EURO WG Revenue Management Workshop: Wednesday, June 28
13:30 - 14:00 Registration, Coffee
14:00 - 14:45 René AïD (University of Paris-Dauphine / EDF)
   A Principal-Agent model for pricing electricity volatility demand
14:45 - 15:30 Franck Orieux and Ferran Garcia (Air France KLM)
   Air Cargo Revenue Management at Air France KLM
15:30 - 16:00 Coffee
16:00 - 16:45 Bjorn Arenoe (Arenoe Marketing Intelligence)
   Dynamic Pricing at Wijnvoordeel.nl
16:45 Drinks

INFORMS RM&P Section Conference: Thursday, June 29
8:00 Registration, Coffee
8:30 - 10:00 Technical sessions
10:00 - 10:30 Coffee
10:30 - 11:15 Plenary Peter Verhoef (University of Groningen)
11:30 - 13:00 Technical sessions & practical talks
13:00 - 14:30 Lunch and open discussion with RM&P Section Board
14:30 - 16:00 Technical sessions & practical talks
16:00 - 16:30 Coffee
16:30 - 17:30 Technical sessions
18:00 Departure by bus from conference location
18:30 - 23:00 Boat tour, dinner

INFORMS RM&P Section Conference: Friday, June 30
8:00 Registration, Coffee
8:30 - 10:00 Technical sessions
10:00 - 10:30 Coffee
10:30 - 11:15 Plenary Maarten van der Lei (Air France KLM)
11:30 - 13:00 Technical sessions
13:00 - 14:30 Lunch
14:30 - 16:00 Technical sessions
16:00 - 16:30 Coffee
16:30 - 18:00 Technical sessions
### Thursday, June 29, Morning Session

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<tr>
<th>Time</th>
<th>Personalized assortments &amp; promotions (Turing)</th>
<th>Pricing: models and analysis (Euler)</th>
<th>Behavioral aspects of RM (L016)</th>
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<tbody>
<tr>
<td></td>
<td>Gustavo Vulcano</td>
<td>Asbjørn Nilsen Riseth</td>
<td>Dongyuan Zhan</td>
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<tr>
<td>9:00</td>
<td>Price and Assortment Optimization in Systems of Reusable Resources</td>
<td>Pricing Ancillary Service Subscriptions</td>
<td>How Consumers's Implicit Cost Influence on Pricing: A Special Case of Free Product</td>
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<td></td>
<td>Zachary Owen</td>
<td>Ruxian Wang (session chair)</td>
<td>Hao Wang</td>
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<td>Deeksha Sinha (session chair)</td>
<td>Mehmet Gumus</td>
<td>So Yeon Chun (session chair)</td>
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<td>10:30</td>
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**Creating Value with Big Data Analytics, Peter Verhoef (Turing)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Assortment optimization (I) (Turing)</th>
<th>Practical problem session (I) (Euler)</th>
<th>Search costs and consumer learning (L016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30</td>
<td>Assortment Optimization with Limited Substitution</td>
<td>Charles Verstegen Transavia</td>
<td>Product Line Pricing in the Presence of Social Learning</td>
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<tr>
<td></td>
<td>Jacob Feldman</td>
<td>Henning Nobmann Beuth Hochschule für Technik Berlin</td>
<td>Nafiseh Sedghi</td>
</tr>
<tr>
<td>12:00</td>
<td>Greedy-like Algorithms for Dynamic Substitution Models Under Multinomial Logit Preferences</td>
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<td>Price Obfuscation and Consumer Surplus in Online Diamond Retail</td>
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<td></td>
<td>Ali Aouad</td>
<td>Rik van Leeuwen, Jeroen de Korte IrevenU</td>
<td>Stanislav Mamonov</td>
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<tr>
<td>12:30</td>
<td>On the Random Consideration Set Choice Model of Manzini and Mariotti</td>
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<td>Learning Fast and Slow: Rational Inattention when Learning Happens on Two Different Speed Levels</td>
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<td>Anran Li (session chair)</td>
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<td>Frank Huettner (session chair)</td>
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### Thursday, June 29, Afternoon Session

**13:00**

**Lunch and Open Discussion with RM&P Section Board (Turing)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Description</th>
<th>Speakers</th>
<th>Session Chair</th>
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<tr>
<td>14:30</td>
<td><strong>Online advertising &amp; mechanism design (I) (Turing)</strong></td>
<td><strong>Practical problem session (II) (Euler)</strong></td>
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<tr>
<td></td>
<td>Lunch and Open Discussion with RM&amp;P Section Board (Turing)</td>
<td><strong>Waterfall Revenue Optimization for Online Advertising</strong></td>
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<td></td>
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<td><em>John Turner</em></td>
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<tr>
<td>15:00</td>
<td><strong>Tight Competitive Ratios for Online Matching/Assortment Problems with a</strong></td>
<td><strong>Waterfall Revenue Optimization for Online Advertising</strong></td>
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<td></td>
<td>Fixed Set of Edge-weights/Prices</td>
<td><em>Daniel Hopman</em></td>
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<td><em>Emirates Airline</em></td>
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<td><em>Oxford Data Science Lab</em></td>
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<td><em>Alwin Haensel</em></td>
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<td><em>Haensel AMS &amp; Cargonexx</em></td>
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<td><em>K.S.S. Iyer</em></td>
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<td><em>Symbiosis Inst. Telecom Management</em></td>
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<tr>
<td>15:30</td>
<td><strong>Listing Policies and Market Thickness in Online B2B Auctions Markets</strong></td>
<td><strong>Waterfall Revenue Optimization for Online Advertising</strong></td>
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<td></td>
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<td><em>Wenchang Zhang (session chair)</em></td>
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**14:30 - 16:30**

**Aircraft RM (Euler)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Presentation Title</th>
<th>Speaker(s)</th>
<th>Session Chair</th>
</tr>
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<tbody>
<tr>
<td>16:30</td>
<td><strong>A Constact-Factor Approximation Algorithm for Capacity Allocation over a</strong></td>
<td><em>Huseyin Topaloglu</em></td>
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<td></td>
<td>Single Flight Leg with Fare-Locking</td>
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<tr>
<td>17:00</td>
<td><strong>Dynamic Programming Approaches for Simultaneous Control of Several Leg</strong></td>
<td><em>Thomas Winter (session chair)</em></td>
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<td>Compartments**</td>
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**16:30 - 17:00**

**RM Practice Prize Award and Dynamic Pricing Challenge**

<table>
<thead>
<tr>
<th>Time</th>
<th>Presentation Title</th>
<th>Speaker(s)</th>
<th>Session Chair</th>
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<tbody>
<tr>
<td>16:30</td>
<td><strong>Pricing Tolls under Uncertainty: Static and Dynamic Models</strong></td>
<td><em>Trivikram Dokka</em></td>
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<tr>
<td>17:00</td>
<td><strong>Pricing Strategy, Capacity Level and Collusion in a Market with Delay</strong></td>
<td><em>Liron Ravner (session chair)</em></td>
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<td>Sensitivity**</td>
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**17:00**

**Departure by bus**
<table>
<thead>
<tr>
<th>Time</th>
<th>Choice models: estimation (Turing)</th>
<th>Pricing and optimal display (Euler)</th>
<th>Pricing in specific applications (I) (L016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30</td>
<td>Unconstraining Demand using Customer Choice Sets</td>
<td>Inducing Optimal Consumer Bid Behavior</td>
<td>Dynamic Pricing Approaches for Electricity Rate Design</td>
</tr>
<tr>
<td></td>
<td>Ger Koole</td>
<td>Chris Anderson</td>
<td>Michael Hinterstocker</td>
</tr>
<tr>
<td>9:00</td>
<td>Predicting User Choice in Video Games</td>
<td>Optimization of the Retail Profit Function under the Multiplicative Demand Model</td>
<td>Nonlinear Pricing for Capacitated Stochastic Container Leasing System with Dynamic Arrivals</td>
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<tr>
<td></td>
<td>Arjun Khandelwal</td>
<td>Kalyan Talluri</td>
<td>Wen Jiao</td>
</tr>
<tr>
<td>9:30</td>
<td>A Comparative Empirical Study of Discrete Choice Models in Operational Contexts</td>
<td>Online Learning, Decision Making and Seasonality under Bayesian Exploration</td>
<td>Dynamic Pricing in the Vehicle Ferry Industry</td>
</tr>
<tr>
<td></td>
<td>Gustavo Vulcano (session chair)</td>
<td>Andria Ellina (session chair)</td>
<td>Christopher Bayliss (session chair)</td>
</tr>
<tr>
<td>10:30</td>
<td>From red to black - how integrated optimization of the airline value chain can yield great results, Maarten van der Lei (Turing)</td>
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</tr>
<tr>
<td>11:30</td>
<td>Online advertising &amp; mechanism design (II) (Turing)</td>
<td>Pricing with side information and pricing under debts (Euler)</td>
<td>Product upgrades and secondary markets (L016)</td>
</tr>
<tr>
<td></td>
<td>Multi-Stage Intermediation in Display Advertising</td>
<td>Personalized Dynamic Pricing: Individualization over Segmentation</td>
<td>To Ration or Not to Ration? Selling to Strategic Customers under Scarcity Effects</td>
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<tr>
<td></td>
<td>Huseyin Gurkan</td>
<td>Bora Keskin</td>
<td>Stephen Shum</td>
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<tr>
<td>12:00</td>
<td>Dynamic Mechanism Design under Positive Commitment</td>
<td>Learning Preferences with Side-Information: Near Optimal Recovery of Tensors</td>
<td>Optimal Manufacturing, Remanufacturing and Trade-In Policies with Secondary Market and Competition</td>
</tr>
<tr>
<td></td>
<td>Ilan Lobel</td>
<td>Andrew Li</td>
<td>Lipan Feng</td>
</tr>
<tr>
<td>12:30</td>
<td>Auctions in the Online Display Advertising Chain: A case for Independent Campaign Management</td>
<td>Dynamic Pricing Under Debt: Spiraling Distortions and Efficiency Losses</td>
<td>Dynamic Pricing and Replenishment with Customer Upgrades</td>
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<td></td>
<td>Amine Allouah (session chair)</td>
<td>Dan Iancu (session chair)</td>
<td>Oben Ceryan (session chair)</td>
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<tr>
<td>Time</td>
<td>Sharing networks: optimal control (Turing)</td>
<td>Bundling and pricing (Euler)</td>
<td>Business-to-business pricing and contract design (L016)</td>
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<tr>
<td>14:30</td>
<td>Surge Pricing Beyond &quot;Matching Supply and Demand&quot;</td>
<td>Setting Prices for Ancillary Items</td>
<td>Optimizing Rates for Service Agreements by Shaping Loss Functions</td>
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<tr>
<td>15:00</td>
<td>Spatial Pricing in Ride-Sharing Networks</td>
<td>Revenue Management With Bundles</td>
<td>Use Supportive Pricing and Purchase Order Financing to Maximize Revenue</td>
</tr>
<tr>
<td>16:30</td>
<td>Assortment Rotation and the Value of Concealment</td>
<td>Discontinuous Demand Functions: Estimation and Pricing</td>
<td>Optimal Assortment Planning under Capacity Constraint for Retailers Using Transshipments</td>
</tr>
<tr>
<td>17:00</td>
<td>A New Mathematical Framework for a Choice-Based Optimization Model</td>
<td>On Network Revenue Management with Forward-Looking Customers</td>
<td>Promotion Planning of Network Goods</td>
</tr>
<tr>
<td>17:30</td>
<td>TV market in China</td>
<td>Expected Revenue Estimation for Multimedia Service Provider using Random Point Process</td>
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**Speakers:**
- Francisco Castro
- John Wilson
- Maarten Oosten
- Kostas Bimpikis
- Tarek Abdallah
- Wei-Di Wu
- Philipp Afèche (session chair)
- Masoud Khakdaman (session chair)
- Nikos Trichakis (session chair)
- Ningyuan Chen (session chair)
- Shadi Sharif Azadeh (session chair)
- Nikos Trichakis (session chair)
- Ningyuan Chen (session chair)
- K.S.S. Iyer (session chair)
Abstracts EURO Working Group Workshop

Wednesday, 14:00 – 14:45, EULER
A principal-agent model for pricing electricity volatility demand

René Aid, University of Paris-Dauphine & EDF

We formulate the problem of pricing demand-side management contracts in electricity markets as a Principal-Agent problem. The Principal is a producer subject to both energy generation cost and variation of generation costs. The Principal observes in continuous-time the consumption of the Agent who is a single consumer, but he does not observe the efforts she makes to reduce her consumption and the volatility of her consumption in her different usages. Using the dynamic programming methods of Cvitanic, Possamai & Touzi (2015), we find the optimal contract that maximises the utility of the principal. Numerical simulations show that the Principal is better off proposing this demand-side management contract even if the agent reveals to be passive. Moreover, we study the possibility to approximate the optimal contract with a sequence of Markovian contracts. Numerical simulations show that the approximate contract succeeds in inducing the efforts of the Agent on the level of her consumption but not on her volatility. This is a joint work with Dylan Possamai and Nizar Touzi.

