Revenue Management under Customer Choice Behaviour with Cancellations and Overbooking[1]

Dirk D. Sierag [1]

[1] Center for Mathematics and Computer Science (CWI), Amsterdam, *dirk@cwi.nl*

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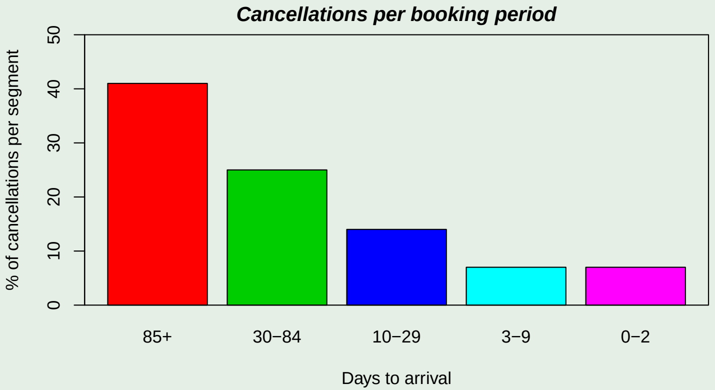
Our Research

- Collaboration with 5 small independent hotels in the Netherlands
- Research motivated by real hotel data

Cancellations



Observations

- 22% of all bookings are cancelled
- Early booking $\implies$ high cancellation probability

Customer Choice Cancellation Model

Properties:

- Customer choice behaviour
- Cancellations
- Overbooking

Related work:

- Subramanian et alii (1999): Cancellations
- Talluri and van Ryzin (2004): Customer choice behaviour
- Newman et alii (2010): Parameter estimation

Other Application Areas

Applying the Cancellation Model in Practice

- Modelling cancellations and customer choice behaviour
- Tractable and well-performing solution methods
- Efficient parameter estimation method

Example (Talluri & van Ryzin, 2004)

Hotel with

- $C = 20$ rooms
- $n = 3$ products with prices

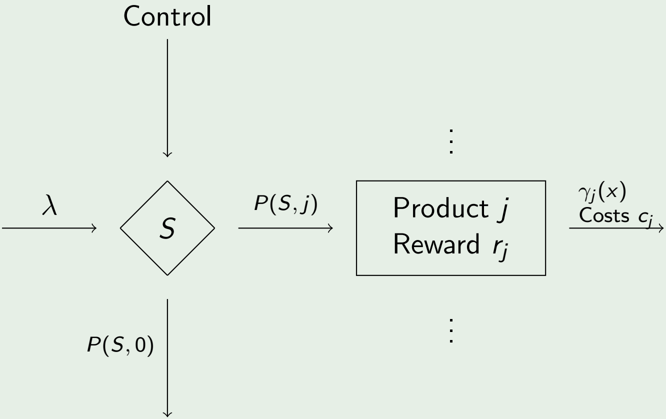
$$r_1 = 160 \qquad r_2 = 100 \qquad r_3 = 90$$

- T days before arrival
- $\lambda = 1/4$ probability that a customer arrives
- x_j number of reservations for product j ($x = (x_1, x_2, x_3)$)
- $\gamma(x_j) = x_j/100$ probability that product j is cancelled
- $c_j = r_j$ costs if product j is cancelled

Example (continued)

- $P(S, j)$ probability that customer buys product j if $S \subset \{1, 2, 3\}$ is offered
- $P(S, 0)$ probability that customer buys nothing
- E.g. $S = \{1, 2\}$ and

$$
\begin{aligned}
P(S, 1) &= 0.1 \\
P(S, 2) &= 0.6 \\
P(S, 3) &= 0 \\
P(S, 0) &= 0.3
\end{aligned}
$$



