Crowdsourcing Predictions

9.2 quintillion

Contributors:
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Dear crowd,

http://predictalot.yahoo.com
How to make a prediction

• What are the chances:

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

<table>
<thead>
<tr>
<th></th>
<th>82%</th>
<th>8%</th>
<th>3.6%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19%</td>
<td>0.003%</td>
<td>67%</td>
</tr>
</tbody>
</table>

???
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
Crowdsource it
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
} Crowdsocre source 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
  - Crowd = \( \frac{1}{n}(\text{Alice} + \text{Bob} + \text{Carol} + \ldots) \)
  - 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

More:
http://www.overcomingbias.com/2007/02/how_and_when_to.html
Can we do better?

- **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)

[Dani et al. UAI 2006]
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:

<table>
<thead>
<tr>
<th>$1 if</th>
<th>2011 the warmest</th>
<th>$0 if</th>
<th>not the warmest</th>
</tr>
</thead>
</table>

http://intrade.com

<table>
<thead>
<tr>
<th>? Contract</th>
<th>B Qty</th>
<th>Bid</th>
<th>Ask</th>
<th>A Qty</th>
<th>Last</th>
<th>Vol</th>
<th>Chge</th>
</tr>
</thead>
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<td>15.0</td>
<td>20.0</td>
<td>10</td>
<td>15.0</td>
<td>1830</td>
<td>0</td>
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2011 Mar 10 12:21pm ET
Example: IEM 1992
**IEM versus Polls: 1996**
(Berg, Nelson and Rietz, 2001)

![Graph showing predicted Clinton winning margin from February 1 to October 25, 1996. The graph includes data points from various sources including Market,Outcome,Rep. Conv.,Dem. Conv.,Debates,Super Tuesday. Polls: A = ABC, C = CBS, N = NBC, G = Gallup, H = Harris, T = Time, L = Hotline, P = CNN/Princeton Survey Res., Z = Zogby.]}
Predictive Accuracy
Berg, Forsythe, Nelson and Rietz (2001)

[Graph showing the relationship between predicted and actual outcomes across different election types, with data points for US Presidential Elections, Other US Elections, and Non-US Elections, each with specified average absolute errors and the number of markets and contracts.]
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]
- 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]
- Market games work [Servan-Schreiber 2004][Pennock 2001]
### Pay a crowd; Part three

With money

<table>
<thead>
<tr>
<th>Contract</th>
<th>B Qty</th>
<th>Bid</th>
<th>Ask</th>
<th>A Qty</th>
<th>Last</th>
<th>Vol</th>
<th>Chg</th>
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<tbody>
<tr>
<td>US RECESSION.OB</td>
<td>1</td>
<td>72.2</td>
<td>73.0</td>
<td>2</td>
<td>74.0</td>
<td>34.9</td>
<td>+3.0</td>
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<tr>
<td>BIRDFLU USA.JUN08</td>
<td>10</td>
<td>6.5</td>
<td>16.0</td>
<td>5</td>
<td>11.2</td>
<td>430</td>
<td>0</td>
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<tr>
<td>BIRDFLU USA.SEP08</td>
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<td>6.0</td>
<td>14.0</td>
<td>5</td>
<td>10.0</td>
<td>1223</td>
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</table>

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<th>Last</th>
<th>Vol</th>
<th>Chg</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSAMA CAPTURE MAR06</td>
<td>5</td>
<td>1.0</td>
<td>3.3</td>
<td>1</td>
<td>2.6</td>
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<tr>
<td>OSAMA CAPTURE JUN08</td>
<td>4</td>
<td>5.1</td>
<td>5.7</td>
<td>25</td>
<td>5.5</td>
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<td>OSAMA CAPTURE SEP08</td>
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<td>8.8</td>
<td>4</td>
<td>9.1</td>
<td>822</td>
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</table>

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<th>A Qty</th>
<th>Last</th>
<th>Vol</th>
<th>Chg</th>
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<tbody>
<tr>
<td>2006 DEM NOH ORAMA</td>
<td>22</td>
<td>71.8</td>
<td>72.6</td>
<td>55</td>
<td>72.9</td>
<td>463.0</td>
<td>-1.3</td>
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<tr>
<td>2006 DEM NOH CLINTON</td>
<td>50</td>
<td>29.5</td>
<td>28.9</td>
<td>4</td>
<td>28.9</td>
<td>549.1</td>
<td>-1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Ask</th>
<th>A Qty</th>
<th>Last</th>
<th>Vol</th>
<th>Chg</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALABAMA DEM</td>
<td>9</td>
<td>-10.0</td>
<td>20</td>
<td>10.0</td>
<td>86</td>
<td>0</td>
<td>0</td>
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<tr>
<td>ALABAMA REP</td>
<td>20</td>
<td>90.0</td>
<td>95.0</td>
<td>5</td>
<td>90.0</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>ALABAMA FIELD</td>
<td>5</td>
<td>0.1</td>
<td>5.9</td>
<td>20</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ALASKA DEM</td>
<td>20</td>
<td>5.0</td>
<td>10.0</td>
<td>17</td>
<td>7.5</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>ALASKA REP</td>
<td>20</td>
<td>0.0</td>
<td>95.0</td>
<td>20</td>
<td>92.5</td>
<td>45</td>
<td>0</td>
</tr>
<tr>
<td>ALASKA FIELD</td>
<td>5</td>
<td>0.1</td>
<td>5.9</td>
<td>20</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### 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*
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, Smarts, Trendio, TwoCrowds
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

