

9.2 quintillion

Crowdsourcing[^] Predictions

David Pennock, Yahoo!

Contributors:

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Dear crowd,

<http://predictalot.yahoo.com>

YAHOO!

How to make a prediction

- What are the chances:

**2011 the warmest year on record?
(Y/N)**

82%

8%

3.6%

19%

0.003%

67%

???

How to make a prediction

- | | | |
|-----------------------|---|----------------|
| 1. Guess | } | DIY |
| 2. Model it: Stats/ML | | |
| 3. Poll an expert | } | Outsource it |
| 4. Pay an expert | | |
| 5. Poll a crowd | } | Crowdsource it |
| 6. Pay a crowd | | |

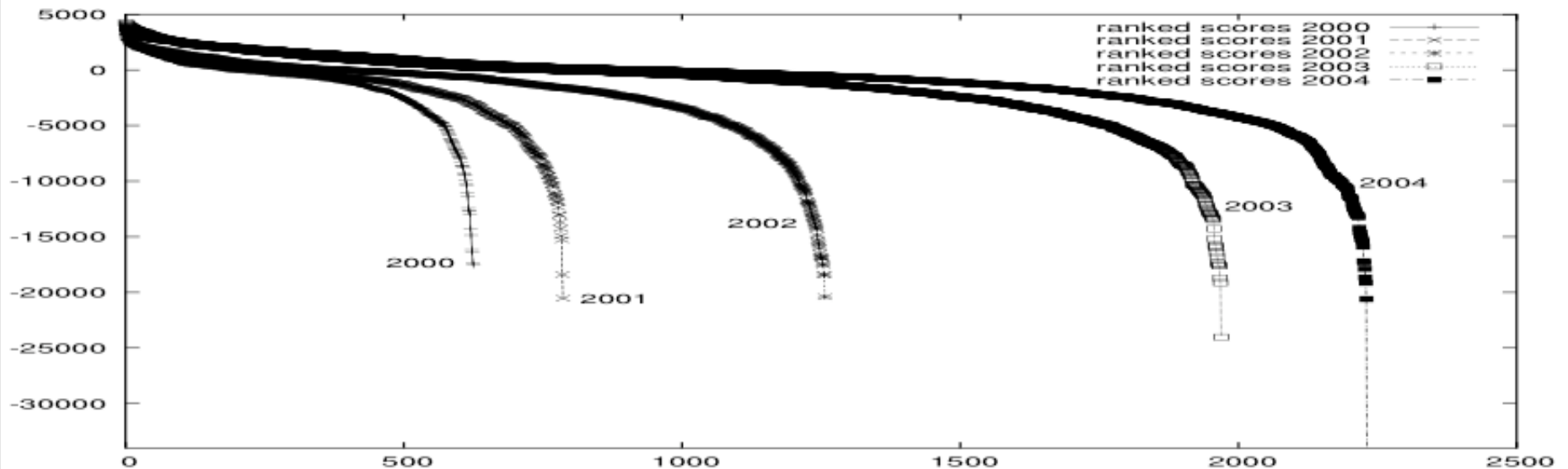
How to make a prediction

1. Guess
 2. Model it: Stats/ML
 3. Poll an expert
 4. Pay an expert
 5. Poll a crowd
 6. **Pay a crowd**
-
- DIY
- Outsource it
- Crowdsourcing it

Pay a crowd; Part one: A “wisdom of crowds” story

- ProbabilitySports.com
- Thousands of probability judgments for sporting events
 - Alice: Jets 67% chance to beat Patriots
 - Bob: Jets 48% chance to beat Patriots
 - Carol, Don, Ellen, Frank, ...
- Reward: Quadratic scoring rule:
Best probability judgments maximize expected score; Top scorers get prizes

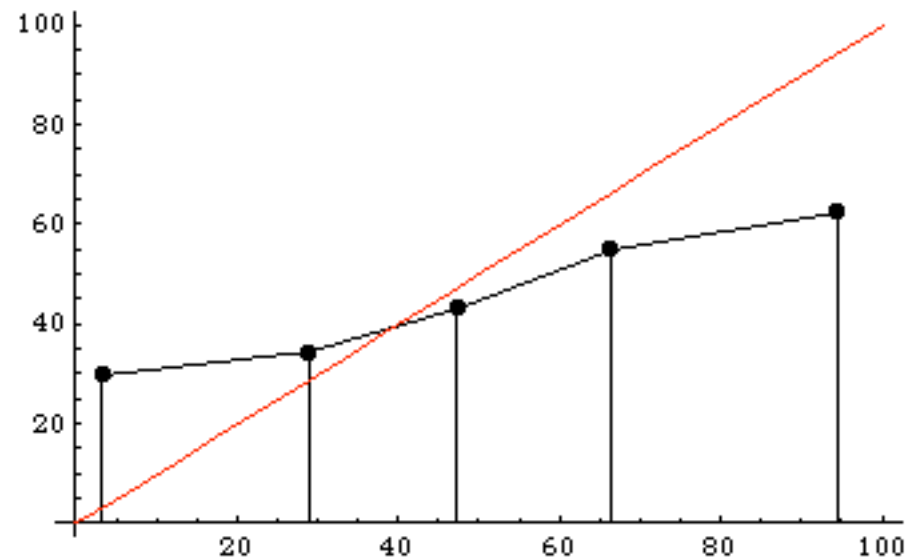
Individuals



- Most individuals are poor predictors
- 2005 NFL Season
 - Best: 3747 points
 - Average: -944 Median: -275
 - 1,298 out of 2,231 scored below zero (takes work!)

Individuals

- Poorly calibrated (too extreme)
 - Teams given < 20% chance actually won 30% of the time
 - Teams given > 80% chance actually won 60% of the time

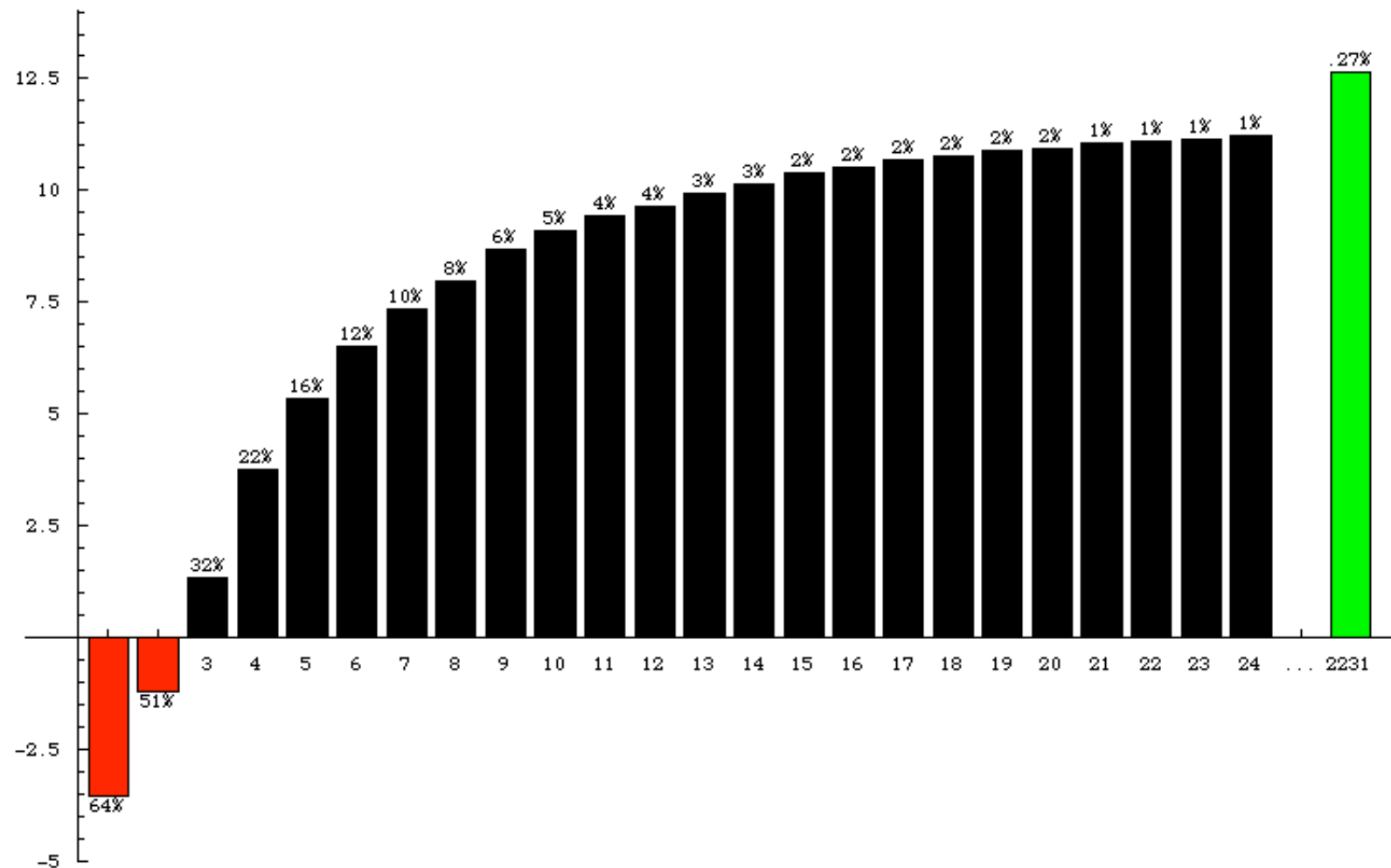


The wisdom of the crowd

- Create a *crowd predictor* by simply averaging everyone's probabilities
 - $\text{Crowd} = 1/n(\text{Alice} + \text{Bob} + \text{Carol} + \dots)$
 - 2005: Crowd scored 3371 points (7th out of 2231) !
- Wisdom of fools: Create a predictor by averaging everyone who scored below zero
 - 2717 points (62nd place) !
 - (the best "fool" finished in 934th place)

The crowd: How big?

