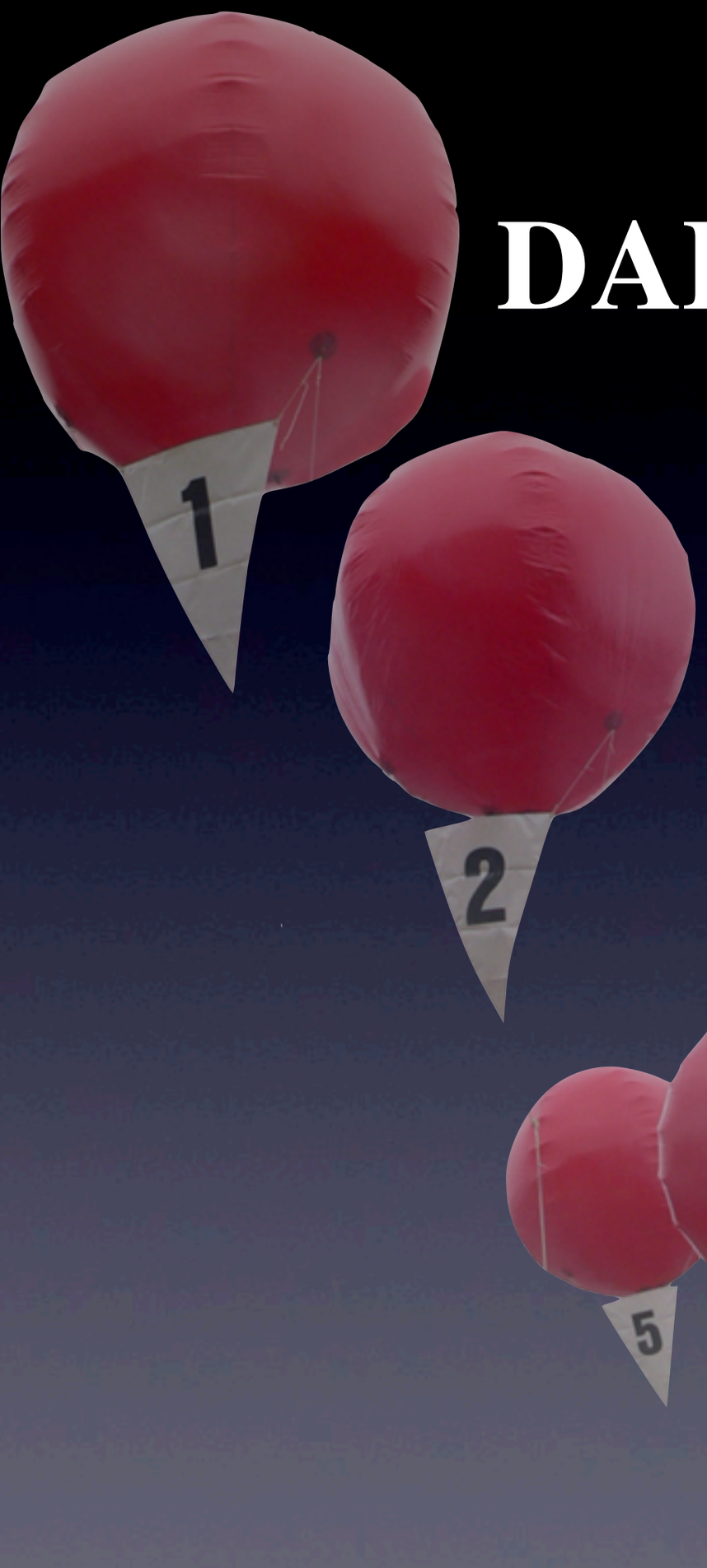


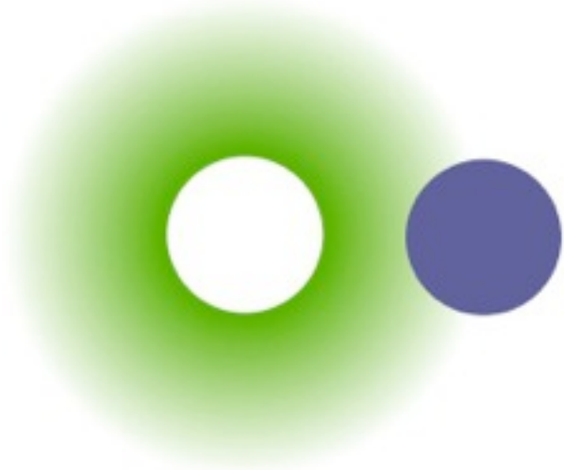
DARPA Network Challenge: Legacy and Future

Manuel Cebrian

THE UNIVERSITY OF MELBOURNE

Singapore-ETH Centre
Future Cities Laboratory
Talk 22 August 2013

SALOON



NICTA

THE UNIVERSITY OF MELBOURNE

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Department of Broadband, Communications and the Digital Economy

Australian Research Council

NICTA Funding and Supporting Members and Partners

Australian National University

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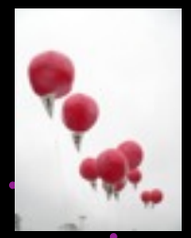
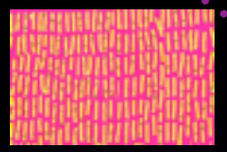
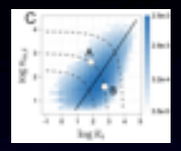
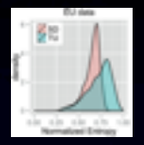


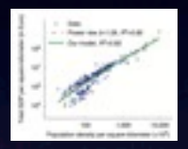
crowdsourcing
(this seminar)



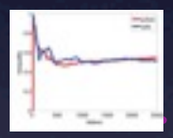
cities

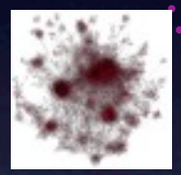


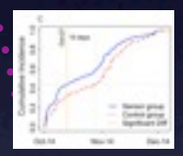




institutions







Harder

Faster

firms

social media

Home
Gallery
FAQ
Rules
DARPA NETWORK CHALLENGE
DARPA
This is an archived web site made available for research purposes. The page is no longer being updated or maintained.
SHREDDER CHALLENGE
Home
Rules
Download Puzzles
FAQ
TAG CHALLENGE
Suspects
About the Contest
News & Updates
Upload Photos
Step 1:
Find the Suspect
A band of jewel thieves is on the run in five cities across the world. We need your help finding them. On March 31, 2012, we'll release their pictures to the public. Be on the lookout.
Play TAG
1. Find The Suspect
1. Find the Suspect
2. Photograph the Suspect
3. Upload the Image
4. Win $5000!

Real world activity
Terrorist
Recruiters
Members
Recruiters (stimuli)
Members
Members
Susceptible

Home | Gallery | FAQ | Rules

DARPA NETWORK CHALLENGE

"Impossible by conventional intelligence"

DARPA
DATE December 5, 2009
PAY TO THE ORDER OF MIT RED BALLOON CHALLENGE TEAM
$40,000.00
Forty Thousand Dollars
MEMO Network Challenge Winner

Alice wins $750
Bob wins $500
Carol wins $1,000
Dave wins $2,000

ALICE
$250
$500

BOB
$500

$1,000

CAROL
$1,000

DAVE
$2,000

Balloon
found!

$2,000

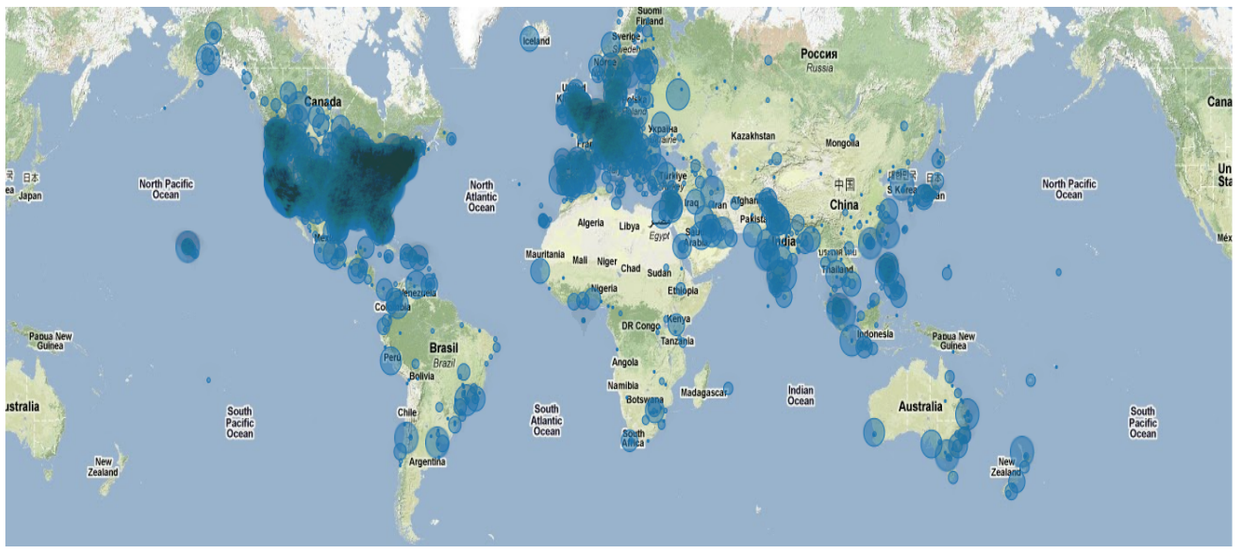
Another
balloon
found!