Control
λ
S
$P(S,j)$
Product j
Reward r_j
$\gamma_j(x)$
Costs c_j
$P(S,0)$

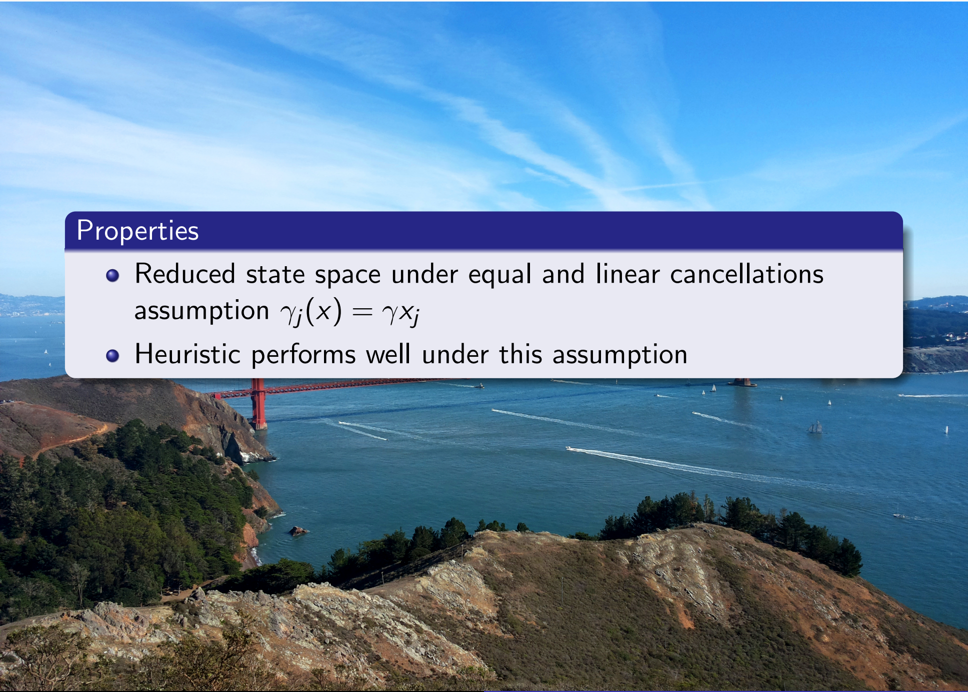
Objective

Which rooms in combination with price and conditions to offer?

Solution

Model as Markov decision process and solve with dynamic programming:

$$
\begin{aligned}
V(x,t) = \max_{S\subset N} \Bigg\{ & \lambda \sum_{j\in S} P(S,j)\big(r_j + V(x+e_j, t-1)\big) \\
& + \sum_{j=1}^{n} \gamma_j(x)\big(-c_j(t) + V(x-e_j, t-1)\big) \\
& + \left(1 - \lambda \sum_{j\in S} P(S,j) - \sum_{j=1}^{n} \gamma_j(x)\right) V(x, t-1) \Bigg\}.
\end{aligned}
$$



Properties

- Reduced state space under equal and linear cancellations assumption $\gamma_j(x) = \gamma x_j$
- Heuristic performs well under this assumption

Estimating Parameters

Maximum Likelihood Function:

$$L(\lambda, \gamma, \beta | x, Z, S, j) = \prod_{t \in D} \left[\lambda P_{tj(t)}(\beta, Z_t, S_t)\right]^{a_\lambda(t)}$$

$$\times \prod_{j=1}^{n} \gamma_j(x_j)^{a_j(t)} \cdot \left[1 - \lambda - \sum_{j=1}^{n} \gamma_j(x_j)\right]^{a(t)}$$

New Parameter Estimation Algorithm

Based on Newman et alii (2010).