Bio: René Aid is a professor of economics at the University of Paris-Dauphine. He started his career at EDF R & D as a research engineer on models for the optimization and valuation of electricity generation assets. He then served as a research team leader. In 2006, he co-founded and managed the Finance for Energy Markets Research Initiative, a joint laboratory between Dauphine, EDF, Ecole Polytechnique and CREST. In 2012, he took on the post of deputy-head of department to EDF R & D before joining the Paris-Dauphine University in 2016. His work focuses on the management of financial risks in the energy markets.

Wednesday, 14:45 – 15:30, EULER
Air Cargo Revenue Management at Air France KLM

Franck Orieux and Ferran Garcia, Air France KLM

Air Cargo Revenue Management differs from Passengers Revenue Management in several aspects due to specific characteristics of cargo business and booking behavior. With overcapacity pushing demand away from profitability, Cargo organizations need to develop Freight Intelligent Technics to maximize Cargo contribution, at lower variable cost, by matching Customer’s demand and Capacity Offer, while facilitating sales to make the right offer and operations to optimize execution.

The purpose of this presentation is to present how Air France-KLM cargo is evolving toward such more data driven approach using Advance Analytics techniques framework to sustain such requirement and to empower organization’s agility for faster business decision in this changing and difficult business environment.

Bio: Franck Orieux began his career at Air France in 1990 at Air France Industry. He joined Air France cargo in 1994 serving in various management positions including abroad assignments in USA, then Air France - KLM for UK &IE and then for Japan and Korea. He has been appointed VP Revenue Management Cargo for Air France- KLM in 2012. A native of Paris, Franck Orieux is a graduate from the French National Graduate School of Engineering of Lyon (INSA LYON), and holds an MBA from the University of Paris I Panthéon-Sorbonne. He is married with two children.

Bio: Born in Barcelona, Ferran Garcia started his studies in the Polytechnic University of Catalonia, then moved to Paris to join the Ecole des Ponts ParisTech for a double degree on Mathematics and Computer Science. He completed his studies obtaining a MSc on Operations Research. He joined the Air France - KLM Operations Research department in 2014 for an internship and switched to a full-time position afterwards. Since the end of 2015 he is in the lead of the Cargo domain in the OR department, a team of 7 Data Scientists dedicated to analytically support all AFKL Cargo businesses.
Abstracts EURO Working Group Workshop

Wednesday, 16:00 – 16:45, EULER
Dynamic Pricing at Wijnvoordeel.nl

*Bjorn Arenoe, Arenoe Marketing Intelligence*

This presentation gives a short account of a pilot project that was carried out during 2015 and 2016 involving The Centre of Mathematics and Computer Science (CWI), Wijnvoordeel.nl (Netherlands largest online wine retailer) and Arenoe Marketing Intelligence (AMI), the author’s own company which specialises in pricing research and dynamic pricing solutions for online retailers.

At the time, Arnoud den Boer was just finalizing his doctoral dissertation on a revolutionary approach to dynamic pricing aimed specifically at (online) retailers. In contrast to the more commonly used practice of analysing historical data to predict probable price changes (which is often highly inaccurate for many reasons), his approach was unique in that it not only relied on price experiments in an actual (online) shopping environment but also implemented a cutting-edge ‘self-learning’ algorithm that dynamically calculated the optimal price points for all products at every time period.

The objective of the project was to translate Arnoud’s model into a prototype to implement Arnoud’s model into Wijnvoordeels regular business thereby increasing their profit margins substantially. Eventually we achieved an average increase in these profit margins by an estimated 40%. Moreover, for the first time ever the marketing managers of Wijnvoordeel.nl had access to a tool with which they could predict the conversion, revenue and profit margin of any suggested price change for all of the tested products before these changes were implemented.

The biggest challenge for us though, was how to transform Arnoud’s analytical algorithms and formula’s into a practical, reliable tool that works even under the worst of circumstances. For that purpose we needed to make quite a few changes to the original model so as to come up with a solution that was acceptable for all parties involved.

Bio: Bjorn Arenoe is CEO of Arenoe Marketing Intelligence, a company that provides dynamic pricing software for (online) retailers and service providers. Before, Bjorn Arenoe was marketing analytics consultant at Accenture and senior lecturer yield & revenue management at the Hotelschool Den Haag.
Thursday, 10:30 – 11:15, TURING
Creating Value with Big Data Analytics

Peter C. Verhoef, University of Groningen

Many organizations are struggling with the explosive growth and diversity of data, or fear missing out. Big Data promises an in-depth understanding of market developments, brand performance and customer behavior, in a way that it creates significant value for both the customer and the firm. I will discuss how firms can create value with big data using a so-called big data value creation model. I will show examples on how firms in different industries have exploited big data and the pitfalls that they face. I will particularly show a case-study, where we show how the Dutch National Railways used big data to understand and improve customer satisfaction.

Bio: Peter C. Verhoef (1972) is Professor of Marketing at the Department of Marketing, Faculty of Economics and Business, University of Groningen, The Netherlands. He is the director of the University of Groningen Business School (UGBS). He obtained his PhD. in 2001 at the School of Economics, Erasmus University Rotterdam, The Netherlands. He published widely in prestigious journals and is a member of multiple editorial boards and area/senior editor of Marketing Science, Journal of Marketing Research and International Journal of Research in Marketing. His research is extremely well cited and has won numerous awards. He is the author of the book Creating Value with Big Data Analytics, published by Routledge.

Friday, 10:30 – 11:15, TURING
From red to black - how integrated optimization of the airline value chain can yield great results

Maarten van der Lei, Air France KLM

Given the complexity of the airline business, optimization questions within an airline can be found on many different levels and departments within the company. Often departments have their own objectives and try in the best way possible to optimize their respective scopes. An approach which is too much silo-based can lead to sub-optimal outcomes for the company as a whole. How can this be avoided? How can integrated optimization of the value chain be achieved? This keynote will focus on these questions by looking at the lessons learned in the recent turnaround of the European network of KLM.

Bio: Maarten van der Lei (44) is currently heading the Pricing and Revenue Management team of KLM Europe. He holds a master of science in both pure (VU) and applied mathematics (TUE). Over the last 18 years he fulfilled various positions within AIRFRANCE KLM in Operation Control, Network Strategy and Planning, Cabin Crew Planning and Pricing and Revenue Management. He lives in Amstelveen, is married and father of six. Last year he ran the Big Sur marathon and Lagavullin is his favorite Single Malt.
Abstracts INFORMS RM&P Section Conference

Technical Sessions & Practical Problem Sessions
Thursday, 8:30 – 10:00, TURING

**Personalized assortments & promotions**

1. **Customized individual promotions: Model, optimization, and prediction**
   
   Gustavo Vulcano, NYU – UTDT, gvulcano@stern.nyu.edu

   We consider the problem of predicting an individual customer's response to a product promotion using historical purchase transactions data, tagged by customer ID. The problem is challenging due to the limited number of observations available for each individual. To extract the signal from the limited data in the most efficient way, we model each individual through a partial-order consisting of two copies of each product: when the product is under promotion and otherwise. We calibrate an MNL model over the partial orders and quantify its prediction power on out-of-sample transactions. Then, we use this information to optimize personalized promotions.

2. **Price and Assortment Optimization in Systems of Reusable Resources**

   Zachary Owen, MIT, zowen@mit.edu

   We develop algorithms for assortment optimization in systems of reusable resources with heterogeneous customer preferences. In this setting, the operator observes the type of arriving customers and may offer a personalized assortment of resources to each. In contrast to the case of consumable products, a purchasing customer consumes a unit of capacity at the chosen resource for a possibly random period of time, after which the resource is returned to the operator. Through their policy, the operator seeks to maximize revenue by efficiently balancing the demand of various customer types across their network of resources. When prices are fixed exogenously, we demonstrate that a heuristic LP-based state-independent policy achieves at least 50% of the revenue attainable by the optimal dynamic assortment policy. We improve upon this result by formulating the problem of finding the optimal state-independent policy as a convex program with an exponential number of variables, but demonstrate that it can be solved efficiently. When real-time utilization information is available, we propose heuristic dynamic policies. We further consider the joint pricing and assortment problem and demonstrate that when price discrimination is feasible, many of the techniques for the assortment-only case carry over. On the other hand, when price discrimination is disallowed, we formulate the fair pricing problem and show that solving this problem is challenging in that the requisite subproblem is NP-hard in general, even under the multinomial logit choice model. Despite this, we demonstrate techniques to develop joint pricing and assortment strategies in a number of practically relevant special cases. Finally, we validate each of our methods using computational experiments based on parking bay utilization data from a borough of London. Our results suggest that pricing and assortment optimization can serve as effective methods for revenue management and inventory control in the management of systems of reusable resources.

3. **Sublinear Time Recommendation Algorithms**

   Deeksha Sinha, MIT Operations Research Center, deeksha@mit.edu

   Recommendations and personalization are now accepted as core competencies in just about every online setting, ranging from media platforms to e-commerce to social networks. While the challenge of estimating user preferences has garnered significant attention, the operational problem of using such preferences to recommend a personalized set of items to a user is not as well understood. The problem is akin to an assortment optimization problem, but the challenges unique to modern settings are a massive number of items and a fast response time requirement: with millions of items and the need to make recommendations in 10 to 100 milliseconds, even enumerating all of the items is impossible. Thus motivated, we propose an algorithm for personalized assortment optimization that runs in time sublinear in the number of products. Our algorithm works for an extremely general class of choice models that includes the mixture MNL model as a special case. We achieve sublinear runtime by leveraging the dimensionality reduction from learning an accurate latent factor model and a class of sublinear time approximate nearest-neighbor algorithms. Our algorithm is entirely data-driven, relying on samples of the user, where a 'sample' refers to the user interaction data typically collected by firms. We show that a constant-factor approximation is achieved when the number of samples is logarithmic in the number of products, and precisely capture a key tradeoff in performance between runtime and number of sample; in particular, one can identify in practice whether the 'bottleneck' in performance is due to lack of computation time or data. We evaluate our approach on a massive content discovery dataset from Outbrain that includes millions of advertisements. Results show that our implementation indeed runs on the order of milliseconds, with limited observations of user browse behavior. Joint work with Vivek Farias and Andrew Li.
Thursday, 8:30 – 10:00, EULER
Pricing: models and analysis

1 Dynamic pricing for diffusion based models
Asbjørn Nilsen Riseth, University of Oxford, riseth@maths.ox.ac.uk

In this presentation, we consider a continuous-time, dynamic pricing problem of one product with stochastic demand. Given an initial amount of stock, our goal is to maximise revenues and minimise the cost of remaining stock after some terminal time. We investigate two diffusion based models for the demand. The first model comes from the literature, but has the unfortunate consequence that, over small timescales, sales are negative with large probability. The second model ensures that sales are non-negative over all timescales. We compare the optimal pricing strategies of the two models for a risk neutral decision maker, and investigate the impact of different risk-aversion profiles on the pricing strategies.

2 Pricing Ancillary Service Subscriptions
Ruxian Wang, Johns Hopkins University, ruxian.wang@jhu.edu

We investigate customer choice behavior in the presence of main products, ancillary services with options of pay-per-use and subscription, as well as the outside option. The willingness-to-pay for service subscription is derived in a closed-form expression, which enables us to characterize the optimal pricing strategy and the impact of service subscription on customer surplus. Analytical results and numerical experiments show that offering service subscriptions may result in “win-win”, “win-win-win”, “win-win-lose”, “lose-lose-win” and other situations for the firm, competitors and customers in a variety of monopolistic and competitive scenarios. The advantages of service subscription remain with heterogeneous customers differing on multiple dimensions, e.g., the nominal utility, uncertainty in the need of ancillary service and purchase frequency. Surprisingly, if the product quality for both firms, measured by nominal utility, is not significantly different, more fierce price competition by offering service subscription may result in higher customer surplus, compared to that without service subscription. Ancillary service subscription can help firms to better price-discriminate heterogeneous customers through different subscription decisions and subsequent purchase behavior.