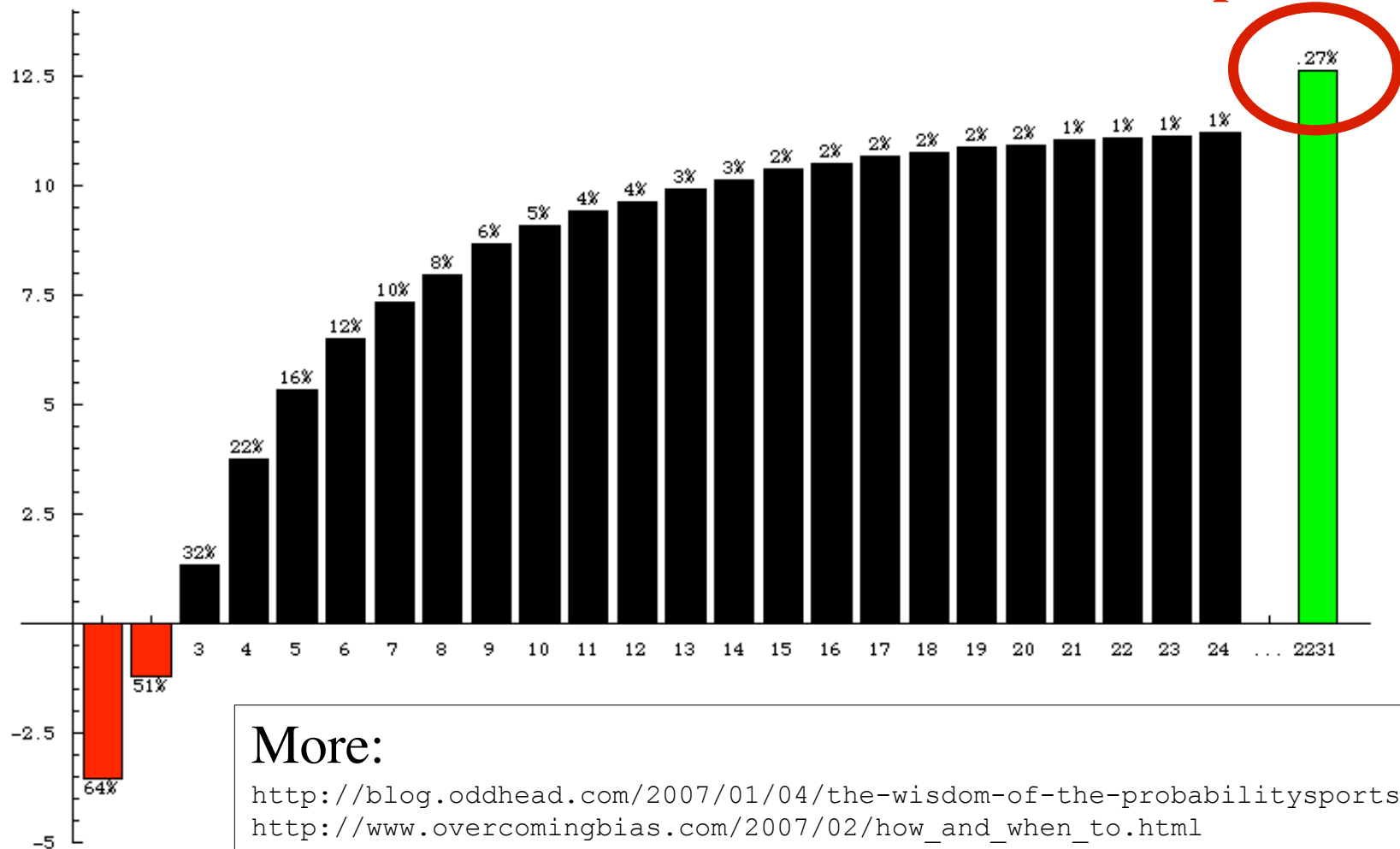
Expected score vs Number of experts aggregated (2004 data)



The crowd: How big?

When to guess:
if you're in the
99.7th percentile

Expected score vs Number of experts aggregated (2004 data)



More:

<http://blog.oddhead.com/2007/01/04/the-wisdom-of-the-probabilitysports-crowd/>
http://www.overcomingbias.com/2007/02/how_and_when_to.html

Can we do better?

[Dani et al. UAI 2006]

- Maybe Not
 - CS “experts algorithms”
 - Other expert weights
 - Calibrated experts
 - Other averaging fn’s (geo mean, RMS, power means, mean of odds, ...)
 - Machine learning (NB, SVM, LR, DT, ...)
- Maybe So
 - Bayesian modeling + EM
 - Nearest neighbor (multi-year)



Can we do better?

Pay a crowd, part two:
Prediction markets

A prediction market

- **A random variable, e.g.**

2011 the warmest year on record?
(Y/N)

- **Turned into a financial instrument**
payoff = realized value of variable

I am entitled to:

\$1 if	2011 the warmest	\$0 if	not the warmest
--------	------------------	--------	-----------------

YAHOO! Research

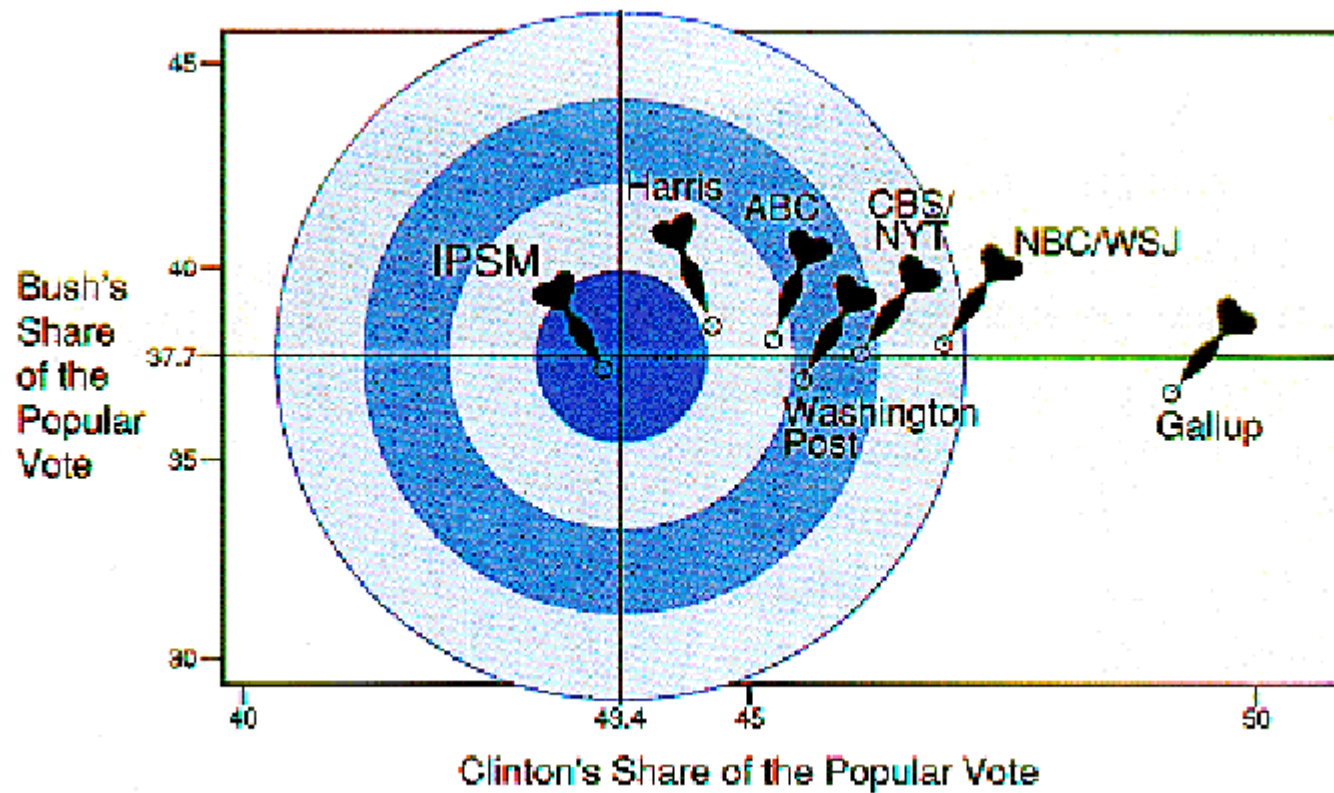


<http://intrade.com>

? Contract		B Qty	Bld	Ask	A Qty	Last	Vol	Chge
Trade 	2011.GLOBALTEMP.WARMEST	140	15.0	20.0	10	15.0	1830	0

