Data-Driven Demand Learning and Dynamic Pricing Strategies in Competitive Markets

Customer Behavior

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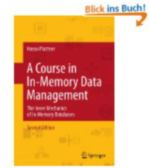
Outline

- Scheduling & Participation
- Goals of today's meeting: Customer Behavior
- How to model customer choice: 3 simple approaches
- Recommended Exercise I: Simulation of Customer Choice
- Recommended Exercise II: Dynamic Pricing Duopoly

Motivation

- Big picture: Modelling dynamic pricing competition
- Separable components: Customers, Strategies & Demand Learning
- 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?

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: Description of Customer Behavior
- Assume: Multiple product features/dimensions (price, quality, etc.)

  A list of competitors’ offers, i.e., a market situation $\vec{s} = (\vec{p}, \vec{q}, \ldots)$

  Stream of interested customers (heterogeneous)
- **Goal:** **Quantify the probability** $P(k, \vec{s})$ that an interested customer

  chooses the **offer *k***, k=1,...,K in a given **market situation** $\vec{s}$

How to Model Customer Choice?

- Any ideas?

- Approach I: Always choose the cheapest offer

- Approach II: Use distribution of sales and price rank

- Approach III: Use a randomized scoring function

- Other: Combinations, data-driven, etc.

Approach I: Cheapest Offer

- Idea: An interested customer always chooses the cheapest offer

- Formula for $P(k,\vec{s})$, $k = 1,...,K$?

- Answer:

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

Approach II: Sales vs. Price Rank

- Idea: Relative frequency of sales and price ranks

- Example: 1000 sales $\rightarrow$ #550 rank 1, #280 rank 2, #100 rank 3, . . .

  i.e., H sales - h_1, h_2, h_3, . . .

- Formula for $P(k,\vec{s})$, $k=1,\ldots,K$?

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

Approach III: Randomized Scoring

- Idea: Different customers use different scoring functions
- C1: $\arg\min_{k=1,\ldots,K} \left\{ p_k - 0.1 \cdot q_k - 0.01 \cdot r_k - 0.01 \cdot f_k^{0.5} + 0.2 \cdot c_k \right\}$
- C2: $\arg\min_{k=1,\ldots,K} \left\{ p_k - 0.15 \cdot q_k - 0.005 \cdot r_k - 0.03 \cdot f_k^{0.5} + 0.1 \cdot c_k \right\}$
- C3: $\arg\min_{k=1,\ldots,K} \left\{ p_k - 0.2 \cdot q_k - 0.05 \cdot r_k - 0.02 \cdot f_k^{0.5} + 0.5 \cdot c_k \right\}$

  . . .

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

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

Approach III: Randomized Scoring

- Idea: Different customers use different scoring functions

- Formula for $P(k,\vec{s})$, $k=1,...,K$?

- Answer: $P(k,\vec{s}) = P(k,\vec{p},\vec{q},\vec{r},\vec{f},\vec{c},...)$

$$= P\left[k = \arg\min_{i=1,...,K} \{ p_i - U(0,0.2)\cdot q_i - U(0,0.1)\cdot r_i - ... \} \right]$$

- Note: Simulation of a customer's choice is easy!

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?

Recommended Exercise I – Simulate Sales Events

- Create random market situations
  with multiple sellers and multiple features

- Simulate customer's selection/choice multiple times
  Check for plausibility

- Extension: Model/simulate an arrival process of interested customers
  Simulate whether an interested customer becomes a buyer

Recommended Exercise II – Duopoly Simulation

- Assume K=2 sellers. Assume only one feature: price

- Define different price reaction strategies $a(p)$, i.e.,

  if the competitor's current price is p, we adjust our price to $a(p)$

  Admissible prices are $a(p) \in \{1, 2, ..., 100\}$

- Let the competitor's response strategy be given by: $p(a) := \max(a-1, 1)$

- We adjust our prices a at times $t = 1, 2, 3, ...$

  The competitor adjusts his prices p at times $t = 0.5, 1.5, 2.5, ...$

Recommended Exercise II – Duopoly Simulation

- In every interval $(t, t+0.5)$, $t = 0, 0.5, 1.0, \ldots$, a sale occurs with probability $1 - \min(a_t, p_t)/100$. With probability $\min(a_t, p_t)/100$ no sale takes place

- If a sale takes place the customer chooses either our offer (k=1) or the competitor's offer (k=2) with probability $P(k, \vec{p})$ according to Approach I, where $\vec{p} = (p^{(1)}, p^{(2)}) = (a, p)$, i.e., $p^{(1)} = a$ (we) and $p^{(2)} = p$ (competitor)

- Simulate until time T=1000. Start with $a_0 = p_0 = 20$ at time $t = 0$

- Which strategy $a(p)$ performs best, i.e., maximizes expected revenues?

Overview

2	April 24/25	Customer Behavior
3	**May 1/2**	**Demand Estimation**
4	May 8/9	Pricing Strategies I
5	May 15/16	no Meeting
6	May 22/23	Pricing Strategies II
7	May 29/30	Dynamic Pricing Challenge & Price Wars Platform
8	June 5/6	Workshop / Group Meetings
9	June 12/13	Presentations (First Results)
10	June 19/20	Workshop / Group Meetings
11	June 26/27	no Meeting
12	July 3/4	Workshop / Group Meetings
13	July 10/11	Workshop / Group Meetings
14	**July 17/18**	**Presentations (Final Results), Feedback, Documentation (Aug/Sep)**