3 Guaranteed Trade-in Price Strategy: Deconstructing Its Value for Consumers and Firms
Mehmet Gumus, McGill University, mehmet.gumus@mcgill.ca

This paper analyzes a guaranteed trade-in program that firms offer to consumers giving them the option, but not obligating them, to return their used durables for a pre-specified resale value when buying an upgraded product in the future. This presumably encourages the consumers to upgrade. We study the value of such a strategy and the source of that value for firms and consumers. The basic framework of our analysis is a two-period model where a firm (retailer) sells a durable product to consumers. Consumers are non-renewable and strategic. We consider two ownership models for them: (i) just “buy” the product, and (ii) buy it with the “guaranteed trade-in” service. Our analysis indicates that this service actually is a win-win situation for both the retailer and the consumers in general, even if it is given for free. Interestingly, deconstruction of the source of this value reveals that, for the consumers, it comes from the optionality feature because of which they can use either the retailer or the spot market channel to trade-in. Although discussion about this strategy focuses on the resale value protection it provides, we demonstrate that this component of the service (without optionality) is actually harmful for the consumers. The retailer, however, extracts benefits from both the optionality and protection features.
Thursday, 8:30 – 10:00, L016
Behavioral aspects of Revenue Management

1 Vertical Probabilistic Selling under Competition: the Role of Consumer Anticipated Regret
Dongyuan Zhan, University College London, d.zhan@ucl.ac.uk

Probabilistic selling is an innovative business practice of selling a random product that mixes several products whose exact identity or attributes are hidden until the purchase has been made. It becomes popular in online traveling platforms (e.g., Hotwire and Priceline). When products involved in probabilistic selling are vertically differentiated, consumers might obtain a product whose quality is lower than expectation and therefore may regret their purchase. We study probabilistic selling with vertically differentiated products when two firms compete and consumers anticipate the potential post-purchase regret raised by possibly obtaining inferior products. We distinguish two types of regret aversion: selection regret and purchase regret. When consumers purchasing random products later find out their purchase is less desirable than an existing but foregone transparent one, they suffer selection regret; when consumers find the no-buy option dominates their purchase and all the transparent products, they suffer purchase regret. These two types of regret aversion have different effects: probabilistic selling yields a higher (lower) profit when consumers exhibit a higher (lower) degree of selection regret than purchase regret, as compared to the case in which no regret is involved. In general, anticipated regret makes the random product less appealing to consumers since the perceived quality is lowered in the presence of regret. The purchase regret makes the perceived quality of the random product follow the nature order (i.e., increasing in consumers’ quality taste), while the selection regret makes the perceived quality reversely ordered: the anticipated regret deteriorates the perceived quality of the random product to a greater extent for higher taste consumers. Under competition, such perceived quality reverse ordering increases the product differentiation at the competition margin, and still maintains sufficient attractiveness for infra-marginal consumers. Our results suggest that, rather than being a curse, anticipated regret can be a blessing for random product providers.

2 How Consumers' Implicit Cost Influence on Pricing: A Special Case of Free Product
Hao Wang, National Taiwan University, wanghao@livemail.tw

Obviously, sales promotion is an efficient solution for firms to increase market share and revenue. Most of economic studies assumes that the monetary saving increases consumer welfare and value. Consumers not only gain benefit but also get good feelings about themselves because the self-perception of a smart shopper. Companies introduce free-charged product or service in marketing campaign in order to bring up the future sales volume. Consumer enjoys free product or service in daily life because zero is a special price. Scholars suggest that consumer evaluates the total value of the zero-price product much higher than regular pricing product. In contrast to cost-benefit model, dramatically more participants choose zero-price product in their experiments. Free products are usually seen as a sample sack. There is no such thing as a free lunch, the famous adage, delivers the idea that free products are attractive, but there will always be a cost. A free meal campaign attracted about 50,000 people in Taiwan, the average waiting time of the first 2,400 customers is 9 hours. This marketing activity aroused a lot of controversy and customer complaint. More important, many people thought that these customers were keen on getting petty advantages. In this study, we conducted a series of experiments to investigate whether the firm’s targeted audiences were shrink back at the sight of the implicit sacrifice of free product. Also, we examined the moderating role of price tactic knowledge in making decision. The result showed that most of firm’s targeted audiences changed their mind because of the implicated physical and psychological hassle costs. Also, customers with high extent of price tactic knowledge will unlikely to buy a free product.

3 Spending or Stockpiling: Loyalty Program Design and Consumer Decisions to Redeem Points
So Yeon Chun, Georgetown University, soyeon.chun@georgetown.edu

In many loyalty programs, customers earn points for their purchases, which they can later exchange for additional products and services. In a sense, points function as a currency that consumers can spend on products instead of spending money. However, we uncover systematic differences in the way consumers spend loyalty points compared with money. We focus on two mechanisms that may explain differences in the way consumers spend loyalty points and money: a systematic bias in the perceived exchange rate between loyalty points and money, and mental accounting (consumers may process loyalty points in a separate mental account). To highlight these two different mechanisms by which loyalty program design characteristics may influence redemption, we first propose a model of the consumer’s choice to redeem points or use money for a specific purchase, and then we conduct a series of studies to investigate the impact of these characteristics on consumers’ choices.
Thursday, 11:30 – 13:00, TURING
Assortment optimization (I)

1 Assortment Optimization with Limited Substitution
   Jacob Feldman, Olin Business School, jbfeldman@wustl.edu

We study a customer choice model that captures purchasing behavior when customers substitute between a small number of products relative to the total number of products. Under this model, we assume each customer is characterized by a ranked preference list of products and will purchase the highest ranking product in her list that is offered. Since we restrict ourselves to settings with limited substitution, we assume that these rankings contain at most k products. We call this model the k-Product Nonparametric choice model. This paper focuses on the assortment optimization problem under this choice model. In this problem, the retailer wants to find the revenue maximizing set of products to offer when the buying process of each customer is governed by the k-Product Nonparametric choice model. We show that this problem is NP-hard even for k = 2, and, motivated by this result, we develop a novel approximation scheme for this optimization problem for general. For k=2, we show that the problem can be formulated as a maximum directed cut problem for which there is a randomized 0.79 approximation. For k>2, we develop a novel randomized LP rounding based approach, which has the best known theoretical guarantees for small k. We conclude with a set of computational experiments that study the marginal benefit of fitting increasingly complex nonparametric choice models to real sushi preference data.

2 Greedy-like Algorithms for Dynamic Substitution Models Under Multinomial Logit Preferences
   Ali Aouad, MIT, aouaad@mit.edu

We study the joint inventory management and assortment planning problem, where stock-out events elicit dynamic substitution effects, described by the Multinomial Logit (MNL) choice model. Special cases of this setting have extensively been studied in recent literature, notably the static assortment planning problem. Nevertheless, the general formulation is not known to admit efficient algorithms with analytical performance guarantees prior to this work, and most of its computational aspects are still wide open. In this paper, we devise the first provably-good approximation algorithm for this class of optimization models under the MNL model, attaining a constant-factor guarantee for a broad class of demand distributions, that satisfy the increasing failure rate property. Our algorithm relies on a combination of greedy procedures, where stocking decisions are restricted to specific classes of products, and the objective function takes modified forms. We demonstrate that our approach substantially outperforms state-of-the-art heuristic methods in terms of performance and speed, leading to an average revenue gain of 6% to 10% on synthetic instances. In the course of establishing our main result, we develop new algorithmic ideas that may be of independent interest. These include weaker notions of submodularity and monotonicity, shown sufficient to obtain constant-factor worst-case guarantees, despite using noisy estimates of the objective function.

3 On the Random Consideration Set Choice Model of Manzini and Mariotti
   Anran Li, Columbia University, al2942@columbia.edu

Manzini and Mariotti (2014) [Manzini, Paola, Marco Mariotti. 2014. Stochastic choice and consideration sets. Econometrica 82(3) 1153-1176] propose a consideration set based choice model that postulates a full preference ordering as well as exogenous attention probabilities from which consideration sets are formed. The model assumes that consumers select the highest ranked product in their consideration set and the heterogeneity among choices are due to randomness in the consideration sets formation process. While Manzini and Mariotti focus on rationalizing this choice model, we look at its operations applicability. We show how to recover the full ordering and attention probabilities given accurate estimates of choice probabilities or from empirical data. Empirical testing of the Random Consideration Set model on our airline partner’s data shows that it outperforms the Logit family models over most of the markets. We show that an assortment that maximizes expected revenues can be found in polynomial time by a dynamic program and the DP can be easily adapted to solve a cardinality constrained assortment problem and a efficient sets discovery problem. We extend the original model to allow multiple market segments with heterogeneous attention probabilities and propose a computationally efficient heuristic with good empirical performance. We also extend the model to allow ties in preferences and show that a revenue-ordered assortment has a 1/2 performance guarantee relative to the optimal assortment. We study the pricing problem where the preference ordering are price aware and show that the value gap, defined as the difference between the value of the product to consumers and its unit wholesale cost has key impact in pricing.
Thursday, 11:30 – 13:00, Euler

Practical problem session (I)

1 Ancillary sale sensitivity
   Charles Verstegen, Transavia, Charles.Verstegen@transavia.com
   Etienne Slagman, Transavia, Etienne.Slagman@transavia.com

Optimization of ticket pricing for an airline is very common based on demand, supplement, timing and experimenting in adding other factors. The sales of ancillaries becomes more important for airlines as well as other leisure focused industries. The price sensitivity is based on demand driven by other travel characteristics like length of stay, distance, etc. Besides, an ancillary product might be selected once the ticket buy decision has been made. We are curious to how to get control over price sensitivity within ancillary product categories as well as the correlation or sensitivity between ticket price and offered ancillary price.

2 Analyzing customer journeys in e-commerce
   Henning Nobmann, Beuth Hochschule für Technik Berlin, henning.nobmann@beuth-hochschule.de

We develop parametric models describing individual customer’s journeys from first contact to an eventual purchase or defection in order to analyze the impact of different marketing channels on the retention and defection probabilities at different stages of the sales funnel. Our data consists of the logged webtraffic of a European short break online platform as well as data on their use of different marketing channels. As individual users are not readily identified from the data, we employ a hierarchical classification algorithm based on an ensemble of technical identifiers of differing accuracy and longevity to arrive at a fuzzy matching of our data to a predefined user base, allowing us to trace individuals’ paths of interaction with the website through time. The goal is to evaluate and optimize the usage of different marketing channels throughout the sales funnel by estimating the conditional odds of retention/defection at different stages of the sales funnel with respect to the marketing tools targeting individual users. In addition, we aim to develop a clustering of users according to their search behaviour in order to be able to identify likely buyers or potential defectors that have a sufficiently high probability of retention if targeted with the appropriate channels early in their journey. Our data exemplifies various challenges in working with data on e-commerce: Identification of individual users depends on a multitude of cookies and internal IDs of varying quality, data formats are subject to continuous change, and the determinants of the often seemingly erratic behavior of customers in the online market place are by no means obvious.

