

计算机科学与工程学院（网络空间安全学院）

Algorithmic Game Theory

算法博弈论



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2019 Fall



Women's Badminton Scandal

The women's badminton scandal at the 2012 Olympics was caused by a **misalignment** of the goal of the teams and that of the Olympic Committee.

Give some suggestions for how to modify the Olympic badminton tournament format to reduce or eliminate the incentive for a team to intentionally lose a match.

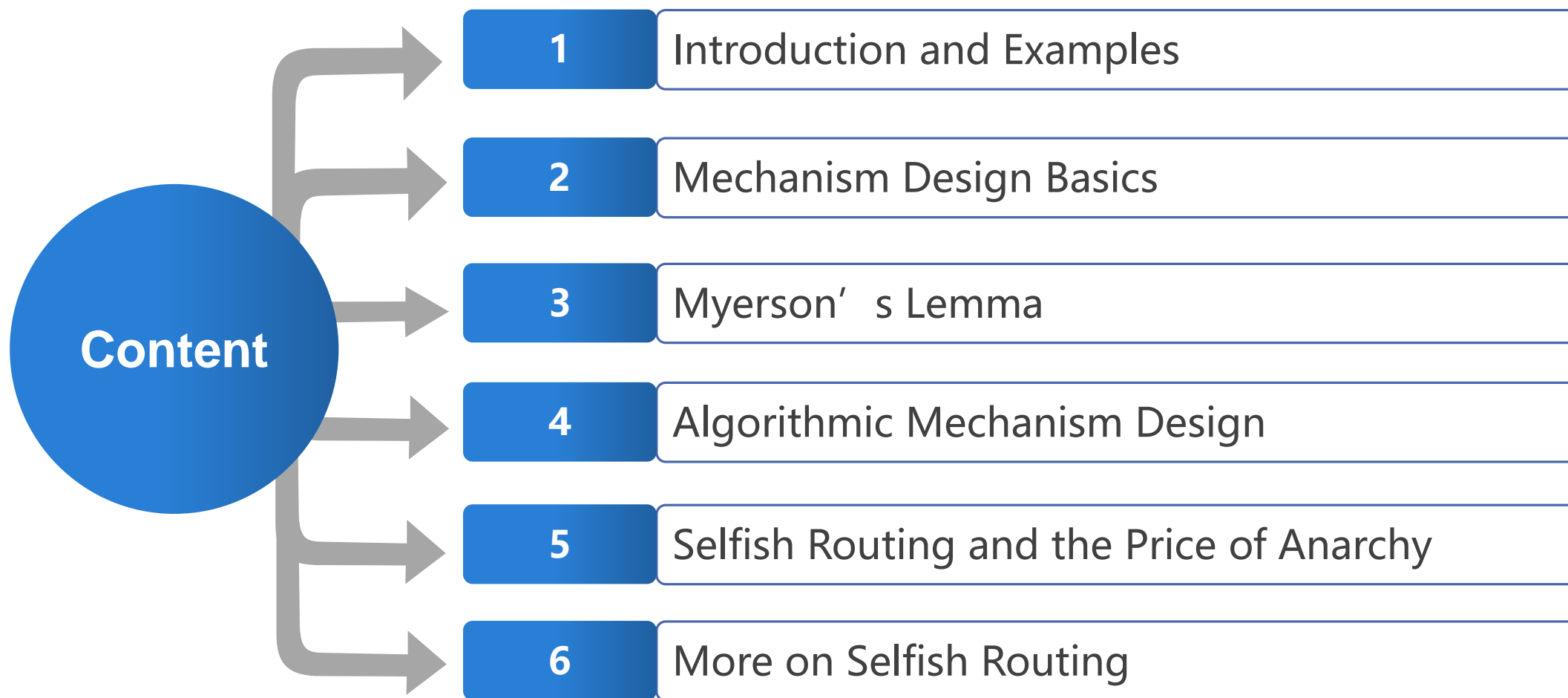


System Designer's Responsibility

The burden lies on the **system designer** to anticipate strategic behavior, not on the participants to behave against their own interests.

Identify a real-world system in which the goals of some of the participants and the designer are fundamentally misaligned, leading to manipulative behavior by the participants.