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
### Does money matter?

**Play vs real, head to head**

<table>
<thead>
<tr>
<th></th>
<th>Probability-Football Avg</th>
<th>TradeSports (real-money)</th>
<th>NewsFutures (play-money)</th>
<th>Difference TS - NF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Absolute Error</strong></td>
<td>0.443</td>
<td>0.439</td>
<td><strong>0.436</strong></td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.011)</td>
<td>(0.012)</td>
<td>(0.016)</td>
</tr>
<tr>
<td><strong>Root Mean Squared Error</strong></td>
<td>0.476</td>
<td>0.468</td>
<td><strong>0.467</strong></td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.023)</td>
<td>(0.024)</td>
<td>(0.033)</td>
</tr>
<tr>
<td><strong>Average Quadratic Score</strong></td>
<td>9.323</td>
<td>12.410</td>
<td><strong>12.427</strong></td>
<td>-0.017</td>
</tr>
<tr>
<td></td>
<td>(4.75)</td>
<td>(4.37)</td>
<td>(4.57)</td>
<td>(6.32)</td>
</tr>
<tr>
<td><strong>Average Logarithmic Score</strong></td>
<td>-0.649</td>
<td><strong>-0.631</strong></td>
<td><strong>-0.631</strong></td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.027)</td>
<td>(0.024)</td>
<td>(0.025)</td>
<td>(0.035)</td>
</tr>
</tbody>
</table>

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”
Try it!

http://predictalot.yahoo.com
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.

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

You sold a prediction
Brazil will advance further than France. Current odds: 77.39%. Won 9.77.

DG made a prediction
Brazil will win cup. Current odds: 50.02%. Risked 500.00 to win 975.86

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

Kelly Hirano joined the group 'ysports'

Sudar sold a prediction
Argentina will win cup. Current odds: 0.62%. Won 17.62.
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

Available: 977.85 Risked: 22.00 Networth: 999.43

Save prediction | Cancel
Hi, Dave P

Available: 977.85
Risked: 22.00
Networth: 999.43

Make a prediction

My predictions » Open predictions

<table>
<thead>
<tr>
<th>Description</th>
<th>Odds</th>
<th>Risked</th>
<th>To Win</th>
<th>Sell Now</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia will advance further than England</td>
<td>21.00%</td>
<td>10</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Spain will win cup</td>
<td>32.43%</td>
<td>12</td>
<td>37</td>
<td>12</td>
</tr>
</tbody>
</table>
The modal dialog opens with a screen to select a prediction type.

Example: Y! Predictalot
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.

Example: Y! Predictalot
Odds are calculated only after the user finalizes on the prediction.

Example: Y! Predictalot
Example: Y! Predictalot
Finally once investments are placed the ‘Make prediction’ button gets enabled.

Example: Y! Predictalot
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

- Sell offers
  - $300
  - $170
  - $160
  - $150
  - $120
  - $90
  - $50
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

- Winning traders
  - $140
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
  - Max[YHOO-10], Max[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
http://intrade.com

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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**
  - Family of bounded-loss MMers [Chen & Pennock 2007]
  - Dynamic pari-mutuel market [Pennock 2004]

[Thanks: Yiling Chen]
Example: weatherbill

does your weather 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 $100.00 for every day when the precipitation level is above .5 inches. Only start paying me after 0 rainy days, and pay me a maximum amount of $500.00.