3 Demand Estimation - External Influences
   Rik van Leeuwen, IrevenU, rik@irevenu.com
   Jeroen de Korte, IrevenU, jeroen@irevenu.com

The problem we would like to address is concerned with demand curves. Every price level has a different demand curve of course. The information from these curves leads to the number of expected reservations at a certain point in time. Traditionally, the curve is being estimated based on transactional (reservations) data of a hotel or airline. A standard approach in airline and hospitality industry is fitting an exponential curve beta*exp(-alpha*t) depending on time until check-in t. The parameters alpha and beta are estimated using least-squares regression. The theory of this method is fine, but in practice, the demand, and so the demand curves as well, depend on a lot of other factors, including competition. In hospitality, for examples, hotels tend to drop prices when the time until check-in is very short, a couple of days. Then following the theory and only keep increasing the price fails, since competitors drop prices and guests will not arrive. Concrete: in practice, the shape of the actual demand does not follow these estimated demand curves according to the exponential curve (or even other ‘simple’ curves).
Thursday, 11:30 – 13:00, L016
Search costs and consumer learning

1  Product line pricing in the presence of social learning
Nafiseh Sedghi, Dept. of Industrial Engineering, Sharif University of Technology, n_sedghi@ie.sharif.edu

This paper investigates the pricing challenge for a firm that offers a product line including two different quality products in the presence of social learning. Consumers are assumed to be heterogeneous with respect to the marginal valuations for quality and they consider buying one of the products in two purchasing time periods. The quality of both products is unknown to consumers who buy the products in the first period. The first period buyers share their experience on quality via online review system and so the later consumers can learn about the true quality. We present a model to investigate the impact of pricing decisions on the learning process and how to utilize the social learning to optimize the prices and profit as well. We demonstrate how the presence of social learning could affect the firm’s decision on the pricing of its product line and how it is different from the cases where the learning is absent or qualities are known. We also analyze the case where consumers have bounded rationality in updating their beliefs about quality and show how this behavioral model impacts the pricing decision. We find that the presence of online reviews has significant impact on the pricing of a product line. Our analysis shows that under some conditions, the firm might strategically set higher prices for one of its products in order to slow down the learning process of that product or stimulate the learning of the other product. We also find that the pricing decision of the firm depends on its estimation of the early consumers who buy the products in the first period with no information on quality.

2  Price obfuscation and consumer surplus in online diamond retail
Stanislav Mamonov, Montclair State University, Univ. of Connecticut, stanislav.mamonov@montclair.edu

Price obfuscation allows retailers to increase consumer search costs and increase price dispersion consequently enabling the retailers to earn extra profits. Much of previous research on price dispersion has focused on examining prices across retailers and across channels. Less is known about how retailers can increase consumer search costs and sustain price dispersion in the context of a single e-commerce site. We draw on the multiattribute decision-making (MDM) theory and we examine the predictions of the MDM theory in the context of an online diamond retailer. We find evidence that is consistent with strategic price obfuscation. The retailer offers significantly more inventory for specific product variants and concomitantly these product variants exhibit markedly higher degree of price dispersion. We also discover that the retailer misdirects consumer attention towards less informative product attributes through marketing and also introduced levels of product attributes that have no direct effect on price, thus further increasing consumer search costs. In addition, we examine whether consumers are able to find relative bargains among the available options by comparing existing product offers with the products that were actually sold. Our results show that consumers are able to earn a surplus, but a relatively small one.

3  Learning fast and slow: rational inattention when learning happens on two different speed levels
Frank Huettner, ESMT BERLIN, frank.huettner@esmt.org

Consumers often do not have complete information about the choices they face and therefore have to spend time and effort in acquiring information, either consciously or subconsciously. Since information acquisition is costly, consumers trade-off the value of better information against its cost, and make their final product choices based on imperfect information. We model this decision using the rational inattention approach and describe the rationally inattentive consumer’s choice behavior when she faces options with uncertainty from two different sources. While uncertainty of type 1 can be learned about rather quickly, uncertainty of type 2 can be learned about rather slowly. To this end, we introduce an information cost function that reflects an exchange between both learning channels. We then analytically describe the optimal behavior and derive the choice probabilities in closed-form. We find that non-uniform learning speed can have a strong impact on product choice, which gets particularly conspicuous when the product alternatives are otherwise very similar. It can also lead to situations where it is disadvantageous for the seller to provide easier access to information for a particular product. Furthermore, it provides a new explanation for strong failure of regularity of consumer behaviour, which occurs if the addition of an inferior (never chosen) product to the choice set increases the market share of another existing product.
Thursday, 14:30 – 16:00, TURING
Online advertising & mechanism design (I)

1 Waterfall Revenue Optimization for Online Advertising
   John Turner, University of California, Irvine, john.turner@uci.edu

In the domain of programmatic advertising, arriving users are matched with ads in real-time. We study the revenue optimization problem of an ad network, which serves ads for numerous websites and seeks to produce the most efficient matches of ads to users. Such an ad network generally involves advertisers in each real-time matching decision using one of two methods. The first method is the second-price auction, in which advertisers compete to show their ad to a user by placing bids, and the winner gets the slot and pays the second-highest bid. The second method is the waterfall, in which advertisers have agreed in advance to pay a contracted price per impression for those impressions that they choose to accept, and the ad network polls advertisers from a list sequentially until either an advertiser accepts the slot or time runs out. Both methods crucially allow the advertiser to use information it knows about the user which the ad network may not, to influence the result of the matching in real-time. In the case of the waterfall method, bid price selection does not need to be handled dynamically, which simplifies each advertiser's computational burden. We study the revenue optimization problem for an ad network using the waterfall method. That is, we formulate a stochastic optimization problem and construct near-optimal waterfall policies. Crucially, there is a trade-off between polling the highest-revenue advertiser first and preferring to poll advertisers who are either most likely to accept or do not use up much of the (very short) time horizon to decide whether they are accepting or rejecting the slot.

2 Tight Competitive Ratios for Online Matching/Assortment Problems with a Fixed Set of Edge-weights/Prices
   Will Ma, MIT, willma@mit.edu

Online bipartite matching, introduced by Karp, Vazirani, and Vazirani in 1990, is a classical problem in the study of online algorithms and competitive analysis. It has since had many generalizations, including online vertex-weighted matching, Adwords, and online assortment, which have found application in internet advertising, personalized e-commerce, and ride-sharing. These problems can be abstracted as follows: there are fixed resources, which must be allocated on-the-fly, without assuming anything about future demand. Two types of algorithms---‘ranking’ and ‘balance’---have been developed for these problems, and achieve a tight competitive ratio of 1-1/e under the integral and fractional, asymptotic settings, respectively. A key assumption in the aforementioned problems is that each resource is sold at a fixed rate when it is allocated. In this paper, we study these problems when each resource could be sold at multiple, known prices. We derive a tradeoff function using the idea of protection levels for different prices, which enables us to generalize the ‘ranking’ and ‘balance’ algorithms. Furthermore, we construct a family of examples which shows that this results in the optimal competitive ratio, for every possible set of prices. As a concrete example of our results, if each resource has two potential prices, then 1-1/sqrt(e) is the tight competitive ratio. Our analysis also provides a system to obtain competitive ratio bounds in the fractional, non-asymptotic setting, which improves existing bounds in the single-price as well. Joint work with David Simchi-Levi.

3 Listing Policies and Market Thickness in Online B2B Auctions Markets
   Wenchang Zhang, University of Maryland, wzhang@rhsmith.umd.edu

Excess inventory amounts to $424 billion a year for big-box retailers. Much of this inventory is sold through online auctions. Based on data from a natural experiment on a major B2B auction platform, we find that increasing the market thickness by concentrating the auction ending times to certain days of the week has a significant positive effect on the platform’s revenues. This finding clearly illustrates the role of listing policies in matching supply and demand in such markets and provides evidence of significant trading frictions associated with the real-time monitoring of the inventory of auctions on the platform. We build on our descriptive analysis and develop a structural model to study the interaction between the platform and its population of bidders. To this end, we provide a characterization of the bidders' equilibrium decision making including their visit rate to the platform, the auctions they choose to participate in, and their bidding strategies. The estimates we obtain from the structural model are consistent with the results from the natural experiment. A counterfactual analysis provides a systematic way for the platform to design its listing policy so as maintain the optimal market thickness given the (exogenous) supply of inventory. The main tradeoff for the platform is between increasing bidder participation for a given auction (competition) and guaranteeing that auctions for substitutable goods do not cannibalize one another (demand satiation). Finally, we showcase how the proposed structural model can be useful in evaluating other market design levers, e.g., a recommendation system.
Thursday, 14:30 – 16:00, EULER
Practical problem session (II)

1 On the discrepancy between demand forecasting and pricing in practice  
Daniel Hopman, Emirate Airline – Oxford Data Science Lab, Daniel.hopman@gmail.com

In this practical talk, I will discuss the difference in detail between demand forecasting and Pricing in practice. Demand forecasting is typically done on a POS/OD/Path/Class/Time level. In practice, pricing is done on a POS/OD/Path basis. This creates the question on whether the forecast should be less detailed, or pricing more detailed. For both approaches I will present practical limitations.

2 Realtime pricing in B2B truck logistics  
Alwin Haensel, Haensel AMS & Cargonexx, alwin@haensel-ams.com

Pricing is delicate when it comes to dynamic changing market prices, especially when current prices are mainly based on countless human negotiations. We have developed a pricing algorithm for the logistics platform Cargonexx (www.cargonexx.de), which is used to derive the current market price for each individual transport request. Cargonexx, an online freight forwarder, is an intermediary between the contractors of the transports and the freight carrier. The proposed price must reflect the current market situation on both market sides as precisely as possible. The presentation will be discussed mainly the challenges of this task and our approaches to it.

3 Commonality in modelling of Revenue management problems in multi media wireless service and Emergency department in healthcare  
K.S.S. Iyer, Symbiosis Institute of Telecom Management, kss_iyer@hotmail.com

Aggregate revenue earned by Internet service providers by offering multi media services to the customers and the aggregate revenue earned by Emergency department of Healthcare have a commonality. The commonality arises in both cases, namely the customers or patients arrive at random times of the day and each triggers a random service time by way of holding time or patient treatment time depending upon severity of emergency. Is it possible to develop a stochastic model to evaluate the expected revenues for both cases for different times of the day?
Thursday, 14:30 – 16:00, L016
Estimation of market characteristics

1  Considering Indivisibility and Interconnectedness is Crucial to Determining Displacement in Meetings and Events Revenue Management
   Aaron Dukes, IDeaS Revenue Solutions, aaron.dukes@ideas.com

Revenue management techniques have been successfully utilized to price hotel guestrooms for several decades. Since a hotel’s guestroom capacity typically consists of hundreds of rooms, and most of its demand consists of individual guests staying for a single night, it is a reasonable approximation to treat the capacity and demand as infinitely divisible. Sophisticated automated revenue management systems currently achieve moderate but significant benefit by considering the interconnectedness of multi-night stays, while maintaining the assumption of independent demands. Extending current revenue management systems to pricing other hotel resources such as meeting room and ballroom space becomes difficult because the above assumptions used to characterize guestroom demand are no longer reasonable for events. The meeting rooms and ballrooms each constitute a large portion of the hotel’s function space, rendering infinite divisibility untenable. Moreover, the demand for function space is very interconnected in that a group typically wants several meeting rooms, over several time blocks, and possibly over several days. Either the entirety of the group’s interconnected demand (which may also include many guestrooms) is accommodated, or it will seek accommodations elsewhere. This invalidates the assumption of independent demands for separate function rooms and nearby time blocks and dates. We will demonstrate the potential magnitude of the impact of the violation of these assumptions on the determination of displacement through some overly simplified examples. We will then show how they can be addressed through an alternate formulation of the displacement problem, which requires a paradigm shift in demand characterization and optimization methodology.

2  A Novel Approach to Measure Price Sensitivity from the Transactional Data of a Retail Company
   Dessy Amirudin, Stream Intelligence (www.streamintelligence.com), amirudin.dessy@id.streamintelligence.com

Price sensitivity is a method to measure the change in demand compared to the change in the price of goods. In behavioral context, when the price of goods is increasing, the demand will decrease. The cause is either consumer buy less or less customer can afford to buy the goods. By plotting the price on the x-axis versus the demand on y-axis ideally, will give us a smooth linear pattern. The price sensitivity is then measured by running a regression with price as independent variable and demand as the dependent variable. However, that is not always the case. We have worked with a retail company and we observed the relation between price and demand from its three years transactional data, we found a bell-shaped curve instead of expected linear pattern. This case happened due to the company’s promotion strategy to design the discount so that the price mostly fell on the middle range within an entire year. In other words, the price would rarely fall on the low and high-end range. This leads to a difficult and unclear pricing strategy recommendation for the retail company. To tackle such problem, we proposed an alternative methodology to measure the price sensitivity. The new measurement was based on the average time gap between transaction for each price bucket. Using the time gap instead of the demand gave a positive result in which we achieved the expected linear pattern. Therefore, we could move towards the regression model to calculate the price sensitivity. In the end, we could predict the expected change in the time gap for every change in the price of goods and provided an insightful recommendation for the company.

