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

Introduction

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April 17, 2018

Outline

- Motivation: Dynamic Pricing under Competition
- Goals of the Course & Grading
- Introduction: Lecturer & Students
- Structure of the Course
- What will be expected from you?

Motivation

- Opportunities:

  Online markets are transparent

  Prices can be easily adjusted

  Market data (offer prices, sales) can be analyzed

  Existing rule-based pricing strategies are suboptimal

- Challenges:

  Stochastic demand, unknown customer behavior

  Many competitors, steadily changing markets

  Derive successful data-driven repricing strategies

Application: Selling Books on Amazon

The Making of a Fly: The Genetics of Animal Design (Paperback)
by Peter A. Lawrence

‹ Return to product information

Always pay through Amazon.com's Shopping Cart or 1-Click.
Learn more about Safe Online Shopping and our safe buying guarantee.

Price at a Glance

List Price: ~~$70.00~~
Used: from **$35.54**
New: from **$1,730,045.91**

Have one to sell? Sell yours here

All | New (2 from $1,730,045.91) | Used (15 from $35.54)

Show ⦿ New ○ Prime offers only (0) — Sorted by Price + Shipping

New 1-2 of 2 offers

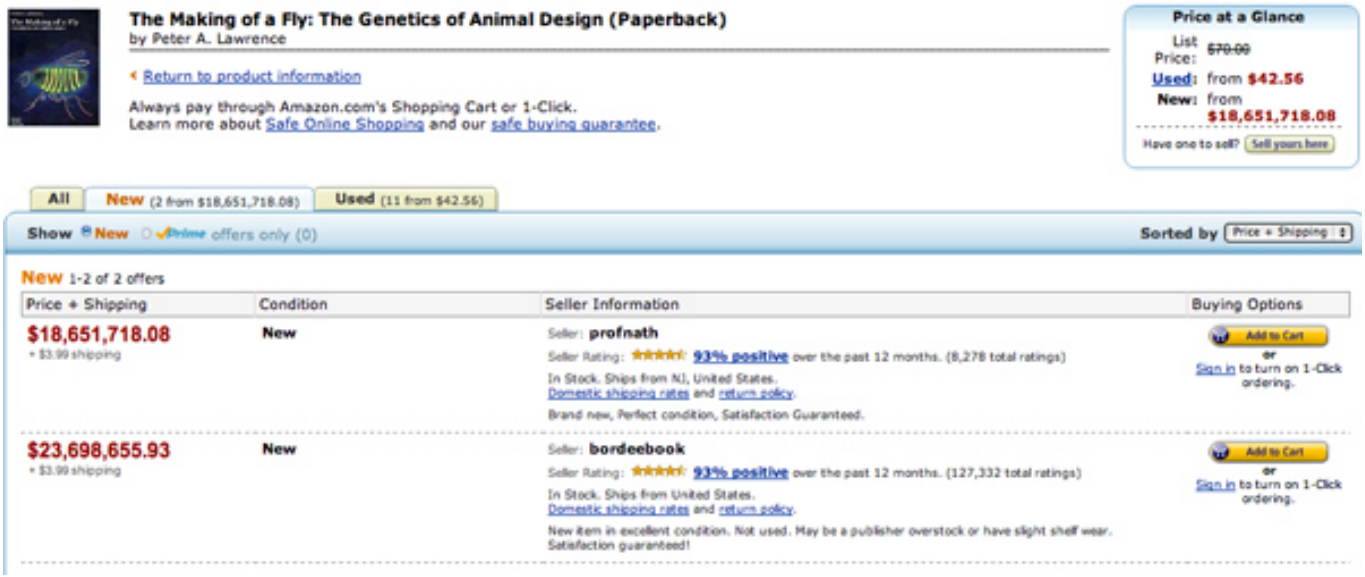
Price + Shipping	Condition	Seller Information	Buying Options
$1,730,045.91 + $3.99 shipping	**New**	Seller: **profnath** Seller Rating: ★★★★★ **93% positive** over the past 12 months. (8,193 total ratings) In Stock. Ships from NJ, United States. Domestic shipping rates and return policy. Brand new, Perfect condition, Satisfaction Guaranteed.	Add to Cart or Sign in to turn on 1-Click ordering.
$2,198,177.95 + $3.99 shipping	**New**	Seller: **bordeebook** Seller Rating: ★★★★★ **93% positive** over the past 12 months. (125,891 total ratings) In Stock. Ships from United States. Domestic shipping rates and return policy. New item in excellent condition. Not used. May be a publisher overstock or have slight shelf wear. Satisfaction guaranteed!	Add to Cart or Sign in to turn on 1-Click ordering.

