WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

AN ON-LINE TECHNIQUE FOR
ESTIMATING AND ANALYZING COMPLEX MODELS

293-67

GLEN L. URBAN

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS 02139
AN ON-LINE TECHNIQUE FOR
ESTIMATING AND ANALYZING COMPLEX MODELS

293-67

GLEN L. URBAN
AN ON-LINE TECHNIQUE FOR ESTIMATING AND ANALYZING COMPLEX MODELS

-ABSTRACT-

This paper describes an on-line interactive trial and error search technique. The technique is based upon the use of a manager as a heuristic to guide and control the search. He prescribes the initial values for the parameters or variables, the number of values to be evaluated, and the increment that will separate each value. A computer program evaluates all combinations of the values and reports the best value for the criterion function specified in the model. Seeing these results, the manager may change the search parameters and thereby approach the optimum with the desired level of accuracy. The search procedure is demonstrated in a data based competitive parameter estimation problem and a dynamic optimum marketing mix determination analysis. The relationship of this man-machine trial and error search routine to other numeric optimization techniques is indicated. The proposed technique appears to be a flexible, simple and relatively efficient method of analyzing marketing models.
AN ON-LINE TECHNIQUE FOR ESTIMATING AND ANALYZING COMPLEX MODELS*

BY GLEN L. URBAN

Introduction

The complexity of many existing models is evident when the number of variables and equations and the intricacy of these equations are examined. But as more difficult problems are attacked, even more complex models will be necessary if the essential characteristics of the problems are to be encompassed. Given a proposed model, the parameters of the model should be estimated from data and decision outputs must be generated. The technique to be used for the analysis of the model should be drawn from a "tool kit" of techniques. The selected techniques should be fitted to the model and not vise versa. For example, the model should not be linearized because linear programming is the tool that a priori has been selected. The tool for analysis should be the one that is most efficient in producing a solution while retaining the essential aspects of the model. This rule would require the use of the analytic techniques of calculus and mathematical programming whenever they do not require assumptions to be placed on the model that would destroy its relevance to the original problem. The difficulty is that the non-linearity, carry-over, product interdependency, threshold, and competitive interaction effects that pervade marketing problems make many algorithmic procedures inappropriate. The purpose of this paper is to discuss a non-algorithmic technique for analyzing complex models that may be used when analytical techniques are not appropriate.

* This paper was written for presentation at the AMERICAN MARKETING ASSOCIATION EDUCATORS CONFERENCE, Dec. 27 - 29, 1967, Washington D.C.
Man-machine Trial and Error Search

The most unrestricted technique for analysis of models is trial and error. This procedure of asking "what if" questions of a model is not constrained by the nature of the problem formulation and can be used to generate normative results. The output may prescribe what parameter estimates should be used or what decision alternatives should be taken. In specifying these normative results, a large number of trials may be required since the trial and error technique is a brute force approach. In the limit, the technique would approach enumeration and therefore does not intuitively appear to be efficient.

The efficiency of the trial and error approach has emerged with the development of on-line time shared computer systems. With an on-line system a marketing manager or researcher can be utilized to control the search and a computer can be utilized to rapidly evaluate a large number of alternatives. The man essentially plays the role of a heuristic in the system. He determines the starting point of the search, the range of variables to be searched, and adapts these decisions as search results are displayed to him.

The technique is simple. Given any model that produces an output criterion measure, a starting point for each variable is specified by the manager from the remote console. Next, he specifies the number of values of each variable he would like to evaluate. Lastly, he specifies the interval between the steps. This procedure specifies the range of value for each variable as $V = \bar{V} - (N/2)\Delta$ to $V = \bar{V} + (N/2)\Delta$ where values $\bar{V}$ = initial value of variable, $N$ = number of values to be evaluated, and

$\Delta$ = interval between values. The value to be tested could be defined by $V = \bar{V} - (N/2)\Delta + n\Delta = \bar{V} + \Delta (n - N/2)$ where $n = 1, 2, \ldots N$.