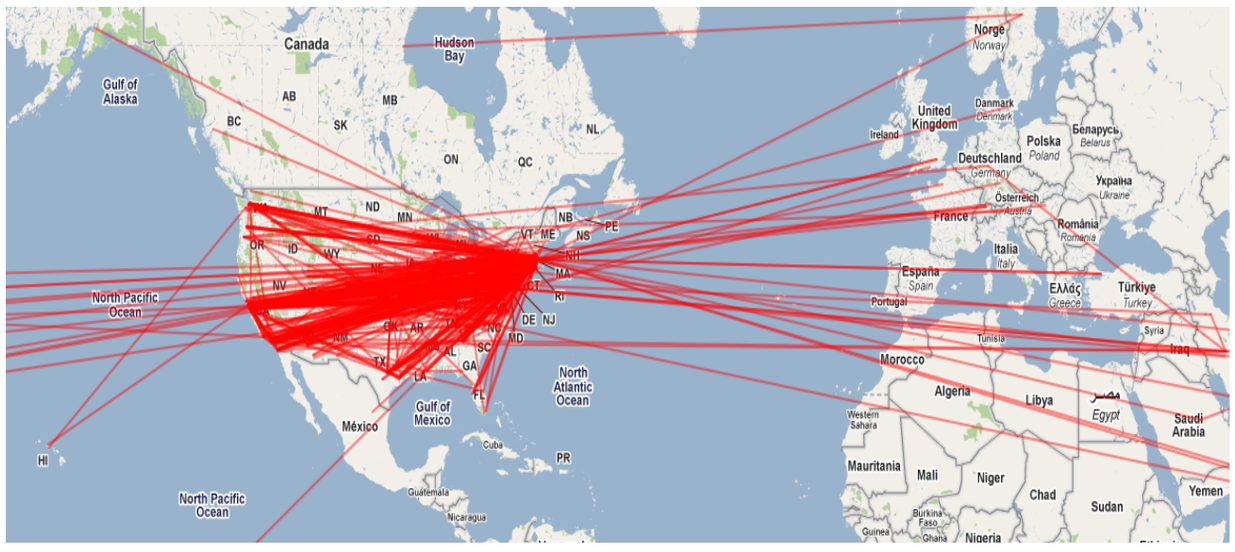
126 countries

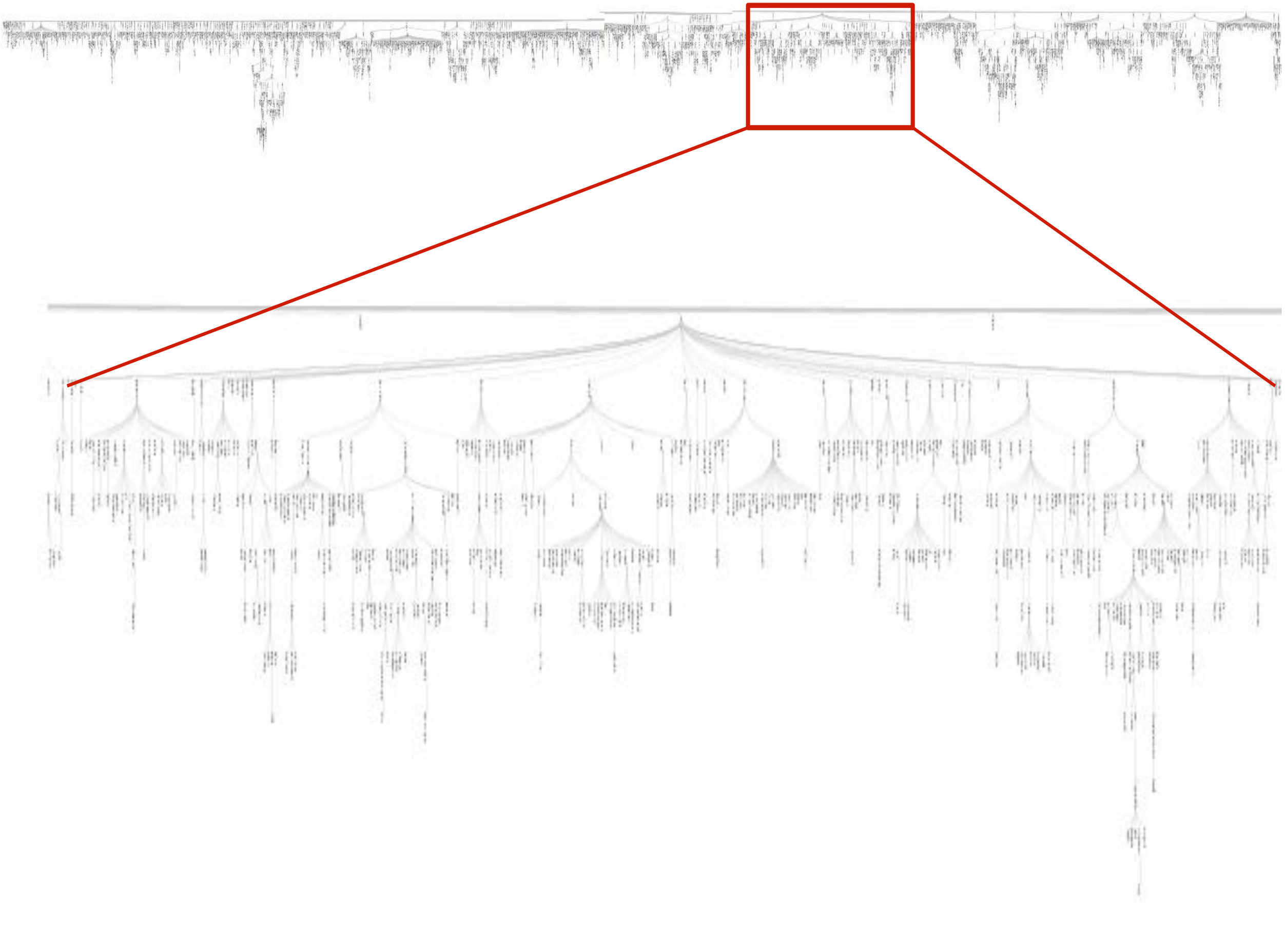
>100,000 Visitors

46 countries

4,521 Team Members







Time-Critical Social Mobilization

Galen Pickard,[1,2]* Wei Pan,[1]* Iyad Rahwan,[1,3]* Manuel Cebrian,[1]* Riley Crane,[1]
Anmol Madan,[1] Alex Pentland[1]†

The World Wide Web is commonly seen as a platform that can harness the collective abilities of large numbers of people to accomplish tasks with unprecedented speed, accuracy, and scale. To explore the Web's ability for social mobilization, the Defense Advanced Research Projects Agency (DARPA) held the DARPA Network Challenge, in which competing teams were asked to locate 10 red weather balloons placed at locations around the continental United States. Using a recursive incentive mechanism that both spread information about the task and incentivized individuals to act, our team was able to find all 10 balloons in less than 9 hours, thus winning the Challenge. We analyzed the theoretical and practical properties of this mechanism and compared it with other approaches.

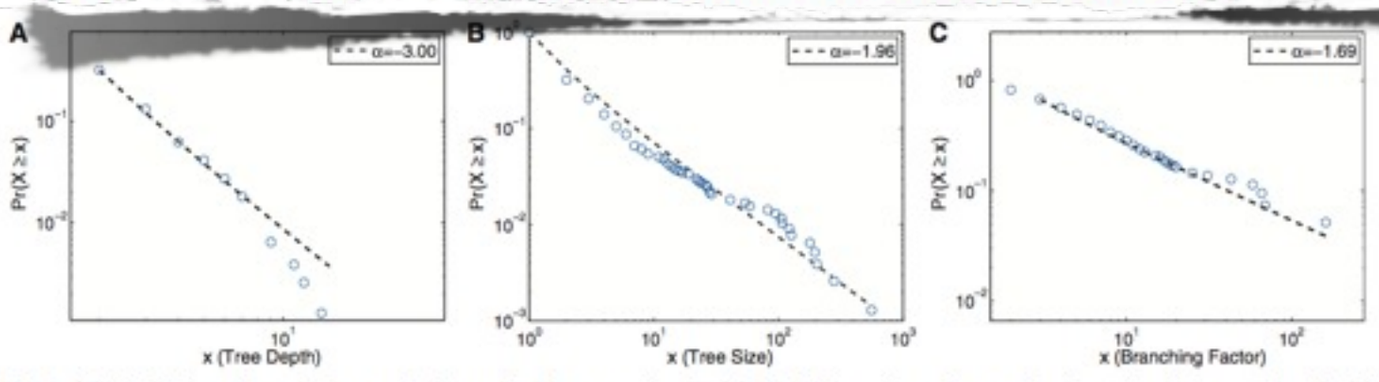


Fig. 1. (**A**) Distribution of tree depth on a log-log scale with a power law fit. (**B**) Distribution of tree size on a log-log scale with a power law fit. (**C**) Distribution of the branching factor on a log-log scale with a power law fit.

