

Optimal Real-Time Bidding for Display Advertising

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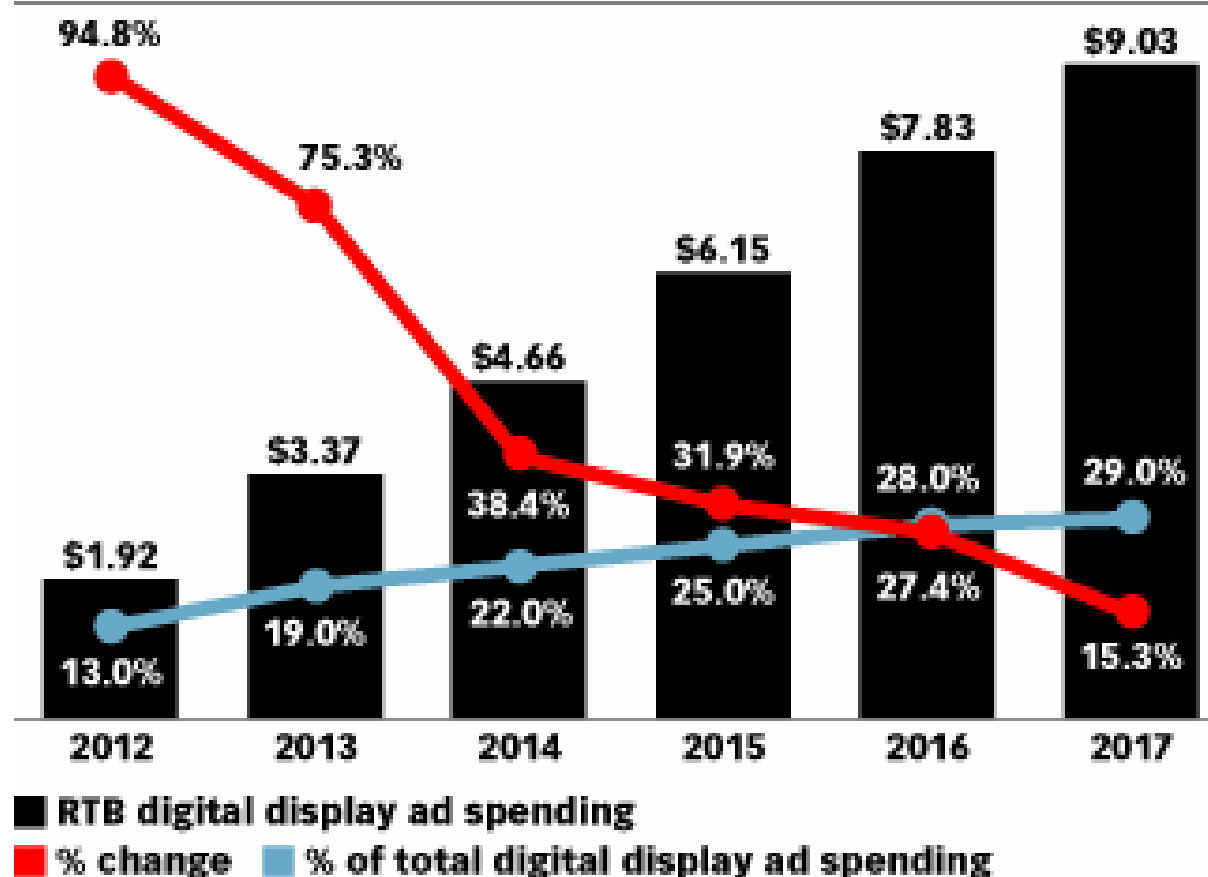
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27 August 2014, KDD

US Real-Time Bidding (RTB) Digital Display Ad Spending, 2012-2017

billions, % change and % of total digital display ad spending



Note: includes all display formats served to all devices

Source: eMarketer, Dec 2013

What is Real-Time Bidding?

- Every online **ad impression** can be evaluated, bought, and sold, all **individually**, and all **instantaneously**.
- Instead of buying a bundle of impressions, advertisers are now buying **users** directly.

An Example

Weinan regularly reads articles on emarketer.com

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Advertisers Continue Rapid Adoption of Programmatic Buying

By 2017, advertisers will spend more than \$9 billion on RTB

Nov 26, 2013

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Advertisers are spending more than expected on real-time bidding, which is expected to account for a significant share of all display ad spending in the US advertising—which includes RTB—continues its rapid transition from infancy to a well-established display purchase method in just a few years.

Year	RTB digital display ad spending (billions)	% change	% of total digital display ad spending
2012	\$1.92	13.0%	19.0%
2013	\$3.37	75.3%	22.0%
2014	\$4.66	38.4%	25.0%
2015	\$6.15	31.9%	27.4%
2016	\$7.83	28.0%	29.0%
2017	\$9.03	15.3%	29.0%

Note: includes all display formats served to all devices
Source: eMarketer, Dec 2013
164097

eMarketer projects RTB digital display ad spending in the US will account for 29.0% of total US digital display ad spending by 2017, or \$9.03 billion. In 2013, it will account for 19.0%, or \$3.37 billion. These estimates are revised slightly upward from our previous forecast in August

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Content-related ads


Weinan recently checked the London hotels









Recently viewed

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Weinan Zhang



 B

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
[home](#) → [uk](#) → [greater london](#) → [london](#) → [search results](#)
 16,378 properties 1,824 properties 1,574 properties London, 2 adults, 11 nights (Jul 14 - Jul 25) [Change dates](#)

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
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Distance:

Check-in Date

 Mon 14

Check-out Date


 Fri 25

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Guests

Search

Search properties



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 Tip: Prices might be higher than normal, so try searching with different dates if possible.

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930 out of 1857 properties are available in and around London

Showing 1 – 15

Sort by:

Recommended

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Location ▼


Price ▼



Review Score ▼


List

Map




 2013

Park Plaza Victoria London ★★★★★
 
 1736

Central London, Westminster, London •  Nearby stop

There are 13 people looking at this hotel.
 Latest booking: 1 hour ago


 Superior Double Room
 7 more room types


Price for 11 nights



We have 5 rooms left!

£2,353.65

Book now



 2013


Central Park Hotel ★★★
 
 1993







6.6

Filter by:

(In fact, no login is required)

Relevant ads on facebook.com




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Family 16

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SJTU 16

UCL 20+

Shanghai Jiao Ton... 16

London, United Ki... 20+

University College... 20+

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Even on supervisor's homepage! (User targeting dominates the context)

DR. JUN WANG
Computer Science, UCL

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CIKM2013 Tutorial: Real-Time Bidding: A New Frontier of Computational Advertising Research