2011 Mar 10 12:21pm ET

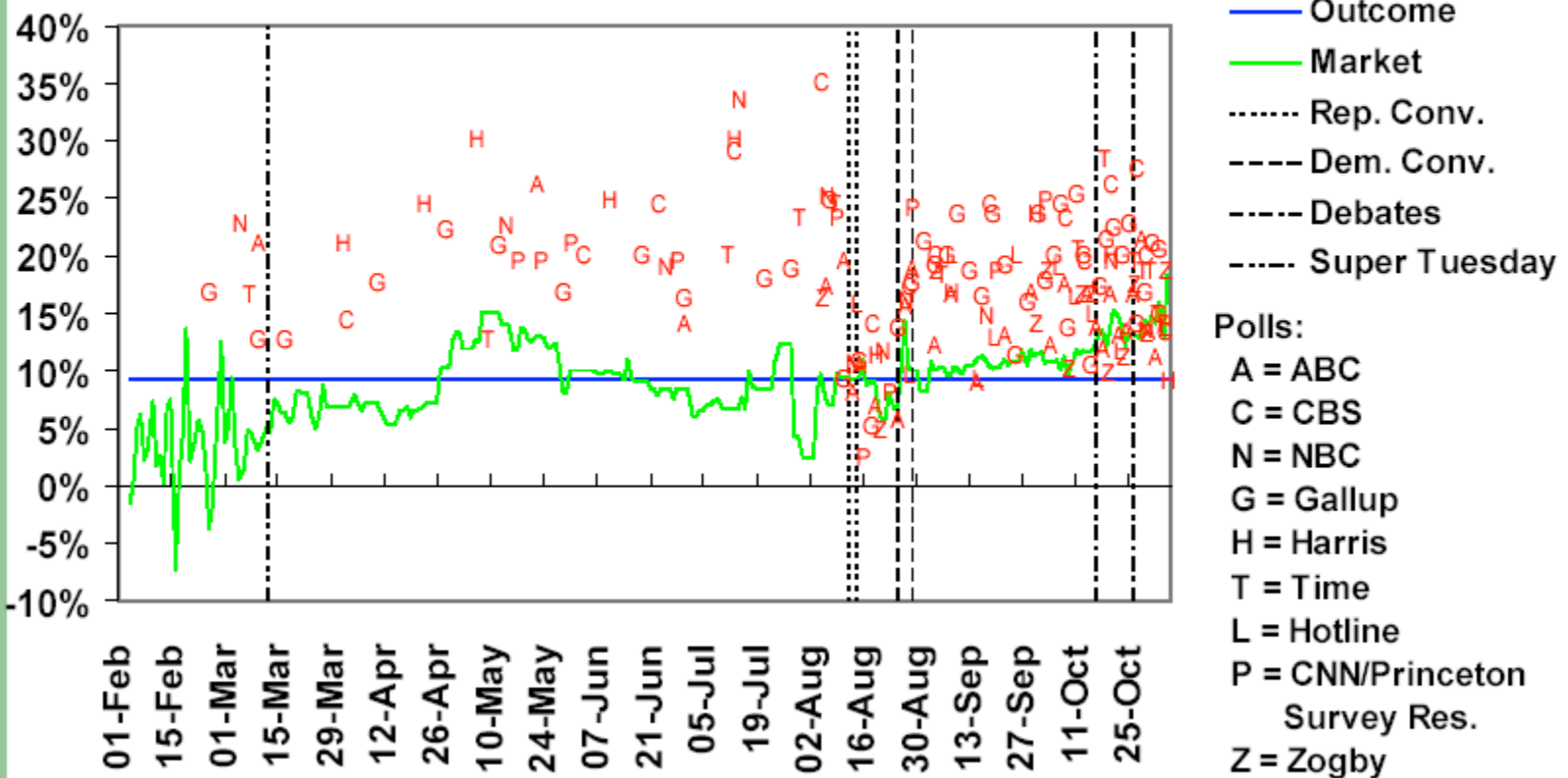
Example: IEM 1992



IEM versus Polls: 1996

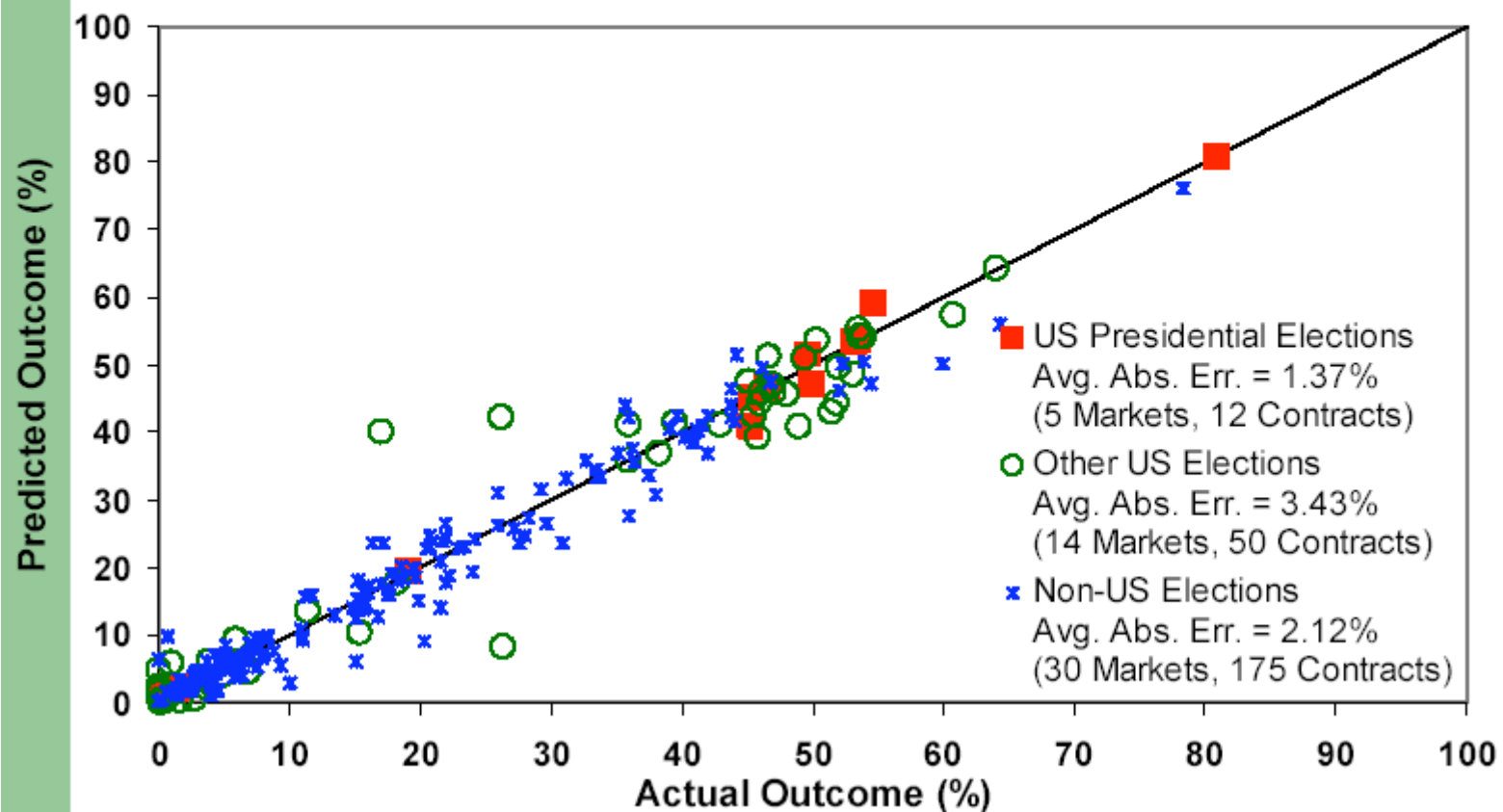
(Berg, Nelson and Rietz, 2001)

Predicted Clinton Winning Margin



Predictive Accuracy

Berg, Forsythe, Nelson and Rietz (2001)



Pay a crowd

- What you can say/learn
 - % chance that
 - Obama wins
 - GOP wins Texas
 - YHOO stock > 30
 - Duke wins tourney
 - Oil prices fall
 - Heat index rises
 - Hurricane hits Florida
 - Rains at place/time
- Where
 - IEM, Intrade.com
 - Intrade.com
 - Stock options market
 - Las Vegas, Betfair
 - Futures market
 - Weather derivatives
 - Insurance company
 - Weatherbill.com

Does it work?

- Yes, evidence from real markets, laboratory experiments, and theory
 - ❖ Racetrack odds beat track experts [Figlewski 1979]
 - ❖ Orange Juice futures improve weather forecast [Roll 1984]
 - ❖ I.E.M. beat political polls 451/596 [Forsythe 1992, 1999][Oliven 1995][Rietz 1998][Berg 2001][Pennock 2002]
 - ❖ HP market beat sales forecast 6/8 [Plott 2000]
 - ❖ Sports betting markets provide accurate forecasts of game outcomes [Gandar 1998][Thaler 1988][Debnath EC'03][Schmidt 2002]
 - ❖ Laboratory experiments confirm information aggregation [Plott 1982;1988;1997][Forsythe 1990][Chen, EC'01]
 - ❖ Theory: “rational expectations” [Grossman 1981][Lucas 1972]
 - ❖ **Market games work** [Servan-Schreiber 2004][Pennock 2001]

Pay a crowd; Part three With money

Trade	Contract	B Qty	Bid	Ask	A Qty	Last	Vol	Chge
	US.RECESSION.08	1	72.2	73.9	2	74.0	34.9k	+3.0

Trade	BIRDFLU.USA.JUN08	100	6.0	14.0	5	10.0	1323	0
-------	-------------------	-----	-----	------	---	------	------	---

Trade	BIRDFLU.USA.SEP08	10	6.5	16.0	5	11.2	430	0
-------	-------------------	----	-----	------	---	------	-----	---

Trade	Contract	B Qty	Bid	Ask	A Qty	Last	Vol	Chge
	OSAMA.CAPTURE.MAR08	5	1.9	3.3	1	2.6	4888	0

Trade	OSAMA.CAPTURE.JUN08	4	5.1	5.7	25	5.5	2019	0
-------	---------------------	---	-----	-----	----	-----	------	---

Trade	OSAMA.CAPTURE.SEP08	5	8.3	8.8	4	9.1	822	0
-------	---------------------	---	-----	-----	---	-----	-----	---

Trade	Contract	B Qty	Bid	Ask	A Qty	Last	Vol	Chge
	2008DEM.NOM.OBAMA	22	71.8	72.0	55	72.0	403.0k	-1.3

Trade	2008DEM.NOM.CLINTON	50	28.5	28.9	4	28.9	549.1k	+1.1
-------	---------------------	----	------	------	---	------	--------	------

Trade	Contract	B Qty	Bid	Ask	A Qty	Last	Vol	Chge
	ALABAMA.DEM	0	-	10.0	20	10.0	56	0

Trade	ALABAMA.REP	20	90.0	95.0	5	90.0	22	0
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Trade	ALABAMA.FIELD	5	0.1	5.0	20	0.1	0	0
-------	---------------	---	-----	-----	----	-----	---	---

Trade	ALASKA.DEM	20	5.0	10.0	17	7.5	23	0
-------	------------	----	-----	------	----	-----	----	---

Trade	ALASKA.REP	20	85.0	95.0	20	92.5	45	0
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Trade	ALASKA.FIELD	5	0.1	5.0	20	0.1	0	0
-------	--------------	---	-----	-----	----	-----	---	---

intradeTM
The Prediction Market

With points

Androids Beat Humans in Soccer (BOTS)

Will a team of androids beat the human World Cup champs at a game of soccer by 2050?

Price: POP\$ 47.75

Status: ACT

Fuel-Cell-Powered Laptop (FCELL)

Will the first fuel-cell-powered laptop go on sale in the U.S. by the end of 2008?

Price: POP\$ 43.75

Status: ACT

Barack Obama will be the Democratic Presidential Nominee in 2008



IPX THE POPSCI
PREDICTIONS EXCHANGE

newsfutures

Pay a crowd in points

- Foresight Exchange
- HSX.com
- InklingMarkets.com
- CrowdCast
- Yahoo! Predictalot
- Newsfutures.com
- CasualObserver.net
- FTPredict.com
- ProTrade.com, StorageMarkets.com, TheSimExchange.com, TheWSX.com, Alexadex, Celebdaq, Cenimar, BetBubble, Betocracy, CrowdIQ, MediaMammon, Owise, PublicGyan, RIMDEX, Smarkets, Trendio, TwoCrowds
- Archive.org: http://www.chrisfmasse.com/3/3/markets/#Play-Money_Prediction_Markets