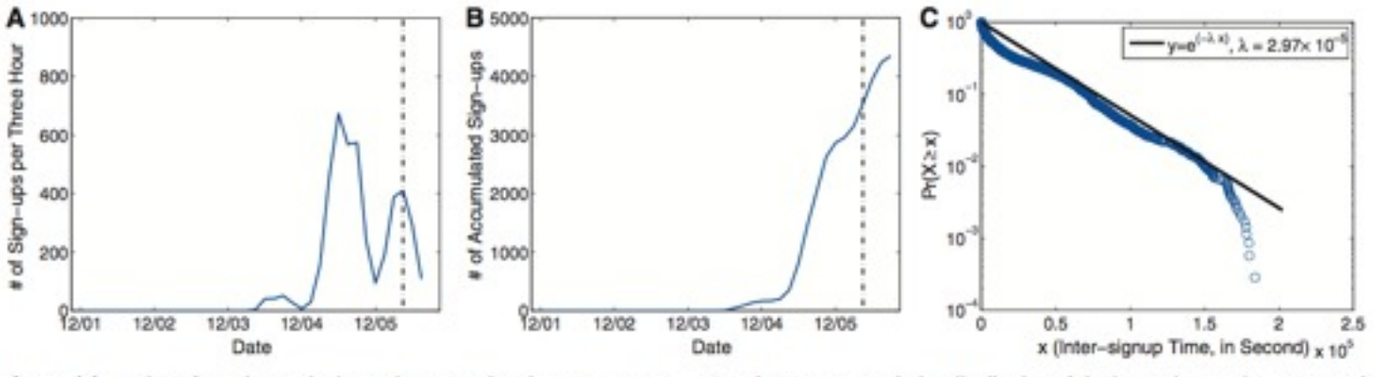


Fig. 2. (**A**) Number of people recruited over time up to the winner announcement. The dotted line indicates the time the balloons were launched into their positions by DARPA. (**B**) Cumulative number of people recruited over time. (**C**) Complementary cumulative distribution of the inter–sign-up time on a semi-log scale with an exponential fit. Shown is a larger-than-exponential drop off at the end of the graph, wich is due to the time-critical nature of the task.

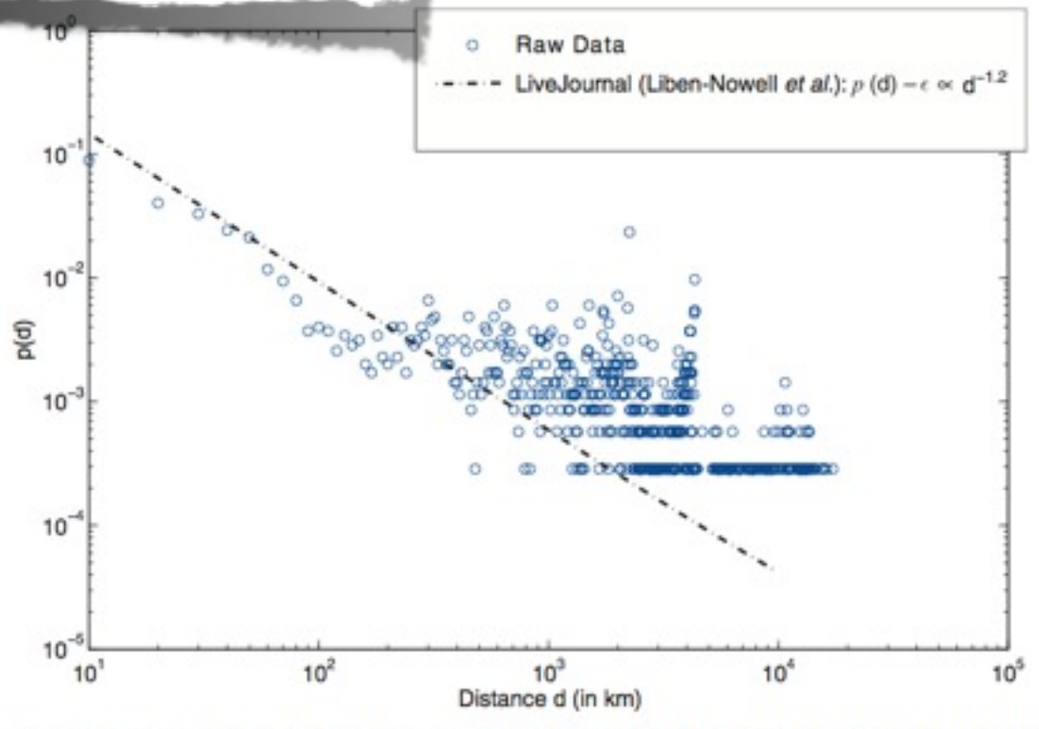


Fig. 3. Distribution of distance between recruiter nodes and their recruits. The dotted line shows the best-fit rank-based friendship model by Liben-Nowell *et al.* (*30*). We apply the same treatment to our data points as in Liben-Nowell *et al.* by rounding distances to multiples of 10 km. Approximate geographic locations were discovered from users' Internet provider addresses during sign-up.

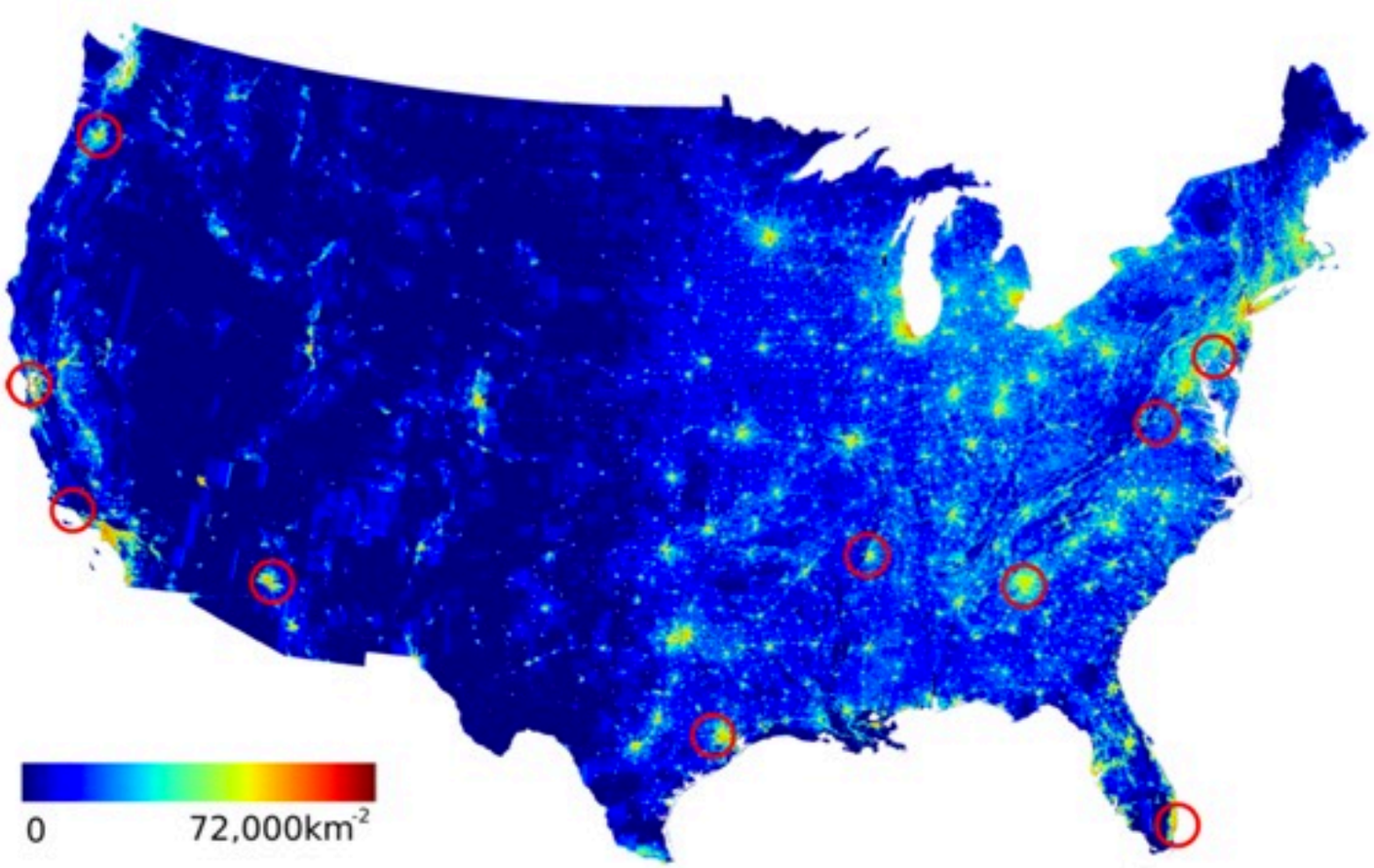
PNAS

Limits of social mobilization

Alex Rutherford[a], Manuel Cebrian[b,c], Sohan Dsouza[a], Esteban Moro[d,e], Alex Pentland[f], and Iyad Rahwan[a,g,1]

