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Optimal Television Adverts Selection, Case Study: Ghana Television (GTV)

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Abstract: The Knapsack Problems are among the simplest integer programs, which are NP-hard. Problems in this class are typically concerned with selecting from a set of given items, each with a specified weight and value, a subset of items whose weight sum does not exceed a prescribed capacity and whose value is maximum. The specific problem that arises depends on the number of knapsacks (single or multiple) to be filled and on the number of available items of each type (bounded or unbounded). In this research paper, we shall consider the application of classical 0-1 knapsack problem with a single constraint to selection of television advertisements at critical periods such as prime time news, news adjacencies, Break in News and peak times using the simple heuristic algorithm.

Key words: Advertisements, integer programming, Knapsack, NP-hard

INTRODUCTION

Nearly every organization faces the problem of allocating limited resources (capital and other scarce resources, including time, people) across projects or other type of investments. There is the need to allocate these resources to maximize the returns from a given investment.

The goal is to select the particular subsets of projects, which can be funded within the budget constraint. One of the greatest resources of broadcasting stations (both Television and Radio) is time. The Television (TV) stations have to schedule programmes interspersed with adverts or commercials, which are the main sources of income of broadcasting stations. The goal in scheduling commercials is to achieve wider audience satisfaction and making maximum income from the commercials or adverts.

A great variety of practical problems can be represented by a set of entities, each having an associated value, from which one or more subsets has to be selected in such a way that the sum of the values of the selected entities is maximized, and some predefined conditions are respected. The most common condition is obtained by also associating a weight to each entity and establishing that the sum of the entity sizes in each subset does not exceed some prefixed bound. These problems are generally called knapsack problems, since they recall the situation of a traveler having to fill up his knapsack by selecting from among various possible objects those which will give him the maximum comfort.

In this paper, we shall adopt the following terminologies. The entities will be called items and their number will be indicated by. The value and size associated with the item will be called profit and weight, respectively, and denoted by p_j and w_j, (j = 1,...,n)

LITERATURE REVIEW

Knapsack problems have been studied intensively in the past decade attracting both theorist and practitioners. The theoretical interest arises mainly from their simple structure which both allows exploitation of a number of combinational properties and permits more complex optimization problems to be solved through a series of knapsack type. From a practical point of view, these problems can model many industrial applications, the most classical applications being capital budgets, cargo loading and cutting stock. We present related works on knapsack problems and applications.

Yield management is an important issue for television advertising. The major part of the research in revenue management focuses on the airline or hotel industry. The TV advertising case has some specifications, where the most important is the decomposition of the offer into a lot of small TV breaks. Martin, (2004) proposed generic solutions based on simulations and approximate dynamical programming.

Pendharkar *et al*. (2006) described an Information Technology Capital Budgeting (ITCB) problem, and showed that the ITCB problem can be modeled as a 0-1 knapsack optimization problem, and proposed two different Simulated Annealing (SA) heuristic solution procedures to solve the ITCB problem. Using several simulations, they empirically compared the performance of two SA heuristic procedures with the performance of

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two well-known ranking methods for capital budgeting. Their results indicated that the Information Technology (IT) investments selected using the SA heuristics have higher after-tax profits than the IT investments selected using the two ranking methods.

Zhong and Young (2009) described the use of an integer programming tool, Multiple Choice Knapsack Problem (MCKP), to provide optimal solutions to transportation programming problems in cases where alternative versions of projects are under consideration.

Glickman and Allison (1973) considered the problem of choosing among the technologies available for irrigation by tube wells to obtain an investment plan, which maximizes the net agricultural benefits from a proposed project in a developing country. Cost and benefit relationships were derived and incorporated into a mathematical model, which is solved using a modification of the dynamic programming procedure for solving the knapsack problem. The optimal schedule was seen to favour small capacity wells, drilled by indigenous methods, with supplementary water distribution systems.

Chu and Beasley (1998a) presented Genetic algorithm (GA) that produce results that are superior in quality to other leading heuristic (which are mostly based on Tabu search) for the Knapsack problem. However, they pointed out that GA is much slower than other heuristics.

GAs often requires the production and evaluation of many different children. However, GA's are capable of generating high-quality solutions to many problems within reasonable computation times. (Beasley and Chu, 1996; Chu and Beasley, 1997, 1998b; Chang *et al*., 2000)

The simple heuristic scheme algorithm has received little attention in literature. This study focuses on using a simple heuristic scheme (Simple flip) for the solution of knapsack problems. This study showed that the results from the heuristic method compares favorably with the well known meta-heuristic methods such as Genetic Algorithm and Simulated Annealing.

