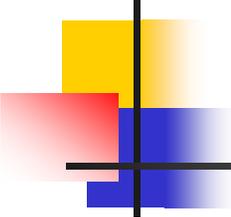


# The Economics of Internet Search

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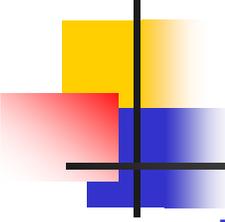
Hal R. Varian  
Sept 31, 2007



# Search engine use

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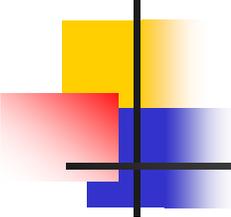
- Search engines are very popular
  - 84% of Internet users have used a search engine
  - 56% of Internet users use search engines on a given day
- They are also highly profitable
  - Revenue comes from selling ads related to queries



# Search engine ads

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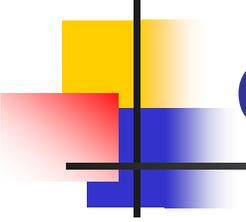
- Ads are highly effective due to high relevance
  - But even so, advertising still requires scale
    - 2% of ads might get clicks
    - 2% of clicks might convert
    - So only .4 out a thousand who see an ad actually buy
    - Price per impression or click will not be large
    - But this performance is good compared to conventional advertising!
- Search technology exhibits increasing returns to scale
  - High fixed costs for infrastructure, low marginal costs for serving



# Summary of industry economies

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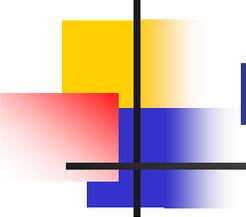
- Entry costs (at a profitable scale) are large due to fixed costs
- User switching costs are low
  - 56% of search engine users use more than one
- Advertisers follow the eyeballs
  - Place ads wherever there are sufficient users, no exclusivity
- Hence market structure is likely to be
  - A few large search engines in each language/country group
  - Highly contestable market for users
  - No demand-side network effects that drive towards a single supplier so multiple players can co-exist



# What services do search engines provide?

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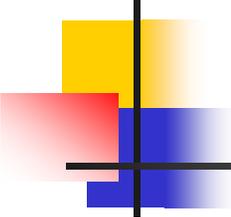
- Google as yenta (matchmaker)
  - Matches up those seeking info to those having info
  - Matches up buyers with sellers
- Relevant literature
  - Information science: information retrieval
  - Economics: assignment problem



# Brief history of information retrieval

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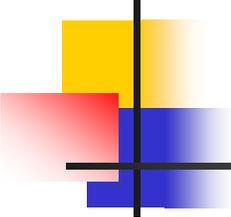
- Started in 1970s, basically matching terms in query to those in document
- Was pretty mature by 1990s
- DARPA started Text Retrieval Conference
  - Offered training set of query-relevant document pairs
  - Offered challenge set of queries and documents
  - Roughly 30 research teams participated



# Example of IR algorithm

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- Prob(document relevant) = some function of characteristics of document and query
  - E.g., logistic regression  $p_i = X_i \beta$
- Explanatory variables
  - Terms in common
  - Query length
  - Collection size
  - Frequency of occurrence of term in document
  - Frequency of occurrence of term in collection
  - Rarity of term in collection



# The advent of the web

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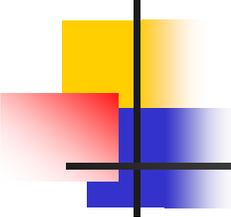
- By mid-1990s algorithms were very mature
- Then the Web came along
  - IR researchers were slow to react
  - CS researchers were quick to react
- Link structure of Web became new explanatory variable
  - PageRank = measure of how many important sites link to a given site
  - Improved relevance of search results dramatically



# Google

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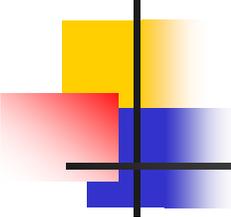
- Brin and Page tried to sell algorithm to Yahoo for \$1 million (they wouldn't buy)
- Formed Google with no real idea of how they would make money
- Put a lot of effort into improving algorithm