[a]Computing and Information Science, Masdar Institute of Science and Technology, Abu Dhabi 54224, United Arab Emirates; [b]Department of Computer Science and Engineering, University of California at San Diego, La Jolla, CA 92093; [c]National Information and Communications Technology Australia, Melbourne, VIC 3010, Australia; [d]Departamento de Matemáticas and Grupo Interdisciplinar de Sistemas Complejos, Universidad Carlos III de Madrid, 28911 Madrid, Spain; [e]Instituto de Ingeniería del Conocimiento, Universidad Autónoma de Madrid, 28049 Madrid, Spain; [f]Media Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139; and [g]School of Informatics, University of Edinburgh, Edinburgh EH8 9AB, United Kingdom

Edited* by Jon Kleinberg, Cornell University, Ithaca, NY, and approved March 1, 2013 (received for review Septemb



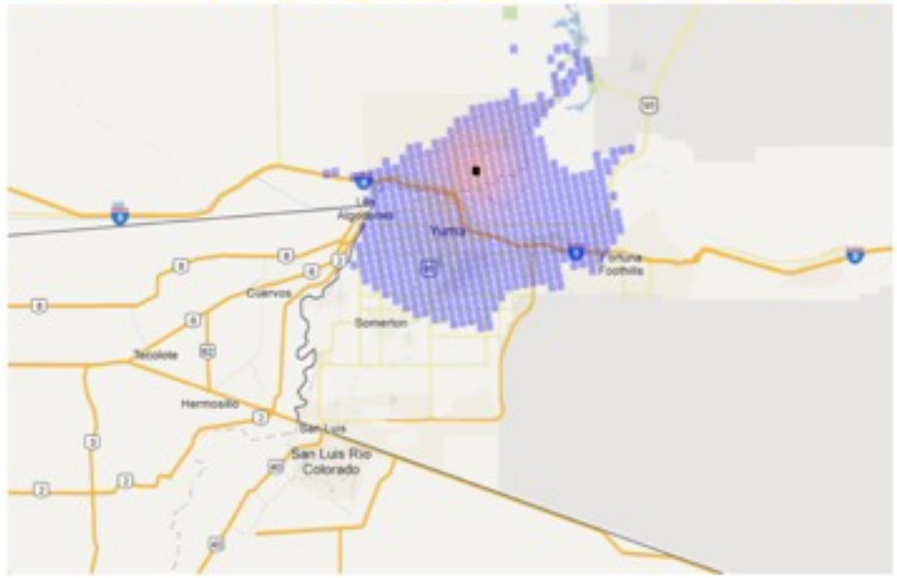


Figure 1: Map of Population Density (logarithmic scale, per km^2) Across Mainland USA and Locations of Balloons in Red Balloon Challenge. (Lambert Azimuthal Equal Area Projection)

Limits of social mobilization

Alex Rutherford[a], Manuel Cebrian[b,c], Sohan Dsouza[a], Esteban Moro[d,e], Alex Pentland[f], and Iyad Rahwan[a,g,1]

[a]Computing and Information Science, Masdar Institute of Science and Technology, Abu Dhabi 54224, United Arab Emirates; [b]Department of Computer Science and Engineering, University of California at San Diego, La Jolla, CA 92093; [c]National Information and Communications Technology Australia, Melbourne, VIC 3010, Australia; [d]Departamento de Matemáticas and Grupo Interdisciplinar de Sistemas Complejos, Universidad Carlos III de Madrid, 28911 Madrid, Spain; [e]Instituto de Ingeniería del Conocimiento, Universidad Autónoma de Madrid, 28049 Madrid, Spain; [f]Media Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139; and [g]School of Informatics, University of Edinburgh, Edinburgh EH8 9AB, United Kingdom

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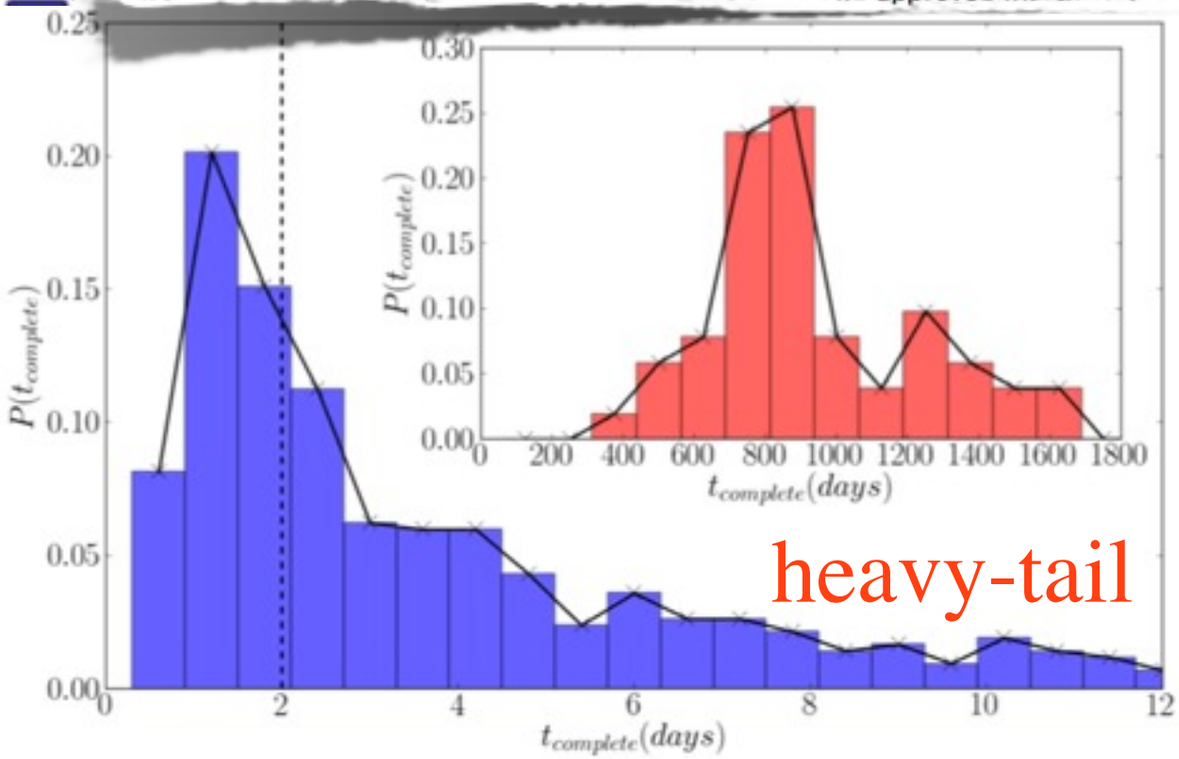