Problem formulation: Suppose the producer of a TV programme wants to select among numerous adverts for the prime time (news at 19:00 h GMT), which is interspersed with five or six spots of adverts of not more than three minutes each. It is self evident that the optimal solution of the knapsack problem above will indicate the best possible choice of investment.

The objects to be considered will generally be called items and their number by n. The value and size associated with the j^{th} item will be called profit (cost of Advert) and weight (duration of advert) of respectively, and denoted by p_j and w_j, (j = 1,....,n)

At this point you may be stimulated to solve the problem. A naïve approach would be to program a computer to examine all possible binary vectors x, selecting the best of those which satisfy the constraint. Unfortunately, the number of such vectors is 2^n, so even a hypothetical computer, capable of one billion vectors per second, would require more than 30 years for n = 30, more than sixty (60) years for n = 60 and ten centuries for n = 65 and so on (Pisinger, 1995). However, specialized algorithms can, in most cases, solve a problem with n = 100,000 in a few seconds on a mini/micro computer.

The 0-1 Knapsack Problem (KP) can be mathematically formulated through the following integer linear programming.

Maximize: $$\sum_{j=1}^{n} p_j x_j$$

Subject to: $$\sum_{j=1}^{n} \left(w_j x_j\right) \le C$$

x_j = 0 or 1, j = 1,...,n

where, P_j is the value (cost of advert) and w_j is the weight (duration of advert) of the j^{th} item respectively and C is the maximum time allocated for adverts.

There are two basic methods for solving the 0-1 knapsack problems (KP): Theses are Branch-and-Bound and dynamic programming methods. However the uses of meta-heuristics including Genetic algorithm, Tabu search and Simulated annealing have been used to solve large scale problems.

The heuristic scheme is outlined as follows:

Step 1: Input the vector of weight and item values
Step 2: Input random initial solution S_0 and Check for feasibility of S_0 by the constraint equation if S0 is not feasible discard and choose another S_0
Step 3: Find a feasible solution and compute the objective function value $f(S_0)$
Step 4: Obtain a New solution S_1 by flip operation and check for feasibility, continue flip operation until the solution S1 so obtained is feasible. Compute the objective function Value $f(S_1)$
If $f(S_1) > f(S_0)$ then put $S_0=S_1$
alse retain S_0 and discard S_1
Step 5: Repeat Step 3 for all feasible solutions
Step 6: Stop for not improving solution over a number of iterations

MATERIALS AND METHODS

This study was undertaken using data collected from Ghana Television (GTV) for the period July to September 2009. The study area is the selection of adverts at Ghana Television (GTV) of Ghana Broadcasting Corporation.

Table 1: GTV adverts rates

Category/time	Rates in GH¢ for July - September 2009 15 sec	30 sec	45 sec	60 sec
Prime time news (19 h GMT)	215.00	375.00	562.00	750.00
News adjacencies	130.00	250.00	375.00	500.00
Break in news	135.75	244.35	362.00	525.00
Break in programmes				
Peak time - Week days	91.00	160.00	220.00	360.00
Peak time - Week ends/holidays	70.00	120.00	164.00	271.00
Off peak	45.00	61.00	120.00	177.00

Table 2: Prime time news adverts-19:00 h GMT

Adverts no.	Time in sec (t)	No. of spots requested(s)	Time requested (weight)	Cost GH¢ (Value)
1	15	2	30	429
2	30	3	90	1125
3	45	1	45	562
4	15	1	15	214
5	30	3	90	1125
6	45	2	90	1124
7	60	1	60	750
8	30	2	60	750
9	45	2	90	1124
10	15	1	15	215
11	15	1	15	215
12	30	1	30	375
13	45	2	90	1124
14	15	2	30	429
15	30	3	90	1125
16	45	2	90	1124
17	30	3	90	1125
18	30	3	90	1125
19	45	2	90	1124
20	60	1	60	750
21	45	1	45	562
22	15	1	15	215
23	15	1	15	215
24	15	1	15	215
25	30	2	60	750
26	30	3	90	1125
27	15	2	30	429
28	60	1	60	750
29	30	3	90	1125
30	15	2	30	429
Total			1710	

GTV is a public broadcaster which depends to the greater extent on government subvention. Ghana Broadcasting Corporation is however mandated to generate revenue to supplement the government subvention. To this end GTV has various ways of generating additional income. These include sponsorship of programmes, social and funeral announcements, advertisements among others. However, this research focused on advertisements, which are slotted in the programmes schedules prepared quarterly to generate additional income to sustain the operations of the TV station. GTV uses an arbitrary method in the selection. In this process an advert is accepted if there is an available time without regard to optimizing revenue.

