Data-Driven Decision-Making
In Enterprise Applications

Dynamic Pricing in Competitive Markets

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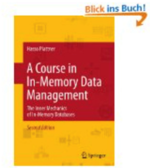
Outline

- Homework: Solution
- Goals of today's meeting: Market Simulations
- How to model customer choice: First approaches
- Simulation of Customer Decisions
- Simulation of Pricing Adjustments

Motivation

- Big picture: Modelling dynamic pricing competition
- Separable components: Customers, Markets, Merchants
- How to describe Customer Behavior?
- We look for a general model which is simple yet reasonable
- How do you decide?

Example: Buying Books on Amazon



A Course in In-Memory Data Management: The Inner Mechanics of In-Memory Databases (Gebundene Ausgabe)
von Hasso Plattner (Autor)
Schreiben Sie die erste Bewertung

Optimieren durch Alles löschen

Versand
- [ ] Prime
- [ ] Versandkostenfrei

Zustand
- [ ] Neu
- [x] Gebraucht
  - [x] Wie neu
  - [x] Sehr gut
  - [x] Gut
  - [x] Akzeptabel

Preis + Versand (inkl. USt)	Zustand	Verkäufer-Information	Lieferung
EUR 44,90 + EUR 3,00 Versandkosten	**Gebraucht - Akzeptabel** Einband intakt und in sehr gutem Zustand, einige Seiten haben kle... » Weitere Informationen	**ialvamani** 100% positiv. (4 alle Bewertungen) Verkäuferinformationen, Impressum, AGB, Widerrufsrecht.	• **Ankunft zwischen** April 26 - Mai 2. • Versandtarife
EUR 45,00 + EUR 3,00 Versandkosten	**Gebraucht - Sehr gut** Versand aus Deutschland / We dispatch from Germany via Air Mail. ... » Weitere Informationen	**lange_und_springer_antiquariat** 98% positiv in den letzten 12 Monaten. (28.584 Bewertungen insgesamt) Verkäuferinformationen, Impressum, AGB, Widerrufsrecht.	• **Ankunft zwischen** April 27 - Mai 2. • Versand aus Deutschland • Versandtarife
EUR 65,60 + EUR 3,00 Versandkosten	**Gebraucht - Wie neu** New, Excellent customer service. Satisfaction guaranteed!!	**Totalbookstore** 89% positiv in den letzten 12 Monaten. (439 Bewertungen insgesamt) Verkäuferinformationen, Impressum, AGB, Widerrufsrecht.	• **Ankunft zwischen** Mai 3-20. • Versandtarife
EUR 79,56 + EUR 3,00 Versandkosten	**Gebraucht - Sehr gut** Publisher: Springer Date of Publication: 2014 Binding: hard... » Weitere Informationen	**Herb Tandree Philosophy Books** 90% positiv in den letzten 12 Monaten. (338	• **Ankunft zwischen** Mai 2-6. • Versand aus Vereinigtes Königreich • Versandtarife

Customer Choice based on a given Market Situation

seller k	price p_k	quality q_k	rating r_k	feedback f_k	shipping c_k
1	**44.90**	**akzeptabel**	**100%**	**4**	**5 Tage**
2	45.00	sehr gut	98%	**28,584**	6 Tage
3	65.60	**wie neu**	**89%**	439	**11 Tage**
4	**79.56**	sehr gut	90%	338	10 Tage
. . .					
K			. . .		

Goals of Today's Meeting

- Task: Understand & describe Customers' Decisions over time

- Assume: A product with multiple features (price, quality, ratings)

  A list of competitors' offers (market situation)

  Stream of interested customers + buying decisions

- Goal: Simulate arriving customer and their buying decision

  given a simulated set of competitors' offers

(1) Stream of Arriving Customer

- Any ideas?
- Simulate random delays (waiting times) between two customers
- Use, e.g., Uniform distributions or Exponential distributions
- Is this doable?

(2) Merchants' Offers & Market Situations

- Simulate offers, i.e., random numbers for prices, quality, ratings

seller k	price p_k	quality q_k	rating r_k
1	**44.90**	**akzeptabel (4)**	**100%**
2	45.00	sehr gut (2)	98%
3	65.60	**wie neu (1)**	**89%**
4	**79.56**	sehr gut (2)	90%
. . .			
K			. . .

(3) Customers' Decision

- Assume: A customer arrives at time t – how does he/she decide?