3  The Assessment of Online Customer Interaction in the Context of Corporate Profit and Churning
   Nicola Winter, Berlin School of Economics and Law, Nicola.Winter@hwr-berlin.de

We discuss a framework to assess activities of customers and suppliers in the context of e-commerce. The different customer profiles - regular customers as well as change customers and churners - can be seen as small subsets in a much bigger pool of users. However, their role as users is not necessarily connected with standardised monetary indicators like the customer lifetime value (CLV) in a simple way. Additionally, non-customer behaviour delivers insight into - in many cases only short-term - possible customer journeys. The way from raw data to a fruitful representation of typical user journeys is sketched. This way also touches explorative and descriptive methods of correction and classification as well as statistical limitations arising from the heterogeneity of the given data. As a clear focus the topic of mean- and short-term user identification in the context of an effective classification is discussed. The traceable journey of all users hardly differs, nevertheless it might be the main base for a decision about general marketing campaigns and individual offers. In this contribution, a case study of an online short break Internet platform serves as example. Of course, there are reasonable presumptions about user behaviour typical on this business area (seasonal demand, standardised offers). However, reliable long-term user identifications are rare. In consequence, robust inferences on the base of many short-term user steps are an important goal.
Thursday, 14:30 – 16:00, L017

Pricing and competition

1  Pricing Competition When Some Customers Are Loyal
   Darius Walczak, PROS Inc., dwalczak@pros.com

We analyze a dynamic game with two competitors introduced by Dudey (1992) and subsequently adapted to the revenue management framework by Martinez-de-Albeniz and Talluri (2011). We generalize the game by allowing some customers to be loyal. The extension is relevant for the airline industry since airlines often have demand that is price-sensitive but dedicated to a particular carrier. We research conditions for the existence and uniqueness of a pure-strategy Nash equilibrium and make a comparison to the case when the capacities of both competitors in the market are pooled.

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2  Dynamic Pricing under Competition: A Heuristic Strategy
   Rainer Schlosser, Hasso Plattner Institute, University of Potsdam, Germany, rainer.schlosser@hpi.de

Most sales applications are characterized by competition and limited demand information. For successful strategies, regular price adjustments as well as anticipation of market dynamics are crucial. Both effects are challenging as computations of dynamic systems are expensive and competitive markets are complex. We analyze stochastic dynamic pricing models under oligopoly competition for the sale of perishable goods. To circumvent the curse of dimensionality, we propose a novel heuristic approach to efficiently compute feedback prices. To demonstrate that our strategy is applicable even if the number of competitors is large and their strategies are unknown, we consider different competitive settings in which competitors frequently and strategically adjust their prices. Using different examples, we show that our heuristic feedback strategy yields excellent results. We compare the performance of our heuristic against upper bounds, which are obtained by optimal strategies that take advantage of perfect price anticipations. We show that adjustment frequencies can have a larger impact on expected profits than price anticipations. Finally, our approach was applied on an online marketplace for the sale of used books. We used a seller’s historical market data to calibrate our model. Sales results show that our data-driven strategy outperforms the rule-based strategy of an experienced seller by a profit increase of more than 20%.

3  A Simulation Platform to Analyze Strategic Interaction under Competition on Online Marketplaces
   Martin Boissier, Hasso Plattner Institute, martin.boissier@hpi.de

E-commerce marketplaces are highly dynamic with steady competition. While this competition is challenging for many merchants, it also provides plenty opportunities. For example, by allowing merchants to automatically adjust prices for changing market situations. But testing automated pricing strategies is time-consuming and potentially hazardous when done in production. We built a continuous time framework to simulate dynamic pricing competition for the sale of durable goods. This setup allows to define a random stream of potential customers whose buying decisions can arbitrarily depend on the current market situation for a specific product. The individual market situations are determined by the offers of different competitors including price and quality. Evaluating the mutual price reactions of the competing strategies we obtain price trajectories and simulate realized sales events. Using different performance measures, we are able to compare repricing strategies in real-time. Our simulation marketplace offers a simple interface via HTTP/REST. Our platform is scalable and allows an arbitrary number of merchants to compete simultaneously. Each merchant can run his preferred repricing strategy to adjust prices on the marketplace. The platform logs each interaction (such as price updates, new offers, sales, etc.), which can be requested and analyzed by each merchant. This way, merchants can deploy both simple rule-based strategies as well as sophisticated data-driven strategies which use machine learning techniques to estimate customers’ behavior. Our framework also makes it possible to analyze how strategy performance is affected by customer behavior, price adjustment frequencies, competitor strategies, and the exit/entry of competitors. We found that adjustment frequencies have a major impact and that data-driven strategies often vastly outperform rule-based ones after a sufficiently large data set has been gathered. Moreover, the platform can be used to identify equilibrium strategies by studying the long-term behavior of self-adapting strategies.
Thursday, 16:30 – 17:30, TURING
Finalists Session

In this session the finalists of the INFORMS Revenue Management & Pricing Section Practice award and the Dynamic Pricing Challenge will present their work.
Thursday, 16:30 – 17:30, EULER
Airline Revenue Management

1 A Constact-Factor Approximation Algorithm for Capacity Allocation over a Single Flight Leg with Fare-Locking
Huseyin Topaloglu, Cornell Tech, ht88@cornell.edu

We study a revenue management model over a single flight leg, where the customers are allowed to lock an available fare. Each customer arrives into the system with an interest in purchasing a ticket for a particular fare class. If this fare class is available, the customer either immediately purchases the ticket by paying the fare or locks the fare by paying a fee. If the customer locks the fare, then the airline reserves the capacity for the customer for a certain duration of time. At the end of this duration of time, the customer makes her ultimate purchase decision at the locked fare. The goal of the airline is to find a policy to decide which set of fare classes to make available at each time period to maximize the total expected revenue. Such fare locking options are commonly offered by airlines today, but the dynamic programming formulation of the revenue management problem with the option to lock an available fare has a high dimensional state variable that keeps track of the locked fares. We develop an approximate policy that is guaranteed to obtain at least half of the optimal total expected revenue. Our approach is based on leveraging a linear programming approximation to decompose the problem by the seats on the flight and solving a dynamic program that controls the capacity on each seat separately. We also show that our results continue to hold when the airline makes pricing decisions, instead of fare class availability decisions. Our numerical study shows that the practical performance of our approximate policy is remarkably good when compared with a tractable upper bound on the optimal total expected revenue.

2 Dynamic Programming Approaches for Simultaneous Control of Several Leg Compartments
Thomas Winter, Beuth University of Applied Sciences Berlin, thomas.winter@beuth-hochschule.de

We consider a problem arising in airline revenue management when a flight leg offers service in different service classes like first class, business class, premium economy and economy class. The corresponding demand includes customer choice options between service and booking classes or different price levels. Typically, the demand is split between the corresponding compartments and the optimization of seats offered at which price is carried out independently for each compartment. Doing so, for each compartment and each offered, a bid price is calculated which is used for controlling the booking process. The coupling of demand between the compartments is usually neglected - or resolved heuristically and very often sub-optimally in a pre-computing step. In our work, we present different dynamic programming approaches for this control problem for several leg compartments. We compare the traditional approach of independent calculation of the compartment dynamic programs to coupled calculation of the dynamic program cores at a predefined subset of the internal decision points. In this context, we also discuss the impact of capacity constraints for service class and possible upgrading scenarios.
Pricing and waiting

1  Pricing tolls under uncertainty: static and dynamic models
   Trivikram Dokka, Lancaster University, t.dokka@lancaster.ac.uk

We study toll pricing problem when the non-toll costs of the road network vary over time whereas toll setter faces constraints in setting toll prices with limited price revising power. We assume that network users have full information of costs before making their decisions. We study static pricing problem and propose a distributionally robust optimization model to set toll prices. We show the performance of these tolls on both simulated and real data sets. We also consider the dynamic pricing problem and propose a robust dynamic programming model to dynamically set the toll prices. We will present some preliminary experiments on robust dynamic toll pricing.

2  Pricing Strategy, Capacity Level and Collusion in a Market with Delay Sensitivity
   Liron Ravner, Tel Aviv University, lravner@post.tau.ac.il

We study price collusion between two firms providing service to delay-sensitive customers. The framework is a discounted repeated game in which the firms set a price in every time period and the customers choose between the servers according to the announced prices. The public perfect equilibrium is fully characterized along with specific conditions for the minimal discount factor that enables collusion. The effect of delay sensitivity (and service value) on the firm’s revenue and ability to collude is further analysed. In particular, we find that in some cases higher customer delay sensitivity (or lower service value) can lead to collusion and in turn to higher revenue for the firms.
Friday, 8:30 – 10:00, TURING

Choice models: estimation

1 Unconstraining demand using customer choice sets
   Ger Koole, Vrije Universiteit Amsterdam, ger.koole@vu.nl

We present a demand estimation methodising customer choice set. The procedure is based on the maximum likelihood method, and to overcome the problem of incomplete data or information we additionally apply the expectation maximization method. It is illustrated with airline and hotel data.

2 Predicting User Choice in Video Games
   Arjun Khandelwal, MIT, arjunsk@mit.edu

We study the consumer choice prediction problem on a new dataset from the video game Prismata. The dataset consists of m users and n items, and each data point consists of a user choosing an item from a random assortment. In the Prismata dataset, each user’s choices are consistent with a hidden preference ordering, which can be represented as a permutation of the items. We take the prior distribution over the n! possible preference orderings to be that implied by a Multinomial Logit (MNL) model on the n items. The weights for the MNL model are estimated using the entire body of transactions. We present a Bayesian algorithm for predicting user choices, which given an assortment and the user's previous transactions, produces approximate samples from the posterior distribution of the item selected. That is, given a new data point, we can estimate the probability of the user choosing each item. This allows us to make predictions based on both the overall preferences of the population and the revealed preferences of the user in a principled manner. On both a simulated dataset and the original Prismata dataset the user-specific algorithm outperforms standard benchmarks in both out-of-sample log-likelihood and out-of-sample Brier score. Finally, we present a new user grouping method which, given the number of clusters and a choice dataset indexed by user, outputs a clustering of similar users in a process similar to the K-Means algorithm. This process recovers the hidden clusters accurately on a simulated dataset, even with a low number of transactions per user.

This is joint work with Will Ma and David Simchi-Levi.

3 A Comparative Empirical Study of Discrete Choice Models in Operational Contexts
   Gustavo Vulcano, NYU/Università di Tella, gvu@nyu.edu

Demand estimation is a fundamental task in retail operations and revenue management, providing the necessary input data for inventory control and price optimization models. The task is particularly difficult in operational contexts when product availability varies over time and customers may substitute. In fact, empirical studies of different industries show that stockout-based substitution is a common occurrence. When the first choice of a customer is not available, demand could be lost or recaptured (i.e., shifted to another product). Unfortunately, this phenomenon is not directly observable from sales transactions, and various statistical techniques have been proposed to correct for them. Moreover, the instantaneous availability of data from online platforms reflecting consumers’ preferences in real time also imply the need for efficient computational procedures to frequently update the estimates of customer preferences. In the last decade or so, several proposals have emerged both in the modeling and computational sides to capture choice-based demand in operational contexts. In addition to the classical Multinomial Logit (MNL) model and its variants (e.g., Nested Logit, latent class MNL), new demand models have been proposed (e.g., the Markov Chain model) or revisited (e.g., the rank-based and exponential models). At the same time, new computational approaches were developed to ease the estimation function. In general, choice-based demand proposals in the recent and prolific OM-related literature are benchmarked versus one or two alternatives, typically the MNL and the independent demand models. In this work, we conduct a systematic, empirical study of different demand models, including the single class MNL, latent class MNL, nested MNL, exponential, Markov chain, independent demand, rank-based, and discrete uniform. We also evaluate alternative state-of-the-art algorithms spanning traditional nonlinear optimization methods to maximize the likelihood functions, expectation-maximization (EM) proposals, and column generation approaches. Through an exhaustive set of numerical experiments on both synthetic and real data, we provide comparative statistics of the quality of the different choice models and estimation methods, and characterize operational environments more suitable for particular model/estimation implementations according to the characteristics of the input data.
Pricing and optimal display

1 Inducing Optimal Consumer Bid Behavior
Chris Anderson, Cornell University, cka9@cornell.edu

The movement towards mobile, app-enabled selling of services provides opportunities for sellers to influence consumer behavior and purchase decisions through control of the limited screen size and touch versus type nature of mobile. Priceline through use of their name-your-own-price model was one of the earliest firms to sell travel via mobile. We develop and empirically validate an analytical model of consumer bidding behavior for a NYOP channel whereby consumer bids are influenced by intermediary app design and layout. Using this model, we develop optimal interface features to maximize Priceline’s revenue managing the tradeoff between consumer participation and bids.