July 30th, 2013

Comments of

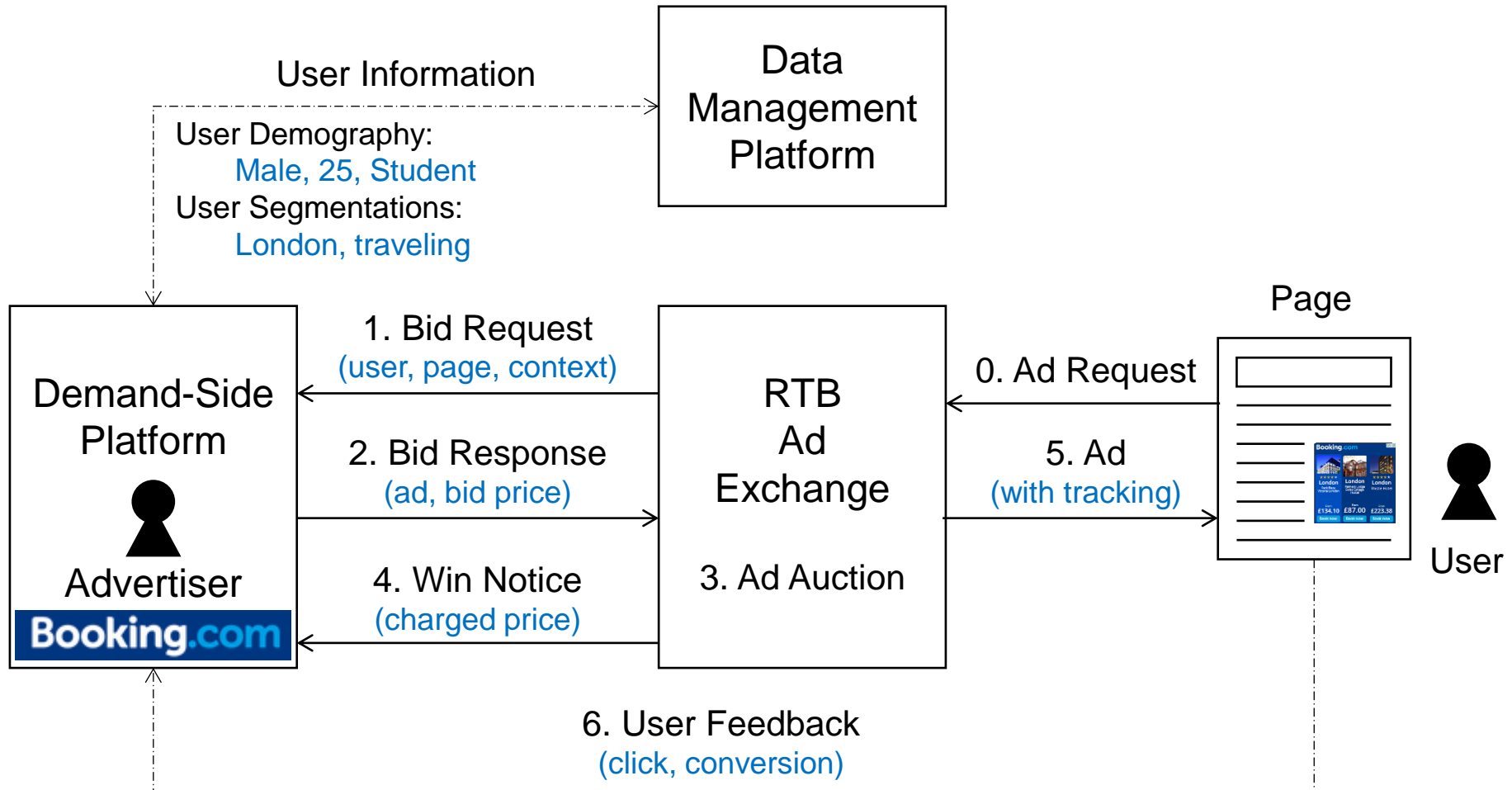
Online advertising is now one of the fastest advancing areas in IT industry. In display and mobile advertising, the most significant development in recent years is the growth of Real-Time Bidding (RTB), which allows selling and buying online display advertising in real-time one ad impression at a time. Since then, RTB has fundamentally changed the landscape of the digital media market by scaling the buying process across a large number of available inventories. It also encourages behaviour (re-)targeting, and makes a significant shift toward buying focused on user data, rather than contextual data. A report from IDC shows that in 2013, global RTB based display ad spend increased by 237% compared to 2010, with the U.S.'s \$2.2 billion RTB display spend leading the way. The market share of RTB-based spending of all display ad spending will grow from 10% in 2011 to 27% in 2016, and its share of all indirect spending will grow from 28% to 78%.

Scientifically, the further demand for automation, integration and optimization in RTB brings new research opportunities in the CIKM fields. For instance, the much enhanced flexibility of

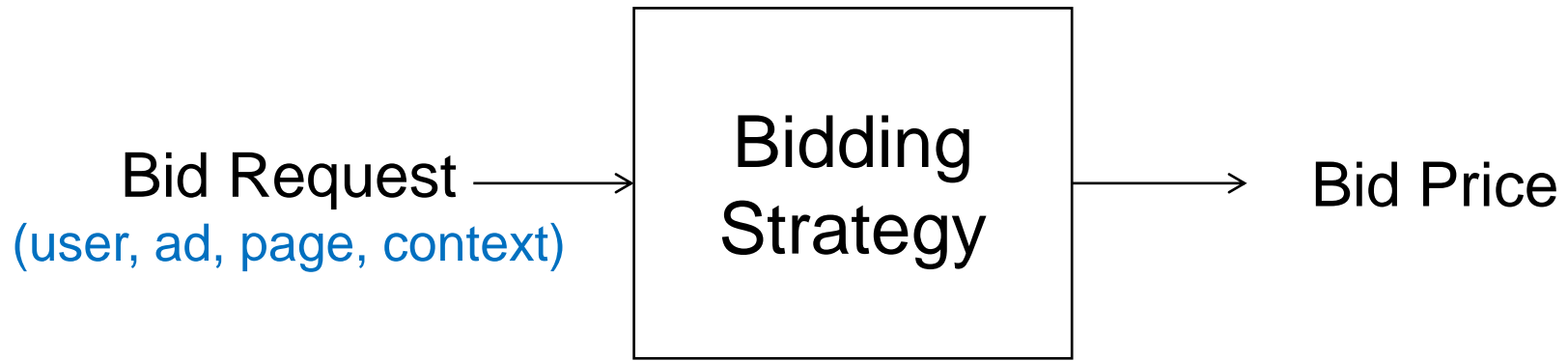
"Relevant" Ads or not?

Hotel	Rating	Price (From)	Book now
Park Plaza Victoria London	★★★★★	£134.10	Book now
Palmer's Lodge Swiss Cottage Hostel	★★★★★	£87.00	Book now
Thistle Hotel	★★★★★	£223.38	Book now

How RTB works



Our Scope



- Objective

$$\begin{aligned} &\max_{\text{bidding strategy}} && \text{KPI} \\ &\text{subject to} && \text{cost} \leq \text{budget} \end{aligned}$$

Campaign's Key Performance Indicator

For example:
Expected click number

Optimal bidder: the formulation

- Functional Optimisation Problem

$$\begin{aligned}
 b()_{OI} \quad b()_{ORTB} = \arg \max_{b()} & \quad N_T \int_{\theta} \overset{\text{winning function}}{\theta} \overset{\text{CTR estimation}}{w(b(\theta))} p_{\theta}(\theta) d\theta \quad \leftarrow \text{context+ad features} \\
 \text{subject to} & \quad N_T \int_{\theta} \overset{\text{bidding function}}{b(\theta)} \overset{\text{Cost upper bound}}{w(b(\theta))} p_{\theta}(\theta) d\theta \leq B\mathcal{B} \quad \leftarrow \text{budget}
 \end{aligned}$$

- Components
 - x , the bid request, user and ad features
 - $\theta(x)$, the **CTR** prediction function
 - $b(\theta(x), x)$, the bidding function
 - $w(b, x)$, the win probability function
- Dependency assumption:

