algorithm is capable of producing and maintaining a set of feasible solutions, maintaining a population of candidate solutions, and evaluating the quality of each candidate solution according to the problem-specific fitness function (Keskintürk and Yildirim, 2011).

Our implementation includes a chromosome of size WXT. Every chromosome represents of total solution of the problem and every cell of chromosome represents xij variables that the number of advertisements of type i assigned to target audience j. Initial population of the problem generates randomly.

The fitness function f for a chromosome to penalize the objective function severely can be calculated as a function of the objective function value as maximize the total percentage of reaching the target audiences.

In a genetic algorithm, chromosomes with a better fitness value receive more chances to survive in the next generations. The roulette wheel selection operator is used to select parents for the next generation.

After parents are selected the crossover operation is applied which we used a single point crossover. Since our chromosomes are matrix we applied the single point in a different two ways: Vertical and horizontal. While vertical crossover is chosen randomly, parents exchange the segments information and in horizontal crossover target audience information are exchanged.

For maintaining diversity in genetic algorithm, mutation operator is used. In this study we applied mutation as random changing of the number of advertisements between zero and upper limit (20) with mutation probability, p_m.

The pseudo-code of the genetic algorithm is presented in Figure 1.

Genetic Algorithm

```
STEP 0:    Generate an initial population

STEP 1:    Evaluate the fitness value of the
chromosomes

STEP 2:    Perform selection operation.

STEP 3:    Perform crossover and mutation
operations according to probabilities.

STEP 4:    Repeat steps 1, 2 and 3 until the
           GA is reached number of
           generations

STEP 5:    Select the best solution.
```

Figure 1. Pseudocode for the genetic algorithm.

4. COMPUTER APPLICATION

A hypothetical example, given in Çetin and Esen (2006) is as follows: Assume that a company is planning to start an advertising campaign for a particular product. The duration is up to the company management. The company takes four target audiences ( ) as morning time, afternoon time, prime time and nighttime of the day. Also, it has fifteen ( ) media vehicles to be advertised as ATV, BTV, CTV, DTV, ETV, FTV, GTV, K Radio, L Radio, Internet, P Newspaper, R Newspaper, billboard, printings and e-mail. From the past rating and circulation observations, the company knows the percentages and unit costs of reaching the target audiences in different time partitions according to media vehicles. The unit refers to different measures for different media vehicles. The percentages (probabilities) are shown in Table 1 while the unit variable costs (in $10.000), advertising capacities, segment weights (marketing values of targets) and the number of advertising required for each target is shown in Table 2.

Table 1. The Probability Matrix

	Morning time (1)	Afternoon time (2)	Prime time (3)	Night time (4)
ATV	0,21	0,12	0,12	0,23
BTV	0,35	0,24	0,12	0,07
CTV	0,19	0,04	0,00	0,19
DTV	0,00	0,26	0,19	0,13
ETV	0,13	0,19	0,25	0,00
FTV	0,24	0,14	0,22	0,09
GTV	0,09	0,00	0,18	0,28
K Radio	0,39	0,17	0,47	0,00
L Radio	0,24	0,31	0,14	0,43
Internet	0,10	0,23	0,03	0,35
P Newspaper	0,12	0,11	0,03	0,09
R Newspaper	0,32	0,23	0,09	0,21
Billboard	0,32	0,10	0,28	0,02
Printings	0,23	0,12	0,08	0,03
E-mail	0,29	0,07	0,04	0,32

In this example, TV, radio and Internet are determined as renewable media, while newspaper, billboard, printings and e-mail are press media. It is seen in Table 1 that some vehicles has 0 probability to reach some targets. As shown in Table 2, prime time is the most important segment, as nighttime is the least important segment for the product. These weights can be changed with respect to the features of the product. Total advertising budget is $B = \$75.000$