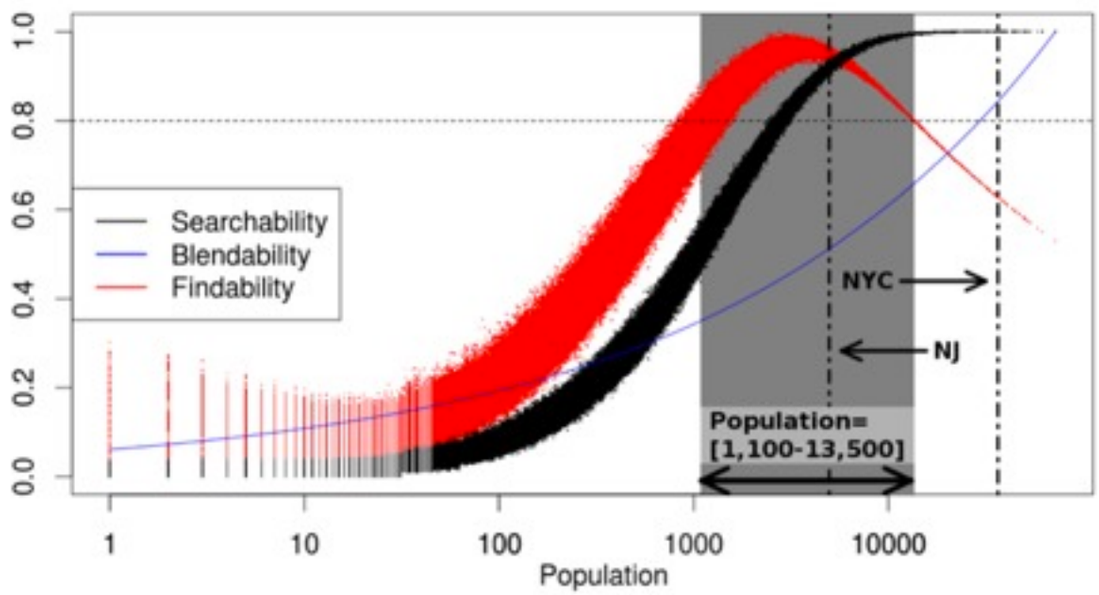

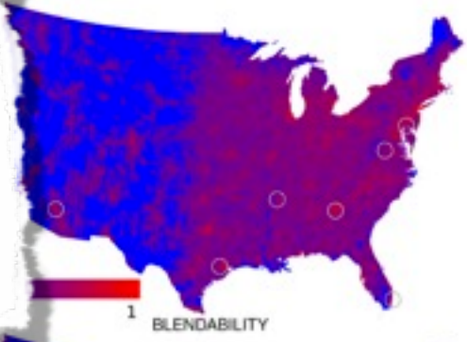

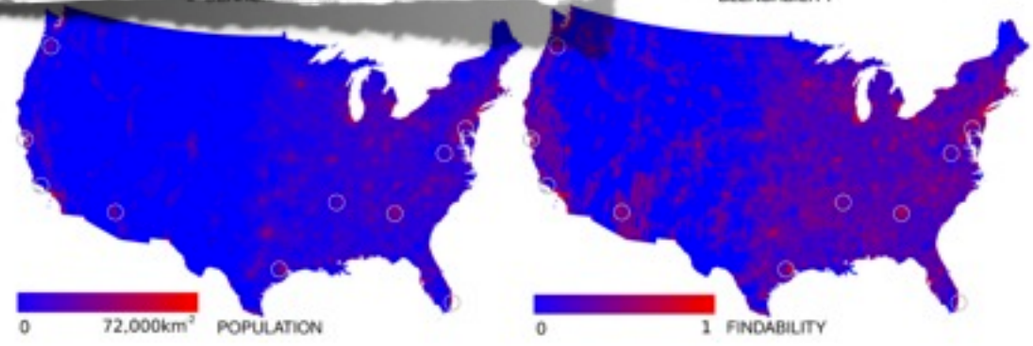

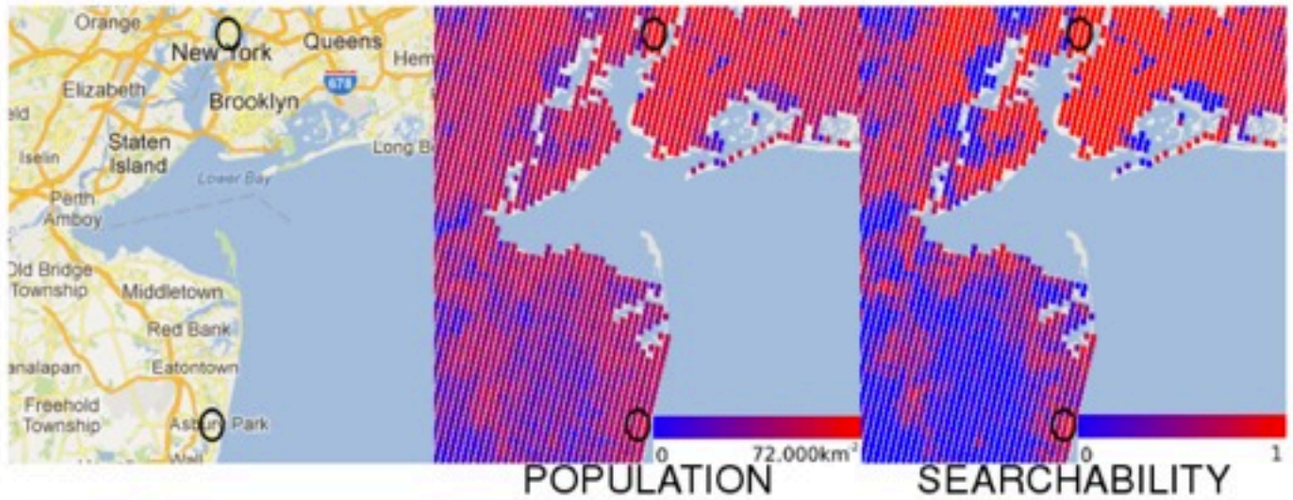

STOC'12, May 19–22, 2012, New York, New York, USA.
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Finding Red Balloons with Split Contracts: Robustness to Individuals' Selfishness

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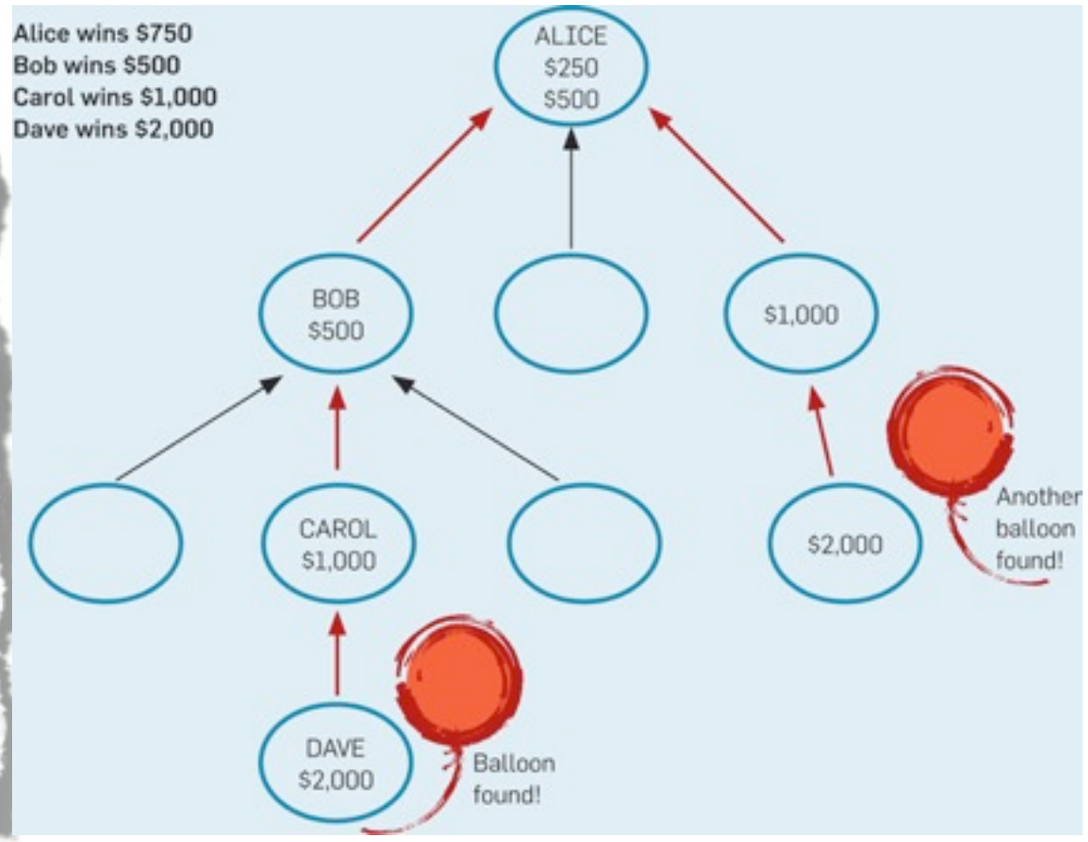
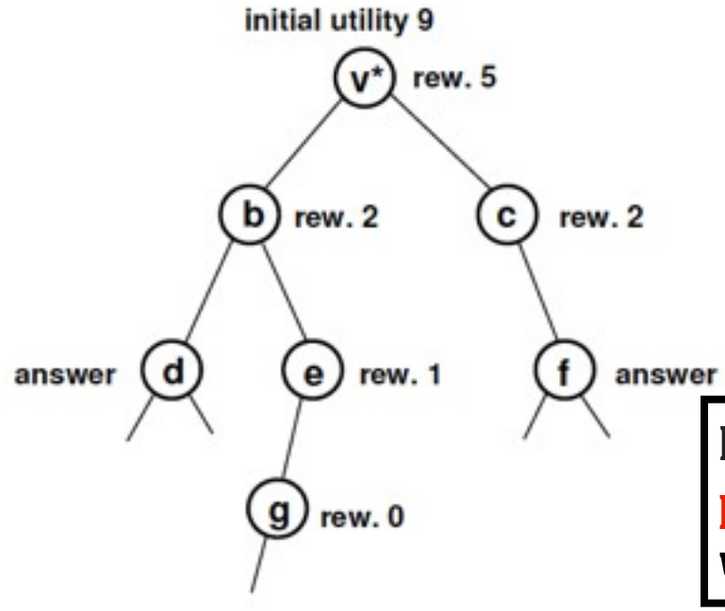


linear investment in any arbitrary Galton-Watson process with **b > 1**

THEOREM 15 (**Efficiency**). *Consider any Galton-Watson branching process with $b > 1$. Then, at equilibrium, the root retrieves the answer with probability at least $\sigma = 1 - \zeta$ provided an investment of*

$$r^* = \frac{4}{\epsilon} \cdot \max\left\{\frac{1}{b-1}, \frac{1}{\epsilon} \cdot \frac{1}{1-\Psi'(\zeta)}\right\} \cdot h_\Psi(\epsilon, n).$$