Course Content and Calendar





Mechanism Design Basics

Lecture 2



OUTLINE



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Sealed-Bid Auctions

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Dominant Strategies

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Case Study:
Sponsored Search Auctions

Introduction-Mechanism Design



Auction

An auction is a process of buying and selling goods or services by offering them up for **bid**, taking bids, and then selling the item to the **highest bidder**



Auction Theory

Auction theory is an applied branch of economics which deals with **how people act** in auction markets and researches the **properties** of auction markets



Typical Auctions

- English auction/Dutch auction
- First-price auction/Second-price auction

Single-Item Auctions

1

Course Goal

Understand how to design systems with strategic participants that have good performance guarantees



System Model

A seller with a single item for sell through an auction



Bidders

There is n of (**strategic!**) bidders who are potentially interested in buying the item



Auction Formats

- Auction can be carried out by various auction formats
- We want to reason about bidder behavior in various auction formats

Key Assumptions



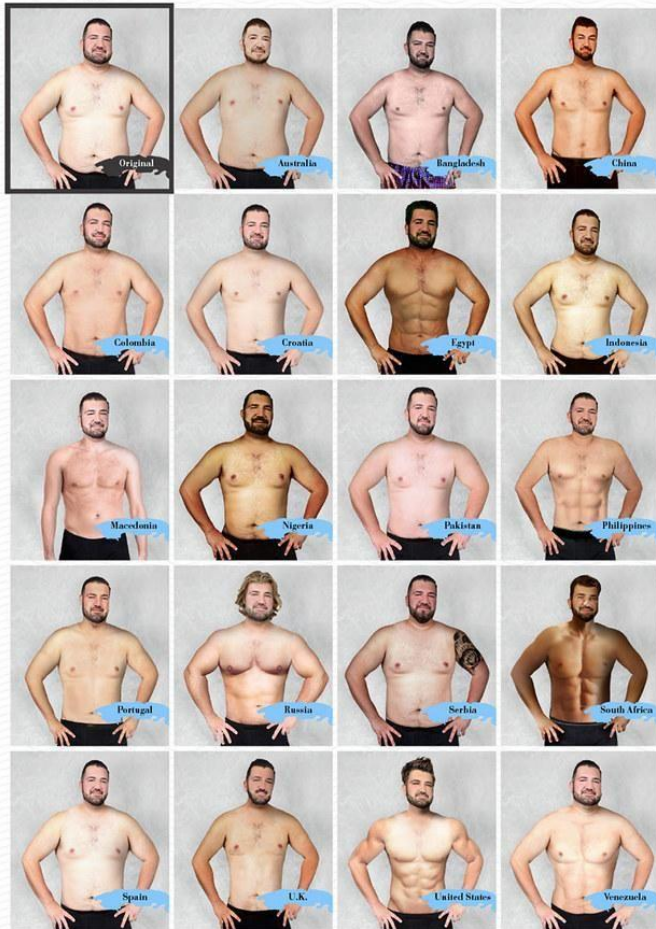
Perceptions of Perfection

PART II: MEN

Fit with their culture's perceptions of beauty and an ideal male form

This is what we sent them

Here is what they sent us



Perceptions of Perfection

You asked designers from 18 countries to sketch an image to:
FIT WITH THEIR CULTURE'S PERCEPTIONS OF BEAUTY AND AN IDEAL FEMALE FORM
Here is what they sent us.



ORIGINAL IMAGE



Independent Private Values

Valuation is **private**, **unknown** to the seller and other bidders



Nonnegative Values

Each bidder i has a **nonnegative valuation** v_i , the maximum willingness-to-pay for the item being sold

Bidder i wants to acquire the item **as cheaply as possible**, provided the selling price is at most v_i



Quasilinear Utility Model

- If a bidder i loses an auction, her utility is 0
- If a bidder wins at a price p , her utility is $v_i - p$

Auction Theory-From the Bidder's Point of View



How to Bid to Maximize Its Own Utility?

Auction Theory-From the Seller's Point of View






**Who of Them Get It?
(Who is the Winner?)**



**How Much Will the Winner Pay?
(To Maximize Seller's Profit)**

Sealed-Bid Auction



-  1) Each Bidder Submit a Bid to Maximize Utility
-  2) Seller Decides Who of Them Get It?
(Who is the Winner?)
-  3) Seller Decides How Much Will the Winner Pay?
(To Maximize Seller's Profit)

Auction Formats



There are traditionally four types of auctions that are used for the allocation of a single item



Open Bid Auctions

1

Ascending-Bid Auction

- English Auction
- Price is raised until only one bidder remains, who wins and pays the **final price**

Descending-bid auction

- [Dutch Auction](#)
- Price is lowered until someone accepts, who wins the object at the **current price**



Sealed Bid Auctions

2

First Price Auction

- **Highest** bidder wins; pays her bid, the highest bid

Second Price Auction

- Vickrey Auction
- **Highest** bidder wins; pays the **second highest** bid

Sealed-Bid Auction



1) Name



2) Birthday



3) Your Valuation

- $(MM+DD)*0.1$
- E.g. $(11+08)*0.1=1.9$



4) Submit Your Bids



5) Experiments

- 1st Price Bidding
- 2nd Price Bidding
- 3rd Price Bidding



Bid to Maximize Your Utility!