The category of adverts selection studied included:

- Prime time news (19.00 h GMT)
- News adjacencies (five minutes before and after news at 12.00, 14.00, 19.00 and 22.30 h GMT)
- Other News time (12.00, 14.00, 19.00, 22.30 h GMT)
- Break in programmes (peak and off peak)

Table 1 shows the various rates for the different categories of adverts at GTV. For example a Primetime News adverts for 15 sec costs GH¢215 while for 60 sec, the rate is GH¢525. The rates are high for Prime time News and news adjacencies. These are periods where most customers want their adverts televised to reach a larger TV audience. The off peak rates are low compared with the peak periods.

Customers usually request for a number of spots for their adverts. Table 2 shows request received by GTV for Primetime News (19 h GMT). Customer 1 requested for two (2) spots of adverts for fifteen (15) sec each at prime time news. The cost of the two adverts is GH¢260 (i.e., 130+130) as indicated in the value column. The weight of this advert is 30 sec. Additionally, customer

Table 3: Adverts for news adjacencies -18:55 -19:00 and 20:00-20:05

Adverts no.	Time requested (weight)	Cost GH¢ (Value)
1	30	260
2	45	375
3	15	130
4	90	750
5	60	500
6	60	250
7	90	750
8	15	130
9	15	130
10	30	250
11	30	260
12	60	500
13	45	375
14	15	130
15	15	130
16	15	130
17	60	250
18	30	260
19	60	500
20	30	260
Total	810	

Table 4: Adverts for Break in News at 22:30 Hours GMT

Adverts no.	Time requested (weight)	Cost GH¢ (Value)
1	30	150
2	45	200
3	15	75
4	90	400
5	60	290
6	60	270
8	15	75
9	15	75
10	30	135
11	30	150
12	60	290
13	45	200
14	15	75
15	15	75
16	15	75
17	60	270
18	30	150
19	60	290
20	30	150
Total	720	

number 5 requested three (3) spots of 30 sec each, i.e. 90 sec (weight) with a cost of GH¢1,125 (value). The total time available for adverts at the prime time news is 20 min (i.e., 1200 sec) but the total time requested is 1710 sec.

Other customers opt for the News Adjacencies. This is 5 min before and after the prime time news at 19.00 h GMT. As shown in Table 3, the total time available is 10 min (600 sec) but the customers requested a total of 810 sec.

Table 4 depicts the weights and the values for the adverts requested for the 22:30 news time. The total time available is 600 sec but the customers requested 810 sec.

Data analysis: The Data collected for GTV was analyzed with the computer software developed in Visual Basic.Net 2008. Visual Basic.net was used as the platform for the simulation of the Adverts selection because of its ease of interface design.

Table 5: Break in programme adverts for peak time on week days

Adverts no.	Time requested (weight)	Cost GH¢ (Value)
1	15	91
2	15	91
3	30	160
4	90	440
5	30	182
6	90	480
7	90	440
8	90	480
9	60	320
10	15	91
11	15	91
12	15	91
13	60	320
14	90	480
15	30	182
16	60	360
17	90	480
18	30	182

Features of the Software: The software allows the user to input data into the program in three ways as shown in the User interface in Fig. 1 by the radio buttons.

- **Enter input manually:** The user may type in the data directly into the textboxes
- **Load from Input file:** The user can load an existing already stored data in the computer
- **Generate random input:** For testing purposes the user can generate data automatically

The program generates an initial solution and shows all feasible solutions for the problem and selects the optimal solution. The optimal solution gives the solution string, the weight and the value. The selected adverts are the listed in a list box to the right as shown in Fig. 2.

RESULTS OF THE ANALYSIS

Results for the analysis of data from the Table 1 to 5 (Prime Time News, news adjacencies, Break in News and Break in programme) are shown below. The optimal selection these adverts yielded GH¢ 26,305. From the Table 6, nineteen (19) adverts were selected from the 30 requested to give an optimal value of GH¢ 15,157. The selection for the break in news, break in programme and a peak period yielded GH¢ 2,820, GH¢ 3,288, GH¢ 5,040, respectively. These are higher, as compared with the results of the arbitrary method used by GTV. Additionally, more adverts for each category of advertisement was selected as compared with the existing method of selection.