2 Optimization of the retail profit function under the multiplicative demand model
Kalyan Talluri, Imperial College Business School, kalyan.talluri@imperial.ac.uk

The multiplicative power-function type demand model is widely used in the retail (groceries, clothes) industries. By taking logarithms on both sides, one can use linear regression to estimate the parameters (including cross-elasticities, promotion and display effects), which partly explains its popularity. Optimizing a revenue or profit function based on this demand model has received considerably less attention. It is a polynomial optimization problem and is difficult to solve by conventional techniques. In this work we propose approximation algorithms that perform very well in terms of speed, and come close to the optimal solution. We report results from a collaboration with a retail price-optimization company.

3 Online learning, decision making and seasonality under Bayesian exploration
Andria Ellina, University of Southampton, ae1g15@soton.ac.uk

We consider a pricing problem in online retail, where the retailers must simultaneously learn about their customers and earn money from transactions. We assume that the retailer must choose between a finite number of options for displaying search results on a web-page. This leads to a decision-making problem where the retailer aims to find the most profitable option amongst a range of sub optimal candidates when he has limited or no initial information about their performance. The objective is to maximise the total revenue or minimise total regret, over the selling period. We focus on an example of an online travel agency that aims to find the most profitable version for their website, but the methodology could be generalised to comparing different advertisements, different articles on a news page or different prices for a specific product. We use Thompson Sampling to find the right trade-off between exploration, the phase where we are collecting new information and exploitation where we are maximising revenue. Thompson Sampling is a Multi-Armed Bandit algorithm based on Bayesian exploration with very good empirical performance. As in all real-world applications, an extra complication that arises is the fact that the performance of the different options is not stationary and it follows some daily seasonality. The proposed solution builds upon the basic Thompson Sampling algorithm by incorporating the idea of contextual bandits. By treating the different days on which the options are being tested as contextual information the algorithm estimates the impact of each day of the week on revenue as well as the effect of each option in order to maximise the overall revenue. At the same time, it keeps exploring all options in order to update its beliefs about their performance. In this talk, we will describe the algorithm we have developed and present preliminary results.
Friday, 8:30 – 10:00, L016
Pricing in specific applications (I)

1 Dynamic Pricing Approaches for Electricity Rate Design

Michael Hinterstocker, Forschungsgesellschaft für Energiewirtschaft mbH, mhinterstocker@ffe.de

Within the scope of the energy transition, the digitalization of the energy sector features new opportunities for its participating actors. In order to integrate large amounts of renewable energy and to maintain a stable grid, it is necessary to establish an intelligent interconnection of generation and consumption by using smart technologies and corresponding financial incentives by designing suitable electricity rates. For comparison and evaluation of these rates, several criteria are defined, which are based on relevant requirements from grid operators, energy suppliers and consumers. From a system perspective, the two crucial requirements towards rate structures are to incentivize both energy saving and demand-side management. The fundamental components of electricity rates are a monthly basic fee, a price per consumed energy, and a demand charge based on peak demand. The energy price can be time-dependent, both in a pre-defined way by distinguishing between different time periods within a day, a week or a year and in a dynamic way by short-term adjustments based on e.g. wholesale prices, grid load or renewable generation. Additional elements include interruptibility in critical situations, progressive rates as an additional incentive for energy saving, and hedging instruments to reduce price risks. Combinations of these elements yield a wide range of possible electricity rates, which are analyzed regarding the described criteria. Conventional static rate structures like time-of-use rates and demand charges, as well as dynamic implementations like critical-peak pricing and real-time pricing can pose the necessary incentives, but detailed analysis shows that the potential of dynamic structures is considerably higher. Especially innovative combinations of rate elements like interruptible demand charges and a mix of critical-peak pricing and demand charges suggest good results. For simulation-based evaluations of these recommendations, further research on customer preferences and reactions is necessary.

2 Nonlinear Pricing for Capacitated Stochastic Container Leasing System with Dynamic Arrivals

Wen Jiao, The Hong Kong Polytechnic University, wendy.j@connect.polyu.hk

Container lease is a relatively new industry which flourishes successfully over the past two decades. In practice, container lease pricing problem is distinct from a consumer product rental pricing in the light of multiple-unit demand, monopolistic supply and oligopolistic demand market. Constrained by finite capacity and dynamic arrivals, the leasing company is grappling for the pricing issue. In this paper, we investigate the dynamic nonlinear pricing problem of a leasing company confronted with low and high type customers who randomly arrive at the company and have specific hire duration preferences. We derive the closed-form optimal pricing and rationing policy and further discuss the effect of capacity constraints and customer dynamic arrivals on the optimal allocation policy. In the setting with the same hire duration preference, the effect of capacity constraint becomes greater over time for customers with the same entry date and the dynamic arrivals intensify the effect of capacity constraints compared with the simultaneous arrivals case. In the setting with different hire duration preferences, the effect of capacity constraint increases for the low type customer and decreases for the high type customer. The dynamic arrivals only aggravate the effect of capacity constraint for the consistent low type customers.

3 Dynamic pricing in the vehicle ferry industry

Christopher Bayliss, University of Southampton, c.bayliss@soton.ac.uk

The global ferry market was valued at over $15 billion in 2012, making it an important part of the international transport network. Here, we describe methods that we have developed, in partnership with a UK ferry company, to find optimal prices for tickets on vehicle ferries. Ferries carry vehicles ranging from motorcycles and private cars to large haulage trucks, and the impact on the remaining space of accepting a sale is not just dependent on a vehicle’s size and shape, but also how well it fits with the previously accepted sales. Therefore, the opportunity cost of accepting a large, awkwardly-shaped product may well be greater than that associated with fitting several smaller products. Thus the algorithms we will describe combine dynamic pricing and optimal packing. A vehicle ferry company sells tickets to customers during a selling season of approximately 6 months duration. Arrivals follow a Poisson Process and customers purchase with a probability dependent on their vehicle type, the price on offer and the time remaining until departure. We use a dynamic program to optimize the prices, where the state space defines the mix of vehicles that have already purchased tickets. The problem of finding a layout of vehicles in which the space used is maximized can be modelled as a mixed integer linear program. Relatively small ferries can be solved to optimality and we will present the formulation and some initial results using this method. For larger ferries, it is necessary to approximate the packing problem. We describe a simulation-based approach that allows the problem to be tackled easily for large, more realistic problem instances. Our results show that the simulation-based approach attains close to optimal solutions for moderate-sized problems. The presentation will focus on describing our methodologies and results in the context of the real-world example.
Online advertising & mechanism design (II)

1 Multi-Stage Intermediation in Display Advertising

Huseyin Gurkan, Duke University, Fuqua School of Business, PhD Candidate, huseyn.gurkan@duke.edu

We consider a setting where advertisers seek to acquire impressions from an advertising exchange through a network of intermediaries, and provide a game theoretic model to study the mechanisms offered by the ad exchange and intermediaries when the advertisers’ values are private. We characterize a subgame perfect equilibrium of the game among the ad exchange and intermediaries within a practically relevant class of mechanisms, and show that economic incentives are not necessarily aligned along the network. We establish that the position in the intermediation network has a significant impact on the profits of the intermediaries, and the most profitable position depends on the underlying value distribution of advertisers. In particular, as the tail of the advertisers’ value distribution gets heavier, intermediaries closer to advertisers (demand side) profit more than the ones closer to the ad exchange (supply side). For intermediation chains, we further provide the equilibrium mechanisms and intermediaries’ profits in closed-form when the advertiser’s value has a generalized Pareto distribution, e.g., exponential, Pareto, uniform distributions. Moreover, we analyze the impact of different network structures on the profits of intermediaries and the seller’s revenue. We conclude by analyzing the incentives of intermediaries to merge both horizontally and vertically.

2 Dynamic Mechanism Design under Positive Commitment

Ilan Lobel, New York University, ilobel@stern.nyu.edu

We consider a firm that sells products that arrive over time to a buyer. We study this problem under a notion we call positive commitment, where the seller is allowed to make binding positive promises to the buyer about items arriving in the future, but is not allowed to commit not to make further offers to the buyer in the future. We model this problem as a dynamic game where the seller chooses a mechanism at each period subject to a sequential rationality constraint. We characterize the perfect Bayesian equilibrium of this dynamic game. We prove the equilibrium is long-term efficient and that the seller’s revenue is a function of the buyer’s ex ante utility under a no commitment model.

3 Auctions in the Online Display Advertising Chain: A case for Independent Campaign Management

Amine Allouah, Columbia University, mallouah19@gsb.columbia.edu

In many auctions, buyers can be represented by an intermediary that manages their bidding process, along with the bidding process of other buyers. Notably, in the real-time online display advertising market, in which advertisers bid for impressions through intermediaries called demand side platforms (DSPs), this is more the norm than the exception. In turn, intermediaries, when deciding what to bid on behalf of their customers, strategize to maximize some internal objective and may only submit a limited number of bids to limit competition on a given item. In the present work, we propose a framework to analyze the implications of such an active role by DSPs, taking as a benchmark the case in which each DSP would manage the bidding process of each advertiser it represents independently of other buyers, a case we refer to as multi-bidding. In particular, we ensure a full alignment of incentives between buyers and intermediaries and analyze the value chain under optimal second price auctions. We show that the adoption of multi-bidding by all intermediaries would lead to an increase in both the social welfare and the seller’s revenues. Furthermore, we analyze the impact on buyers in two regimes: i.) with a single intermediary and two buyers, and ii.) with a large number of intermediaries and buyers. Quite remarkably, we establish that multi-bidding would also lead to an increase in buyers’ surplus (buyers together with intermediaries) under a very broad set of market characteristics. In particular, as long as the average number of buyers interested in an item is moderate and the coefficient of variation of buyers’ values is not too small, moving from an active role to multi-bidding for intermediaries leads to a Pareto improvement in the value chain.
Friday, 11:30 – 13:00, EULER
Pricing with side information and pricing under debts

1. **Personalized Dynamic Pricing: Individualization over Segmentation**
   
   *Bora Keskin, Fuqua School of Business, Duke, bora.keskin@duke.edu*

   We investigate a monopolist seller who employs personalized dynamic pricings by utilizing information about customers’ characteristics, encoded as a d-dimensional feature vector. We assume a linear demand model, with the intercept and the price sensitivity coefficient depending on s out of the d features. The seller initially does not know the relationship between the customer characteristics and the product demand, but learns this through sales observations over a selling horizon of T periods. We establish that the seller’s expected regret against a clairvoyant who knows the underlying demand relationship is at least of order s T under any admissible policy. We then design a near-optimal pricing policy for a semi-clairvoyant seller, who knows which s of the d features are true demand predictors, that achieves expected regret of order $s \sqrt{T} \log(T)$.

   We extend this policy for the real seller who does not know the true demand predictors by employing lasso regularization, and show this has an expected regret of order $s \sqrt{T} (\log(d) / \sqrt{T} + \log(T))$, which is near-optimal if d does not grow exponentially in T. We further show that other intuitive and/or widely-practiced policies, namely (i) myopic pricing, (ii) optimal pricing for the average customer, and (iii) pricing by customer segmentation, can perform poorly for the problem, with regret growing linearly with T.

2. **Learning Preferences with Side-Information: Near Optimal Recovery of Tensors**
   
   *Andrew Li, MIT Operations Research Center, aali@mit.edu*

   A number of recent problems of great interest in e-commerce - such as demand learning with side information, context and location aware recommendations, personalized learning, etc. - can be cast as large-scale problems of matrix recovery, with side information in the form of additional matrices of conforming dimension. Viewing the matrix we seek to recover and the side information we have as slices of a tensor, we consider the problem of Slice Recovery, which is to recover specific slices of “simple” tensors from their noisy observations. We propose a definition of simplicity that is motivated by a compelling generative model and subsumes low-rank tensors for the most popular definitions of tensor rank. We provide an efficient algorithm for slice recovery that is practical for gigantic datasets and provides a significant performance improvement over state of the art incumbent approaches to tensor recovery. Further, we establish near-optimal recovery guarantees that in an important regime represent an order improvement over the best available results for this problem. Experiments on data from an online music streaming service demonstrate the performance and scalability of our approach.