Second-Price Auctions and Dominant Strategies

2

Proposition 2.1 (Incentives in Second-Price Auctions)

In a second-price auction, every bidder i has a dominant strategy: set the bid b_i equal to her private valuation v_i .



Dominant Strategy

A strategy (i.e., a bid) that is guaranteed to maximize a bidder's utility, no matter what the other bidders do



Easy to Participate

When selecting a bid, a bidder doesn't need to reason about the other bidders in any way—how many there are, what their valuations are, whether or not they bid truthfully, etc



Advantage over First-Price Auction

In First-Price Auction, it never makes sense to bid one's valuation—this guarantees zero utility
The optimal amount to underbid depends on the bids of the other bidders

2

Proposition 2.1 (Incentives in Second-Price Auctions)

In a second-price auction, every bidder i has a dominant strategy: set the bid b_i equal to her private valuation v_i .



System Model

Bidder i , valuation v_i , bid b_i , bids from the other bidders b_{-i}

$$B = \max_{i \neq i} b_{-i}$$



Bidder i 's Utility

If lose, utility is 0; If win, utility is $v_i - p$, where p is the second-highest bid



Case 1: $v_i < B$

Bid truthfully $b_i = v_i$. Lose, receive utility 0



Case 2: $v_i \geq B$

Bid truthfully $b_i = v_i$. Win, receive utility $v_i - B > 0$

Second-Price Auctions and Dominant Strategies

2

Proposition 2.2 (Nonnegative Utility)

In a second-price auction, every truthful bidder is guaranteed **nonnegative** utility.



If a bidder i is the winner

Its utility is $v_i - p$, where p is the second-highest bid. Since i is the winner (and hence the highest bidder) and bid her true valuation, $p < v_i$ and hence $v_i - p \geq 0$.



If a bidder i is the loser

Losers receive utility 0



Dominant Strategy

A **truthful** bidder—meaning one that bids her **true valuation**—never regrets participating in a second-price auction

Cheating is not the Dominant Strategy in Second Price Auctions

Bidding your value weakly dominates bidding HIGHER

Suppose your value is \$10 but you bid \$15. Three cases:



There is a bid higher than \$15 (e.g. \$20)

You lose either way: no difference



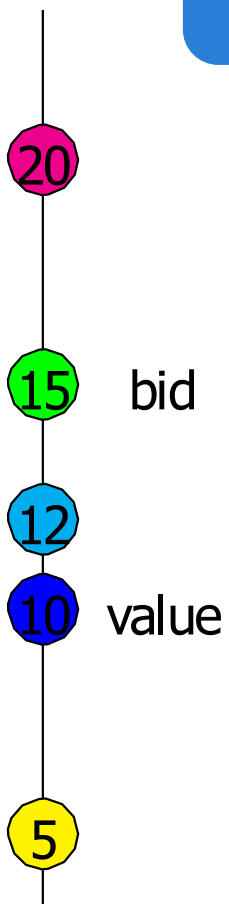
2nd highest bid is lower than \$10 (e.g. \$5)

You win either way and pay \$5: no difference



2nd highest bid is between \$10 and \$15 (e.g. \$12)

- Cheating: You win with \$15: **lose** \$2
- Bidding Truthfully: You lose with \$10: zero payoff



Cheating is not the Dominant Strategy in Second Price Auctions

Bidding your value weakly dominates bidding LOWER

Suppose your value is \$10 but you bid \$5. Three cases:



There is a bid higher than \$10 (e.g. \$12)

You loose either way: no difference



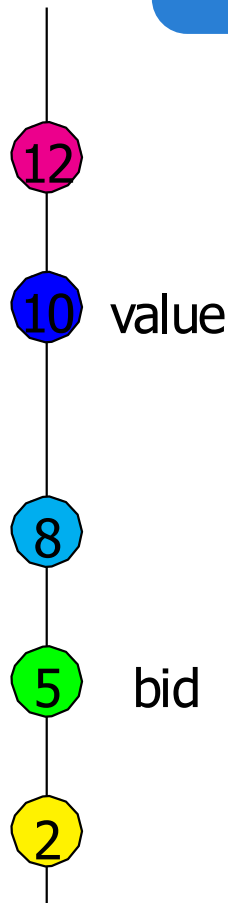
2nd highest bid is lower than \$5 (e.g. \$2)

You win either way and pay \$2: no difference



2nd highest bid is between \$5 and \$10 (e.g. \$8)

- Cheating: You loose with \$5: zero payoff
- Biding Truthfully: You win with \$10: **earn** \$2