Optimal bidder: the formulation

- Functional Optimisation Problem

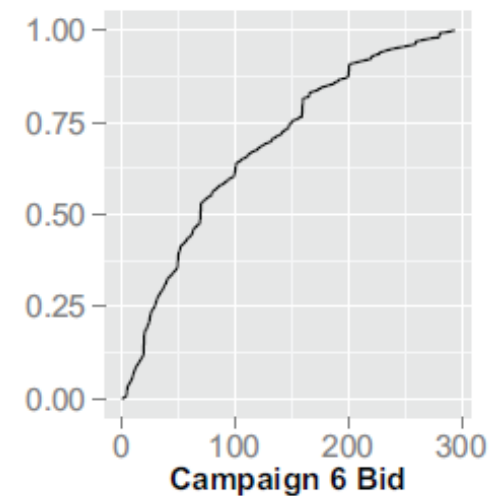
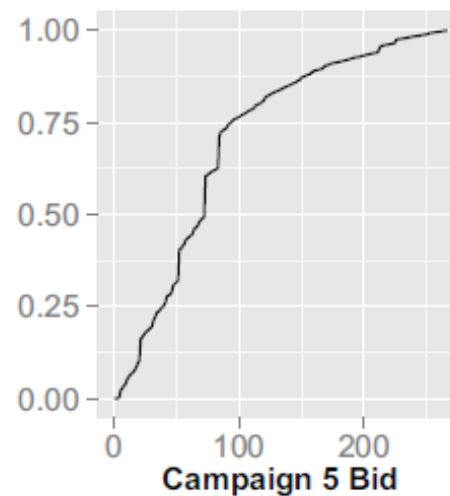
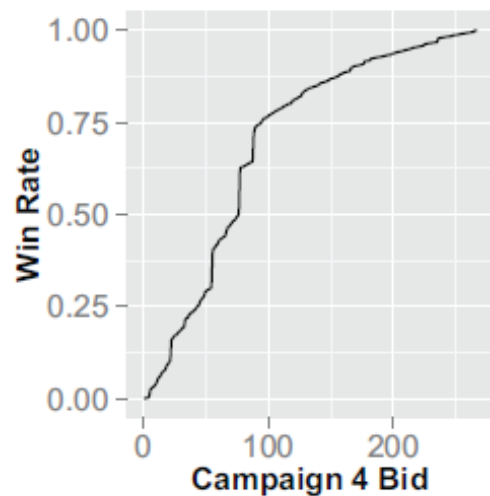
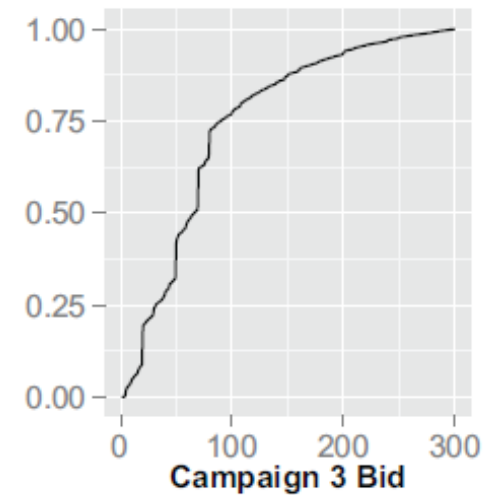
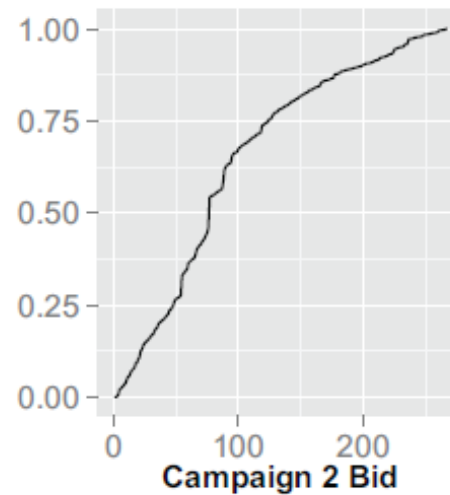
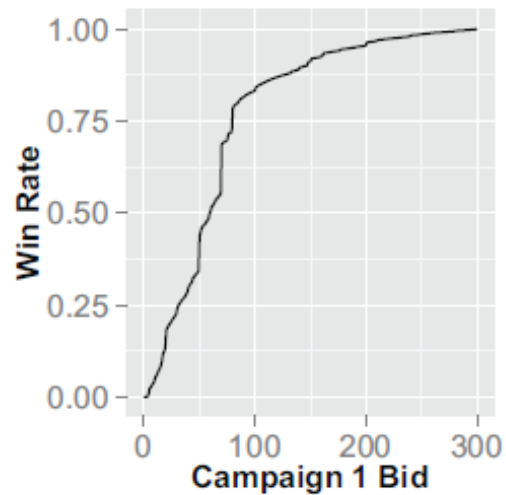
$$\begin{aligned}
 & \text{winning function} \quad \text{CTR estimation} \\
 & b(\cdot)_{\text{OI}} \quad b(\cdot)_{\text{ORTB}} = \arg \max_{b(\cdot)} N_T \int_{\theta} \theta w(b(\theta)) p_{\theta}(\theta) d\theta \quad \leftarrow \text{context+ad features} \\
 & \text{subject to} \quad N_T \int_{\theta} b(\theta) w(b(\theta)) p_{\theta}(\theta) d\theta \leq B\mathcal{B} \quad \leftarrow \text{budget} \\
 & \quad \quad \quad \text{bidding function} \\
 & \quad \quad \quad \text{Cost upper bound}
 \end{aligned}$$

- Solution: Calculus of variations

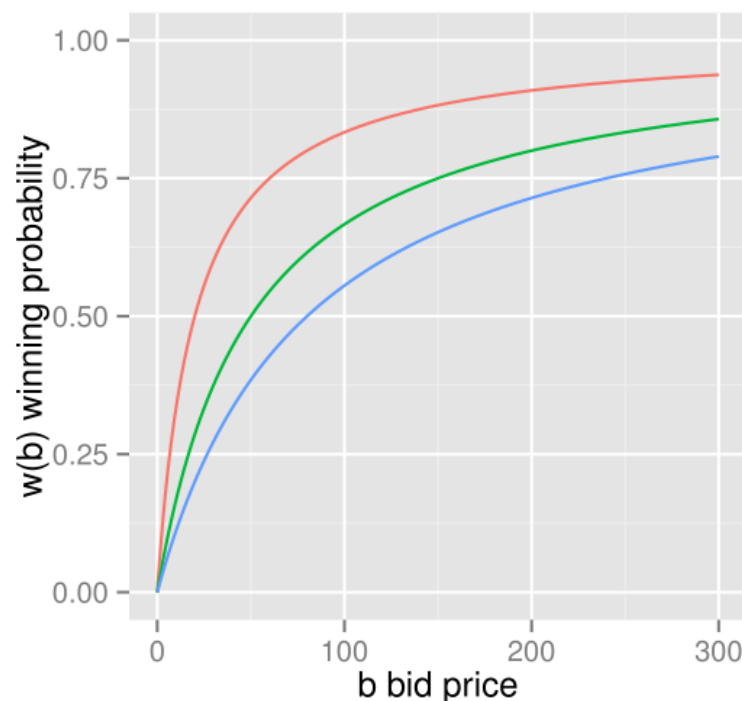
$$\mathcal{L}(b(\theta), \lambda) = \int_{\theta} \theta w(b(\theta)) p_{\theta}(\theta) d\theta - \lambda \int_{\theta} b(\theta) w(b(\theta)) p_{\theta}(\theta) d\theta + \frac{\lambda B}{N_T}$$

$$\lambda w(b(\theta)) = \left[\theta - \lambda b(\theta) \right] \frac{\partial w(b(\theta))}{\partial b(\theta)}$$