Suboptimal Response Strategies in a Duopoly

	(*small*) profnath	(*big*) bordeebook	profnath over previous bordeebook	bordeebook over profnath
8-Apr	$1,730,045.91	$2,198,177.95		1.27059
9-Apr	$2,194,443.04	$2,788,233.00	0.99830	1.27059
10-Apr	$2,783,493.00	$3,536,675.57	0.99830	1.27059
11-Apr	$3,530,663.65	$4,486,021.69	0.99830	1.27059
12-Apr	$4,478,395.76	$5,690,199.43	0.99830	1.27059
13-Apr	$5,680,526.66	$7,217,612.38	0.99830	1.27059

Which strategies are applied? Response times? Relevant factors?

How to find Smart Pricing Strategies?



Are there better strategies? Any ideas? Are you interested?

Technical Information

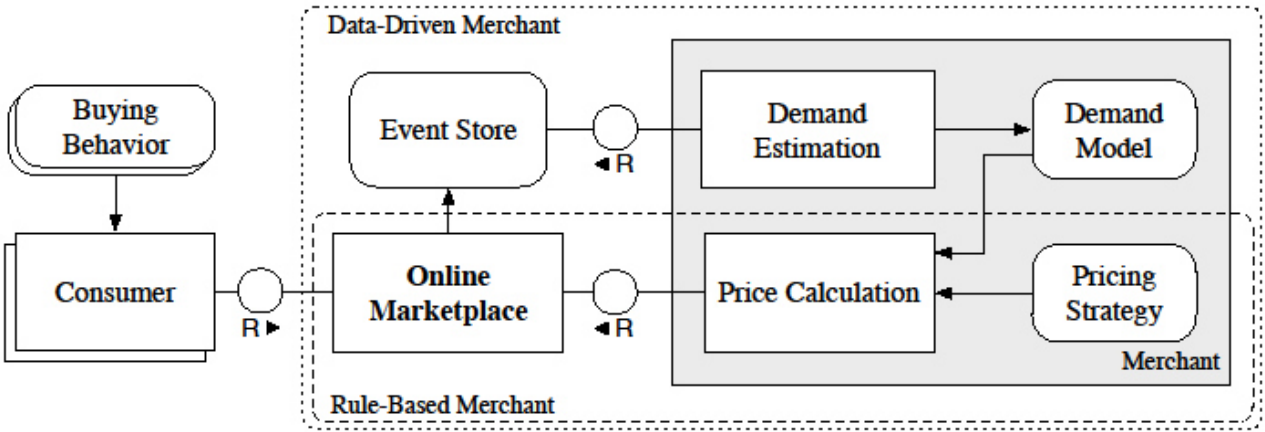
- Credits: 4 SWS (V/Ü), 6 ECTS (graded)
- When? Monday/Tuesday 13.30 - 15.00, weekly
  Start: April 17, 2018, End: July 17, 2018
- Where? D-E 9/10
- Who? Rainer Schlosser, rainer.schlosser@hpi.de
  Martin Boissier, martin.boissier@hpi.de
- Slides? HPI, Teaching, Summer 2018

Goals of the Course & Grading

- Goal: Build data-driven dynamic pricing strategies for competitive online markets
- Learn: Demand estimation + Optimization + Simulation
- Do: Apply approaches & Measure performance
- Grading:
  - 10% Regular attendance / Personal engagement
  - 20% Performance / Design of strategies
  - 30% Presentations
  - 40% Documentation / Paper (End of semester)

Example: Dynamic Pricing Strategies under Competition

Rule-Based vs. Data-Driven Pricing



Demand Learning

time t	**sales** $y_t^{(i)}$	**price** $a_t^{(i)}$	rank $r_t^{(i)}$	competitor's prices for product i (ISBN) $p_{t,1}^{(i)}$	$p_{t,2}^{(i)}$	$p_{t,3}^{(i)}$	$p_{t,4}^{(i)}$	... $p_{t,K}^{(i)}$
1	**0**	**19**	3	13	17	20	25	
2	**0**	**15**	2	13	17	20	25	
3	**1**	**10**	1	13	15	20	/	
4	**0**	**10**	1	13	15	20	22	
5	**1**	**12**	2	11	15	20	24	
...								