Pay a crowd
With *money*

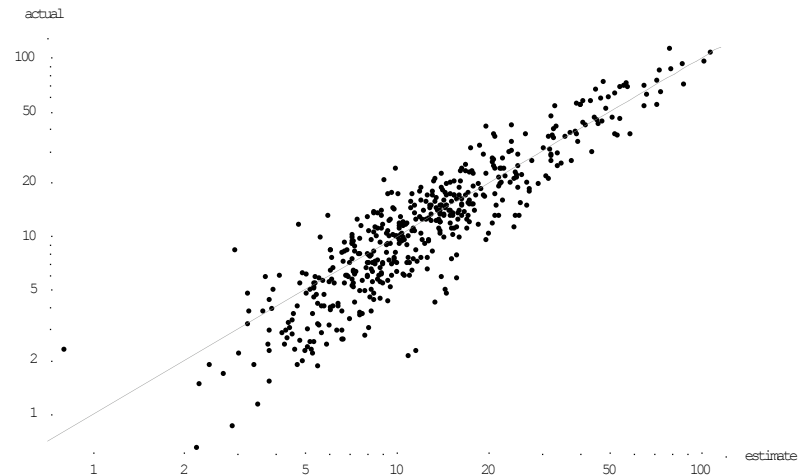
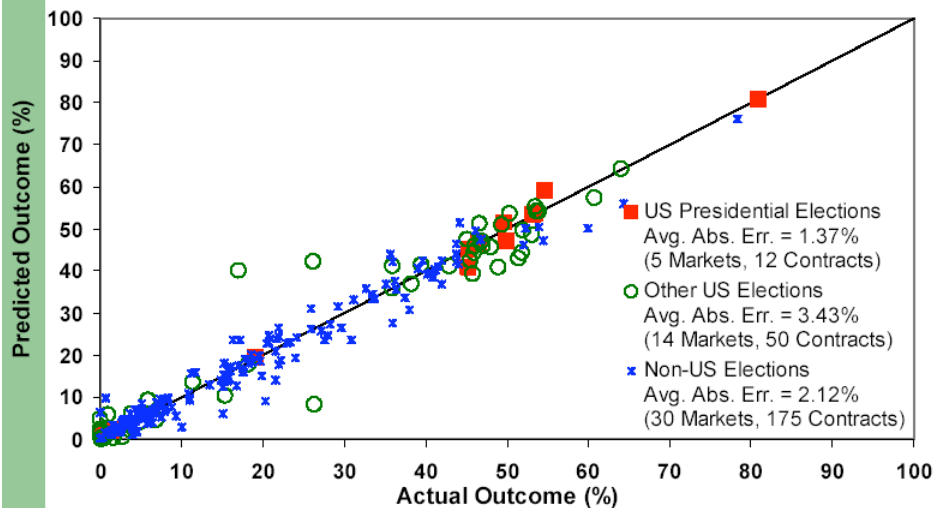
IEM: 237 Candidates

With *points*

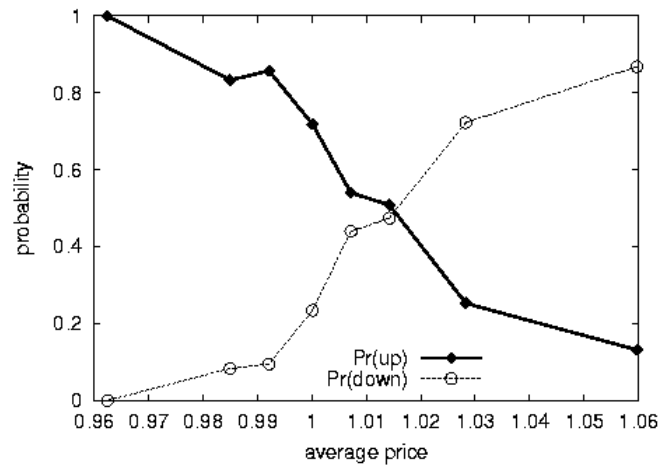
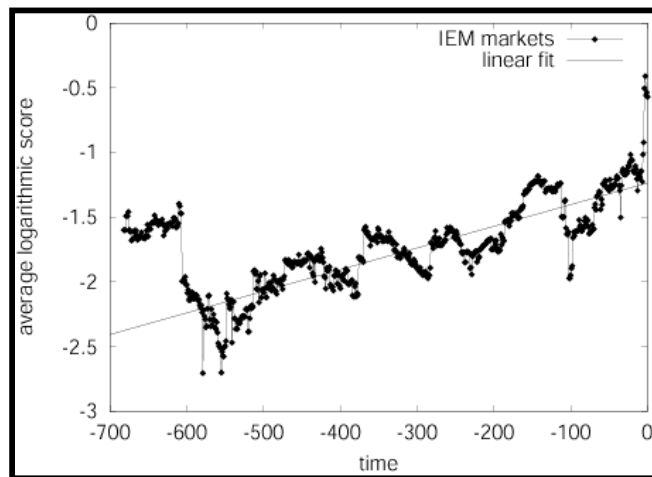
HSX: 489 Movies

Predictive Accuracy

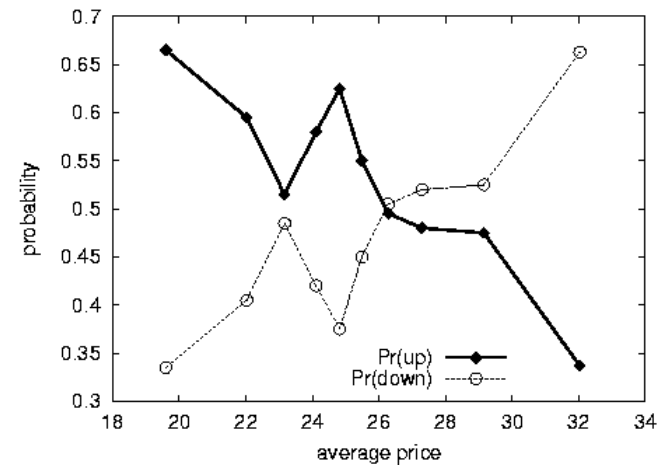
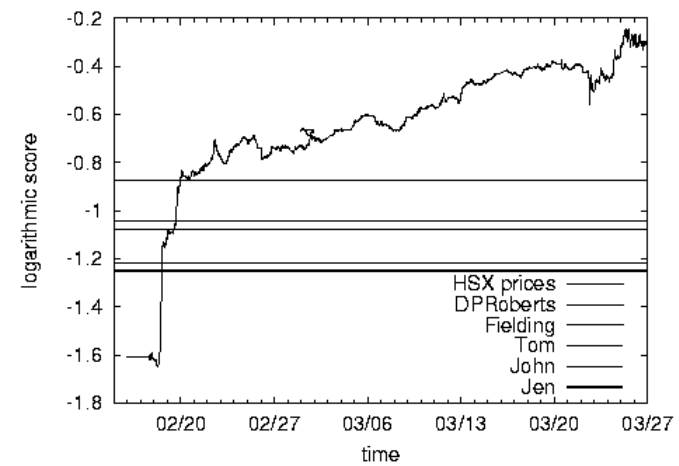
Berg, Forsythe, Nelson and Rietz (2001)



Pay a crowd With *money*



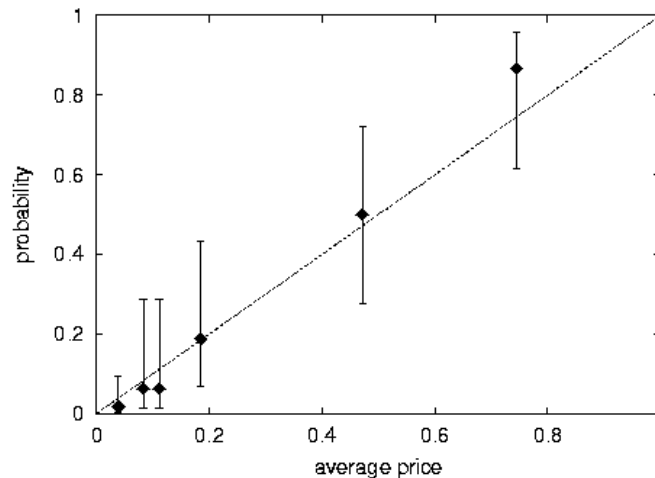
With *points*



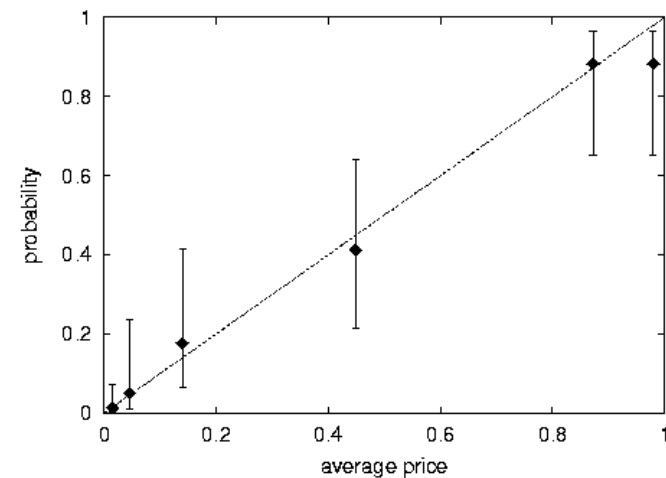
Real markets vs. market games

probabilistic
forecasts

HSX



FX, F1P6



forecast source	avg log score
F1P6 linear scoring	-1.84
F1P6 F1-style scoring	-1.82
betting odds	-1.86
F1P6 flat scoring	-2.03
F1P6 winner scoring	-2.32

Does money matter? Play vs real, head to head

Experiment

- 2003 NFL Season
- ProbabilitySports.com Online football forecasting competition
 - Contestants assess probabilities for each game
 - Quadratic scoring rule
 - ~2,000 “experts”, plus:
 - NewsFutures (play \$)
 - Tradesports (real \$)
 - Used “last trade” prices

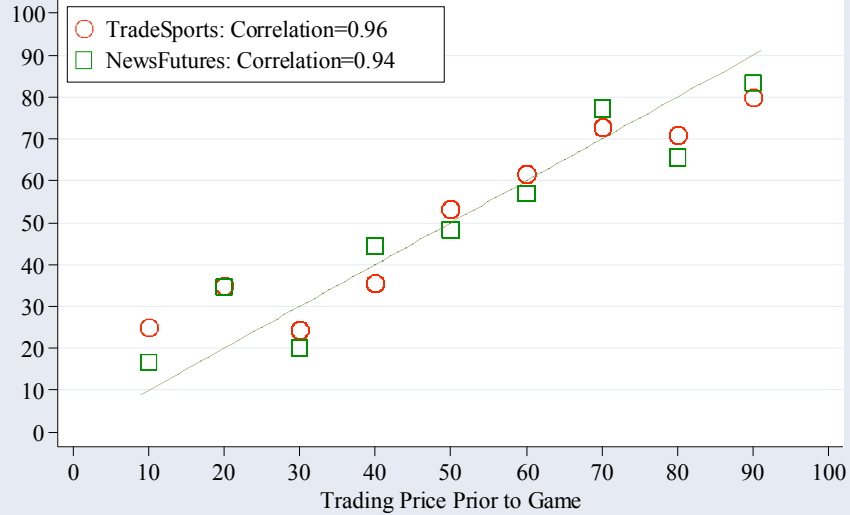
Results:

- Play money and real money performed similarly
 - 6th and 8th respectively
- Markets beat most of the ~2,000 contestants
 - Average of experts came 39th (caveat)