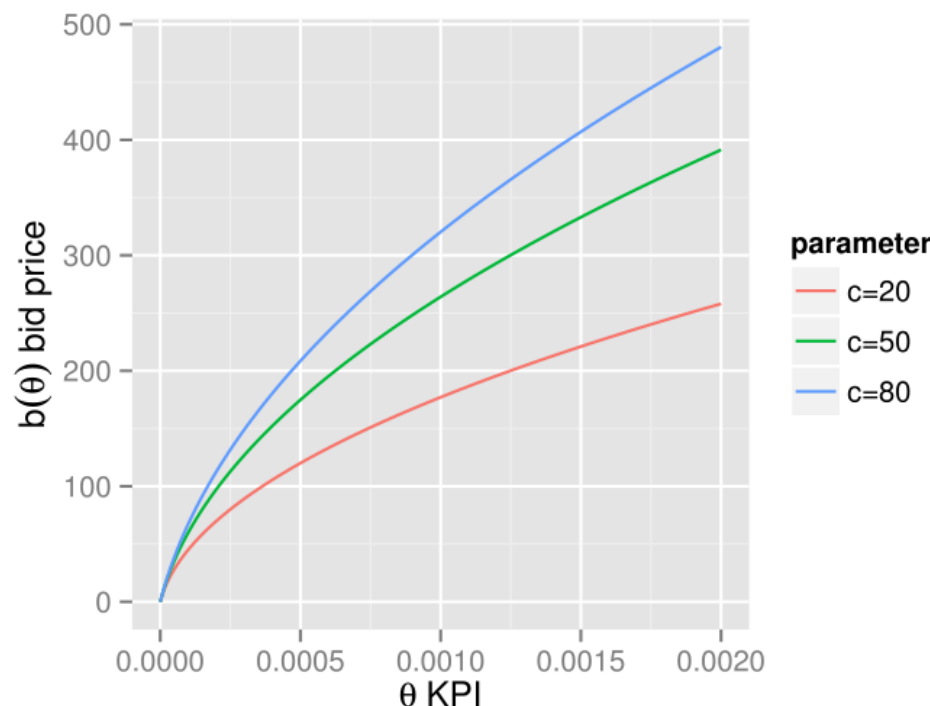
Bid Landscape: $w(\text{bid})$



Optimal bidding strategy: the solution



(a) Winning function 1.



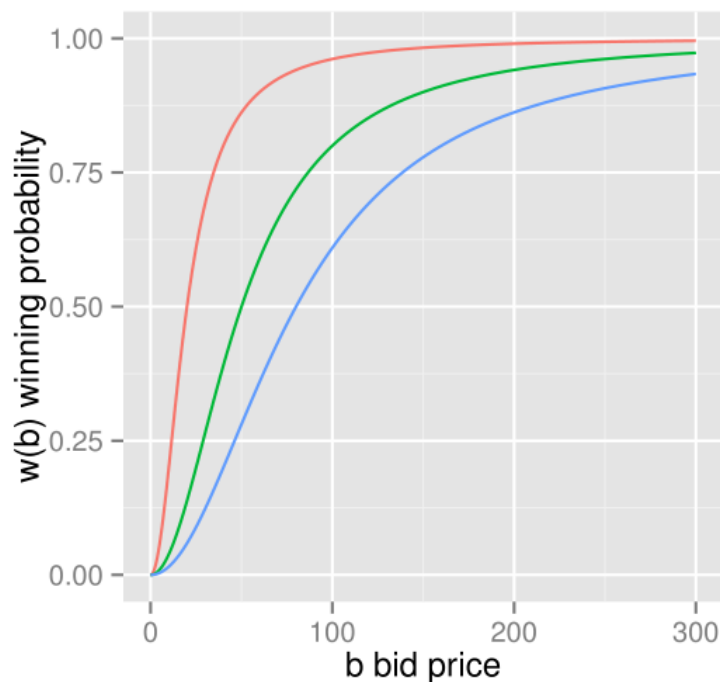
(b) Bidding function 1.

$$w(b(\theta)) = \frac{b(\theta)}{c + b(\theta)}$$

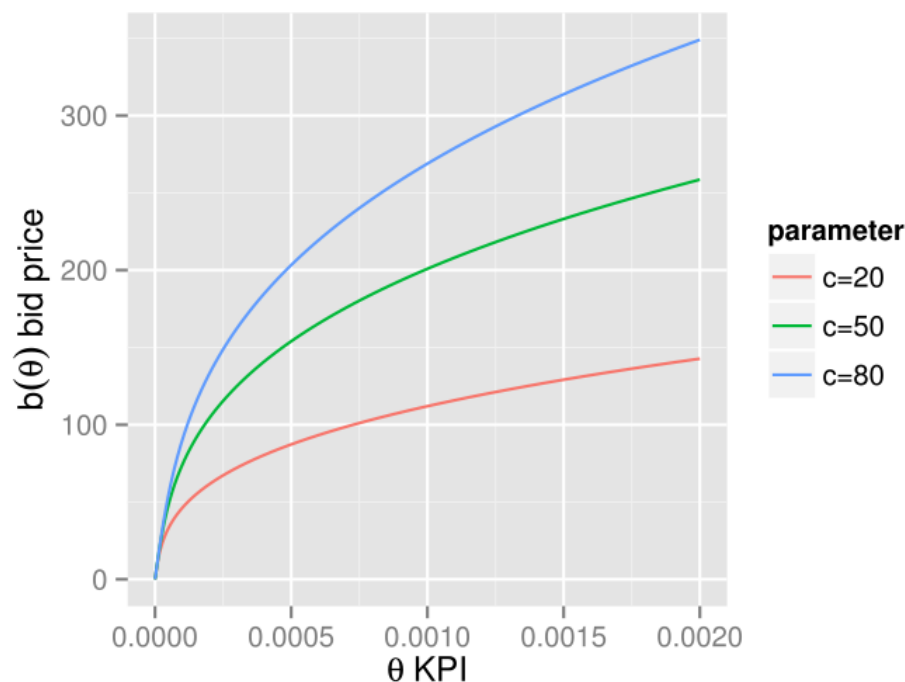
$$b_{\text{ORTB1}}(\theta) = \sqrt{\frac{c}{\lambda}\theta + c^2} - c$$

$$\lambda w(b(\theta)) = \left[\theta - \lambda b(\theta) \right] \frac{\partial w(b(\theta))}{\partial b(\theta)}$$

Optimal bidding strategy: the solution



(a) Winning function 2.