$$\arg\max_{\vec{\beta}} P\left(Y_1 = y_1 \mid a_1, \vec{s}_1, \ \ldots, Y_N = y_N \mid a_N, \vec{s}_N\right)$$

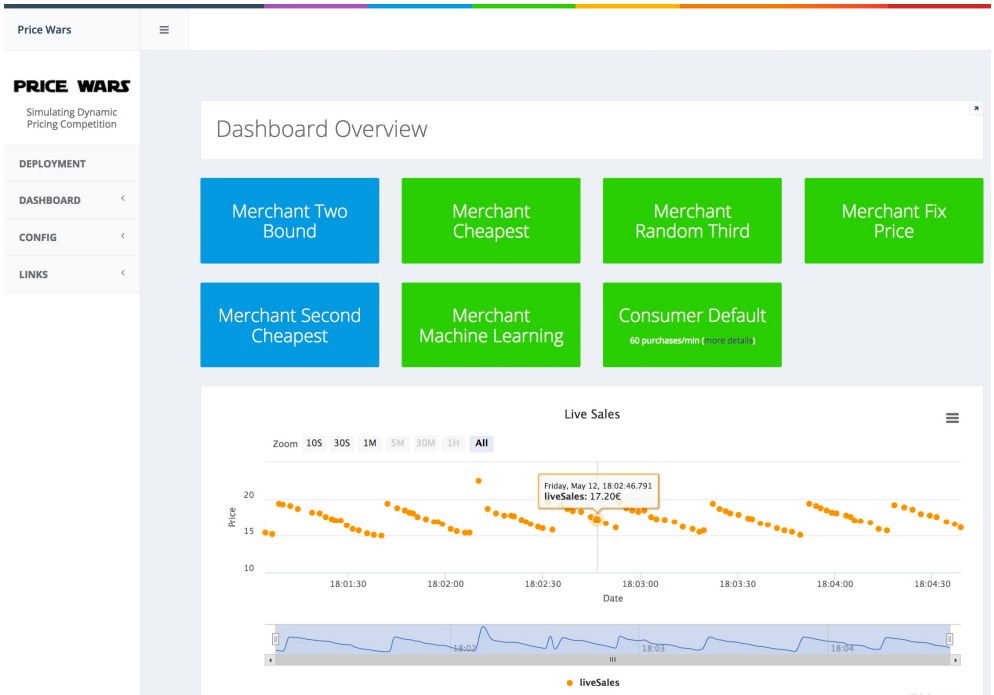
$$= \arg\max_{\beta_m \in \mathbb{R}, m=1,\ldots,M} \left\{ \sum_{i=1}^{N} \left(y_i \cdot \ln\left(\frac{e^{\vec{x}(a_i,\vec{s}_i)'\vec{\beta}}}{1+e^{\vec{x}(a_i,\vec{s}_i)'\vec{\beta}}} \right) + (1-y_i) \cdot \ln\left(1 - \frac{e^{\vec{x}(a_i,\vec{s}_i)'\vec{\beta}}}{1+e^{\vec{x}(a_i,\vec{s}_i)'\vec{\beta}}} \right) \right) \right\}$$