# Why online business are different

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- Online businesses (Amazon, eBay, Google...) can continually experiment
  - Japanese term: *kaizen* = "continuous improvement"
  - Hard to really do continuously for offline companies
    - Manufacturing
    - Services
  - Very easy to do online
    - Leads to very rapid (and subtle) improvement
    - Learning-by-doing leads to significant competitive advantage



# Business model

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- Ad Auction
  - GoTo's model was to auction search results
  - Changed name to Overture, auctioned ads
  - Google liked the idea of an ad auction and set out to improve on Overture's model
- Original Overture model
  - Rank ads by bids
  - Ads assigned to slots depending on bids
    - Highest bidders get better (higher up) slots
  - High bidder pays what he bid (1<sup>st</sup> price auction)

# Search engine ads

The screenshot shows a Mozilla Firefox browser window displaying Google search results for the query 'rental'. The address bar shows the URL: <http://www.google.com/search?hl=en&lr=&safe=off&q=rental&btnG=Search>. The search bar contains the word 'rental'. The results are categorized as 'Web' and show 'Results 1 - 10 of about 165,000,000 for rental [definition]. (0.18 seconds)'. The results are split into two columns: organic search results on the left and sponsored links on the right.

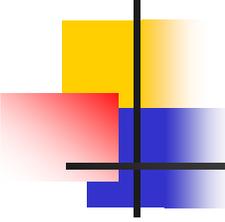
**Organic Search Results:**

- Search Local Apartments** (Sponsored Links)  
[www.Rent.com](http://www.Rent.com) Rent.com: Free Search, \$100 Reward! Find Roommates and Moving Services.
- Apartment Rentals**  
[base.google.com](http://base.google.com) Find or list apartment rentals with Google Base. Free listing.
- Hertz**  
Interactive reservations, special offers, vehicle guide, a listing of locations, and a directory of the company's programs and services.  
[www.hertz.com/](http://www.hertz.com/) - 1k - [Cached](#) - [Similar pages](#)
- Avis -- Rent a Car**  
Providing information for leisure and corporate travel, world wide, including the fleet by country, driving maps, rental rates, and on-line booking.  
[www.avis.com/](http://www.avis.com/) - 72k - [Cached](#) - [Similar pages](#)
- National Car Rental offers expedited rental car service for ...**  
NationalCar.com is a direct source for the lowest online rates , reservations, and weekly specials for business and leisure car rentals.  
[www.nationalcar.com/](http://www.nationalcar.com/) - 4k - Jan 18, 2006 - [Cached](#) - [Similar pages](#)
- Thrifty Car Rental. Rent a car with our easy online reservation**

**Sponsored Links:**

- Rental**  
Looking for Rental?  
Find exactly what you want today  
[www.eBay.com](http://www.eBay.com)
- Apartments.com**  
Apartment Listings. View Thousands of Apartments. Take a Virtual Tour!  
[www.Apartments.com](http://www.Apartments.com)
- Apartment Finder**  
Find 1000's of rental listings.  
Excellent apartment search.  
[www.apartment-renting.net](http://www.apartment-renting.net)
- Snowmass Condo Rentals**  
Super Value Ski-in/Ski-out  
Studio, Studio/loft, 2Bdrm/loft  
[www.aspenwoodcondo.com](http://www.aspenwoodcondo.com)
- Rental**

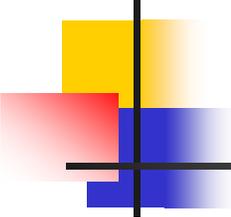
- Ads are shown based on query + keywords
- Ranking of ads based on expected revenue



# Google auction

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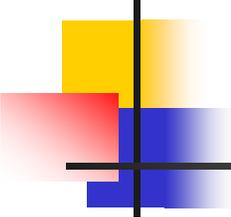
- Rank ads by bid x expected clicks
  - Price per click x clicks per impr = price per impression
  - Why this makes sense: revenue = price x quantity
- Each bidder pays price determined by bidder below him
  - Price = minimum price necessary to retain position
  - Motivated by engineering, not economics
- Overture (now owned by Yahoo)
  - Adopted 2<sup>nd</sup> price model
  - Currently moving to improved ranking method



# Alternative ad auction

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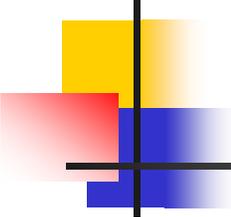
- In current model, optimal bid depends on what others are bidding
- Vickrey-Clarke-Groves (VCG) pricing
  - Rank ads in same way
  - Charge each advertiser cost that he imposes on other advertisers
  - Turns out that optimal bid is true value, no matter what others are bidding