In the case of a ray, with $b = 1$ and $c_0 = \zeta = 0$, an investment of $r^* = 4 \cdot \frac{n}{\epsilon^2} \cdot h_\Psi(\epsilon, n) = 4 \cdot \frac{n^2}{\epsilon^2} \ln \frac{1}{\epsilon}$ suffices.



Kleinberg-Raghavan
polinomial investment
with **b < 2**

Finding 10 balloons across the U.S. illustrates how the Internet has changed the way we solve highly distributed problems.

BY JOHN C. TANG, MANUEL CEBRIAN, NICKLAUS A. GIACOBE, HYUN-WOO KIM, TAEMIE KIM, AND DOUGLAS "BEAKER" WICKERT

Reflecting on the DARPA Red Balloon Challenge

Figure 5. Fabricated photo posted during the challenge (left) (http://twitpic.com/s9kun) and photo taken by a pre-recruited observer in Albany, NY (right).

Figure 3. Typical real (top) and false (bottom) locations of balloons, with bottom map depicting five submissions with identical locations.

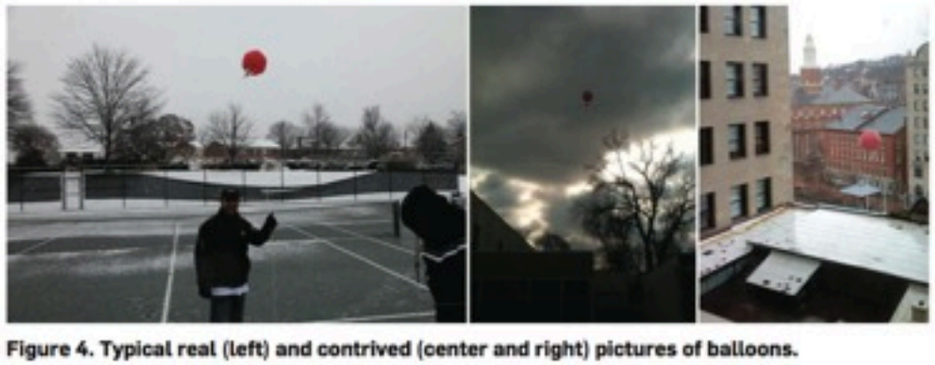


Figure 4. Typical real (left) and contrived (center and right) pictures of balloons.

Comment by LittleDagny on December 3, 2009 at 11:09pm
Other teams we need to infiltrate!!

http://balloon.media.mit.edu/ - the MIT team
http://balloonfinder.superfunhappy.com/doku.php
http://theredballoons.com/ - seems pretty dead-ish
http://www.darpaballoon.com/ - Stiff competition, they even have "outreach posts" for facebook, myspace, twitter, etc.
http://www.ispyaredballoon.com/ - Georgia Tech's group

flickr from YAHOO!
Home The Tour Sign Up Explore

someone else's balloon

Darpa red balloon challenge going on... a friend of mine in Boulder sent this pic to me... wow, hope they win!

We had a good time romping about and sending balloons up in Cambridge, Belmont, Somerville and some other places. We didn't have time to stick around and pretend to be DARPA employees, but once back home, we uploaded some photos from iphones with hacked exif data to modify the GPS coordinates.

(a) Correct Locations

(b) Submissions

85% of submissions were incorrect.

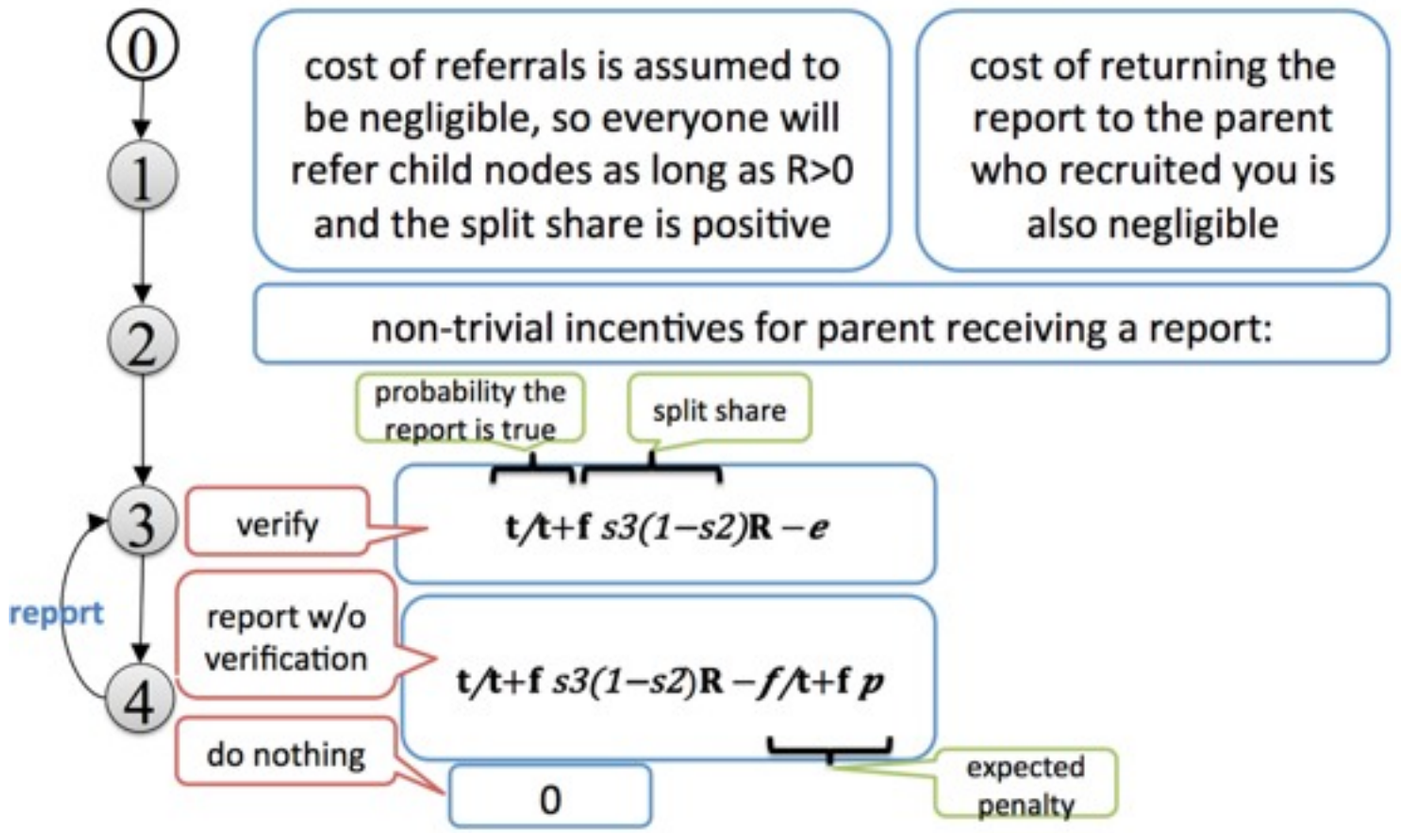
OPEN ACCESS Freely available online

PLOS | ONE

Verification in Referral-Based Crowdsourcing

Victor Naroditskiy[1]*, Iyad Rahwan[2,3], Manuel Cebrian[4,5], Nicholas R. Jennings[1,6]

1 Electronics and Computer Science, University of Southampton, Southampton, United Kingdom, **2** Masdar Institute of Science and Technology, Abu Dhabi, United Arab Emirates, **3** School of Informatics, University of Edinburgh, Edinburgh, United Kingdom, **4** Department of Computer Science and Engineering, University of California at San Diego, La Jolla, California, United States of America, **5** National Information and Communications Technology Australia, Melbourne, Victoria, Australia, **6** Department of Computing and Information Technology, King Abdulaziz University, Jeddah, Saudi Arabia