Stochastic Dynamic Optimization

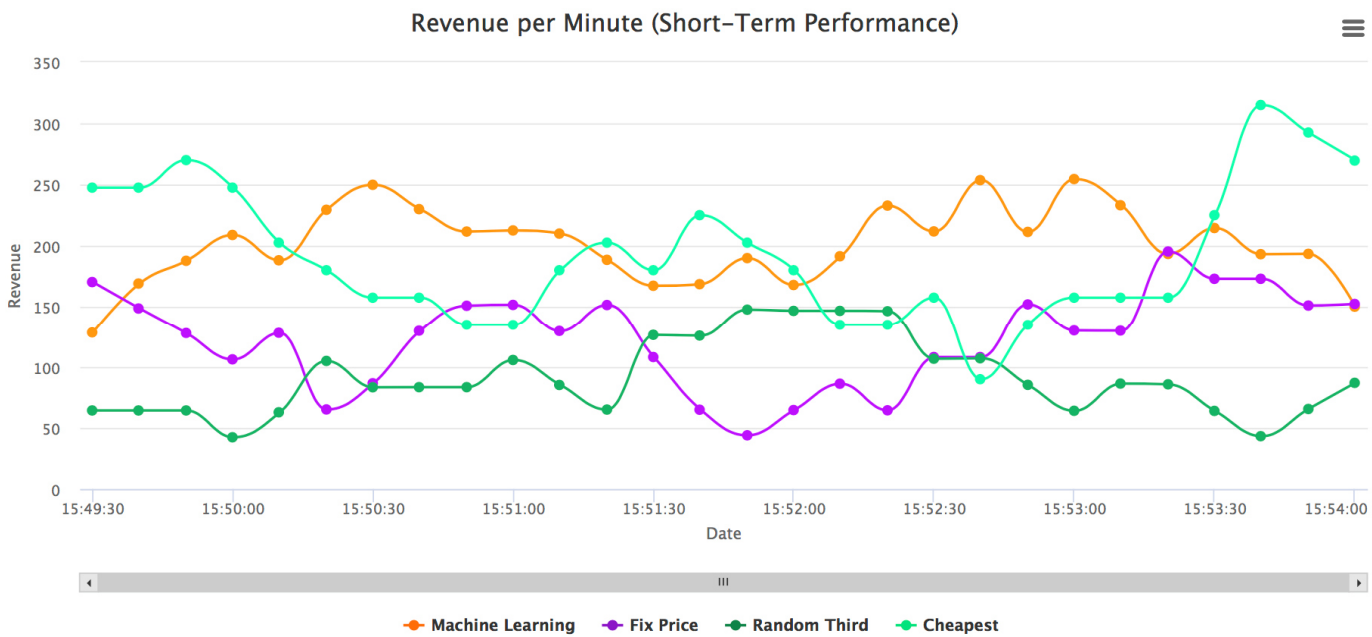
$$\max E\left[\sum_{t=0}^{T} \underbrace{\delta^t}_{\substack{discount\\factor}} \cdot \left(\sum_{i_t \geq 0} \underbrace{P(i_t, a_t, S_t)}_{\substack{probability\ to\ sell\ i_t\ items\\at\ price\ a_t\ in\ situation\ S_t}} \cdot \underbrace{i_t}_{sales} \cdot \underbrace{a_t}_{price}\right) \middle| \underbrace{S_0 = s_0}_{initial\ state}\right], \quad 0 < \delta \leq 1$$

$$V_t(p) = \max_{a \geq 0} \left\{ \sum_{i \geq 0} \underbrace{P(i,a,p)}_{probability} \cdot \left(\underbrace{i \cdot a}_{\substack{today's\ profit}} + \underbrace{\delta \cdot V_{t+1}\left(F(a)\right)}_{\substack{best\ disc.\ exp.future\ profits\ of\ new\ state}} \right) \right\}$$

Price Wars Platform



Pricing under Competition: Performance Measuring



Prerequisites

- Programming

  Parameters, Data Preparation & Analysis
  Loops, Recursions

- Basic Mathematical Background

  Sets, Vectors
  Probabilities, Random Variables, Expected Values

- More does not harm

  Regression Analysis
  Machine Learning Techniques
  Game Theory

Introduction: Lecturer & Students

- Lecturer: Background / Education
  Interests / Field of Research
  Expectations

- Students: Background / Education?
  Interests / Field of Research?
  Expectations?

Structure of the Course

- Meetings: Lectures on „Dynamic Pricing“:
  - (i) Pricing Simulation Platform
  - (ii) Customer Behavior
  - (iii) Demand Estimation
  - (iv) Pricing Strategies
  - (v) Dynamic Pricing Challenge
- June/July: Apply & Improve Data-Driven Strategies
  Input/Support, Questions/Answers, Presentations
- Aug/Sep: Documentation of Projects Results

What will be expected from you?

- Use Machine Learning to Estimate Demand / Sales Probabilities
- Implement Algorithms to Compute Optimized Prices
- Simulate the Outcome of Dynamic Pricing Strategies
- Measure the Performance of Strategies
- Document your Results

Overview

2	April 23/24	Price Wars Platform
3	April 30/1	Customer Behavior
4	May 7/8	Demand Estimation I
5	May 14/15	Demand Estimation II
6	May 21/22	Pricing Strategies
7	May 28/29	Dynamic Pricing Challenge / Projects
8	June 4/5	no Meeting
9	June 11/12	Workshop / Group Meetings
10	June 18/19	Presentations (First Results)
11	June 25/26	Workshop / Group Meetings
12	July 2/3	Workshop / Group Meetings
13	July 9/10	no Meeting
14	**July 16/17**	**Presentations (Final Results), Feedback, Documentation (Aug/Sep)**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