The three inputs are supplied for each of the variables in the analysis and a computer is called upon to evaluate all combinations of the values in the range of each variable. The computer program contains an executive sector which accepts input and generates all combinations of the trial values by a simple series of nested DO loops. The values are evaluated in a subroutine which contains the mathematical model and criterion function. The form of the model is unconstrained and no specific response assumptions are necessary.
The output section of the search program records the criterion value for each set of trial values and reports the best set of parameter or variable values and the optimum criterion value generated by the model subroutine. Two examples of this technique will be presented and then the place of this kind of man-machine trial and error search routine will be discussed in the context of general numeric optimization methods.

On-line Trial and Error Search and Parameter Estimation: An Example

The need to develop data-based models is widely recognized, but existing techniques for parameter estimation may not be appropriate for estimation in complex models. Even if functions are transformed by logarithms or other functions, they may not be estimable with existing econometric techniques. For example, let us look at a not so complex two variable market share equation:

\[
MS_1 = \frac{P_1^{EP_1} F_1^{EF_1}}{P_1^{EP_1} F_1^{EF_1} + P_2^{EP_2} F_2^{EF_2}}
\]

\(MS_1\) = Market share of firm one  
\(P_i\) = Price of firm i  
\(F_i\) = Number of self facings for firm i's product  
\(EP_i\) = Price sensitivity of firm i  
\(EF_i\) = Facing sensitivity of firm i

This expression can not be estimated directly by econometric methods, but a trial and error search approach is useful in deriving estimates of the parameters. The parameters of this equation have been estimated using an on-line search to minimize the total variation between the actual and predicted market shares. The actual market shares are based on one hundred observed store audit data points. The predicted share is based on equation (1), the observed self price and facings, and a set of trial sensitivities.

---

1 See Ronald Frank "Use of Transformations" JOURNAL OF MARKETING RESEARCH III (August, 1966), p. 247-253 for transformations that can make some models amenable to regression procedures.
Figure one depicts a typical console session for the estimation of the model's parameters. The program is loaded and the manager or researcher is asked to specify the number of data points for the estimation. The "I" in the instructions indicates the input should be integer (i.e. no decimal point). The input supplied by the manager at the console is indicated by an asterisk. The next inputs are the initial price and facing sensitivities. These are based on the manager's best subjective judgements of market response. These initial values are to be incremented by deltas of five tenths. The last search parameter is the number of values to be evaluated for each parameter. In this case two price and two facing parameter values are to be tested. Next, the computer prints out the number of cycles the program will make through the one hundred data points in calculating the total variation. The value of 16 appears to be a reasonable computational burden. If the numbers of cycles had been excessive, a "1" would have been typed and new search parameters would have been entered.