Second-Price Auctions and Dominant Strategies

2

Definition 2.3 (Dominant-Strategy Incentive Compatible)

An auction is dominant-strategy incentive compatible (DSIC) if truthful bidding is always a dominant strategy for every bidder and if truthful bidders always obtain nonnegative utility



Social Welfare

The social welfare of an outcome of a single-item auction by $\sum_{i=1}^n v_i x_i$



Parameters

x_i is the indicator, 1 if i wins and 0 if i loses

- There is only one item: feasibility constraint $\sum_{i=1}^n x_i \leq 1$



Key Insights

- The **social welfare** is just the **valuation of the winner**, or 0 if there is no winner
- An auction is **welfare maximizing** if, when bids are **truthful**, the auction outcome has the maximum possible social welfare



一美元拍卖陷阱

传销不挣钱为啥还有这么多人参与？美国大选为啥总是两党之争？

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First Price Auctions



First Price Auction

A large red circle with a yellow border contains the text 'First Price Auction'. A large red arrow points from this circle towards the Google Ad Manager logo and text.

Highest bidder wins and pays her bid

Would you bid your value?



What happens if bid **less than your value?**

- You get a positive payoff if you win
- But your chances of winning are smaller
- Optimal bid reflects this **tradeoff**



Google Ad Manager

Second-Price Auctions and Dominant Strategies

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Winner's Curse



Common Value

- Value of the item is the same for everybody
- But nobody knows the true value
- Each bidder obtains an independent and unbiased estimate of the value



How much do you bid?

- Your estimate is \$1 million
- Suppose everybody, including you, bids their estimate and you are the winner



What did you just learn?

- Your estimate must have been larger than the others'
- The true value must be smaller than \$1 million
- You **overpaid**

Winner's Curse



If everybody bids her estimate winning is “bad news”: Winner's Curse

Optimal strategies are complicated

Bidders bid much **less than their value** to prevent winner's curse



Auction formats are not equivalent in common value auctions

Open bid auctions provide information and ameliorates winner's curse

- Bids are more **aggressive**

Sealed bid auctions do not provide information

- Bids are more **conservative**

To prevent winner's curse

Base your bid on expected value conditional on winning

Auction Design: Failures

Winning Bid	Second Highest Bid
NZ\$100,000	NZ\$6,000
NZ\$7,000,000	NZ\$5,000
NZ\$1	None

Source: John McMillan, "Selling Spectrum Rights," *Journal of Economic Perspectives*, Summer 1994



New Zealand Spectrum Auction (1990)

- Used **second price auction** with **no reserve price**
- Estimated revenue NZ\$ 240 million
- Actual revenue NZ\$36 million



Problems

- Second price format politically problematic
- Public sees outcome as selling for less than its worth
- No **reserve price**

Auction Design: Failures

Initial Bid	Final Price
A\$212 mil.	A\$117 mil.
A\$177 mil.	A\$77 mil.

Source: John McMillan, "Selling Spectrum Rights," *Journal of Economic Perspectives*, Summer 1994



Australian TV License Auction (1993)

- Two satellite-TV licenses
- Used first **price auction**



High bidders had no intention of paying

- They bid high just to guarantee winning
- They also bid lower amounts at \$5 million intervals



They defaulted

- Licenses had to be re-awarded at the next highest bid
- Those bids were also theirs



Problem

- **No penalty for default**

Auction Design: Failures



Turkish GSM license auction (2000)

- Two GSM 1800 licenses to be auctioned
- Round 1: **First price sealed bid auction**
- Round 2: **First price sealed bid auction** with **reserve price**
 - Reserve price is the winning bid of Round 1



Bids in the second round

- NONE!
- All four bidders exit license auction



Problem

- **Facilitates entry deterrence**



Bids in the first round

Bidder	Bid Amount
Is-Tim	\$2.525 bil.
Dogan+	\$1.350 bil.
Genpa+	\$1.224 bil.
Koc+	\$1.207 bil.
Fiba+	\$1.017 bil.

Auction Design Challenge

The book cover has a dark blue background. At the top, there are scattered white, blue, and pink confetti dots. The title 'MAKE YOUR AUCTION AWESOME' is centered, with 'MAKE YOUR' and 'AUCTION' in white and 'AWESOME' in pink. Below the title, the subtitle 'THE #LAYNEWAY' is written in white. At the bottom, there is a row of colorful balloons in green, pink, purple, and yellow.