Table 2. The costs, number of ads and segment weights

	Morning time (1)	Afternoon time (2)	Prime time (3)	Night time (4)	Ad capacity
ATV	0,140	0,120	0,140	0,150	8
BTV	0,110	0,130	0,150	0,100	7
CTV	0,100	0,043	0,100	0,085	9
DTV	0,130	0,130	0,130	0,125	5
ETV	0,130	0,135	0,140	0,140	6
FTV	0,150	0,150	0,150	0,150	8
GTV	0,160	0,160	0,160	0,180	3
K Radio	0,015	0,010	0,010	0,010	10
L Radio	0,025	0,020	0,020	0,027	15
Internet	0,050	0,050	0,050	0,065	12
P Newspaper	0,100	0,100	0,100	0,100	8
R Newspaper	0,160	0,160	0,160	0,160	4
Billboard	0,096	0,096	0,096	0,096	4
Printings	0,020	0,020	0,020	0,020	4
E-mail	0,008	0,008	0,008	0,008	4
Number of ads required	16	18	25	10	
Segment weights	2	3	4	1	

The management wants to restrict total TV, radio and newspaper expenditure shares with $\rho_1 = 0{,}55$, $\rho_2 = 0{,}15$ and $\rho_3 = 0{,}25$ respectively. The problem is the media and budget allocation subject to the constraints so that the total probability of reaching the target audiences is maximized (in theory) within the given budget (Çetin and Esen, 2006).

Results of genetic algorithm are obtained on Pentium Dual Core Machine with 4GB of memory and 120 GB of hard drive using MATLAB R2009a as the programming medium. Probability of crossover and mutation are selected as .9 and .01 respectively. Population size is 20 and number of generation is 1000.

Table 3. MS Excel Solver Results

	Morning time (1)	Afternoon time (2)	Prime time (3)	Night time (4)
ATV	1	0	0	0
BTV	7	0	0	0
CTV	7	0	0	2
DTV	0	5	0	0
ETV	0	0	6	0
FTV	0	0	5	0
GTV	0	0	0	0
K Radio	2	0	8	0
L Radio	0	15	0	0
Internet	0	0	0	12
P Newspaper	2	2	2	2
R Newspaper	1	1	1	1
Billboard	1	1	1	1
Printings	1	1	1	1
E-mail	1	1	1	1

Table 4. Genetic Algorithm Results

	Morning time (1)	Afternoon time (2)	Prime time (3)	Night time (4)
ATV	0	0	0	0
BTV	7	0	0	0
CTV	6	1	0	2
DTV	0	5	0	0
ETV	0	0	6	0
FTV	2	0	5	0
GTV	0	0	0	0
K Radio	2	0	8	0
L Radio	0	14	0	1
Internet	0	0	0	12
P Newspaper	2	2	2	2
R Newspaper	1	1	1	1
Billboard	1	1	1	1
Printings	1	1	1	1
E-mail	1	1	1	1

The problem is solved using MS Excel's classical Solver in Çetin and Esen (2006) and the objective function is found 9,995405062449 when the problem with the same data is solved and found in this study 9.99564671899946 (which is again near-optimal) as the total weighted exposure of the target audiences. We see that this solution could not be improved by further genetic algorithm iterations. Thus, genetic algorithm metaheuristic employed in this study improved the previous solution .004%.

5. CONCLUSIONS

In this effort, we propose genetic algorithm technique as a metaheuristic tool for the solution of weapon-target assignment based media allocation problem presented, which is solved by MS Excel's Solver, in Çetin and Esen (2006). Our genetic algorithm produces better solutions than MS Excel's Solver for this problem.

We believe that genetic algorithm approach is a good and feasible alternative for the solution of this type class of problems. As a further research, we may employ genetic algorithm approach for the problem with many target audiences (such as, in terms of hours or minutes) and many advertising tools and multiple companies as well. In addition, we employ different operators, parameter optimization efforts and some local search techniques for the advanced of our solution method. What is more, it may be used some heuristic and metaheuristic techniques such as ant colonies algorithm for the solution of weapon-target based media allocation problem.

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