The initial output is now printed and it indicates that a total variation between the observed and predicted market shares is 2.848 when the price sensitivity is -.5 for firm one and -1.0 for firm two and when the facing sensitivity is .7 for firm one and 1.2 for firm two. Firm one was less sensitive with respect to both parameters than originally estimated by the reference input values. The observed data had a total variation of 5.836, so the model with the initial search parameters reduced the total variation by 1.99. Seeing these results the manager revises the search deltas and steps. The new iterations are based on deltas of .25 and 64 cycles are requested. The new minimum variation estimates are now printed. The total variation has been reduced by an additional .15 and the new sensitivities are reported. This process of narrowing the search intervals was continued six times and the final iterations are shown in figure two for deltas of .005 for price and .01 for facing sensitivity. The search process resulted in a minimum variation of 2.515. This implies that the search explained fifty-four percent of the variance in the market share data. The facing sensitivities were higher than the initially specified trial values. The price response for firm one was less sensitive than originally estimated while the response to price changes by firm two was more sensitive than initially predicted. The final line in figure two indicates that 274 seconds or about 4.5 minutes of IBM 7094 computer time were required for this estimation.
LOADGO LINEX CHISQR VARI
W 1942.8
EXECUTION.
TYPE NO. DATA POINTS, I
* 100
TYPE INITIAL PRICE ELAST. FOR EACH PROD, F
* -1.0
* -1.0
TYPE INITIAL FACE ELAST. FOR EACH PROD, F
* .70
* .70
TYPE DELTAS FOR PRICE ELASTICITY FOR EACH PRODUCT, F
* .5
* .5
TYPE DELTAS FOR FACINGS ELAST. FOR EACH PRODUCT, F
* .5
* .5
TYPE EVEN NO. PRICE STEPS, I
* 2
TYPE EVEN NO. FACING STEPS, I
* 2
NUMBER OF CYCLES SPECIFIED IS 16
IF WANT TO REVISE DELTAS- STEPS TYPE 1, OTHERWISE 0
*0
MIN. ESTIMATOR VALUE IS 2.848
BEST PRICE ELASTICITY IS -.5000
BEST PRICE ELASTICITY IS -1.0000
BEST FACING ELASTICITY IS .70
BEST FACING ELASTICITY IS 1.20
IF WANT TO TRY MORE DELTA- STEPS TYPE 1, OTHERWISE 0,1
*1
DELTA S ARE FROM THIS BEST ELAST.
TYPE DELTAS FOR PRICE ELASTICITY FOR EACH PRODUCT, F
* .25
* .25
TYPE DELTAS FOR FACINGS ELAST. FOR EACH PRODUCT, F
* .25
* .25
TYPE EVEN NO. PRICE STEPS, I
* 4
TYPE EVEN NO. FACING STEPS, I
* 2
NUMBER OF CYCLES SPECIFIED IS 64
IF WANT TO REVISE DELTAS- STEPS TYPE 1, OTHERWISE 0,1
*0
MIN. ESTIMATOR VALUE IS 2.702
BEST PRICE ELASTICITY IS -.7500
BEST PRICE ELASTICITY IS -1.2500
BEST FACING ELASTICITY IS .95
BEST FACING ELASTICITY IS 1.20
IF WANT TO TRY MORE DELTA- STEPS TYPE 1, OTHERWISE 0,1
*1

FIGURE NO. 1
ON-LINE COMPETITIVE ESTIMATION
DELTAS ARE FROM THIS BEST ELAST.
TYPE DELTAS FOR PRICE ELASTICITY FOR EACH PRODUCT, F
*.005
*.005
TYPE DELTAS FOR FACINGS ELAST. FOR EACH PRODUCT, F
*.01
*.01
TYPE EVEN NO. PRICE STEPS, I
*4
TYPE EVEN NO. FACING STEPS, I
*2
NUMBER OF CYCLES SPECIFIED IS 64
IF WANT TO REVISE DELTAS- STEPS TYPE 1, OTHERWISE 0, I.
*0
MIN. ESTIMATOR VALUE IS 2.515
BEST PRICE ELASTICITY IS -0.8550
BEST PRICE ELASTICITY IS -1.2450
BEST FACING ELASTICITY IS 1.13
BEST FACING ELASTICITY IS 1.20
IF WANT TO TRY MORE DELTA- STEPS TYPE 1, OTHERWISE 0, I
*0
EXIT CALLED. PM MAY BE TAKEN.
R 243.766+30.016

FIGURE NO. 2
FINAL ITERATION IN COMPETITIVE ESTIMATION
Interactive Search and Strategy Determination: An Example

Although interactive trial and error search procedures are useful in estimation, their greatest contribution will probably be in the area of strategy decisions. To demonstrate this potential, let us look at the problem of determining the optimal marketing mix for each year of a given planning period. Let us quickly develop an aggregate model of the market and then examine how an on-line search program can be useful.

Let us presume the sales in a year "t" are:

\[ q_t = f \text{ (industry sales forecast, industry marketing mix effects, competitive effects, carry over effects.)} \]

Using a constant elasticity response form, a reasonable three variable representation would be:

\[ q_t = a \bar{X}_t (P_{EP1}^{EP1} A_{EAI}^{EAI} D_{EDI}^{EDI}) [P_{EP1}^{EP1} A_{EAI}^{EAI} D_{EDI}^{EDI} + P_{EP2}^{EP2} A_{EA2}^{EA2} D_{DE2}^{DE2}] (LAGG_t) \]

where

\[ LAGG_t = P_{LEP}^{LEP} A_{LEA}^{LEA} D_{LED}^{LED} \]

