Determining optimal advertisement frequency capping policy via Markov decision processes to maximize click through rates

James G. Shanahan                  Dirk Van den Poel
Independent Consultant (USA)    Ghent University (Belgium)

Methodology
Goal: Maximize long term revenue (CTR) of site visitor by treating problem as a joint optimization of both visitor segmentation and frequency cap policy determination (similar to [1] for direct mail).

Operationalization
Use genetic algorithms to search through possible segmentations of visitors (k-Means, Dtree) where the fitness of each candidate solution is the total discounted revenue over an infinite time horizon. GA-MDP ALGORITHM

Input: RFM dataset
Output: Segmentation of visitors (variables and breakpoints), and policy for each segment
• Create initial pool of candidate segmentations (size = 100)
• For each candidate segmentation
  • Set up data
    1. Draw 100 bootstrap samples
    2. Transition prob. matrices $P_{ij}$
    3. Reward vector $R_i$
  • Determine optimal policy via MDP
    • fitness = total discounted revenue revenue (mean – stdev)
  • Create next generation using mutation and crossover
UNTIL set number of generations

MDP (S, D, T, R, $\gamma \geq 0.9$, Horizon=Infinite)
S: possible state of visitor at time $t$
D: Frequency capping policy during the next time period given the state observed at the end of this time period.
P: Probability to move from state $s_i$ to state $s_{i+1}$
given the frequency capping policy
R: Observed revenue (RFM) from the visitor in each state when policy is applied in the current period

VALUE ITERATION (repeat till convergence):

$V^*(s) = \max_a \left\{ R(s,a) + \gamma \sum_{s'} P(s'|s,a) V^{*}(s') \right\}$

OPTIMAL POLICY

$D^*(s) = \arg \max_a \left\{ R(s,a) + \gamma \sum_{s'} P(s'|s,a) V^{*}(s') \right\}$

Introduction
The term “frequency capping” refers to restricting (capping) the amount of times (frequency) a specific visitor is shown a particular advertisement within a period of time. For example, a frequency cap of “3 per 24” for an ad means that after exposing the user to the same ad 3 times, the visitor will not be shown that ad for 24 hours.

Some of the key benefits of frequency capping are:
• Increased reach – frequency capping is an efficient way to increase reach by expanding the number of people that see the ad.
• Prevent burnout – Click Through Rates (CTR) have been shown to drop precipitously after the first exposure and to plateau at four because of “ad blindness” wherein the user becomes so used to seeing the ad that the user essentially becomes blind to that ad.
• Maintain quality scores – maintain a competitive quality score, a core component of expected CPM-based ranking.

Currently, the frequency capping policy for an ad is heuristically set and is optimized for short term gain and set globally (one-size-fits-all).

Propose to set frequency capping policies for different online marketing segments using Markov decision processes (MDP).

Advantages:
• A data driven approach that optimizes the life time value of site visitors.
• Optimal policy for each segment

Experiments
Experiments on frequency capping work is ongoing at major publisher.

Loyalty card for apparel retailer. Policies:
(0) Do nothing;
(1) Send thank you letter
(2) Send letter plus 1 movie tickets
(3) Send letter plus 3 movie tickets
(4) Send thank you letter plus expensive dinner.

Eight variables: length of relationship, recency of last purchase, total purchased (over 3 time periods), frequency of purchases (13,000 customers)

Figure 1. Search space of possible segmentations and select segmentation that provides highest long term value as determined by MDP. This solution corresponds to a frequency cap policy for each segment.

Table 1. Optimal segmentation (just over lifetime spend variable) and corresponding optimal policy.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Visitor</th>
<th>Policy</th>
<th>Value function</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>1</td>
<td>D (s) = $\max_a \left{ R(s,a) + \gamma \sum_{s'} P(s'</td>
<td>s,a) V^{*}(s') \right}$</td>
<td>270.39</td>
</tr>
<tr>
<td>A1</td>
<td>2</td>
<td>D (s) = $\max_a \left{ R(s,a) + \gamma \sum_{s'} P(s'</td>
<td>s,a) V^{*}(s') \right}$</td>
<td>190.03</td>
</tr>
<tr>
<td>A2</td>
<td>3</td>
<td>D (s) = $\max_a \left{ R(s,a) + \gamma \sum_{s'} P(s'</td>
<td>s,a) V^{*}(s') \right}$</td>
<td>338.31</td>
</tr>
<tr>
<td>A3</td>
<td>4</td>
<td>D (s) = $\max_a \left{ R(s,a) + \gamma \sum_{s'} P(s'</td>
<td>s,a) V^{*}(s') \right}$</td>
<td>381.50</td>
</tr>
</tbody>
</table>

Conclusions
Setting frequency capping policies using the proposed approach optimizes the long term revenue of a site visitor.

The experiments on frequency capping are ongoing. Results on loyalty card program are very encouraging.

Literature

For further information
Please contact James.Shanahan@gmail.com; Dirk.VandenisPoel@UGent.be