Joint work with Vivek Farias.

3. **Dynamic Pricing Under Debt: Spiraling Distortions and Efficiency Losses**
   
   *Dan Iancu, Stanford University, daniancu@stanford.edu*

   Firms often finance their inventory through debt, and subsequently sell their inventory to generate profits and service the debt. Pricing of products is consequently driven by both inventory and debt servicing considerations. We show that limited liability under debt induces sellers to charge higher prices and to discount products at a lower pace. We find that these distortions result in revenue losses that compound over time, leading to some form of performance spiral down. We quantify the extent to which these inefficiencies can be mitigated by practical debt contract terms that emerge as natural remedies from our analysis, and find debt amortization or financial covenants to be the most effective, followed by debt relief and early repayment options.
Friday, 11:30 – 13:00, L016

Product upgrades and secondary markets

1  To Ration or Not to Ration? Selling to Strategic Customers under Scarcity Effects
   Stephen Shum, College of Business, City University of Hong Kong, swhshum@cityu.edu.hk

We study the dynamic pricing and availability decisions of a firm that repeatedly introduces new generations of a product over time. Customers are strategic and at the same time they are affected by scarcity effects. Firm-induced scarcity is never optimal in the absence of scarcity effects but it can be optimal when customers are affected by scarcity effects. We study the long-run optimal policy of the firm and characterize when firm-induced scarcity is optimal. Our results show that, the firm’s long-run optimal policy may be a constant availability policy or a varying availability policy, depending on the intertemporal difference in margin, the market size and asymmetry in customers’ perception. In addition, a stronger scarcity effect may sometimes lead to a higher availability level. We also consider an extension in which customers are heterogeneous in the degrees to which they discount future utilities.

2  Dynamic Pricing and Replenishment with Customer Upgrades
   Oben Ceryan, Drexel University, oceryan@drexel.edu

We study a joint implementation of price- and availability-based product substitution to better match demand and constrained supply across vertically differentiated products. Our study is motivated by firms that utilize dynamic pricing as well as customer upgrades, as ex-ante and ex-post mechanisms, respectively, to mitigate inventory mismatches. To gain insight into how offering product upgrades impacts optimal price selection, we formulate a multiple period, nested two-stage model where the firm first sets prices and replenishment levels for each product while the demand is still uncertain, and after observing the demand, decides how many (if any) of the customers to upgrade to a higher quality product. We show that the optimal upgrade policy is defined by a protection level on the higher quality product, the optimal replenishment policy follows partially decoupled, modified base-stock levels, and the pricing policy consists of various regions of price surcharges, list prices, and price discounts. Regarding the impact of upgrades on pricing, we establish that firms having greater flexibility to offer product upgrades can restrain their reliance on dynamic pricing and thus are able to select prices that are closer to list prices, enabling them to better reflect the list-price differentiation between the products. We also show how the quality differential between the products and changes in the replenishment cost structures influence the optimal pricing, replenishment, and upgrade policies. Finally, we consider an extension in which the firm dynamically sets upgrade fees in each period and show that the firm will charge more for an upgrade if the availability of the higher quality product is lower and charge less if the number of customers who were unable to get the lower quality product is higher.

3  Optimal manufacturing, remanufacturing and trade-in policies with secondary market and competition
   Lipan Feng, Nankai University, lpfeng@mail.nankai.edu.cn

This paper seeks to explore the effects of the existence of secondary market on the manufacturer’s optimal manufacturing, remanufacturing and trade-in policies. To achieve these, we establish a two-period model where a monopolistic manufacturer sells new products in the first period and implements trade-in program in the second period in the primary market. Meanwhile, these collected used products from the primary market are remanufactured and sold in the secondary market, which implies there is an internal constraint of the quantity of remanufactured products. We obtain conditions under which the manufacturer should collect all/partial/no used products and remanufacture all/partial none of them, and then sell all/partial/no of remanufactured products in the secondary market. In addition, we extend our research to a competition case where an incumbent selling low or high quality competitive products exists in the secondary market, and find some similar results which help to show the robustness of our findings. Furthermore, we observe that the barriers to entry secondary market for the manufacturer, under a competitive situation, heavily depend on the product differentiation between remanufactured products and competitive products, maximal willingness to pay of customers in secondary market and its competitor’s production cost.
Friday, 14:30 – 16:00, TURING

Sharing networks: optimal control

1 Surge Pricing Beyond "Matching Supply and Demand"
   
   Francisco Castro, Columbia Business School, fcastro19@gsb.columbia.edu

   Pricing strategies used in the ride-sharing market by platforms such as Uber and Lyft have attracted considerable attention. In this market, drivers are self-interested and are free to move from one point to another with better "conditions" to maximize profits. Ride-sharing platforms facilitate this movement and the matching of supply to demand through real-time location-based pricing. The focus of this work is to understand the structure of optimal pricing strategies in a geographical network with self-interested supply agents. We anchor our analysis around a Stackelberg game. We model a city through a network in which each node or location has a mass of riders and drivers. The platform first sets prices at nodes. Based on the prices and the anticipation of interested riders, drivers strategically decide to travel to other locations incurring in a transportation cost if they do so. When deciding a driver also considers the probability of being matched. The platform shares revenues with drivers. In turn, we assume the objective of the platform is to maximize revenues. We establish that for the followers' game an equilibrium always exists. Furthermore, we establish that, at any equilibrium, the network can be split into two types of nodes: from which drivers leave and to which drivers travel. Then we show the platform may need to price higher than prices that would balance supply and demand. Our results elucidate different layers of surge pricing needed. While a first layer is needed to balance initial supply and demand and a second layer is needed to incentivize drivers to travel, a third layer emerges to ensure that drivers move to the "right" locations. In particular, we shed light on the impact of flexible supply on the form of an optimal pricing policy and how supply incentive constraints shape the policy.

2 Spatial Pricing in Ride-Sharing Networks
   
   Kostas Bimpikis, Stanford University and University of Chicago, kostasb@stanford.edu

   Ride-sharing platforms are in the process of disrupting transportation by better matching the supply of drivers with the demand for rides. One of main tools at their disposal to facilitate this matching is their pricing/compensation policy. The design of a pricing policy may be challenging as prices serve a dual role: match supply and demand in time and also in space. Much attention so far has focused on how to employ surge-pricing techniques to mitigate the impact of temporal demand fluctuations on profits at a given location. Our goal in this paper is to complement existing literature by focusing squarely on the demand pattern for rides across a network's locations and its impact on the platform's prices, profits, and consumer surplus. To this end, we consider a stationary environment that ensures our analytical findings isolate the impact of the demand pattern's spatial structure and study how the platform should price rides differently depending on where they originate. Our contributions can be summarized as: first, we develop a tractable model to study a platform operating on a network of locations that may differ in their demand size and the rider's destination preferences. The model features drivers who endogenously determine not only whether to provide service but also where to relocate themselves when they are idle. Second, we provide a characterization of how the demand pattern affects the platform's prices, profits, and induced consumer surplus. We show that the demand pattern's "balancedness" succinctly summarizes the profit potential of a given network for the platform. Finally, we explore the benefits and limitations of a number of schemes through a combination of analytical results and simulations on real-world networks. Our findings illustrate the shortcomings of schemes commonly employed in practice, as well as the benefits of price differentiating rides based on their origin.

3 Ride-Hailing Networks with Strategic Drivers: The Impact of Platform Control Capabilities on Performance
   
   Philipp Afèche, Rotman School of Management, University of Toronto, afeche@rotman.utoronto.ca

   This work is motivated by the emergence of ride-hailing platforms such as Uber, Lyft and Gett that match demand (passengers) with service capacity (drivers) over a geographically dispersed network. This matching problem is complicated by two challenges. (i) There are significant demand imbalances in the network. (ii) Drivers are self-interested and behave strategically in deciding whether to join, and if so, how to reposition (route) themselves when not transporting passengers. To address these challenges we study the value of two operational controls, demand-side admission control and supply-side repositioning control, on the performance of a revenue-maximizing ride-hailing platform. Considering a fluid model of a two-location network in a game-theoretic framework, we characterize the system equilibrium under three operating regimes, ranging from minimal control to centralized admission and repositioning control. These results contribute novel insights on the interplay between the platform's admission control and the drivers' strategic routing decisions. Specifically, we show under what conditions it is optimal to reject demand at one location to induce drivers to reposition to the other location. We also discuss various financial controls to induce desired driver behavior. Furthermore, we quantify the impact of control capabilities on the platform revenue, the capacity and the per-driver profits. The value of control is largest at moderate utilization and increases with demand imbalances.
Friday, 14:30 – 16:00, EULER
Bundling and pricing

1 Setting prices for ancillary items
   John Wilson, Ivey School of Business, jwilson@ivey.ca

In the airline industry, ancillary fees such as baggage fees have become very important to the financial health of the industry. The amount to charge for ancillary products has not yet been extensively studied. There is some overlap with the literature on bundling of products. We consider the case of n possible ancillary products such as priority boarding, extra bags, etc. These items may be bundled into specific collections. We present results for the case of static pricing and look at extensions to dynamic pricing.

2 Revenue Management With Bundles
   Tarek Abdallah, NYU, Stern School of Business, tabdalla@stern.nyu.edu

The literature on network revenue management often ignores the interplay between the choice of the selling mechanism and the dynamic pricing policy. On the other hand, the literature on bundling often ignores the impact of limited inventory on the bundling policy. In this paper, we study the joint problem of choosing the optimal dynamic bundling mechanism along with the corresponding dynamic pricing policy. We formulate the problem as a classical network revenue management problem but with an exponential number of pricing policies. In this case, the classical fluid regime, where both the demand and the inventory is scaled, is intractable. For this reason, we study different asymptotic regimes for this problem. For some of these regimes, we provide closed form solutions for the optimal bundling and pricing policy. Our results, provide new insights into the bundling problem with inventory.

3 Managing discount rates for airline ancillary bundles: The case of Low-Cost Carriers
   Masoud Khakdaman, Delft University of Technology, m.khakdaman@tudelft.nl

Introducing bundles for airline ancillary products is common practice in low-cost carriers (LCCs) to improve revenue in the airline competitive market. Predicting potential revenue drawn by introducing ancillary bundles is very dependent on the passenger’s behavior and market conditions. Putting some discounts for ancillary bundles, LCCs are trying to attract à la carte buyers to shift to a bundle. Although predicting potential ancillary revenue growth might not be accurate, ensuring zero revenue dilution can be accurately planned when determining price structures for ancillary bundles. While several studies are conducted on pricing and revenue management strategies for LCCs aiming at maximizing ancillary revenues and forecasting the revenue growth, less work is done to prevent revenue dilution in presence of ancillary bundle discounts. In this regard, the main concern of LCCs which is the question of “up to which point we can give discounts so that our revenue dilution would be zero for all possible scenarios?” needs to be addressed. A mathematical model is developed in this research to find the maximum possible discount rates that ensure no revenue dilution for all routes of an LCC. It is applied to one of the major world LCCs and won a prestigious airline ancillary award in 2016. Results show practicality and robustness of the model.
Business-to-business pricing and contract design

1. Optimizing Rates for Service Agreements by Shaping Loss Functions
   
   Maarten Oosten, SAS Institute, maarten.oosten@sas.com
   
   One of the optimization challenges within Business-to-Business pricing is the task of setting rates for a set of services. A common practice is to model the likelihood of winning a service within the agreement by means of a win-rate curve. It may be tempting to treat this curve as a regular demand curve, however, the variability of the demand around the expected value is very different depending on the price point. This risk needs to be addressed in the optimization model. The financial services industry faces similar challenges of managing risk, for example in the context of portfolio optimization. Recently, value-at-risk and conditional value-at-risk have become popular procedures for shaping loss functions. In this presentation, we will explore opportunities to apply these procedures to manage the risk inherent to setting rates for service agreements. We will cast the examples in the context of rate optimization for cargo rail services.