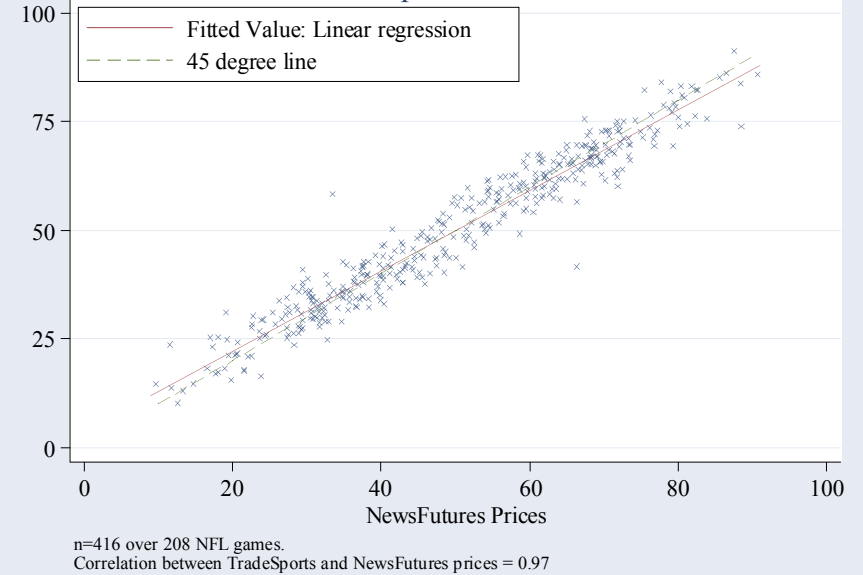
Electronic Markets, Emile Servan-Schreiber, Justin Wolfers, David Pennock and Brian Galebach

Prediction Accuracy

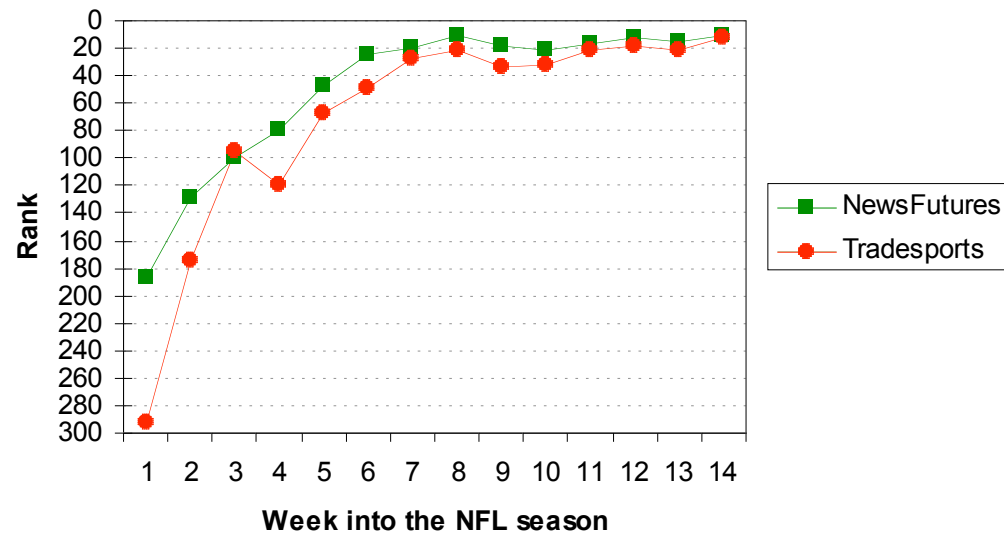
Market Forecast Winning Probability and Actual Winning Probability



Prices: TradeSports and NewsFutures



Prediction Performance of Markets Relative to Individual Experts



Does money matter? Play vs real, head to head

	Probability- Football Avg	TradeSports (real-money)	NewsFutures (play-money)	Difference TS - NF
Mean Absolute Error	0.443	0.439	0.436	0.003
= <i>lose_price</i>	(0.012)	(0.011)	(0.012)	(0.016)
[lower is better]				
Root Mean Squared Error	0.476	0.468	0.467	0.001
= <i>Average(lose_price²)</i>	(0.025)	(0.023)	(0.024)	(0.033)
[lower is better]				
Average Quadratic Score	9.323	12.410	12.427	-0.017
= <i>100 - 400*(lose_price²)</i>	(4.75)	(4.37)	(4.57)	(6.32)
[higher is better]				
Average Logarithmic Score	-0.649	-0.631	-0.631	0.000
= <i>Log(win_price)</i>	(0.027)	(0.024)	(0.025)	(0.035)
[higher (less negative) is better]				

Statistically:
TS ~ NF
NF >> Avg
TS > Avg

Pay a crowd; Part four

- Pay a crowd a little bit for information on *exponentially many* things
- “Combinatorial prediction market”



<http://predictalot.yahoo.com>



Predictalot - Beta

[Share](#)[Settings](#)[Options](#) ▾Hi, **Dave P**

Available:	Risked:	Networth:
977.85	22.00	1,001.35

[Overview](#)[Predictions](#)[Groups](#)[Leaderboard](#)**About Predictalot**

Predictalot is a game that lets you predict almost anything about a sports tournament, like **Spain will advance further than Brazil** in the World Cup, or **a team will win that has never won before**. You can compose any of millions of predictions and sell them any time for virtual points, even in the middle of a match, just like the stock market.

[Make a prediction](#)**How to play**

A step by step guide to playing the game

Recent Activity**Mohammad** made a prediction

Fewer than 2 teams from South America will advance to Quarterfinals. Current odds: 33.68%. Risked 800.00 to win 2,209.48

[29 days ago](#)**You** sold a prediction

Brazil will advance further than France. Current odds: 77.39%. Won 9.77.

[52 days ago](#)**DG** made a prediction

Brazil will win cup. Current odds: 50.02%. Risked 500.00 to win 975.86

[52 days ago](#)**Steve M** made a prediction

Ghana will advance further than United States. Current odds: 14.90%. Risked 1,000.00 to win 5,340.54

[52 days ago](#)**Kelly Hirano** joined the group 'ysports'[52 days ago](#)**Sudar** sold a prediction

Argentina will win cup. Current odds: 0.62%. Won 17.62.

[53 days ago](#)

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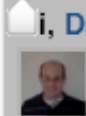
Apps


Guestbook

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 **Predictalot - Beta**

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 **i, Dave P**

Available:
 977.85

Riskd:
22.00

Networth:
999.43

Make a prediction

1. **Select prediction:**

How many teams in what region will advance to what stage

2. **Set prediction:**

Fewer than 6 teams from Europe will advance to Quarterfinals

3. **Odds:**

75%

4. **Place investments:**

Risk: 30

To Win: 40

1488977

16431278

Save prediction

Cancel

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 **Predictalot - Beta**

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Hi, **Dave P**



Available:
977.85

Riskd:
22.00

Networth:
999.43

Overview

Predictions

Groups

Leaderboard

Make a prediction

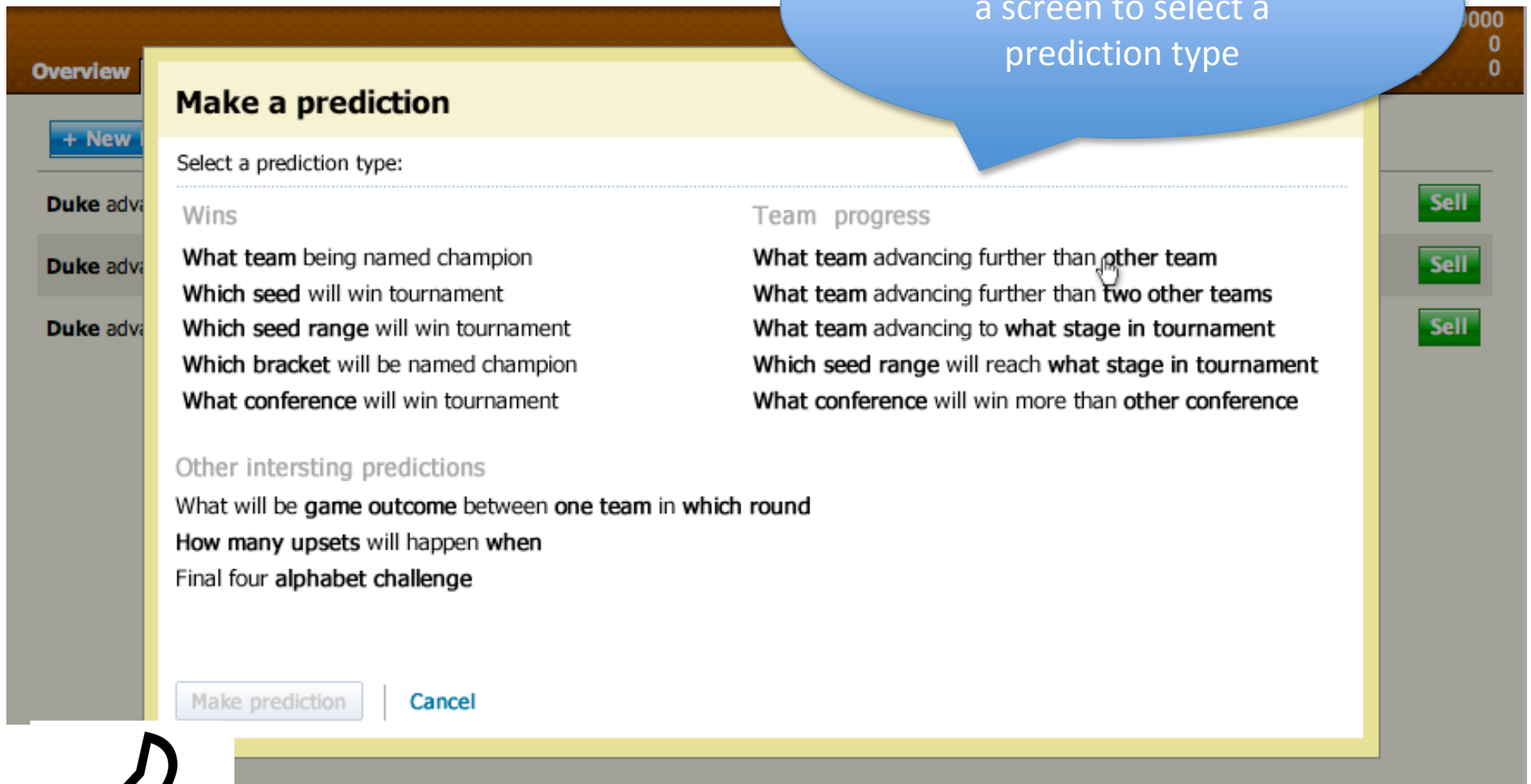
Show:

Open predictions

My predictions » Open predictions

Description	Odds	Riskd	To Win	Sell Now
Australia will advance further than England	21.00% 	10	50	10 <div>Sell</div>
Spain will win cup	32.43% 	12	37	12 <div>Sell</div>

YAHOO!