Proposition 2. *The minimum reward sufficient to encourage participation of node i is*

$$r_i^{\min} = e\frac{t+f}{(1-s_{i-1})s_i t} = \frac{e}{(1-s_{i-1})s_i}(1+\frac{f}{t}) \qquad (3)$$

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PLOS ONE

Verification in Referral-Based Crowdsourcing

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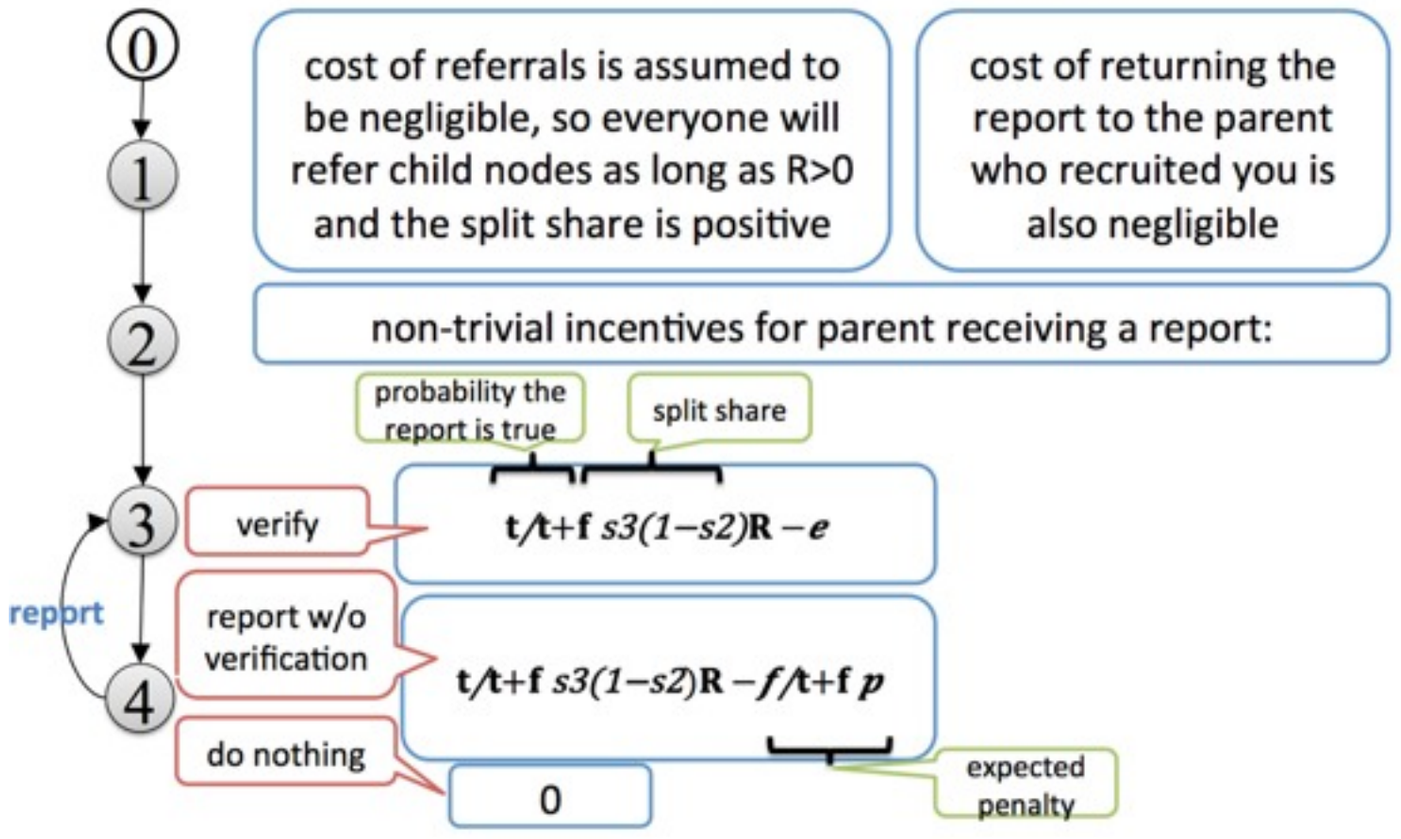
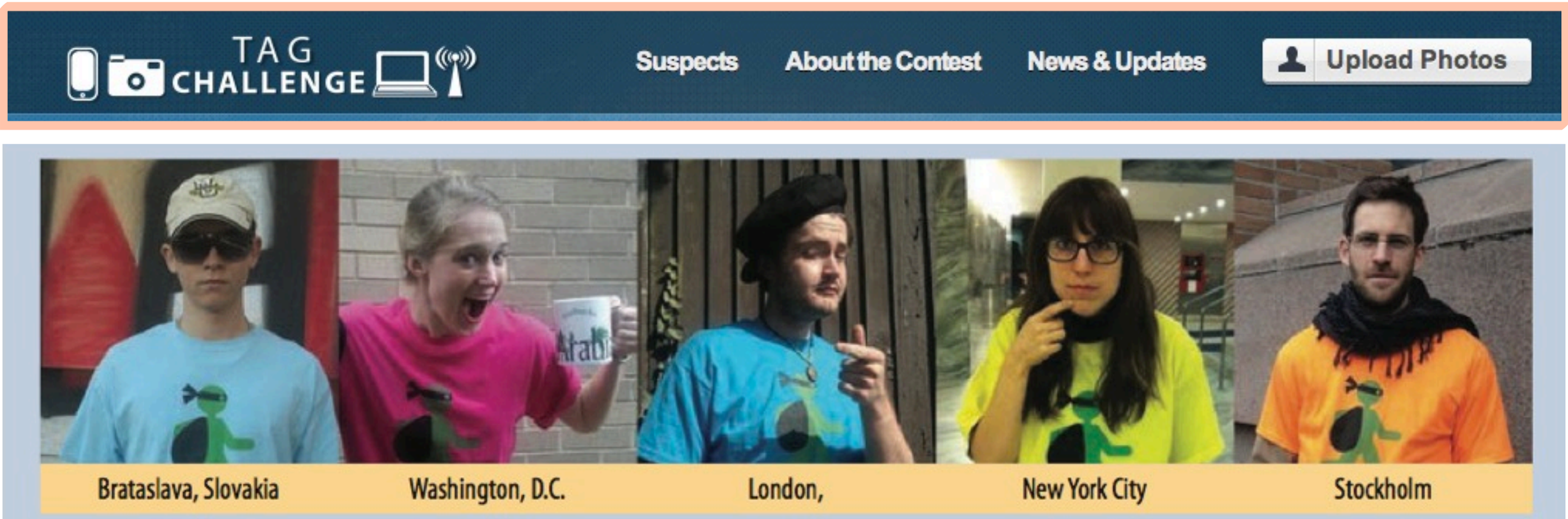
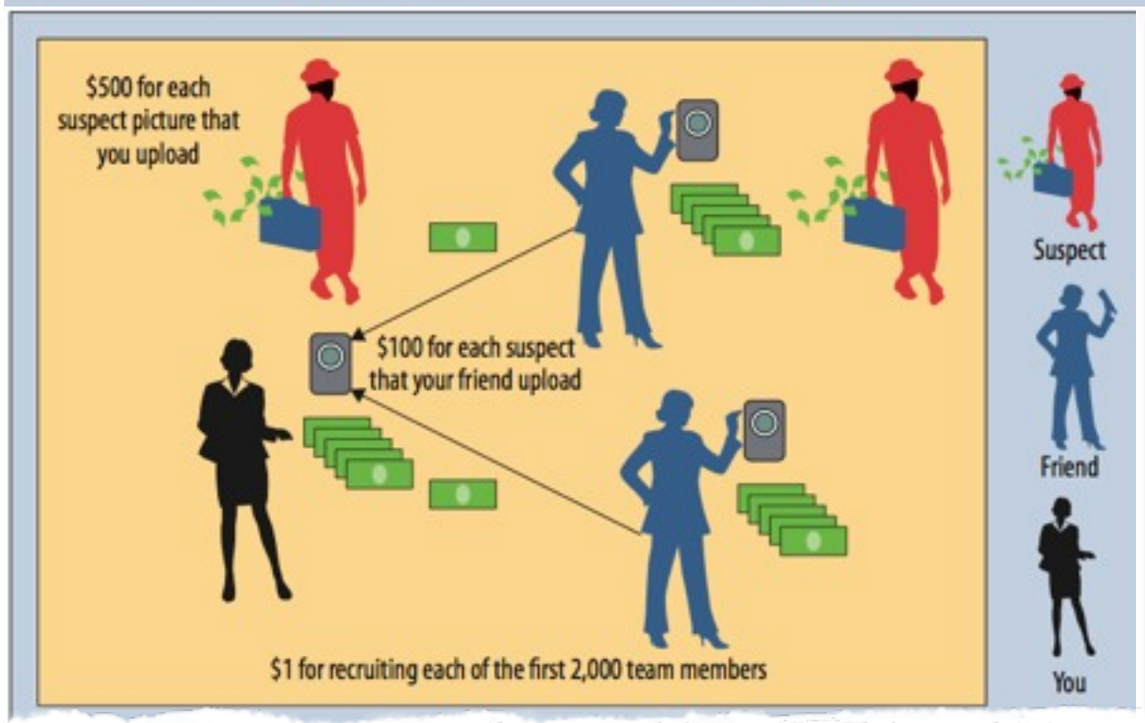