MAKE YOUR
AUCTION
AWESOME
THE #LAYNEWAY



Objective

One common objective is to maximize expected revenue



Auction Design is a Challenge When

- Values are correlated
- Bidders are risk averse
- Collusion
- Entry deterrence
- Reserve price

Auction Design Challenge



Strategies

- **Correlated values:** Ascending bid auction is better
- **Risk averse bidders**
Second price auction: risk aversion does not matter
- **Collusion: ?**
- **Entry deterrence:** Sealed bid auctions are better to promote entry



胆小鬼博弈

人类接近毁灭的危机：古巴导弹危机是怎么解决的？

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Theorem 2.4 (Second-Price Auctions Are Ideal)

A second-price single-item auction satisfies the following



1) Strong incentive guarantees

It is a DSIC auction



2) Strong performance guarantees

It is welfare maximizing



3) Computational efficiency

It can implemented in **time polynomial** (indeed, linear) in the size of the input, meaning the number of bits necessary to represent the numbers v_1, v_2, \dots, v_n

2

Theorem 2.4 (Second-Price Auctions Are Ideal)

A second-price single-item auction satisfies the following



1) Strong incentive guarantees

It is a DSIC auction



From Bidder's Perspective

Makes it particularly easy to choose a bid, and levels the playing field between sophisticated and unsophisticated bidders



From Seller's Perspective

Makes it much easier to reason about the auction's outcome



Only Assumption

A bidder with an obvious dominant strategy will play it

From Bidder's Perspective

From Seller's Perspective

The Only Assumption

2

Theorem 2.4 (Second-Price Auctions Are Ideal)

A second-price single-item auction satisfies the following



Strong performance guarantees

It is welfare maximizing



DSIC is not enough

An auction that gives the item away for free to a random bidder is DSIC, but it makes no effort to identify which bidders actually want the item

DSIC is not enough



SW maximization

Even though the bidder valuations are a priori unknown to the seller, the auction nevertheless identifies the bidder with the highest valuation!

With SW maximization



Second-Price Auction

It solves the social welfare maximization problem as well as if all of the bidders' valuations were known in advance

second-price auction

2

Theorem 2.4 (Second-Price Auctions Are Ideal)

A second-price single-item auction satisfies the following



Computational Efficiency

It can be implemented in time polynomial (indeed, linear) in the size of the input, meaning the number of bits necessary to represent the numbers v_1, v_2, \dots, v_n



Computational Efficiency

To have potential practical utility, an auction should run in a reasonable amount of time

Computational Efficiency



Online Advertising

Auctions for online advertising, generally need to run in real time.

Online Advertising

OUTLINE



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Background



Google 成都GRE

Baidu 成都GRE

百度一下

百度首页 消息 设置 25...8@qq.com

网页 资讯 视频 图片 知道 文库 贴吧 采购 地图 更多»

百度为您找到相关结果约5,020,000个

搜索工具

【新东方官方网校】成都gre 冲刺330分

新东方成都gre,购课享免息分期付款,赠名师写作精批,更有新东方专业申请指导!新东方在线汇聚全国新东方名师资源,直击美国TOP20名校,无条件免费重读!

www.koolearn.com 2019-08 - 评价 广告

【新东方官方网校】成都新东方gre 用专业让备考更高效

成都新东方gre「名师线上直播」「50人小班授课」「专业申请指导」每日学习计划,强势伴学督学,直击美国TOP20名校!

www.koolearn.com 2019-08 - 评价 广告

成都gre培训_思拓国际_专业GRE培训机构

成都gre培训,金牌名师1对1小班授课,免费课后辅导,让您轻松上320分,学习顾问全程规划,助教辅导,班主任督促,严格管理才能出成绩!咨询电话!

www.studytop.net 2019-08 - 评价 广告

成都gre-选【智课教育】gre暑期班火热招生

「智课教育」专注gre语言培训,全托管课程,五对一教学,成都gre就选智课!小班教学,时间灵活,网上预约可免费试听

培训优势: 5对1陪伴式学习 翻转课堂教学模式 个性化定制课程

热门课程: 托福90分班 托福基础班 托福冲刺班

p.smartstudy.com 2019-08 - 评价 广告

gre成都_21天gre集训班_轻松拿下gre高分

gre成都,gre成都,暑期gre培训班火热招生中,轻松拿下gre高分,21天gre集训班,GRE精品课程,GRE高分冲刺,智课出国精英学习中心,独享智课全方位gre高分攻略...