and

\[ a = \text{scale constant} \]
\[ \bar{X}_t = \text{reference industry sales forecast in year "t"} \]
\[ P_{It} = \text{industry average price in year "t"} \]
\[ A_{It} = \text{industry total advertising in year "t"} \]
\[ D_{It} = \text{industry total distribution (measured in man-years of sales effort)} \]
\[ \text{EPI = industry price elasticity} \]
\[ \text{EAI = industry advertising elasticity} \]
\[ \text{EDI = industry distribution elasticity} \]
\[ P_{it} = \text{price of firm } i \text{ in year } t \]
\[ A_{it} = \text{advertising of firm } i \text{ in year } t \]
\[ D_{it} = \text{distribution of firm } i \text{ in year } t \]
\[ \text{EPI = price sensitivity of firm } i \]
\[ \text{EAI = advertising sensitivity of firm } i \]
\[ \text{EDI = distribution sensitivity of firm } i \]
\[ \text{LEP = lagged elasticity of price} \]
LEA = lagged elasticity of advertising
LED = lagged elasticity of distribution
LL = two period lagged elasticity

When equation (2) is multiplied by price and when costs are subtracted from this, the profit in year "t" is specified. The problem is to find the most profitable combination of price, advertising, and distribution in each of six years, using equation (2) as the basis of the profit generating model. The criterion in this example is total discounted profit.

The trial and error search procedure is depicted in figure three. First the competitive sensitivity, reference forecasts, and reference variable values are submitted. These inputs are supplied on-line to facilitate sensitivity testing. All the inputs are in units of thousands except the unit price and the unit cost which are in dollars, the sensitivities which are unitless, and the distribution which is in units of man-years of sales effort devoted to this product. All of the other parameters (elasticities and lagged elasticities) have been pre-specified in the model. After initialization, the search parameters are prescribed and the evaluations begin.

The first iteration evaluated 10,000 values of mix elements and indicated that the best strategy is to increase price and advertising and reduce distribution given that the competitor is a follower. The reference program profit was $398,000 so the initial search increased a profit of almost $200,000. The deltas utilized in the first search iteration are wide so the search was repeated using increasingly smaller deltas until after six iterations, a maximum profit of $628,450 was specified. See figure 4 for the last iteration. The final marketing mix indicates that basically higher prices, higher advertising, and lower distribution will yield substantially more profit than the reference program. The advertising expenditures are increased over the six years while price is maintained essentially at a constant level of about 32.40 dollars. Year three's price

2 The author would like to acknowledge that the basic FORTRAN statements for this program were written by Mr. Len Lodish.
LOADGO MIXF
w 1907.5
EXECUTION.
  TYPF ELASTS OF PRICE, ADV, DIST
  PRFR1PRFR2ADFR1ADFR2DFR1DFR2
  XX.XXXX.XXXXXX.XXX.XXX.XX
  * -1.30-1.5001.0000.7501.0000.90
  TYPE OUR REF SALES
  PER1 PER2 PER3 PER4 PER5 PER6
  XX.XXXX.XXXX.XXXX.XXX.XX
  * 20.0021.0023.0025.0026.0026.50
  TYPE REFERENCE INDUSTRY SALES
  PER1 PER2 PER3 PER4 PER5 PER6
  XX.XXXX.XXXX.XXXX.XXX.XX
  * 40.0042.0046.0050.0052.0053.00
  TYPE OUR FIRM'S REF PRICE
  PER1 PER2 PER3 PER4 PER5 PER6
  XX.XXXX.XXXX.XXXX.XXX.XX
  * 30.0030.0030.0030.0030.0030.00
  TYPE OUR FIRMS REF ADVER
  PER1 PER2 PER3 PER4 PER5 PER6
  XX.XXXX.XXXX.XXXX.XXX.XX
  * 40.0040.0040.0040.0040.0040.00
  TYPE OUR FIRMS REF DISTR
  PER1 PER2 PER3 PER4 PER5 PER6
  XX.XXXX.XXXX.XXXX.XXX.XX
  * 10.0010.0010.0010.0010.0010.00
  TYPE COSTS
  UNIT FXED UNDIST
  XX.XXXX.XXX.XX
  * 16.0060.0010.00
  TYPE SEARCH PARAMETERS
  DELP STEPSDELA STEPSDELD STEPS
  XX.XXXX.XXXX.XXXX.XXX.XX
  * 01.0008.0002.00008.0001.0006.00
  TYPE 1 IF FIRM 2 IS FOLLOWER, ELSE 2
  * 1
  TOTAL PROFIT DISCOUNTED 596.83
  YEAR 1 PRICE 32.00 ADV 35.99 DIST 6.99 PROFIT 83.9 SALES 16.7
  YEAR 2 PRICE 32.00 ADV 37.99 DIST 6.99 PROFIT 79.3 SALES 17.6
  YEAR 3 PRICE 30.00 ADV 48.00 DIST 9.99 PROFIT 70.6 SALES 23.6
  YEAR 4 PRICE 32.00 ADV 48.00 DIST 6.99 PROFIT 137.0 SALES 28.9
  YEAR 5 PRICE 32.00 ADV 48.00 DIST 6.99 PROFIT 121.6 SALES 30.0
  YEAR 6 PRICE 32.00 ADV 48.00 DIST 6.99 PROFIT 104.4 SALES 30.6
  IF MORE TRIALS, TYPE 1, ELSE 2 CONT.
  * 1

