(Approximate) Dynamic Programming in Revenue Management

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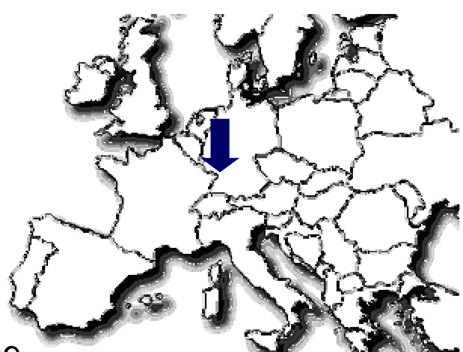
Who I am...

- Diploma and PhD in Industrial Engineering from Universität Karlsruhe (TH), Germany

(Karl's rest - where margrave Karl rests)



- Postdoc at Chicago Booth 2007-2009

- Joined the Decision, Operations, and Technology Management Group at UCLA Anderson in 2009

- Teaching: „Data Analysis and Management Decisions" for MBAs, „Applied Stochastic Processes" in PhD program

- Research: approximate dynamic programming in resource allocation, revenue management, hospital admission, inventory and scheduling

Overview

Markov Decision Processes:

Application in Revenue Management

Idea of Risk Aversion in Revenue Management

Current Research Topics:

Approximate Dynamic Programming

Risk-Averse Revenue Management

1978: Deregulation of US airline industry

Low cost carriers enter the market

Flights of traditional airlines were only half full on average

Offer „empty“ seats at a low price!

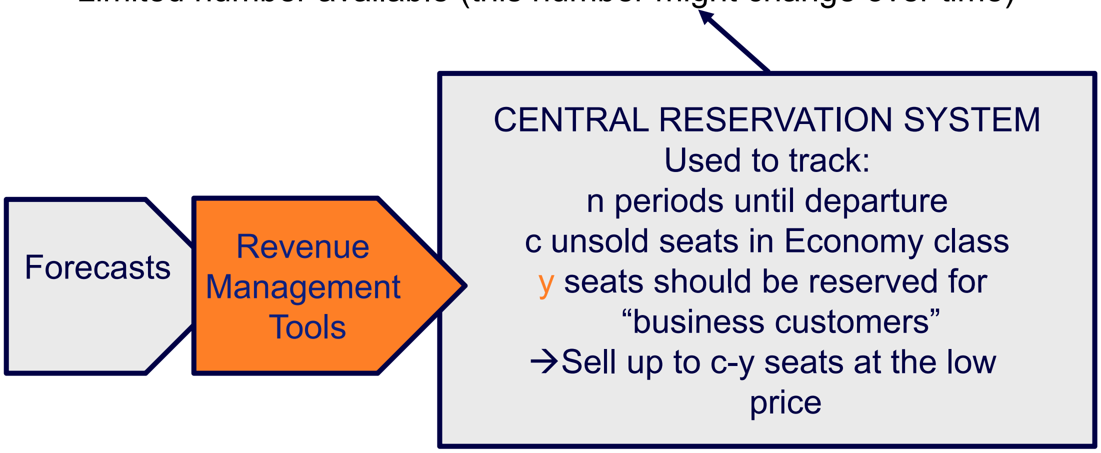
→ positive impact on revenue if cannibalization is prevented and if only seats are offered that would fly empty.

Revenue Management

1978: Deregulation of US airline industry

1985: American Airlines introduces Ultimate Super Saver Tickets

- Very low price
- Many booking restrictions (→ unattractive for business customers)
- Limited number available (this number might change over time)



Revenue Management

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1986/87: People Express is sold

> Burr: "Obviously, People Express failed. We didn‘t get our hands around the Yield Management and automation issues. [If I were starting today], the number one priority on my list every day would be to see that my people got the best possible information technology tools.[...] Traffic on the margin in driven by the best use of information technology."

1990s: Increased academic interest in revenue management (airline-driven)

Today: More and more companies use information technology enabeling them to use revenue management practices

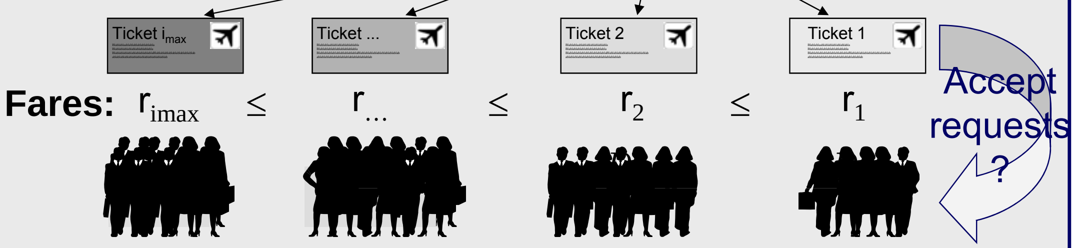
The Risk-Neutral Approach to Revenue Management: A Markov Decision Process

Assumptions:
- Fixed perishable capacity C, variable costs neglegible
- Given number of fare classes $i=1,..,i_{max}$ with given fares $r_1,...,r_{imax}$, cost of overbooking π is high
- Distribution of arrivals D_i known for every fare class $p_i(d)$, $i=1,..,i_{max}$
- Demand is independent between classes and of the capacity controls
- Customers arrive in a strict low to high price order

Goal: Maximize expected revenue

Capacity: C homogeneous units, perish at a given time

Products/ Classes:



The Risk-Neutral Approach to Revenue Management: A Markov Decision Process

Optimal policy is of protection level type!