[培训] 成都锦江gre培训班

[甄选] 成都gre培训哪里好

[区别] 雅思托福gre的区别

相关机构

朗阁 ILONGRE 2004优秀雅思培训机构

成都朗阁培训中心 隶属朗阁教育集团旗下

新东方 XDF.cn 成都新东方学校

搜索热点

1 林允终止与CK合作 新	1156万 ↑
2 张艺兴工作室声明	851万 ↑
3 比伯海莉九月办婚礼	844万 ↑
4 演员梁舜燕病逝	821万
5 香港机票处置方案 新	816万 ↑
6 杨方旭被禁赛 新	813万
7 国泰机长通报信	789万
8 斗鱼上市首份财报 新	784万 ↑
9 谢娜晒张碧晨合影	774万 ↑
10 郭麒麟不想继承	769万 ↑

查看更多>>

Web Search Results

A list of **organic search results**

- Deemed relevant to your query by an algorithm like **PageRank**

A list of **sponsored links**, which have been paid for by advertisers

Sponsor's Search Auction

Every time you type a search query into a search engine, an auction is run in **real time** to decide

- 1) Which advertisers' links are shown
- 2) How these links are arranged visually
- 3) What the advertisers are charged

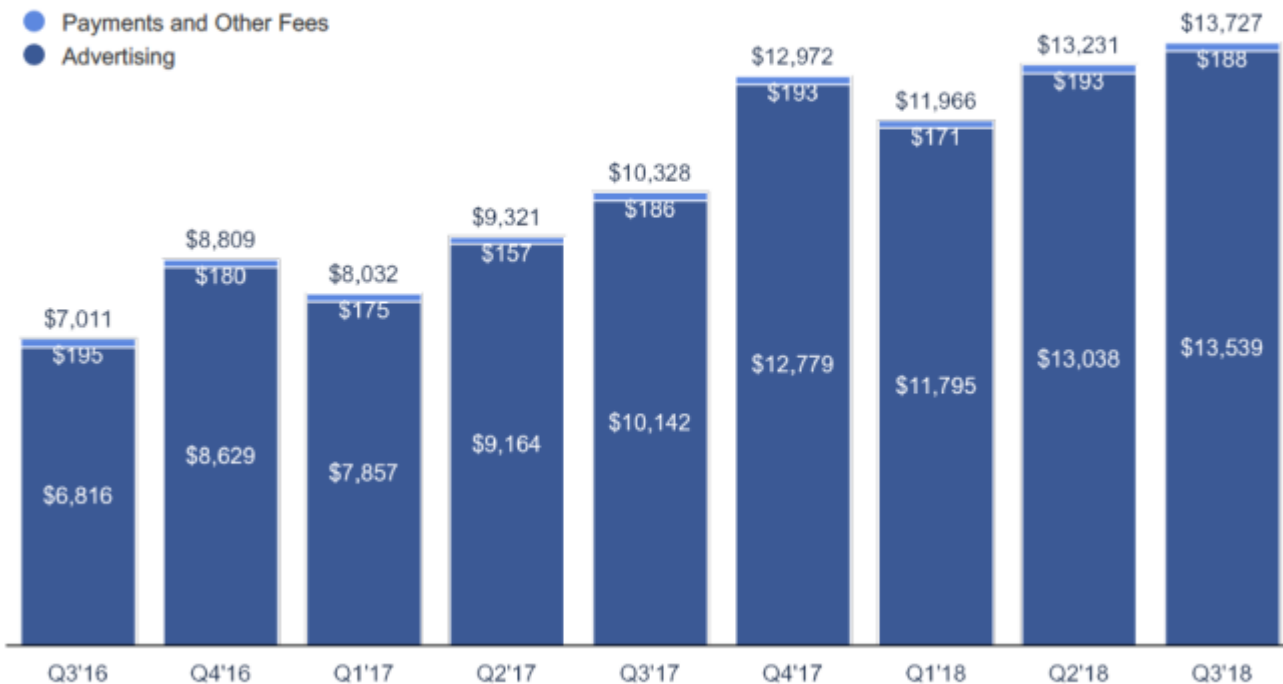
Background



Revenue

In Millions

- Payments and Other Fees
- Advertising



Huge Revenue

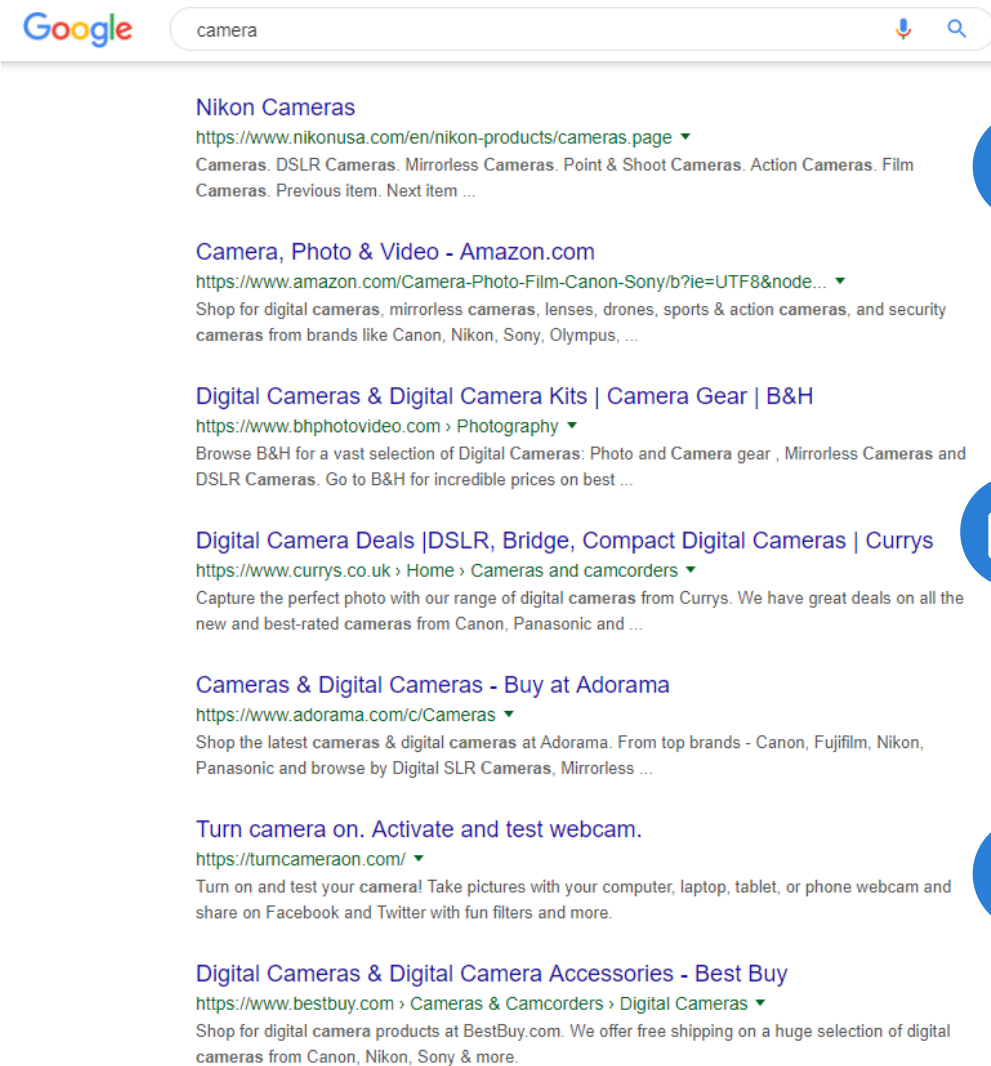
Sponsored search auctions generated roughly **98%** of Google's revenue



Internet Economy

Online advertising is now sold in many different ways: social network, live streaming
Sponsored search auctions continue to generate tens of billions of dollars of revenue every year

The Basic Model of Sponsored Search Auctions

A screenshot of a Google search results page for the keyword 'camera'. The search bar at the top shows 'camera' with a microphone icon and a search button. Below the search bar, there are five search results listed. Each result includes a title in blue, a URL in green, and a brief description in black. The results are from Nikon, Amazon, B&H, Currys, Adorama, and Best Buy.