Example: Y! Predictalot

Overview

+ New

Duke adv

Duke adv

Duke adv

Make a prediction

1. Prediction type: What team advancing further than other
2. Set prediction: Select team advances further than Select team

Make prediction | Cancel

999000
0
0

Sell

Sell

Sell

On selecting the template for prediction type the other controls are displayed progressively



Example: Y! Predictalot

Here the user then sets the prediction parameters, but note that the 'make prediction' button is disabled till all parameters are set

Overview

+ New

Duke adv

Duke adv

Duke adv

Available: 999000
Picked: 0
Worth: 0

Sell

Sell

Sell

Make a prediction

1. Prediction type: What team advances further than
2. Set prediction: Select team advances further than Select team

|

Albany
Binghamton
Boston
Duke
Ellington
Hartford



Example: Y! Predictalot

Available: 999000
Picked: 0
Worth: 0

Overview

+ New

Duke adv

Duke adv

Duke adv

Make a prediction

1. Prediction type:
2. Set prediction: Albany
3. Odds:

Calculate odds

Make prediction | Cancel

Sell

Sell

Sell

Odds are calculated only after the user finalizes on the prediction



Example: Y! Predictalot

Available: 999000
Picked: 0
Worth: 0

Overview

+ New

Duke adv

Duke adv

Duke adv

Make a prediction

1. Prediction type: What team advancing further than other team
2. Set prediction: Albany advances further than Hartford
3. Odds: Calculate odds Calculating odds...

Make prediction | Cancel

Sell

Sell

Sell



Example: Y! Predictalot

Available: 999000
Picked: 0
Worth: 0

Overview

+ New

Duke adv

Duke adv

Duke adv

Make a prediction

1. Prediction type: What team
2. Set prediction: Albar
3. Odds: 13.6%
3. Place investments:
Risk: 1 500 1000
To Win: 0 2 1000 2000

Make prediction | Cancel

Finally once investments are placed the 'Make prediction' button gets enabled.

Sell

Sell

Sell



Example: Y! Predictalot

Available: 999000
Picked: 0
Worth: 0

Overview

+ New

Duke adva

Duke adva

Duke adva

Make a prediction

1. Prediction type: What team advancing further than other team
2. Set prediction: Albany advances further than Hartford
3. Odds: 13.6%
3. Place investments:
Risk: 500
To Win: 1000
1 500 1000
2 1000 2000

Make prediction | Cancel

Sell

Sell

Sell



Example: Y! Predictalot



Who and how

- With Mani Abrol, Janet George, Tom Gulik, Mridul Muralidharan, Sudar Muthu, Navneet Nair, Abe Othman, David Pennock, Dan Reeves, Pras Sarkar
- Y! engineers turned mad scientist's idea into reality
- Yahoo! Application Platform
 - Takes care of login/auth, friends, sharing
 - Easy to create; good sample code; Google open social
 - Small view on my.yahoo, yahoo.com (330M)
 - Activity stream can appear across Y!
(e.g., mail, sports, finance, profiles)



Continuous double auction

Uber-hammer of the financial world

- Buy offers

ACME stock

\$150
\$120
\$90
\$50

- Sell offers

\$300
\$170
\$160



Continuous double auction

Uber-hammer of the financial world

- Buy offers

ACME stock

\$150
\$120
\$90
\$50

- Sell offers

\$300
\$170
\$160
\$140



Continuous double auction

Uber-hammer of the financial world

- Buy offers

ACME stock

price = \$150

✓ \$150
\$120
\$90
\$50

- Sell offers

\$300

\$170

\$160

\$140

✓ Winning traders



Continuous double auction

Uber-hammer of the financial world

- Buy offers

ACME stock

- Sell offers

\$300

\$170

\$160

\$120

\$90

\$50



Continuous double auction

Uber-hammer of the financial world

- Used everywhere
 - Stocks, options, futures, derivatives
 - Gambling: BetFair, InTrade
- Related bets? Just use two CDAs
 - $\text{Max}[\text{YHOO}-10]$, $\text{Max}[\text{YHOO}-20]$
 - Horse wins, Horse finishes 1st or 2nd
 - “Power set” instruments: Mutual funds, ETFs, butterfly spreads, “Western Conference wins”
 - Treats everything like apples and oranges, even ‘fish’ and ‘fish and chips’



Continuous double auction

Uber-hammer of the financial world

- CDA was invented when auctioneers were people
- Had to be dead simple
- Today, auctioneers are computers...
- ...Yet CDA remains the standard

YAHOO! Research



<http://intrade.com>

? Contract		B Qty	Bld	Ask	A Qty	Last	Vol	Chge
Trade 	2011.GLOBALTEMP.WARMEST	140	15.0	20.0	10	15.0	1830	0

2011 Mar 10 12:21pm ET



Combinatorial market: Like ordering a Wendy's hamburger

- Informal definition: *A combinatorial market* is one where users construct their own bets by mixing and matching options in myriad ways
- Wendy's bags circa March 2008: *"We figured out that there are 256 ways to personalize a Wendy's hamburger. Luckily someone was paying attention in math class."*



Combinatorial bids vs. Combinatorial outcomes

- Combinatorial *bids*
 - Bundling: “Western conference will win”,
“Gas prices between 3.25-4.00”
 - If bids are divisible, almost no disadvantage:
use linear programming
- Combinatorial *outcomes*
 - Outcome space exponential:
March Madness, horse racing
 - Needs combinatorial bids too
 - Usually intractable but don’t give up hope

Auctioneer vs. market maker

- An **auctioneer** matches traders: no risk
- An automated **market maker** always offers a price for *anything*. “Infinite” liquidity.
 - Without market maker, traders lost in exponential sea
 - Illiquidity discourages trading: Chicken and egg
 - Subsidizes information aggregation:
Circumvents no-trade theorems
- Market makers bear risk. But can **bound the loss**
 - Market scoring rules [Hanson 2002, 2003, 2006]
 - Family of bounded-loss MMers [Chen & Pennock 2007]
 - Dynamic pari-mutuel market [Pennock 2004]



Example: weatherbill

at weather do you need to protect against?

Select a Contract

Pick the contract that best suits your needs

Description

A Rainy Day Contract will pay you a specified amount for every day that the precipitation level is above a specified threshold.

Choose Dates of Coverage

06/30/08 to 07/04/08 including weekends and weekdays (5 days)

Select Location

[\(please read disclaimer\)](#)

USA
postal/zip code
 find weather station
or NJ - Atlantic City Intl AP

Choose Payment Terms

Pay me USD 100.00 for every day when the precipitation level is above 0.5 inches.
Only start paying me after 0 rainy days, and pay me a maximum amount of 500.00.

Price

\$42.62

BUY NOW

Year	Payout	Year	Payout
2007	\$0	1992	\$0
2006	\$0	1991	\$0
2005	\$100	1990	\$0
2004	\$0	1989	\$0
2003	\$100	1988	\$0
2002	\$0	1987	\$100
2001	\$100	1986	\$100
2000	\$100	1985	\$0
1999	\$0	1984	\$0
1998	\$0	1983	\$0
1997	\$0	1982	\$100

YAHOO!



Example:

bet365

SOCCER - ZAGLEBIE LUBIN V LEGIA WARSAW



Live In-Play.



Book Closes 04 Dec 19:00

Full Time Result

Zaglebie Lubin	4.33	Draw	3.40	Legia Warsaw	1.85
----------------	------	------	------	--------------	------

Double Chance

Correct Score



Others On Request

Zaglebie Lubin Win		Match Draw		Legia Warsaw Win	
1-0	8.50	0-0	7.50	1-0	5.50
2-0	23.00	1-1	7.00	2-0	7.50
2-1	15.00	2-2	17.00	2-1	8.00
3-0	67.00	3-3	51.00	3-0	15.00
3-1	41.00	4-4	401.00	3-1	15.00
3-2	41.00				
4-0	151.00				

Half Time/Full Time

Zaglebie Lubin - Zaglebie Lubin	8.00
Zaglebie Lubin - Draw	15.00
Zaglebie Lubin - Legia Warsaw	29.00
Draw - Zaglebie Lubin	9.50
Draw - Draw	5.00
Draw - Legia Warsaw	4.50
Legia Warsaw - Zaglebie Lubin	41.00
Legia Warsaw - Draw	15.00
Legia Warsaw - Legia Warsaw	2.87

Corners

Under 10 Corners	2.10	Exactly 10 Corners	8.50	Over 10 Corners	1.90
Total Goals					
Under 2.5	1.50	Over 2.5	2.50		



Example: Cantor Fitzgerald

- From Wall Street to Las Vegas Blvd
- “In-running” betting
- Intelligent market maker “The Oracle”