FIGURE NO. 3
ON-LINE DYNAMIC MARKETING MIX DETERMINATION
TYPE SEARCH PARAMETERS
DELP STEPSDELA STEPSDELD STEPS
XX.XXXX.XXXX.XXXX.XXXX.XXXX.XX
00.1006.0000.1006.0000.2010.00
TYPE 1 IF FIRM 2 IS FOLLOWER, ELSE 2

<table>
<thead>
<tr>
<th>Year</th>
<th>Price</th>
<th>ADV</th>
<th>DIST</th>
<th>Profit</th>
<th>Sales</th>
<th>Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32.50</td>
<td>33.09</td>
<td>2.79</td>
<td>96.8</td>
<td>14.4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>32.10</td>
<td>43.29</td>
<td>4.19</td>
<td>87.2</td>
<td>16.8</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>30.20</td>
<td>58.20</td>
<td>8.09</td>
<td>76.2</td>
<td>23.3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>32.40</td>
<td>59.30</td>
<td>5.29</td>
<td>139.0</td>
<td>28.1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>32.40</td>
<td>59.30</td>
<td>5.49</td>
<td>123.3</td>
<td>29.3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>32.40</td>
<td>59.30</td>
<td>5.49</td>
<td>105.8</td>
<td>29.9</td>
<td></td>
</tr>
</tbody>
</table>

IF MORE TRIALS, TYPE 1, ELSE 2 CONT.

FIGURE NO. 4
ITERATION MARKETING MIX DETERMINATION
deviates about two dollars from this average value. The irregularity in year three also appears in the distribution recommendations. The distribution is uniformly increased except in the third year where a jump to 8.09 is specified. This irregularity might be the result of the lagged mechanism specified in equation (2) which would reward demand stimulation efforts at that time or it might result because of the limited accuracy in the consideration of the lagged effects which were occasioned by the limited computer research budget for this project. A sensitivity check of the results indicated that if the price in year three were increased to 32.00 and the distribution in year three were reduced to 5.00, the total profit would change by less than one half of one percent.

One competitive alternative is available in this simple model. The strategy implication of a non-adaptive competitor can be analyzed. Figure 5 depicts the continuation of the search with a non-adaptive competitor. In this case the competitor is shown as a price cutter. Only the final iteration of this search is given in Figure 5. The search procedure specifies a high but decreasing price and an advertising and sales force allocation of about 7.5 men as the best counter to the competitor's price cutting strategy.

The IBM 7094 computer time required for these marketing mix optimizations was 13.1 minutes.