- Approach I: Always choose the cheapest offer

- Approach II: Use distribution of sales and price rank

- Approach III: Use (randomized) scoring functions

- Other: Combinations, data-driven, etc.

Approach I: Cheapest Offer

- Idea: An interested customer always chooses the cheapest offer

- Easy / deterministic?

- In case of identical prices use probabilities:

$$P(k,\vec{s}) = P(k,\vec{p},\ldots) = \begin{cases} \dfrac{1}{\left|\left\{k=1,\ldots,K : p_k = \min\limits_{i=1,\ldots,K} p_i\right\}\right|} & ,k=1,\ldots,K : p_k = \min\limits_{i=1,\ldots,K} p_i \\ 0 & ,k=1,\ldots,K : p_k > \min\limits_{i=1,\ldots,K} p_i \end{cases}$$

Approach II: Sales vs. Price Rank

- Idea: Relative frequency of sales and price ranks

- Example: 100 sales → #60 rank 1, #30 rank 2, #10 rank 3, . . .

  i.e., H sales - $h_1 = 60$, $h_2 = 30$, $h_3 = 10$, . . .

- Simulate the buying probability $P(k, \vec{s})$ that rank k is chosen, $k = 1, \ldots, K$

  where
$$P(k, \vec{s}) = P(k, \vec{p}, \ldots) = \frac{h_{rank(p_k, \vec{p})}}{\sum_{i=1,..,K} h_i}$$

Approach III: Randomized Scoring

- Idea: Different customers use different scoring functions
- Customer Type1: $\arg\min_{k=1,\ldots,K} \left\{ p_k + 0.1 \cdot q_k - 0.01 \cdot r_k - 0.01 \cdot f_k^{0.5} \right\}$
- Customer Type 2: $\arg\min_{k=1,\ldots,K} \left\{ p_k + 0.15 \cdot q_k - 0.005 \cdot r_k - 0.03 \cdot f_k^{0.5} \right\}$
- Customer Type 3: $\arg\min_{k=1,\ldots,K} \left\{ p_k + 0.2 \cdot q_k - 0.05 \cdot r_k - 0.02 \cdot f_k^{0.5} \right\}$

  . . .

- We can model the decision of a random customer as follows:

$$\arg\min_{k=1,\ldots,K} \left\{ p_k + U(0,0.2) \cdot q_k - U(0,0.1) \cdot r_k - U(0,0.05) \cdot f_k^{0.5} \right\}$$

How to Simulate Customer Choice?

- We need: Realisations of (stochastic) buying behavior for various market situations in our models
- Approach I+II: "*Inverse Verteilungsmethode* for $P(k, \vec{s})$ via U(0,1)"
- Approach III:
  - simulate random scoring coefficients, e.g., U(0,0.05)
  - compute scores for all *K* offers
  - choose the offer with the best score
- Do you think you can do this?

(4) Combination: Arriving and Buying Customers

- Assume a generated market situation
- Simulate arriving customers over time
- Simulate customers' individual decisions
- Doable?

(5) Extensions: Changing Market Situations

- (i) Entry / Exit of firms
- (ii) Price adjustments
- Simulate streams of points in time of a merchant’s actions (“arrivals”)
- Doable?

(6) Demand Learning

- Idea: explain the „dependent variable“ by „explanatory variables“
- „Dependent variable“: number of sales y (of our firm within periods)
- „Explanatory variables“: price rank r
  price difference to best competitor’s price
  ratings, shipping time, . . .
- Remember: Derive the β^* – coefficients for every explanatory variable by linear/logistic regression
- Doable?

(7) Response Strategies

- Assume a merchant can place his/her action at time *t*

- Apply a rule-based price reaction strategy

  (i) Use a random price

  (ii) Undercut the cheapest competitor price

  (iii) Undercut others or raise the price if prices are too cheap

  (iii) Maximize short-term profit

- Doable?

Overview

2	April 25	Linear Programming I
3	April 29	Linear Programming II
4	May 2	Linear/Logistic Regression + Homework (3 weeks time)
5	May 16	Exercise Implementations
6	May 20	Dynamic Programming
7	May 23	Pricing in Competitive Markets
8	**May 27**	**Project Assignments + Homework 2 (until June 13)**
9	June 3	Robust Optimization
10	June 13	Workshop / Group Meetings
11	June 20	Presentations (First Results)
12/13	June 24/27	Workshop / Group Meetings
14/15	July 1/4	Workshop / Group Meetings
16	July 11	Presentations (Final Results), Feedback, Documentation (Aug 31)