`http://www.wired.com/magazine/
2010/11/ff_midas/all/1`



Example: Y! Predictalot

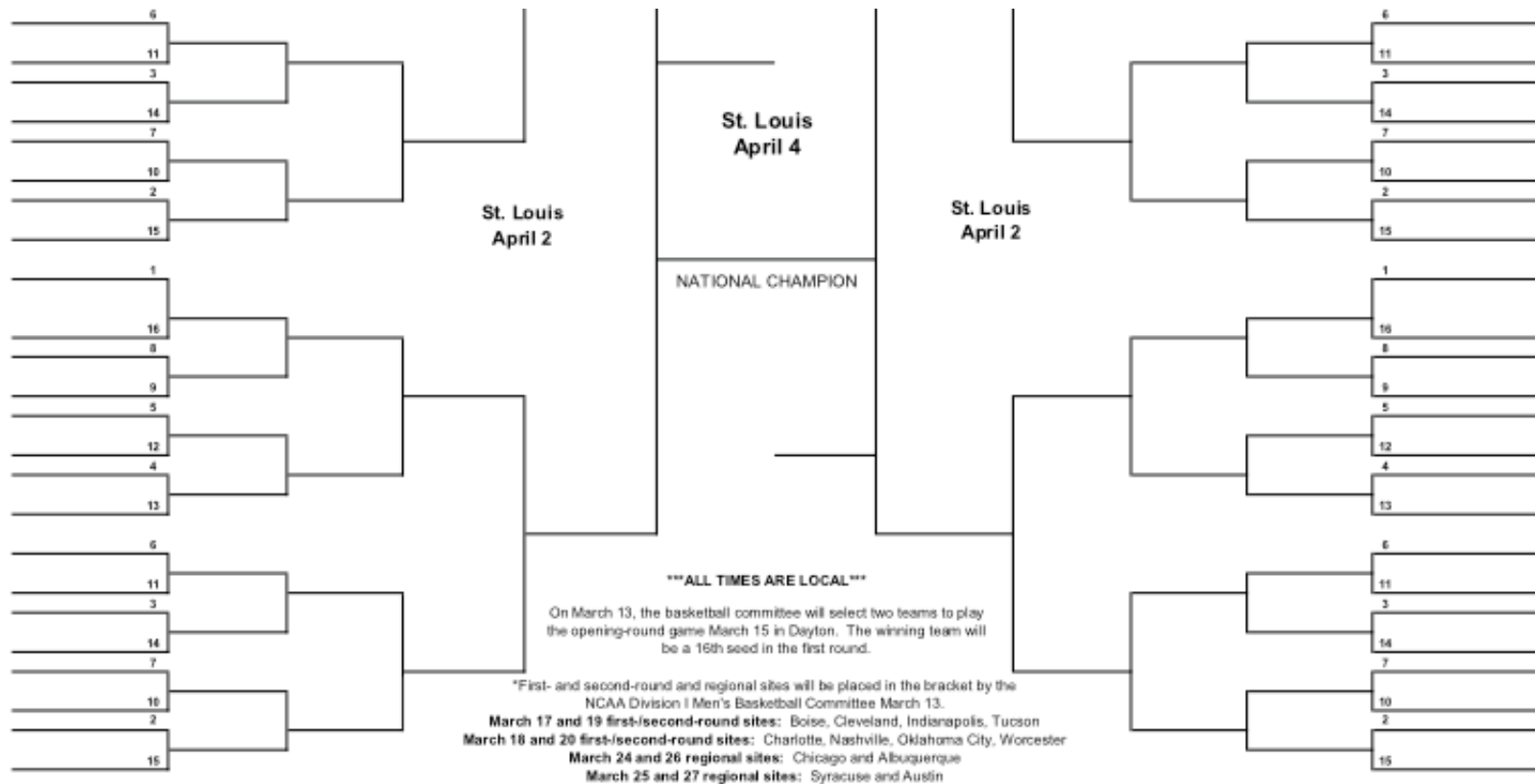




Example: Y! Predictalot



9.2 quintillion outcomes



The pitch (to gamers)

- Predict *any* property
 $2^{2^{63}}$ possible in theory [gogol,gogolplex]
 - Duke wins >3 games
 - Duke wins more than UNC, less than NCST
 - Sum (seeds of ACC teams in final8) is prime
- We'll instantly quote odds for any of them
- Effects related predictions automatically
 - Predict Duke wins tournament
⇒ Odds Duke wins rnd 1 goes up

The pitch (to economists)

- Information is everything
 - Traders (people) focus on information
Provide it in whatever form they like
 - Mechanism (computer) handles logical & Bayesian propagation - what it's good at
- No redundancy, no exec risk, everything is 1 trade
- More choices -- better hedges
- More information
- Smarter budgeting

Example: Y! Predictalot

- Typical today
Non-combinatorial
 - Team wins Rnd 1
 - Team wins Tourney
 - A few other “props”
 - Everything explicit
(By def, small #)
 - Every bet indep:
Ignores logical & probabilistic relationships
- Combinatorial
 - *Any* property
 - Team wins Rnd k
Duke > {UNC, NCST}
ACC wins 5 games
 - $2^{2^{63}}$ possible props
(implicitly defined)
 - 1 Bet effects related
bets “correctly”;
e.g., to enforce logical constraints



Predictalot live

- First live version ran for 2010 March Madness, the NCAA basketball playoffs. Over 10,000 people placed 100,000 predictions. We averaged a prediction every 21 seconds (peak: 80/min).
- Version 0.2 ran for the 2010 FIFA World Cup, at one point the most popular game on Yahoo! Apps
- Users said: "wicked fun", "great idea", "could be huge". The app was cited in **NYTimes** and **Wired**, among others.
- From a science point of view, we have over 100,000 real predictions of over 10,000 types to test on



LMSR market maker

- Robin Hanson: Logarithmic market scoring rule market maker

Event = E = e.g. Duke wins > 3

Outcome = o = complete unfolding of tour

$$\text{Price of } E = \frac{\sum_{o \in E} e^{q_o/b}}{\sum_{o \in \text{TRUE}} e^{q_o/b}}$$



LMSR market maker

- $$\frac{\sum_{o \in E} e^{q_o/b}}{\sum_{o \in \text{TRUE}} e^{q_o/b}}$$
- Impossible: Store 2^{63} numbers
- Complex: Sum over 2^{63} numbers
- Doable: Approx sum over 2^{63} nums
*tricks required to do it well/fast



Main loop

Input: event E

for 1 to NUM_SAMPLES

sample o

foreach bet (F, q_F)

$q_o += q_F$ if $o \in F$

numer += $e^{q_o/b}/p(o)$ if $o \in E$

denom += $e^{q_o/b}/p(o)$

return numer/denom



Other market maker functions

- Point price is all we need!
- From price we can compute
 - Total cost of any number of shares q_E
 - Number of shares purchasable for any dollar amount (inverse cost)
 - New price after purchasing q_E shares



Sampling

- Sampling is accurate when outcomes are chosen proportional to $e^{q/b}$
- Can't be done (#P-hard)
- *Can* sample proportion to q , if size of event is known
- For now, we sample according to seed-based prior fit to historical data and the current score (dynamic model)
- Next: Metropolis-Hastings

- No guarantees
- Erratic convergence
 e^{10} dwarfs e^8
- Linear scan of all bets in inner loop!
- Now getting serious about improving sampling: 1) fast, 2) stable, 3) accurate

- If E is a snippet of code, then testing $o \in E$ requires an 'eval' of the code
- Slow in interpreted languages + can be gamed + serious security risk
- Proceeded in phases: 1) Mathematica, 2) PHP, 3) Now implemented a mini language parser in Java: much faster



[<< Hide Examples](#)

<code>seed(champ())==3</code>	A #3 seed wins the tournament
<code>wins(Duke)>wins(UNC)</code>	Duke advances further than North Carolina
<code>gmp_prob_prime(array_sum(array_map("seed",finalfour()))>0</code>	Sum of seeds of final four is prime

Enter any proposition:

Your Predictions

Prediction	You Played	To Win	Sell Now For	Action
<code>sum(array_map("seed",winners(6))) > 5</code>	49	468.153873424186	-	<input type="button" value="Sell"/>
<code>max(array_map("seed",winners(3))) < 12</code>	5	33.9255213749424	-	<input type="button" value="Sell"/>
<code>seed(champ())==2</code>	3	14.032125779331	-	<input type="button" value="Sell"/>
<code>upsets(5) == 1</code>	44	112.219182030833	-	<input type="button" value="Sell"/>
<code>seed(champ())>=3 && seed(champ())<=16</code>	22	60.1808519731104	-	<input type="button" value="Sell"/>
<code>sum(array_map("seed",winners(3))) < 50</code>	14	194.774794722934	-	<input type="button" value="Sell"/>

March Madness Bet Constructor

Enter any proposition

[Examples](#)

<code>seed[champ[]]==3</code>	(* "A number 3 seed wins the whole tournament" *)
<code>wins[UL]>wins[MSU]</code>	(* "Louisville advances further than Michigan State" *)
<code>Sum[Boole[seed[winner[1,g]]>8],{g,1,2^(n-1)}]==0</code>	(* "There are no upsets in the first round" *)

[Source code](#)





Overview: Complexity results

	Permutations			Boolean			Taxonomy		
	General	Pair	Subset	General	2-clause	Restrict Tourney	General	Tree	
Auction- eer	NP-hard EC'07	NP-hard EC'07	Poly EC'07	NP-hard DSS'05	co-NP- complete DSS'05	?	?	?	
Market Maker (LMSR)	#P-hard EC'08	#P-hard EC'08	#P-hard EC'08	#P-hard EC'08 Approx STOC'08	#P-hard EC'08	Poly STOC'08	#P-hard AAMAS '09	Poly AAMAS '09	