Always reserve a quantity y_i for fare classes i and lower, sell as much as possible of the remaining $c-y_i$ seats to fare classes i+1 and higher.

- Demand is independent between classes and of the capacity controls
- Customers arrive in a strict low to high price order

$V_i(c,d)$= Maximum expected revenue given c empty seats and facing demand d of class i for integer seats c and integer demand $d \geq 0$.

t=0: $V_0(c,d)=0$ for all c, $d \geq 0$,
$V_0(c,d)=c\,\pi$ for all $c \leq 0$, $d \geq 0$

$t=1,..\,i_{max}$: $V_i(c,d)= \max_{0\leq a \leq d} \left\{ a\, r_a + \sum_{d'} p_{i-1}(d')V_{i-1}(c-a,d') \right\}$

Given seats c, demand d, and stage t, the optimal action is one that maximizes the right hand side.

The Risk-Neutral Approach to Revenue Management: A Markov Decision Process

Example data:

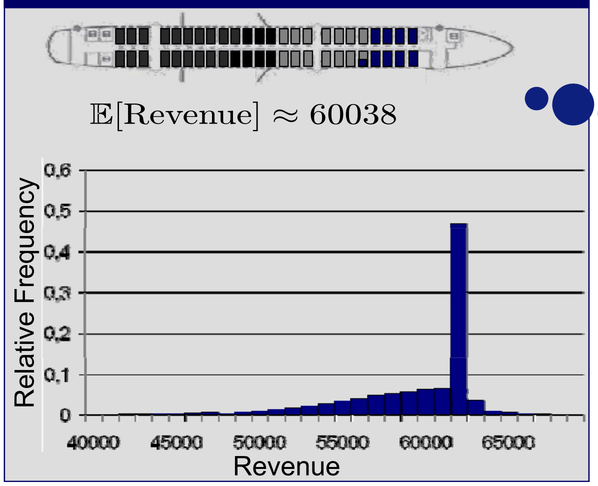
r_4=350	r_3=527	r_2=567	r_1=1050
μ_4=19.8	μ_3=73.6	μ_2=45.1	μ_1=17.3
σ_4=6.6	σ_3=17.4	σ_2=15.0	σ_1=5.8

$C = 100$

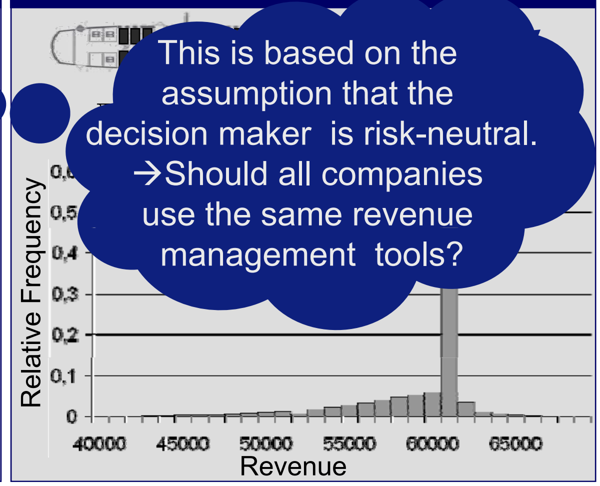
D_i~N(μ_i,σ_i)

$\gamma = 0.0001$

$y_3^* = 133 \quad y_2^* = 44 \quad y_1^* = 17$



$y_3^{\gamma *} = 118 \quad y_2^{\gamma *} = 39 \quad y_1^{\gamma *} = 15$



This is based on the assumption that the decision maker is risk-neutral.
→Should all companies use the same revenue management tools?

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Approximate Dynamic Programming

Most (all?) decision problems can be formulated as a Markov Decision Problem, but the curse of dimensionality often prevents a solution for problems of realistic size.

Solution: Approximate Dynamic Programming

Postulate a certain structure of V, e.g. $V_i(c,d) = \omega_i + \phi_i d + \lambda_i c$.
Then, use techniques from operations research or regression to estimate the parameters. Use price-directed control-heuristics.

Applications I am working on:
- Network (passenger) revenue management
- Cargo revenue management
- Production Planning
- Resource Allocation
- Patient Admission

Thank you!

Topics I am interested in: Optimization in business applications or just for fun, in particular approximate dynamic programming

What I would love to work on, but I don't have time for at the moment (maybe you have?):
-Testing the quality of a novel approximation for network revenue management through simulation
- Analyzing hospital admission data to estimate input parameters for a patient admission problem
- If I get the data: analyzing air cargo data to estimate input
- Using approximate dynamic programming to find a good strategy in Yahtzee

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