Google camera

Nikon Cameras
<https://www.nikonusa.com/en/nikon-products/cameras.page> ▼
Cameras. DSLR Cameras. Mirrorless Cameras. Point & Shoot Cameras. Action Cameras. Film Cameras. Previous item. Next item ...

Camera, Photo & Video - Amazon.com
<https://www.amazon.com/Camera-Photo-Film-Canon-Sony/b?ie=UTF8&node...> ▼
Shop for digital cameras, mirrorless cameras, lenses, drones, sports & action cameras, and security cameras from brands like Canon, Nikon, Sony, Olympus, ...

Digital Cameras & Digital Camera Kits | Camera Gear | B&H
<https://www.bhphotovideo.com > Photography> ▼
Browse B&H for a vast selection of Digital Cameras: Photo and Camera gear , Mirrorless Cameras and DSLR Cameras. Go to B&H for incredible prices on best ...

Digital Camera Deals |DSLR, Bridge, Compact Digital Cameras | Currys
<https://www.currys.co.uk > Home > Cameras and camcorders> ▼
Capture the perfect photo with our range of digital cameras from Currys. We have great deals on all the new and best-rated cameras from Canon, Panasonic and ...

Cameras & Digital Cameras - Buy at Adorama
<https://www.adorama.com/c/Cameras> ▼
Shop the latest cameras & digital cameras at Adorama. From top brands - Canon, Fujifilm, Nikon, Panasonic and browse by Digital SLR Cameras, Mirrorless ...