The efficiency was in part due to a dynamic programming decomposition of the problem. The dynamic programming recursion used in the search was:

\[ \text{Pr}_t(S_t) = \max_{m_t \in M_t} [f(m_t, S_t) + \text{Pr}_{t+1}(G(M_t, S_t))] \]

and

\[ \text{Pr}_{pp}(S_{pp}) = \max_{m_{pp} \in M_{pp}} [f(m_{pp}, S_{pp})] \]
Where

\[ S_t = G(M_{t-1}, S_{t-1}), \]

where

- \( m_t \) = combination of price, advertising, and distribution chosen for period "t"
- \( M_t \) = total set of possible price, advertising and distribution values for period "t"
- \( S_t \) = Laggs associated with post marketing mixes
  (see LAGG_t in equation 2)

- \( pp \) = last year in the planning period

\[ Pr(S_1) = \text{maximum profit over the planning period} \]
\[ Pr_t(S_t) = \text{total profit earned in year "t" and following years in the planning period} \]
\[ Pr_{pp}(S_{pp}) = \text{profit accrued in the last year of the planning period} \]

\[ f(m_t, S_t) = \text{profit gained from sales (based on equation 2).} \]

The total set of price, advertising, and distribution values based on incremented initial values was generated for each period. Then the profit associated with each mix and the dynamic programming recursion were utilized in defining the optimum marketing mix. The use of the man-machine search procedure and the dynamic programming decomposition enabled a high level of efficiency to be gained while preserving the man-machine interaction and the simple trial and error approach necessary to allow maximum utilization of the manager's good business judgement.
IF NEW COMP WANTED, TYPE 1, ELSE 2, ENDS

* 1
TYPE OUR REF SALES
PER1 PER2 PER3 PER4 PER5 PER6
XX.XXX.XXX.XXX.XXX.XXX.XX
* 20.0019.0018.0017.0016.0015.00
TYPE REFERENCE INDUSTRY SALES
PER1 PER2 PER3 PER4 PER5 PER6
XX.XXX.XXX.XXX.XXX.XXX.XX
* 40.0042.0046.0050.0052.0053.00
TYPE OUR FIRM'S REF PRICE
PER1 PER2 PER3 PER4 PER5 PER6
XX.XXX.XXX.XXX.XXX.XXX.XX
* 30.0030.0030.0030.0030.00
TYPE OUR FIRMS REF ADVER
PER1 PER2 PER3 PER4 PER5 PER6
XX.XXX.XXX.XXX.XXX.XXX.XX
* 40.0040.0040.0040.0040.00
TYPE OUR FIRMS REF DISTR
PER1 PER2 PER3 PER4 PER5 PER6
XX.XXX.XXX.XXX.XXX.XXX.XX
* 10.0010.0010.0010.0010.00
TYPE COSTS
UNIT FXED UNDST
XX.XXX.XXX.XXX
* 16.0060.0010.00

TYPE SEARCH PARAMETERS
DELP STEPSDELA STEPSDELD STEPS
XX.XXX.XXX.XXX.XXX.XXX.XX
* 0.5004.0002.0020.0000.5004.00
TYPE 1 IF FIRM 2 IS FOLLOWER, ELSE 2

* 2
TYPE FIRM 2 PRICE
PER1 PER2 PER3 PER4 PER5 PER6
XX.XXX.XXX.XXX.XXX.XXX.XX
* 30.0028.0024.0020.0017.0016.00
TYPE FIRM 2 ADVER
PER1 PER2 PER3 PER4 PER5 PER6
XX.XXX.XXX.XXX.XXX.XXX.XX
* 40.0035.0034.0032.0031.0030.00
TYPE FIRM 2 DISTR
PER1 PER2 PER3 PER4 PER5 PER6
XX.XXX.XXX.XXX.XXX.XXX.XX
* 10.0010.0005.0005.0005.0005.00
TOTAL PROFIT DISCOUNTED 498.70
YEAR 1 PRICE 51.00 ADV 88.00 DIST 7.99 PROFIT 136.0 SALES 11.2
YEAR 2 PRICE 49.00 ADV 84.00 DIST 7.49 PROFIT 96.3 SALES 10.8
YEAR 3 PRICE 46.00 ADV 85.00 DIST 8.49 PROFIT 60.5 SALES 11.1
YEAR 4 PRICE 45.00 ADV 80.00 DIST 7.49 PROFIT 85.8 SALES 13.5
YEAR 5 PRICE 45.00 ADV 80.00 DIST 7.49 PROFIT 71.6 SALES 13.6
YEAR 6 PRICE 42.00 ADV 79.00 DIST 7.49 PROFIT 48.5 SALES 13.8
IF MORE TRIALS, TYPE 1, ELSE 2 CONT.