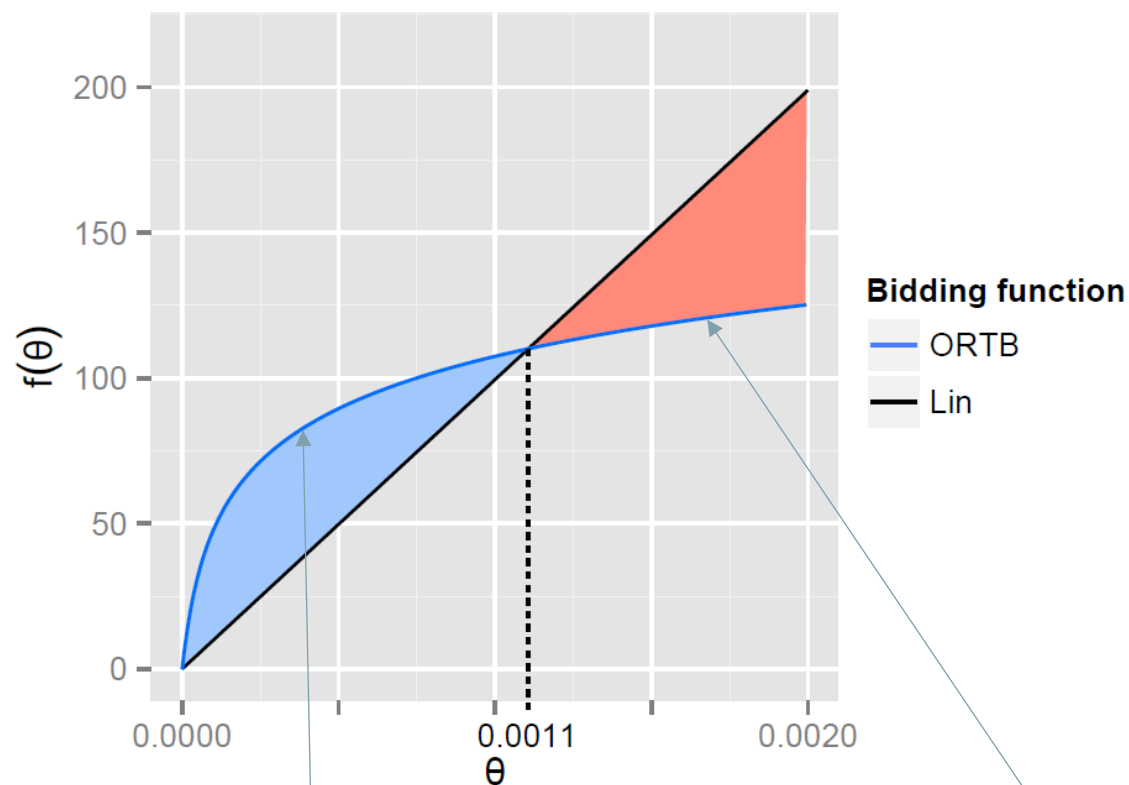


(b) Bidding function 2.

$$w(b(\theta)) = \frac{b^2(\theta)}{c^2 + b^2(\theta)} \quad b_{\text{ORTB2}}(\theta) = c \cdot \left[\left(\frac{\theta + \sqrt{c^2 \lambda^2 + \theta^2}}{c \lambda} \right)^{\frac{1}{3}} - \left(\frac{c \lambda}{\theta + \sqrt{c^2 \lambda^2 + \theta^2}} \right)^{\frac{1}{3}} \right]$$

$$\lambda w(b(\theta)) = \left[\theta - \lambda b(\theta) \right] \frac{\partial w(b(\theta))}{\partial b(\theta)}$$