The adverts selected from Tables 2, 3, 4 and 5 using the software are as follows:

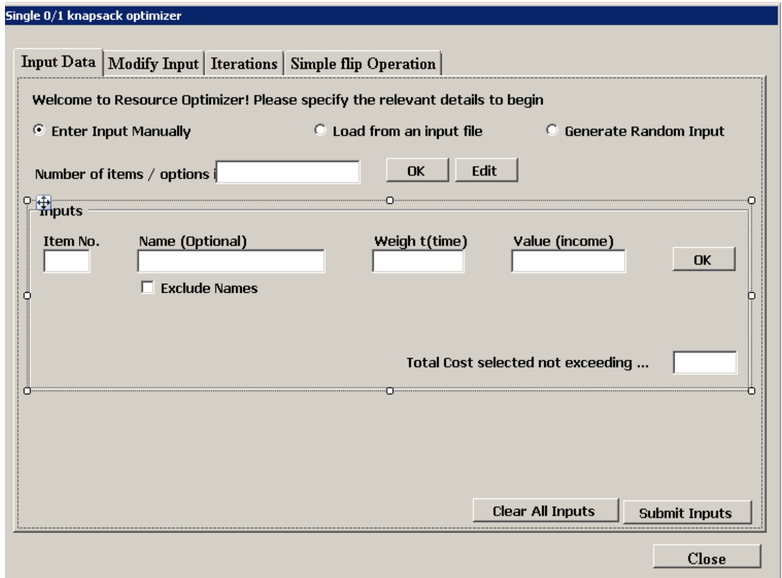

Fig. 1: User Interface for the Knapsack Optimizer

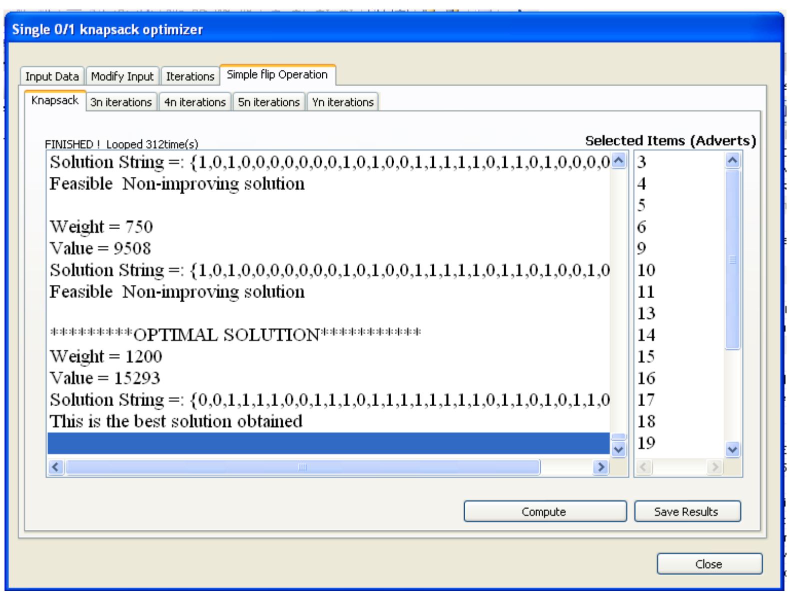

Fig. 2: The optimal solution for prime time adverts

Table 6: (Provide self explanatory caption)

Advert category	No. of adverts requested	No. of adverts selected	Time available (sec)	Optimal value GH¢
Prime Time	30	19	1200	15,157
News Adjacencies	20	14	600	5,040
Break in News	20	14	600	2,820
Break in Programme	20	13	600	3,288
Total				26,305

- Prime Time News - {3,6,8,9,12,13, 15,16,17,18,19, 21,23,24,25,27,28,29,30}
- News Adjacencies - {1,2,4,57,8,910,12,13,15,16, 19,20}
- Break in News - {1,4,5,6,9,10,11,12,13,14,15, 16,17, 18}
- Break in Programme - {1,2,3,5,6,7,9,11,12,13,14, 16,18}

CONCLUSION

The amount of GH¢26,305 obtained from adverts selected for the four categories of adverts, is far in excess of the arbitrary selection method used by GTV. This translates to GH¢2,367,450 for a three (3) month period. The use of the software is systematic and transparent as compared with the arbitrary method. Higher returns can be achieved by GTV by the use of this software in their selection of adverts in the critical situations analyzed.

Marketing Managers/Programme Producers may benefit from the proposed approach for selecting adverts to guarantee maximized profits for their TV stations. In an event where management may have to include certain adverts for national interest these could be isolated before selecting the others to compete for the limited time slots. The software can be used for any problem that can be modeled as a 0/1 knapsack problem.

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