Turn camera on. Activate and test webcam.
<https://turncameraon.com/> ▼
Turn on and test your camera! Take pictures with your computer, laptop, tablet, or phone webcam and share on Facebook and Twitter with fun filters and more.

Digital Cameras & Digital Camera Accessories - Best Buy
<https://www.bestbuy.com > Cameras & Camcorders > Digital Cameras> ▼
Shop for digital camera products at BestBuy.com. We offer free shipping on a huge selection of digital cameras from Canon, Nikon, Sony & more.



Search for One Category of Items

- The items for sale are k “slots” for sponsored links on a search results page
- The bidders are the advertisers who have a standing bid on the keyword that was searched on



Multi-Item Auction

Such auctions are more complex than single-item auctions

- First, there are generally **multiple items** for sale (i.e., $k > 1$)
- Second, these items are **not identical** (SUV, SmartPhone....)



Orders/Ranks

If ads are displayed as an ordered list, then **higher** slots in the list are **more valuable** than lower ones

- Since people generally scan the list from top to bottom

Click-Through Rates (CTRs)



Baidu search results for "成都GRE". The page shows various search results related to GRE preparation in Chengdu, including advertisements for Koolearn, Studytop, and other educational institutions. The search results are displayed in a grid format with images, titles, and brief descriptions.



Click-Through Rates (CTRs)

Quantify the difference between different slots

The CTR α_j of a slot j represents the **probability** that one user clicks on the link on this slot

- Or, the fraction of impression, the fraction of being shown on the page



Assumptions on Ordering of CTR

- 1) **Ordering** the slots from top to bottom, with the reasonable assumption that $\alpha_1 \geq \alpha_2 \geq \dots \geq \alpha_k$
- 2) Unreasonable assumption that the CTR of a slot is **independent of its occupant**
- 3) Bidders have private valuation v_i about the clicks on its link







Expected Value for Each Slot

- The expected value derived by advertiser i from slot j is $v_i \alpha_j$

Steps in Sponsored Search Auction

How Does the Sponsor Search Auction Carry Out?

-  1) There are k Slots for Auction
-  2) Whom Are the k Winners from the n Advertisers?
-  3) What Order to Put the k Winning Advertisers in the Slots?
-  4) How Much Should Each of the k Winning Advertisers Pay?

What We Want

Is there an ideal sponsored search auction? Our desiderata are:



1) DSIC

Truthful bidding should be a **dominant strategy**, and leads to **non-negative utility**



2) Social welfare maximization

The assignment of bidders to slots should maximize $\sum_{i=1}^n v_i x_i$,

- x_i denotes the **CTR** of the slot to which i is assigned (or 0 if i is not assigned to a slot)

Constraint: Each slot can only be assigned to one bidder, and each bidder gets only one slot



3) Computational efficiency

The running time should be **polynomial** (or even near-linear) in the size of the input

v_1, v_2, \dots, v_k

Since zillions of these auctions need to be run every day!

Design Approach



2

What's hard about auction design problems is that we have to design jointly two things:

The choice of who wins what
The choice of who pays what

Step 1

Ensure properties (2) and (3)

Assume, without justification, that bidders bid truthfully. Then, how should we assign bidders to slots so that the above properties (2) and (3) hold?

Step 2

Ensure property (1)

Given our answer to Step 1, how should we set selling prices so that the above property (1) holds?

If we efficiently solve both of these problems, then we have constructed an ideal auction

把大象放进冰箱需要几步?

Q: 把大象放进冰箱需要几步?



1



2



3



OUTLINE



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Single-Item Auction

There is one seller with **one item** and **multiple bidders** with private valuations
Single-item auction design is a simple but canonical example of mechanism design



Dominant-Strategy Incentive Compatible (DSIC)

An auction is **DSIC** if truthful bidding is a dominant strategy and if **truthful** bidders always obtain **nonnegative utility**



Welfare Maximizing

An auction is **welfare maximizing** if, assuming **truthful** bids, the auction outcome always has the **maximum possible social welfare**.

The Upshots



Ideal Auction

Second-price auctions are “**ideal**” in that they are **DSIC**, **welfare maximizing**, and can be implemented in **polynomial time**



Sponsored Search Auctions

Sponsored search auctions are a huge component of the Internet economy. Such auctions are **more complex than single-item auctions** because there are **multiple slots** for sale, and these slots vary in quality



Designing Ideal Auctions

A general **two-step approach** to designing ideal auctions is to first assume truthful bids and understand how to allocate items to **maximize the social welfare**, and second to design selling prices that turn **truthful bidding** into a **dominant strategy**



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Algorithmic Game Theory

感谢聆听



张彦如
2019 Fall