* 2
IF NEW COMP WANTED, TYPE 1, ELSE 2 ENDS

* 2
EXIT CALLED. PM MAY BE TAKEN.
R735.633+64.199

FIGURE NO. 5
ON-LINE MIX DETERMINATION WITH NON-ADAPTIVE COMPETITOR
Man-machine Trial-error Search and Optimum Seeking Methods

The man-machine search technique demonstrated in this article is part of a wider class of techniques called optimum seeking methods. Two classes of general search techniques can be identified: indirect and direct. Indirect techniques make use of the necessary optimum conditions of calculus (i.e. the partial first derivative must equal zero at the optimum). Both restricted and unrestricted problems can be analyzed by indirect methods. A common indirect search rule is based on movement from an initial search point in the direction of steepest ascent (descent) for maximization (minimization). The gradient of the function is used to define this direction. Direct methods are based on examining specific values of the objective function and thereby locating the best value. These methods typically start an initial point and move from it by search rule. For example, Hooke and Jeeves have developed a "Pattern Search" which examines the area around the initial point and moves in steps in the direction of improvement. After no more improvement is found, the last point is perturbed a given amount by a pattern move rule and the local exploration and move sequence continues. The search ends when the perturbation step size is as small as desired. The trial and error approach outlined in this paper is not academically as attractive as these direct and indirect routines but there are some compensating features. First, the man-machine grid search avoids some of the restrictive assumptions of the indirect search routines. Indirect routines in general require that the function be once or twice differentiable and some require very restrictive assumptions such as strict convexity. Trial and error programs do not face these restrictions. Some of the problems of indirect search may be overcome with direct search, but direct search routines face limitations of their own.

---


They may "hang up" at a local optimum or at the point at which the search pattern meets a constraint. The trial and error approach is less likely to do this since it drops a grid on the total surface first and then searches more locally.

The flexibilities offered by the interactive trial and error approach may be duplicated in more sophisticated search routines. For example, the local optimum problem can be minimized by repeating the search for different initial points. The problem of artificially settling at a constraint can be eased by programming movement along the constraint or by allowing a stochastic interpretation of the constraint and thereby gaining freedom of movement at the bounds.

These issues suggest questions of computational efficiency. Search routines utilizing elaborate rules for movement will not be able to evaluate as many points per minute as a simple trial and error routine. But the overall efficiency depends upon the time necessary to generate good solutions. The most efficient search method for solving any problem will depend upon the special nature of the problem. Problems with relatively smooth contours and few local optima are most efficiently solved by direct and indirect methods while highly constrained, multivariate discontinuous problems are relatively inefficient to solve using elaborate search routines. It has been the author's experience that marketing problems are characterized by many local optima and that the trial and error programs are effective in moving away from such local conditions. This is due to the simple search rules which allow efficient evaluation of many points and the utilization of a marketing manager's subjective business judgement to guide the search.

It should be remarked that direct and indirect routines can be placed on-line and thereby use the man as an additional heuristic. This capability is useful for the researcher but many routines are complex and would be difficult for a marketing manager to understand and utilize.

---

6 For example, Hooke and Jeeves' program has been placed on-line by Alberto Leon at MIT's project MAC under the name of LOOKMAC.
The simplicity of the trial and error search methodology promotes its understanding and implementation. The computer is essentially doing evaluations the manager would like to do if he had a great deal of time. Another simplicity of the simulation approach is that the programming is not difficult. This is not trivial point, since it has been the author's experience that bringing up a sophisticated search routine is not an easy task. The programs are complex and may contain statements particular to certain classes of problems or computation facilities which require modification or examination of the core statements. The simplicity of programming and methodology make man-machine trial and error search an easy system to implement.

Summary

This paper has outlined the use of an on-line trial and error search program in generating normative model parameter estimates and decision outputs. The on-line search procedure was demonstrated for a data based competitive sensitivity estimation problem and a dynamic optimum marketing mix determination analysis. Finally, the proposed routine was placed in the context of numeric optimization techniques. For marketing problems man-machine trial and error search appears to be a flexible, simple, and efficient method for estimating and analyzing models.