1. Estimate $\hat{\gamma}$ (cancellations)
2. Estimate $\hat{\beta}$ (customer choice behaviour)
3. Estimate $\hat{\alpha}$ and $\hat{\lambda}$ using $\hat{\beta}$ (market demand)

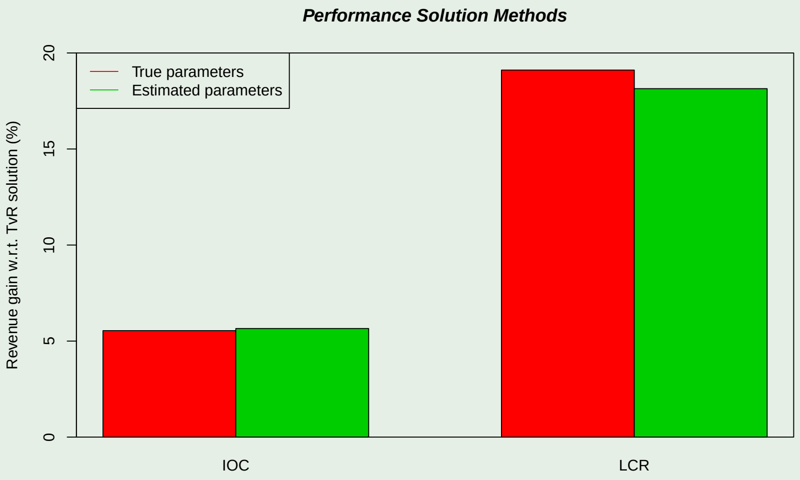
Upside: Fast; accurate; consistent

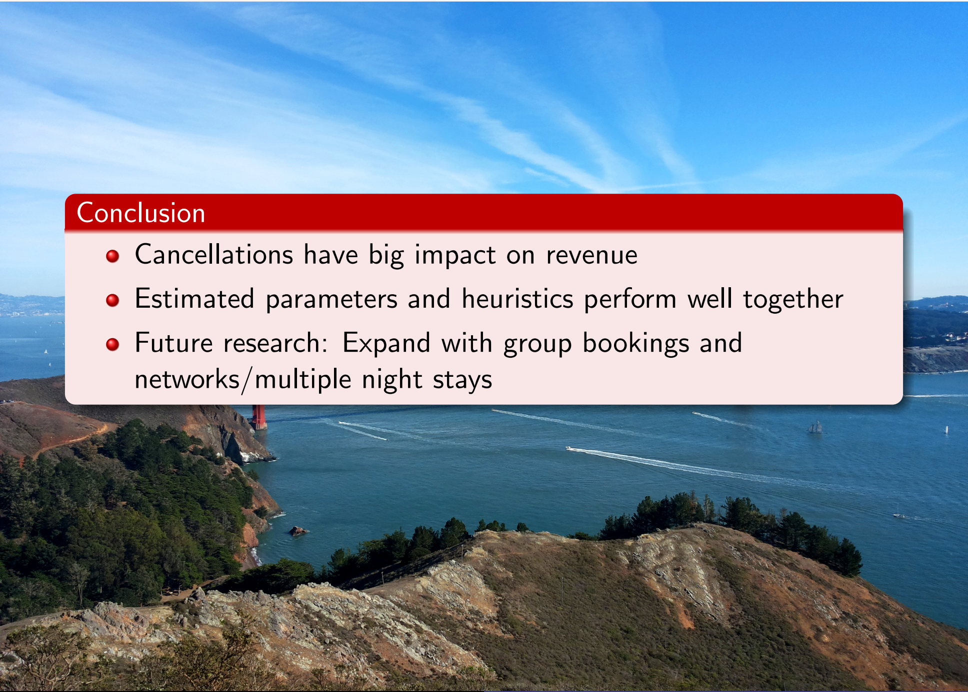
Downside: Data collection difficult for independent hotels

Example: computation time

Observation days	Computation time
10	50.47
20	55.39
50	64.52
100	81.22
200	112.98

Computation time (seconds) of the estimation method for different number of observation days, using $C = 200$, $T = 1000$, $n = 10$.


Performance Solution Methods
Revenue gain w.r.t. TvR solution (%)
0
5
10
15
20
True parameters
Estimated parameters
IOC
LCR



Conclusion

- Cancellations have big impact on revenue
- Estimated parameters and heuristics perform well together
- Future research: Expand with group bookings and networks/multiple night stays