2. Use Supportive Pricing and Purchase Order Financing to Maximize Revenue
   
   Wei-Di Wu, National Chung Hsing University, andyw@nchu.edu.tw
   
   We build up a Stackelberg model to describe a two-echelon tandem supply chain where a business buyer purchases valuable items from a capital-constrained and random-yield supplier. Buyer can use Cash In Advance (CIA) and Price Supporting Purchase Order Financing (PSPOF) when her order is so large that may become burdensome to supplier. By using CIA prior to supplier’s sourcing and production, buyer directly covers partial or all supplier’s pre-shipment expenditure. By using PSPOF, buyer allows higher purchasing price, which indirectly helps supplier to finance his operations through a 3rd-party financial institution. In the model, buyer can use both the strategies simultaneously and design her best order accordingly (i.e., setting purchase price, quantity, and advance amount); while supplier decides production inputs and loan amount in response. Both the entities pursue their own maximal benefit. When buyer’s CIA budget has no limit, pure CIA strategy is optimal and supply chain integration can be achieved under this scheme. Nevertheless, if buyer also lacks capital for CIA, we identify the conditions where using pure PSPOF becomes a better option. Furthermore, if it is feasible to separate the item demands into independent orders for processing, the buyer’s optimal strategy is using dual-financing sources by taking PSPOF as the backup.

3. Transfer Pricing Contract between a Global Brand Seller and its Offshore Manufacturer considering Local Brand Introduction in the Offshore Market under Green Tax
   
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   A global brand seller in a developed country has outsourced its manufacturing process to an offshore manufacturer in a developing country. Though the global brand seller enjoys a monopoly in the global market, it faces a price competition in the market of the developing country as the offshore manufacturer also manufactures and sells a local brand in its domestic market. This paper has designed an effective offshore manufacturing contract for both the firms which finds the optimal transfer price for the global brand by using bilevel programming. This paper also finds the retail prices of the global brand both in the markets of the developed and the developing countries and the retail price of the local brand in the market of the developing country. The contract takes into consideration of the green tax that the manufacturer must pay to its government apart from the export and import duties and the transportation cost of shipping the manufactured global brand from the developing country to the developed country.
1. Assortment Rotation and the Value of Concealment
   Kris Ferreira, Harvard Business School, kferreira@hbs.edu

Assortment rotation - the retailing practice of changing the assortment of products offered to customers - has recently been used as a competitive advantage for both brick-and-mortar and online retailers. Fast-fashion retailers have differentiated themselves by rotating their assortment multiple times throughout a standard selling season. Interestingly, the entire online flash sales industry was created using this idea as a cornerstone of its business strategy. We identify and investigate a new reason why frequent assortment rotations can be valuable to a retailer, particularly for products where consumers typically purchase multiple products in a given category during a selling season. Namely, by distributing its seasonal catalog of products over multiple assortments rotated throughout the season - as opposed to selling all products in a single assortment - the retailer effectively conceals a portion of its full product catalog from consumers. This injects uncertainty into the consumer’s relative product valuations since she is unable to observe the entire catalog of products that the retailer will sell that season. Rationally acting consumers may respond to this additional uncertainty by purchasing more products, thereby generating additional sales for the retailer. We refer to this phenomenon as the value of concealment. A negative value of concealment is possible and represents the event that rationally acting consumers respond to the additional uncertainty by purchasing fewer products. We develop a consumer choice model and finite-horizon stochastic dynamic program to study when the value of concealment is positive or negative. We show that when consumers are myopic, the value of concealment is always positive. In contrast, we show that when consumers are strategic, the value of concealment is context dependent; we present insights and discuss intuition regarding which product categories likely lead to positive vs. negative values of concealment.

2. A new mathematical framework for a choice-based optimization model
   Shadi Sharif Azadeh, Erasmus University Rotterdam, sharifazadeh@ese.eur.nl

Combining customer behaviour models in optimization provides a better understanding of the preferences of clients to policy makers while planning for their systems. These preferences are formalized with discrete choice models. However, their complexity leads to mathematical formulations that are highly nonlinear and nonconvex in the variables of interest. On the other hand, we are also interested in discrete optimization models where supply and demand closely interact, which is typically the case in transportation. Such models are associated with (mixed) integer optimization problems, whose discrete variables are used to design and configure the supply. The goal of this research is to develop a general methodology which integrates both supply and demand under the framework of discrete choice models whose associated mixed integer linear problems are scalable and solvable within reasonable time.
Pricing with incomplete information

1 Discontinuous Demand Functions: Estimation and Pricing
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Discontinuous demand functions naturally arise in many pricing applications, especially ones that involve price-rankings of sellers. For example, a higher position in an online price-ranking can offer better visibility, leading to a positive and discontinuous jump in demand. Motivated by such applications, we consider a dynamic pricing problem with an unknown and discontinuous demand function. There is a seller who dynamically sets the price of a product over a multi-period time horizon. The expected demand for the product is a piecewise continuous and parametric function of the charged price, allowing for possibly multiple discontinuity points. The seller initially knows neither the locations of the discontinuity points nor the parameters of the demand function, but can infer them by observing stochastic demand realizations over time. We measure the seller’s performance by the revenue loss relative to a clairvoyant who knows the underlying demand function with certainty. We first demonstrate that ignoring demand discontinuities in dynamic pricing can be extremely costly. Then, we construct a dynamic estimation-and-pricing policy that accounts for demand discontinuities, derive the convergence rates of discontinuity- and parameter-estimation errors under this policy, and prove that it achieves near-optimal revenue performance. We also extend our analysis to the cases of time-varying demand discontinuities and inventory constraints. This is joint work with Arnoud V. den Boer.

2 On Network Revenue Management with Forward-Looking Customers
   Nikos Trichakis, MIT Sloan School of Management, ntrichakis@mit.edu

We consider a canonical network revenue management model in which a seller offers multiple products, which consume capacitated resources, for sale to customers who are forward looking. We focus on a dynamic game in which the seller moves first and commits to an anonymous posted-price policy. Arriving customers respond by choosing when, whether, and which product to purchase so as to maximize their utility. Customers’ choices are driven by heterogeneous product valuations that decay over time at heterogeneous rates. Both initial valuations and decay rates are private information. We derive for all non-anticipating dynamic pricing policies an upper bound to expected revenues. We showcase the usefulness of our bound through numerical studies. We further illustrate how our analysis can be employed to derive theoretical performance guarantees for heuristic pricing policies, in particular, static pricing policies.
Friday, 16:30 – 17:30, L016
Transshipments and network goods

1  Optimal Assortment Planning under Capacity Constraint for Retailers Using Transshipments
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Transshipments may help retailers to satisfy customer demand timely and at a lower cost than receiving emergency shipments from manufacturer in case of stock unavailability. While the effects of considering transshipments along with inventory decisions are extensively investigated, transshipments may also affect more strategic level decisions such as assortment planning. In this study, our objective is to find the optimal assortments in a centralized retailer system, where retailers can utilize transshipments for the products they don’t keep. We use an exogenous demand model and consider an assortment capacity constraint for each retailer. If a product is not carried by any of the retailers, then it is considered that a customer can be willing to substitute his/her demand with another product, which can be either directly satisfied from the retailer’s inventory or by transshipment.

2  Promotion Planning of Network Goods
   Ningyuan Chen, Hong Kong University of Science and Technology, nychen@ust.hk

With the emergence of social networks and other contemporary communication platforms, the propagation of a new product or service in the population has become increasingly dependent on the interaction among users. This is particularly true for network goods, formally defined as products or services for which the utility of unit-consumption for an agent depends on the usage of others. We consider a monopolist who offers a divisible good (or service) to a network of potential consumers over an infinite horizon. The network effects among consumers are captured by a weighted adjacency matrix. The firm's objective is to use a promotion/pricing policy to exploit network effects and maximize the total discounted revenue. We show that the optimal policy is a threshold policy: stop the promotion and charge a regular price when the total network externality exceeds a threshold. Moreover, the network structure plays a key role in the optimal policy and total revenue: (1) A more strongly connected network always benefits the firm. The firm should offer promotion for a longer period and charge a higher price. (2) Imbalance (different connectivities among consumers) in the network benefits the firm. (3) The firm's optimal policy and revenue become less sensitive to the network structure when the network is becoming more balanced.
Friday, 16:30 – 18:00, L017

Pricing in specific applications (II)

1  An application of artificial neural network approach to electric vehicle pricing in US automobile market
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Today, the increasing environmental and economic concerns lead to a significant growth in plug-in electric vehicle market. Deployment of new battery production technologies, coupled with the gradual decrease of electric vehicle costs, is leading to pure electric and plug-in hybrid car prices becoming affordable for public purchase. Without any doubt, car manufacturer's pricing strategies will be playing a key role in the future automotive industry, in which incumbents and new rivals are already in competition. This study aims to construct an artificial neural network (ANN) to model and simulate the US electric vehicle market pricing behavior. In the proposed model, automobiles’ product characteristics, specifications, green consumption parameters and customer preferences are considered as price indicators for 2017 model automobiles. The MATLAB Artificial Neural Network toolbox is used in the creation of the model, as well for the simulation process, while the optimum network architecture and number of neurons are achieved through trial and error. The findings of the study suggest that the created model is indeed suitable not only for determining an average market price for a given product with specific characteristics in order to make entry into the electrical vehicle market, but also to evaluate an existing product’s price to efficiently compete.

2  Expected revenue estimation for multimedia service provider using random point process
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Estimation of expected revenue earned by multimedia service providers is increasingly become complex due to the advent of several mobile applications like voice, browsing, e-mail, streaming video, interactive gaming etc coming into use. Revenue is proportional to service usage by the subscribers. Revenue at any time is a random variable depending upon the time of arrival of request followed by service usage time. Services requirements arrive at random points of time and the usage time is also random. This fits into a class of Stochastic Point Process, where random processes like service requirements are triggered at random points of times, known as Random Point Process (RPP). This technique has been used in problems of nuclear particles, cancer and population growth. In this paper, we demonstrate the possibility of obtaining aggregate revenue earned over a period of time and its fluctuations for time dependent arrival rates using two techniques of stochastic point process namely Product density and RPP. Consider customers requesting for services at random instants of time. We associate with each point of time a random load of \( I_i \) (in bytes). Let \( h_j(t-t_i) \) represents the charging function for the service type \( j \). For time based charging \( h_j(t-t_i) = r_j(t-t_i) \) where \( r_j \) represents the charge per unit time for j-th type service. The aggregate revenue for all types of services at any time \( t \), \( R(t) \) can be written as \( R(t) = \sum_j R_j(t) \) where \( j = 1,2,3 \), \( R_j(t) \) represents the different types of services, \( R_j(t) = \sum_i h_j(t-t_i) H(t-t_i) \), where \( H \) is Heaviside unit function and can be dropped if it is borne in mind \( h \) is zero for \( t \) less than \( t_i \). Thus the aggregate revenue is expressed as a linear function of the product of services arrival time, rate of charge and the usage time. Though the theory of linear cumulative problems is well established, the extension to time dependent problems (non stationary) have not attracted sufficient attention. \( R_j(t) \) is non Markovian and normal Markovian analysis cannot be used. However, we show how to obtain closed form solution for Poisson service arrival rates. For non Poisson arrival rates, we define product density, suitable for the problem and obtain the first two moments of \( R_j(t) \). The expected revenue and its fluctuations can be obtained from the first two moments. This model can assist service providers in understanding fluctuations in aggregate revenue and can devise pricing strategies to maximise the total revenue.

3  TV Market in China
Yongsik Nam, Cheil PengTai China, yskwak@gntech.ac.kr

TV market in China is at big bang! The total volume of TV in China was 220 million including 25 million on UHD TV in 2016. The price competition among retailers and wholesalers is so intensive all year round. The purpose of this research is to develop a comprehensive dynamic price response function that marketers in TV industry in China can use to set price level and to forecast quantity at competitive situation. Based on the Gutenberg’s dynamic pricing model and mixture regression model at segment level, researchers developed the integrated dynamic price response function consisting of the price level effect, the buyers’ price expectation, carry-over effect, competitive price effect and event effect. Mixture model is to divide the observations, to identify the segments, and to estimate the parameters of the density function underlying the observed data within each segment. Although the applications of the mixture model for segmentation are well documented in academic field, the report of application of mixture model to the pricing in practice has been relatively rare. The researchers also aim to try to full this gap by applying a mixture regression model to dynamic pricing modeling for TV market’s sales data in China. The integrated model is analytically tractable and improve the models’ diagnostics, fit and predictions for sales volume for a multinational TV manufacturer in China.