# Google and game theory

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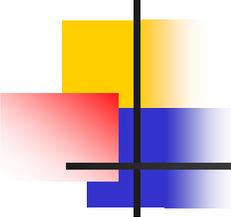
- It is fairly straightforward to calculate Nash equilibrium of Google auction
  - Basic principle: in equilibrium each bidder prefers the position he is in to any other position
  - Gives set of inequalities that can be analyzed to describe equilibrium
  - Inequalities can also be inverted to give values as a function of bids



# Implications of analysis

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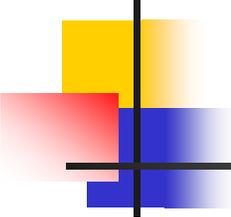
- Basic result: *incremental cost per click has to be increasing in the click through rate.*
- Why? If incremental cost per click ever decreased, then someone bought expensive clicks and passed up cheap ones.
- Similar to classic competitive pricing
  - Price = marginal cost
  - Marginal cost has to be increasing



# Simple example

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- Suppose all advertisers have same value for click  $v$ 
  - Case 1: Undersold auctions. There are more slots on page than bidders.
  - Case 2: Oversold auctions. There are more bidders than slots on page.
- Reserve price
  - Case 1: The minimum price per click is (say)  $p_m$  ( $\sim$  5 cents).
  - Case 2: Last bidder pays price determined by 1<sup>st</sup> excluded bidder.



# Undersold pages

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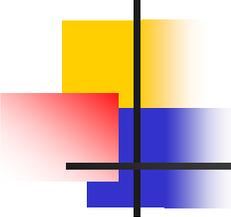
- Bidder in each slot must be indifferent to being in last slot

$$(v - p_s)x_s = (v - r)x_m$$

- Or

$$p_s x_s = v(x_s - x_m) + r x_m$$

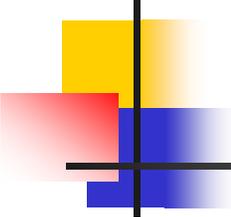
- Payment for slot s = payment for last position + value of incremental clicks



# Example of undersold case

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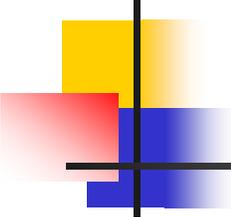
- Two slots
  - $x_1 = 100$  clicks
  - $x_2 = 80$  clicks
  - $v=50$
  - $r=.05$
- Solve equation
  - $p_1 100 = .50 \times 20 + .05 \times 80$
  - $p_1 = 14$  cents,  $p_2=5$  cents
  - Revenue =  $.14 \times 100 + .05 \times 80 = \$18$



# Oversold pages

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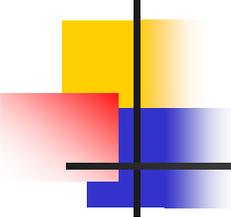
- Each bidder has to be indifferent between having his slot and not being shown:
- So  $(v - p_s)x_s = 0$   
$$p_s = v$$
- For previous 2-slot example, with 3 bidders,  $p_s = 50$  cents and revenue =  $.50 \times 180 = \$90$
- Revenue takes big jump when advertisers have to compete for slots!



# Number of ads shown

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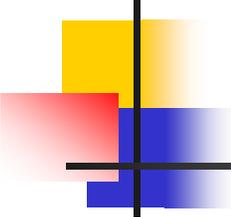
- Show more ads
  - Pushes revenue up, particularly moving from underold to oversold
- Show more ads
  - Relevancy goes down
  - Users click less in future
- Optimal choice
  - Depends on balancing short run profit against long run goals



# Other form of online ads

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- Contextual ads
  - AdSense puts relevant text ads next to content
  - Advertiser puts some Javascript on page and shares in revenue from ad clicks
- Display ads
  - Advertiser negotiates with publisher for CPM (price) and impressions
  - Ad server (e.g. Doubleclick) serves up ads to pub server
- Ad effectiveness
  - Increase reach
  - Target frequency
  - Privacy issues



# Conclusion

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- Marketing as the new finance
- Availability of real time data allows for fine tuning, constant improvement
- Market prices reflect value
- Quantitative methods are very valuable
- We are just at the beginning...