Optimal bidding strategy: the solution



Slight increase at low bids is more effective

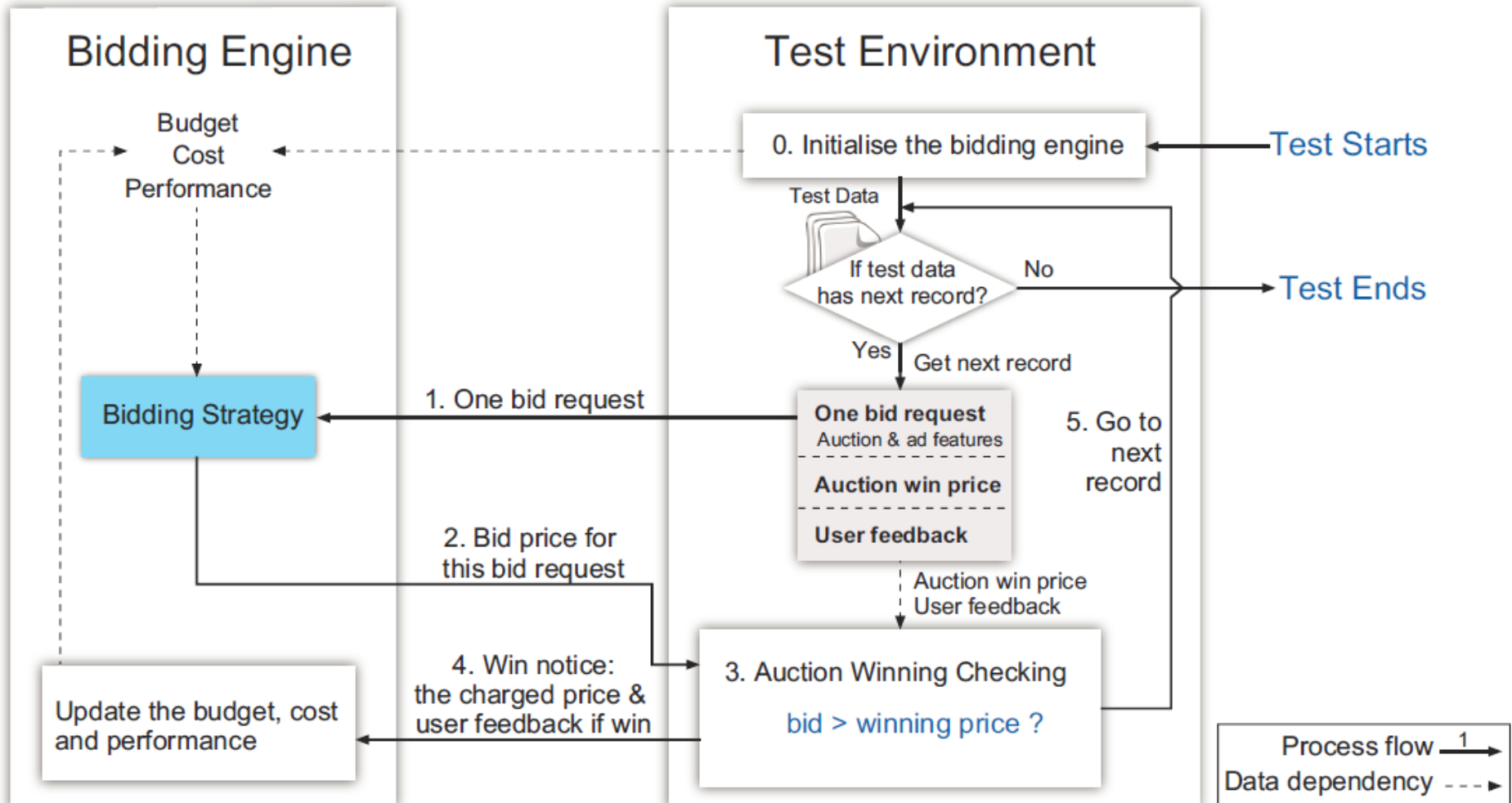
Thus reduce the bids at high CTR or CVR

Experiment

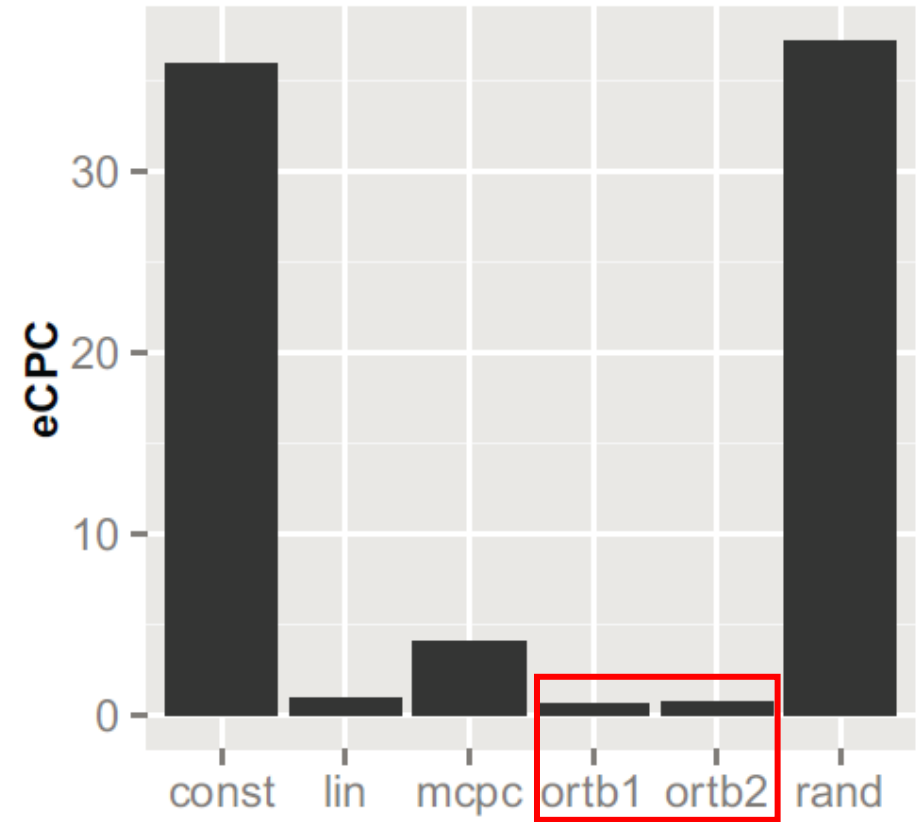
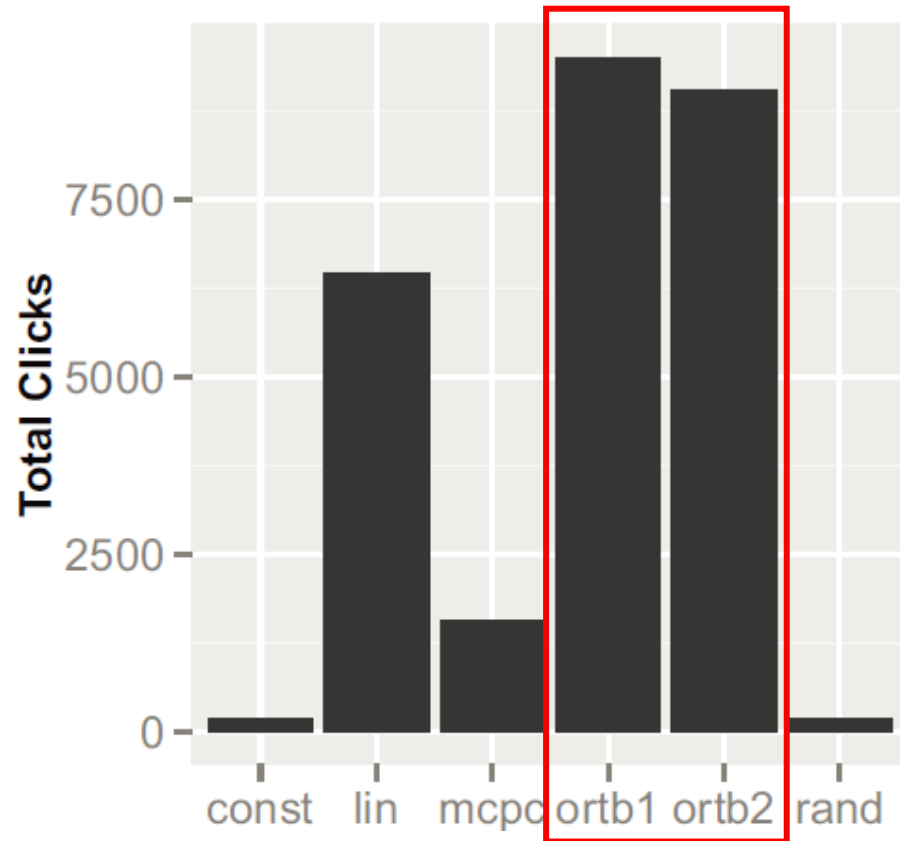
- We used iPinYou's dataset¹
 - 9 Campaigns, 15M impressions, 11K clicks, 935 conversions
- Evaluated bidding strategies
 - **Const**: Constant
 - **Rand**: Random
 - **Mcpc**: Bidding based on advertiser's given max eCPC [Chen et al. 2011]
 - **Lin**: Linear to pCTR [Perlich et al. 2012]
 - **ORTB1, ORTB2**: Optimal bidding strategies with two forms of winning rate functions

¹<http://data.computational-advertising.org>

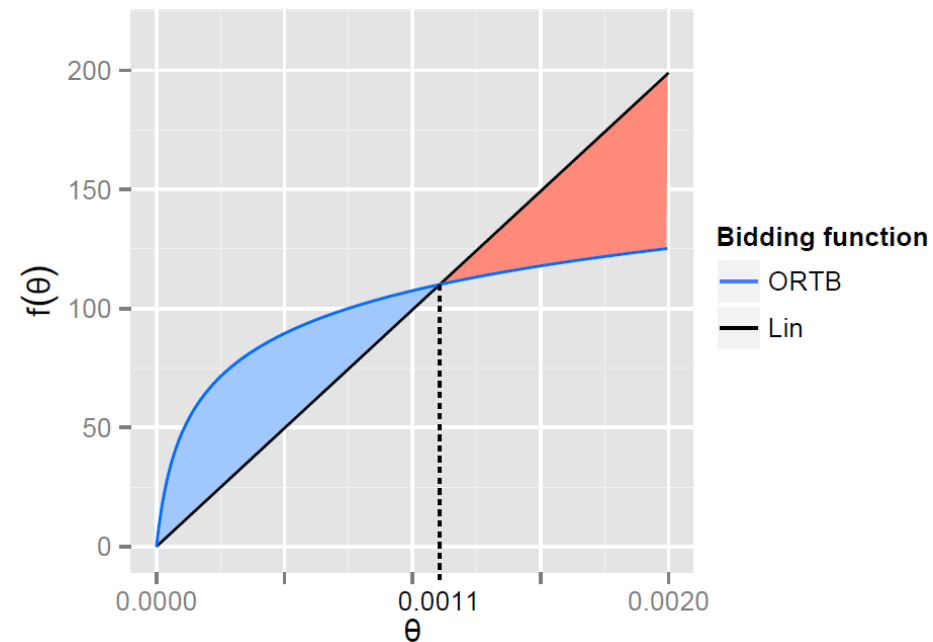
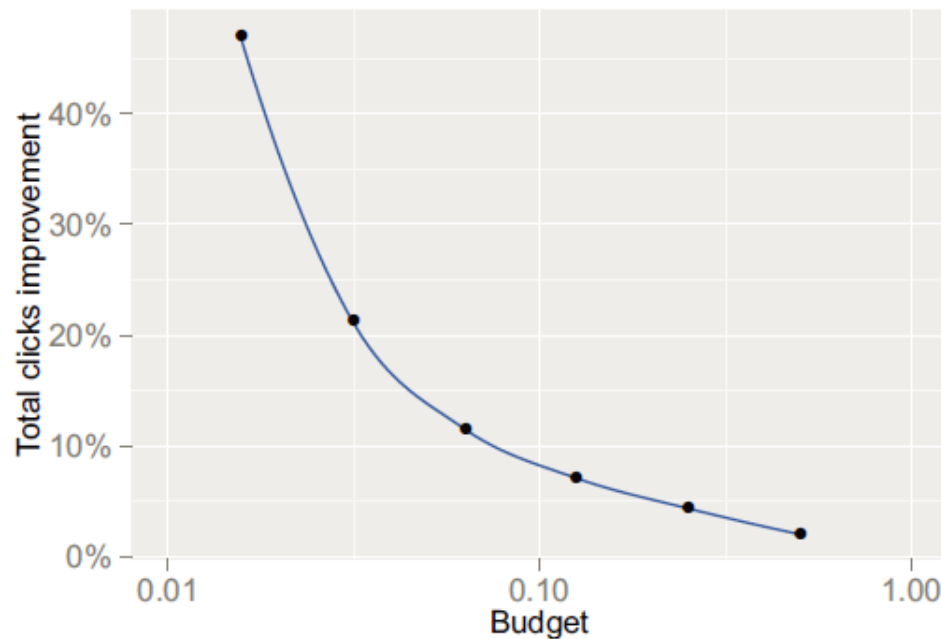
Offline Test Evaluation Flow