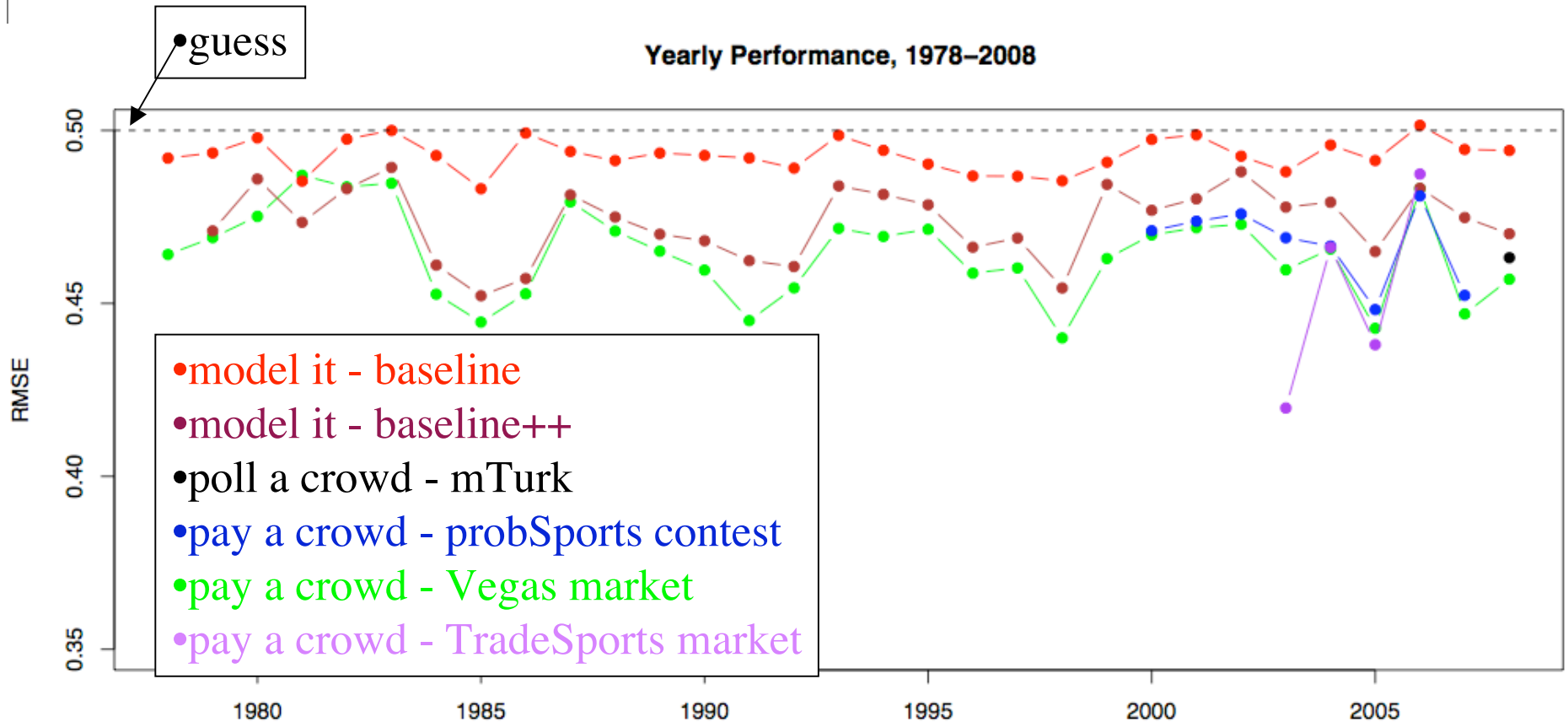


More Info

**What is (and what good is) a
combinatorial prediction market?**

`http://bit.ly/combopm`

Methods compared: NFL

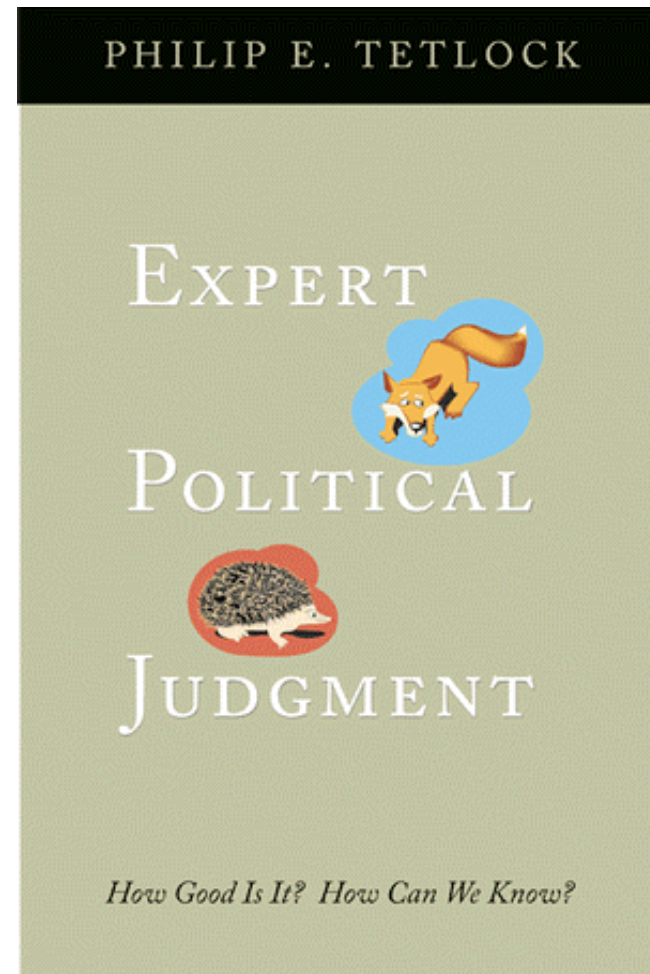


How to make a prediction

1. Guess *if 99.7th percentile*
2. Model it: Stats/ML *if data*
3. Poll an expert
4. Pay an expert
5. Poll a crowd
6. Pay a crowd

How to make a prediction

1. Guess
2. Model it: Stats/ML
3. **Poll an expert**
4. Pay an expert
5. Poll a crowd
6. Pay a crowd



How to make a prediction

1. Guess *if 99.7th percentile*
2. Model it: Stats/ML *if data*
3. Poll an expert *Tetlock says no*
4. Pay an expert *& hard to ID*
5. Poll a crowd
6. Pay a crowd

How to make a prediction

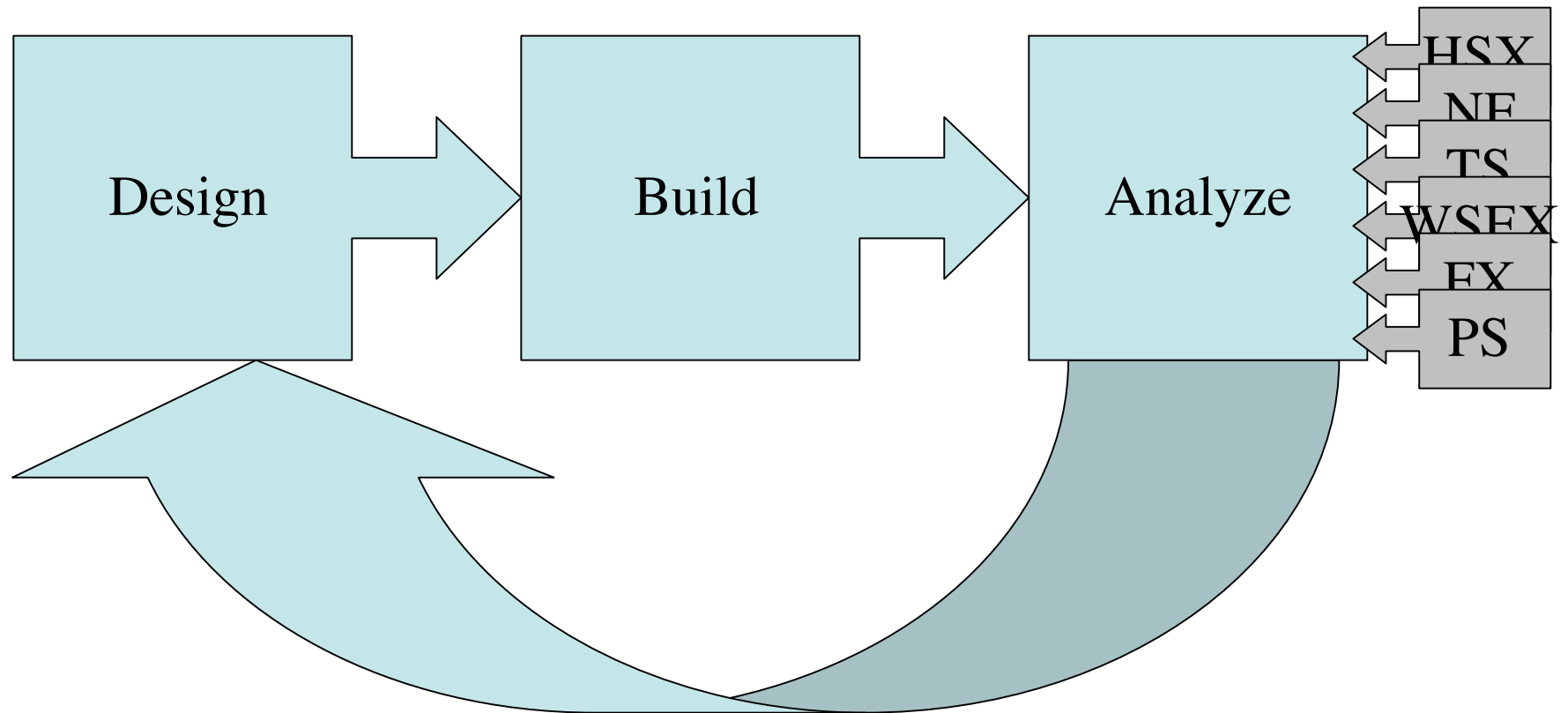
- | | | |
|-----------------------|---------------------------|---|
| 1. Guess | | <i>if 99.7th percentile</i> |
| 2. Model it: Stats/ML | | <i>if data</i> |
| 3. Poll an expert | | <i>Tetlock says no</i> |
| 4. Pay an expert | | <i>& hard to ID</i> |
| 5. Poll a crowd | <i>nice
trade-off</i> | <i>cheap, easy, works</i> |
| 6. Pay a crowd | | <i>>cost, complex, better</i> |

A research agenda: *Chance Tech*

- Technology to
 - Manage chance: prediction, finance
 - Mitigate chance: insurance
 - Manufacture chance: gambling
- In: Wisdom of crowds, prediction markets, stock picking, money management, online betting exchanges, computer poker, custom insurance, adversarial ML
- Out: Roulette, human poker, chess

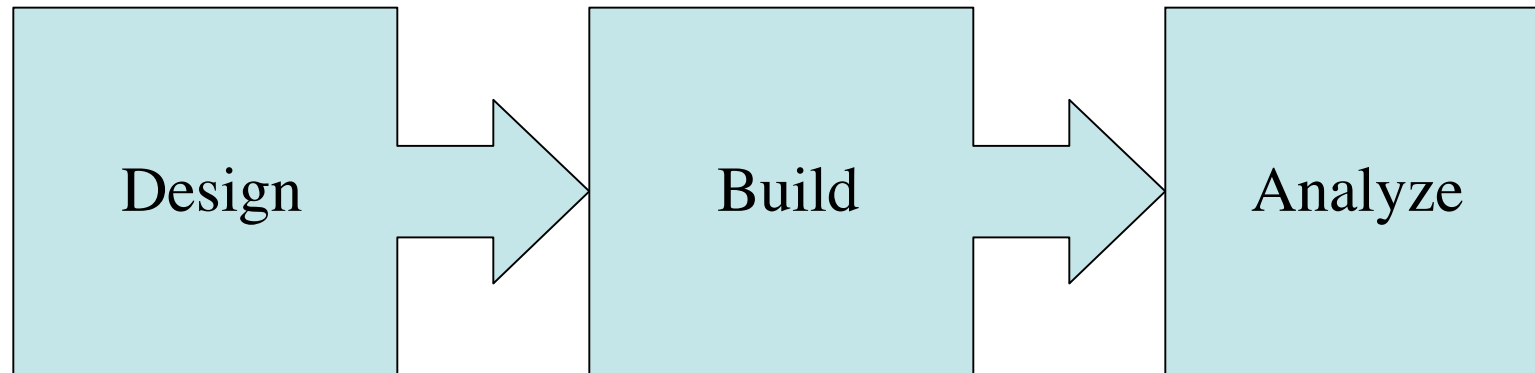


A research methodology

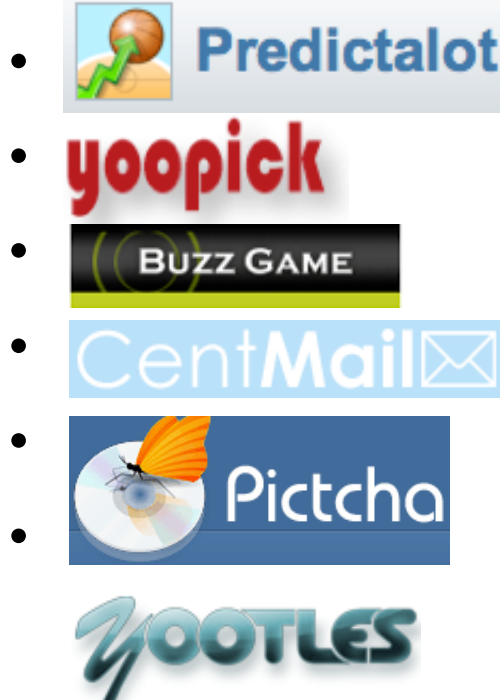




Examples



- Prediction markets
 - Dynamic parimutuel
 - Combinatorial bids
 - Combinatorial outcomes
 - Shared scoring rules
 - Linear programming backbone
- Ad auctions
- Spam incentives



- Computational complexity
- Does money matter?
- Equilibrium analysis
- Wisdom of crowds: Combining experts
- Practical lessons