Price

$42.62

BUY NOW
### Soccer - Zaglebie Lubin v Legia Warsaw

#### Live In-Play

- **Full Time Result**
  - Zaglebie Lubin: 4.33
  - Draw: 3.40
  - Legia Warsaw: 1.85

#### Double Chance

#### Correct Score

<table>
<thead>
<tr>
<th>Zaglebie Lubin Win</th>
<th>Match Draw</th>
<th>Legia Warsaw Win</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-0</td>
<td>8.50</td>
<td>7.50</td>
</tr>
<tr>
<td>2-0</td>
<td>23.00</td>
<td>7.00</td>
</tr>
<tr>
<td>2-1</td>
<td>15.00</td>
<td>17.00</td>
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<tr>
<td>3-0</td>
<td>67.00</td>
<td>51.00</td>
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<td>3-1</td>
<td>41.00</td>
<td>401.00</td>
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<tr>
<td>3-2</td>
<td>41.00</td>
<td></td>
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<tr>
<td>4-0</td>
<td>151.00</td>
<td></td>
</tr>
</tbody>
</table>

#### 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

#### Corners

<table>
<thead>
<tr>
<th>Under 10 Corners</th>
<th>2.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exactly 10 Corners</td>
<td>8.50</td>
</tr>
<tr>
<td>Over 10 Corners</td>
<td>1.90</td>
</tr>
</tbody>
</table>

#### Total Goals

<table>
<thead>
<tr>
<th>Under 2.5</th>
<th>1.50</th>
<th>Over 2.5</th>
<th>2.50</th>
</tr>
</thead>
</table>
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 $2^{63}$ 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
    $\Rightarrow$ 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
  • $2^{63}$ possible props
    (implicitly defined)
  • 1 Bet effects related
    bets “correctly”;
    e.g., to enforce logical constraints
• 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.
• Robin Hanson: Logarithmic market scoring rule market maker

Event = E = e.g. Duke wins > 3
Outcome = o = complete unfolding of tourn

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 ∈ F
    numer += e^{q_o/b}/p(o) if o ∈ 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 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.
Sampling

- No guarantees
- Erratic convergence
  \[ e^{10} \text{ dwarfs } e^8 \]
- 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
Your Predictions

<table>
<thead>
<tr>
<th>Prediction</th>
<th>You Played</th>
<th>To Win</th>
<th>Sell Now For</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>sum(array_map(&quot;seed&quot;, winners(6))) &gt; 5</td>
<td>49</td>
<td>468.153873424186</td>
<td>-</td>
<td>Sell</td>
</tr>
<tr>
<td>max(array_map(&quot;seed&quot;, winners(3))) &lt; 12</td>
<td>5</td>
<td>33.9255213749424</td>
<td>-</td>
<td>Sell</td>
</tr>
<tr>
<td>seed(champ()) == 2</td>
<td>3</td>
<td>14.032125779331</td>
<td>-</td>
<td>Sell</td>
</tr>
<tr>
<td>upsets(5) == 1</td>
<td>44</td>
<td>112.219182030833</td>
<td>-</td>
<td>Sell</td>
</tr>
<tr>
<td>seed(champ()) &gt;= 3 &amp; seed(champ()) &lt;= 16</td>
<td>22</td>
<td>60.1808519731104</td>
<td>-</td>
<td>Sell</td>
</tr>
<tr>
<td>sum(array_map(&quot;seed&quot;, winners(3))) &lt; 50</td>
<td>14</td>
<td>194.774794722934</td>
<td>-</td>
<td>Sell</td>
</tr>
</tbody>
</table>

March Madness Bet Constructor

Enter any proposition

Examples

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

Source code
## Overview: Complexity results

<table>
<thead>
<tr>
<th></th>
<th>Permutations</th>
<th>Boolean</th>
<th>Taxonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General</td>
<td>2-clause</td>
<td>General</td>
</tr>
<tr>
<td>General</td>
<td>NP-hard</td>
<td>co-NP-complete</td>
<td>Approx STOC’08</td>
</tr>
<tr>
<td>Pair</td>
<td>NP-hard</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Subset</td>
<td>Poly</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auctioneer</td>
<td>EC’07</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Market Maker (LMSR)</td>
<td>#P-hard</td>
<td>#P-hard</td>
<td>#P-hard</td>
</tr>
<tr>
<td></td>
<td>EC’08</td>
<td>EC’08</td>
<td>STOC’08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#P-hard</td>
<td>AAMAS ‘09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EC’08</td>
<td>Poly AAMAS ‘09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Approx STOC’08</td>
<td>Poly AAMAS ‘09</td>
</tr>
</tbody>
</table>
What is (and what good is) a combinatorial prediction market?

Methods compared: NFL

- model it - baseline
- model it - baseline++
- poll a crowd - mTurk
- pay a crowd - probSports contest
- pay a crowd - Vegas market
- pay a crowd - TradeSports market
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
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How to make a prediction

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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
   - 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
   - cheap, easy, works
   - nice trade-off
6. Pay a crowd
   - >cost, complex, better
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

Design → Build → Analyze

HSX, NF, TS, WSEX, FX, PS
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

Design → Build → Analyze