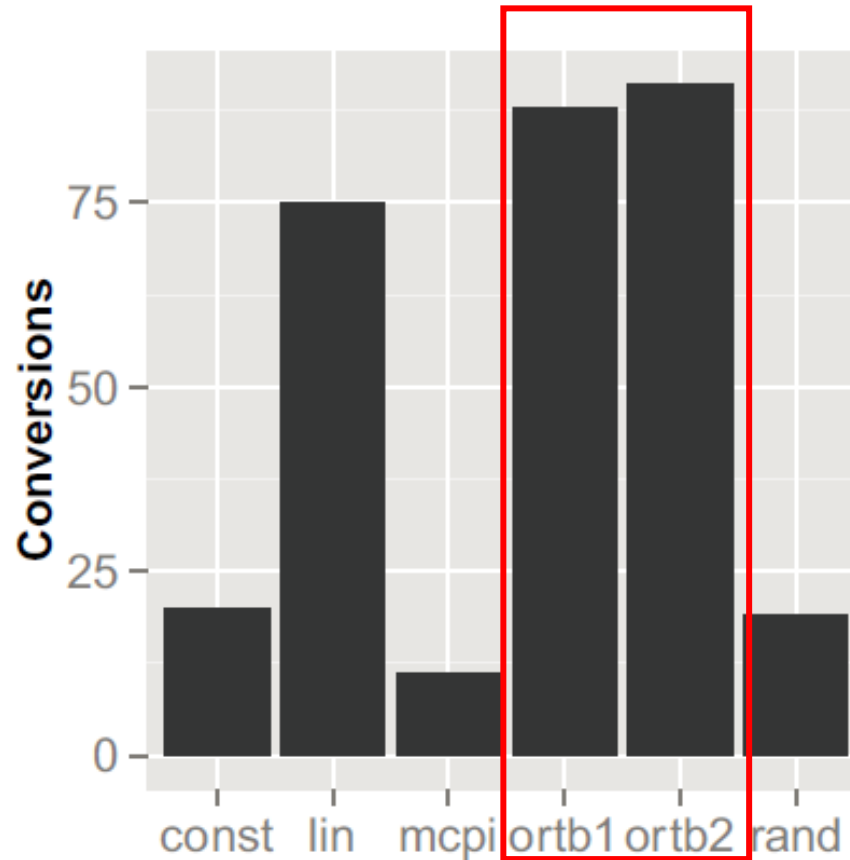
Overall performance – Optimising Clicks



Higher improvement when budget is more limited



Overall performance – Optimising Conversions



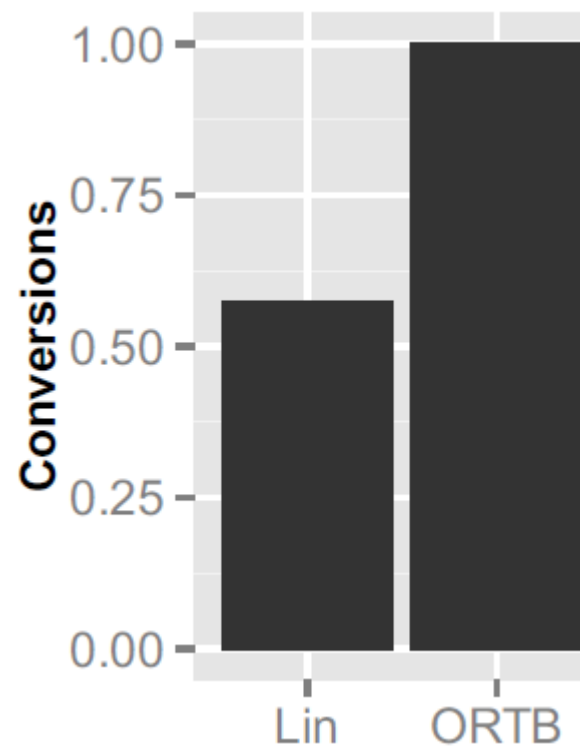
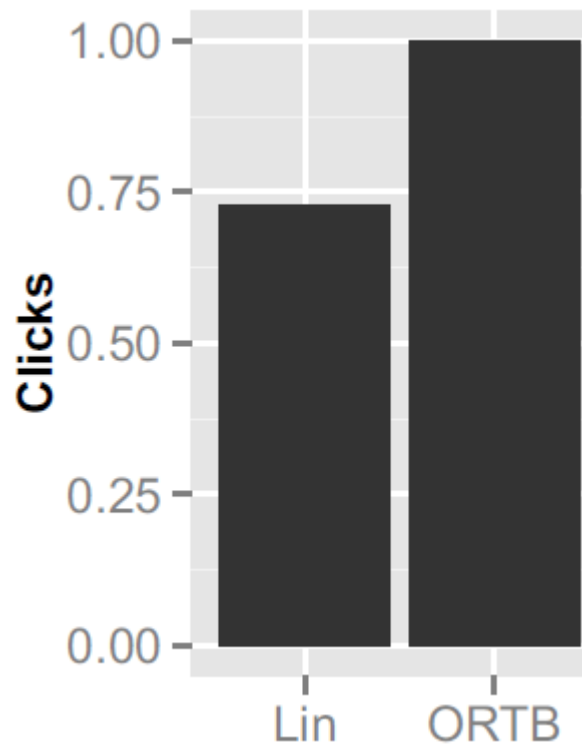
Online Evaluation Result of iPinYou Bidding Algorithm Competition Third Season

The iPinYou global RTB bidding algorithm competition third and last season has been successfully concluded. The UCL-CA, V_V, PoundsXXX, Run_Fast and Tiger teams have participated in the **three-day online finals** from Dec 26th,2013 to Dec 28th,2013. The final results, which have been carefully checked by the committee and audited by the jury, are as follows:

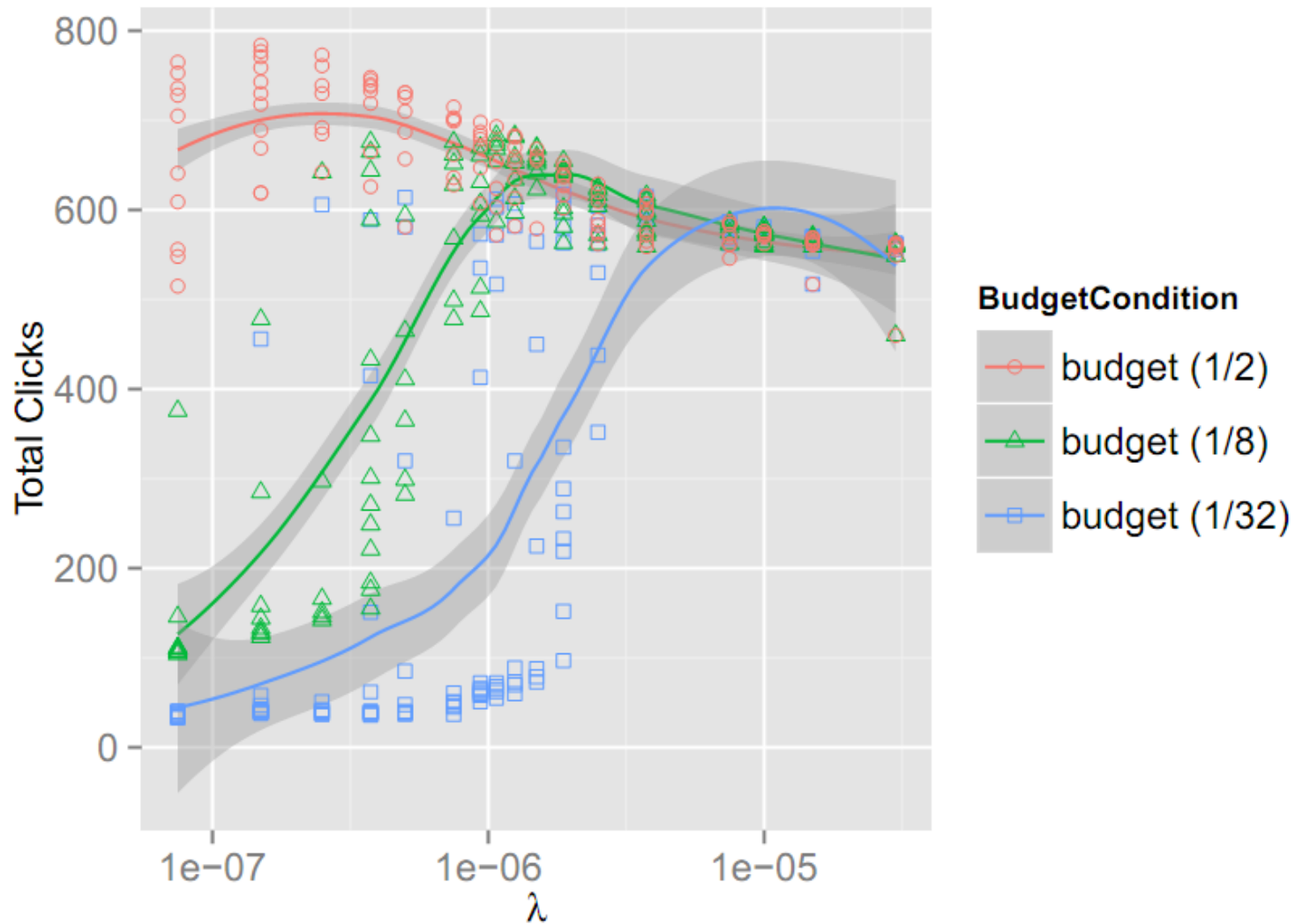
rank	team	score
1	UCL-CA	1304
2	V_V	983
3	Run Fast	901
4	PoundsXXX	885
5	Tiger	744

where the final **score = clicks + N * reaches, N = 1** The sensible choice of N does not influence the final ranking.

Online Test



Parameter tuning – λ for ORTB1



Summary

Utility

CTR/CVR
Estimator

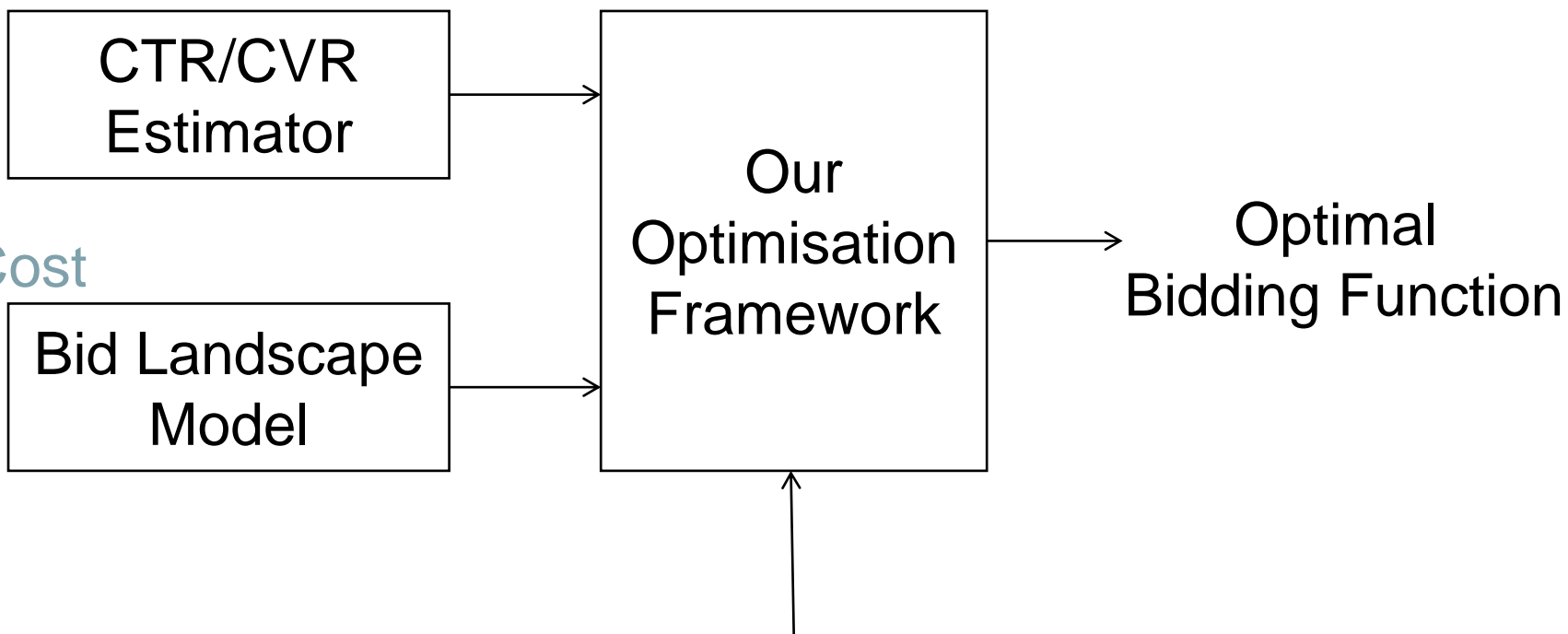
Cost

Bid Landscape
Model

Our
Optimisation
Framework

Optimal
Bidding Function

Budget, Auction Volume



Future works

- More detailed bid landscape
 - From $\text{bid} \rightarrow P(\text{win})$ to $(\text{bid}, \text{features}) \rightarrow P(\text{win})$
- Control the dynamics
- Cold start problems

Thank You!

Questions?

See our work on publisher-side optimisation:
Shuai Yuan et al. **An Empirical Study of Reserve Price
Optimisation in Real-Time Bidding**
1PM Wednesday, industrial & gov. track