Theorem 1. *The $\frac{1}{2}$-split contract minimizes the reward required to recover the answer.*





Targeted social mobilization in a global manhunt

Alex Rutherford [1,*], Manuel Cebrian [3,4,*], Iyad Rahwan [1,2,*,†], Sohan Dsouza [1], James McInerney [5], Victor Naroditskiy [5], Matteo Venanzi [5], Nicholas R. Jennings [5], J.R. deLara [6], Eero Wahlstedt [7], Steven U. Miller [8]

[1]Computing and Information Science, Masdar Institute of Science and Technology, Abu Dhabi 54224, UAE; [2]School of Informatics, University of Edinburgh, Edinburgh EH8 9AB, UK; [3]National Information and Communications Technology Australia, Melbourne, Victoria 3010, Australia; [4]Department of Computer Science and Engineering, University of California at San Diego, La Jolla, CA 92093, USA; [5]School of Electronics and Computer Science, University of Southampton, Southampton SO17 1BJ, UK; [6]George Washington University, Washington DC 20052, USA; [7]University of Oxford, Oxford OX1 2JD, UK; [8]Champlain College, Burlington, VT 05401, USA

*A.R., M.C., and I.R. contributed equally to this work.

†To whom correspondence should be addressed: Email: irahwan@acm.org

FOR IMMEDIATE RELEASE
April 4, 2012

www.tag-challenge.com
tagchallenge@gmail.com

Crowdsourcing contest ends with partial victory for MIT team

Simulated person search sheds light on reach of social media;
Winning team locates "suspects" in three out of five cities in a single day.

Washington, D.C. – The 2012 TAG Challenge drew competition from teams across North America, Europe, and the Middle East, as participants organized online in an effort to locate five fictitious "jewel thieves" in the U.S. and Europe.

The best performing team, the MIT-affiliated CrowdScanner, found suspects in Bratislava, Washington DC, and New York City, and submitted their photographs to the contest website by 7:17pm EST, 17 hours after the contest began.

Targeted social mobilization in a global manhunt

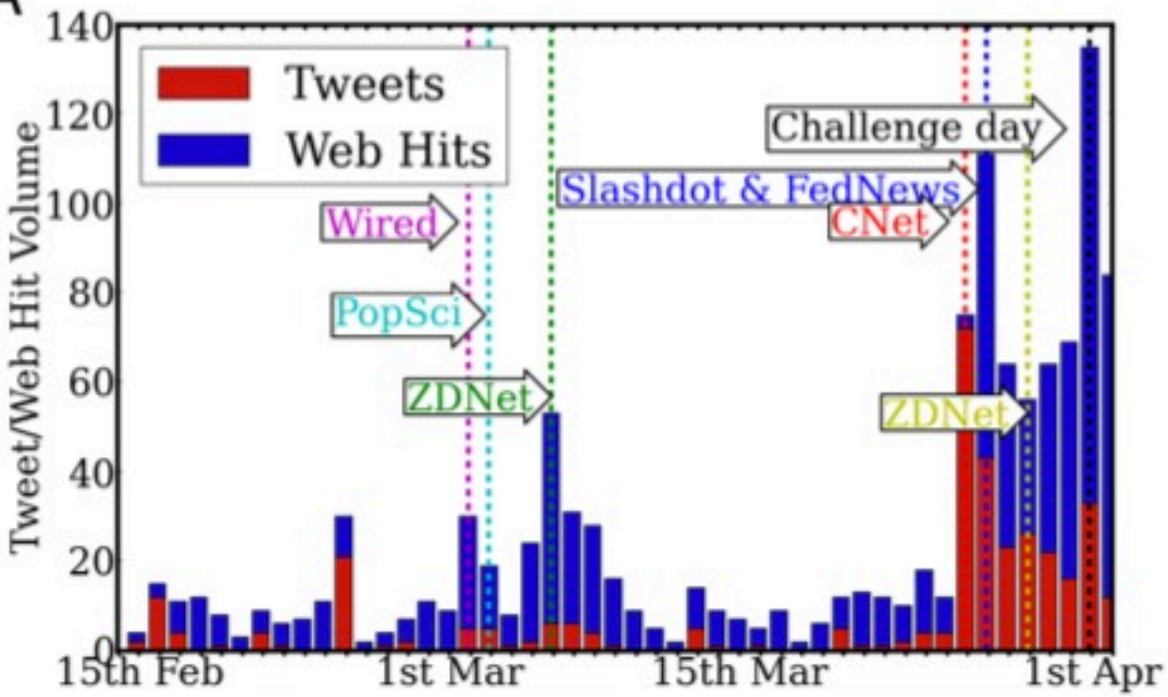
Alex Rutherford [1,*], Manuel Cebrian [3,4,*], Iyad Rahwan [1,2,*,†], Sohan Dsouza [1], James McInerney [5], Victor Naroditskiy [5], Matteo Venanzi [5], Nicholas R. Jennings [5], J.R. deLara [6], Eero Wahlstedt [7], Steven U. Miller [8]

[1]Computing and Information Science, Masdar Institute of Science and Technology, Abu Dhabi 54224, UAE; [2]School of Informatics, University of Edinburgh, Edinburgh EH8 9AB, UK; [3]National Information and Communications Technology Australia, Melbourne, Victoria 3010, Australia; [4]Department of Computer Science and Engineering, University of California at San Diego, La Jolla, CA 92093, USA; [5]School of Electronics and Computer Science, University of Southampton, Southampton SO17 1BJ, UK; [6]George Washington University, Washington DC 20052, USA; [7]University of Oxford, Oxford OX1 2JD, UK; [8]Champlain College, Burlington, VT 05401, USA

*A.R., M.C., and I.R. contributed equally to this work.

†To whom correspondence should be addressed; E-mail: irahwan@acm.org

A



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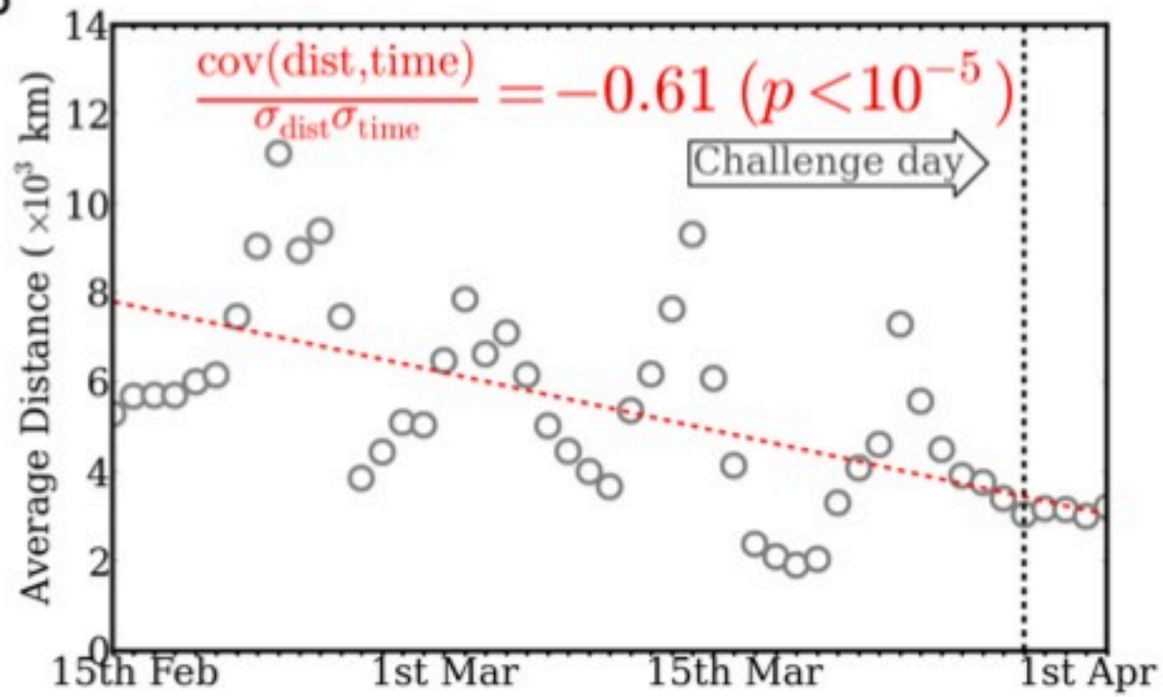

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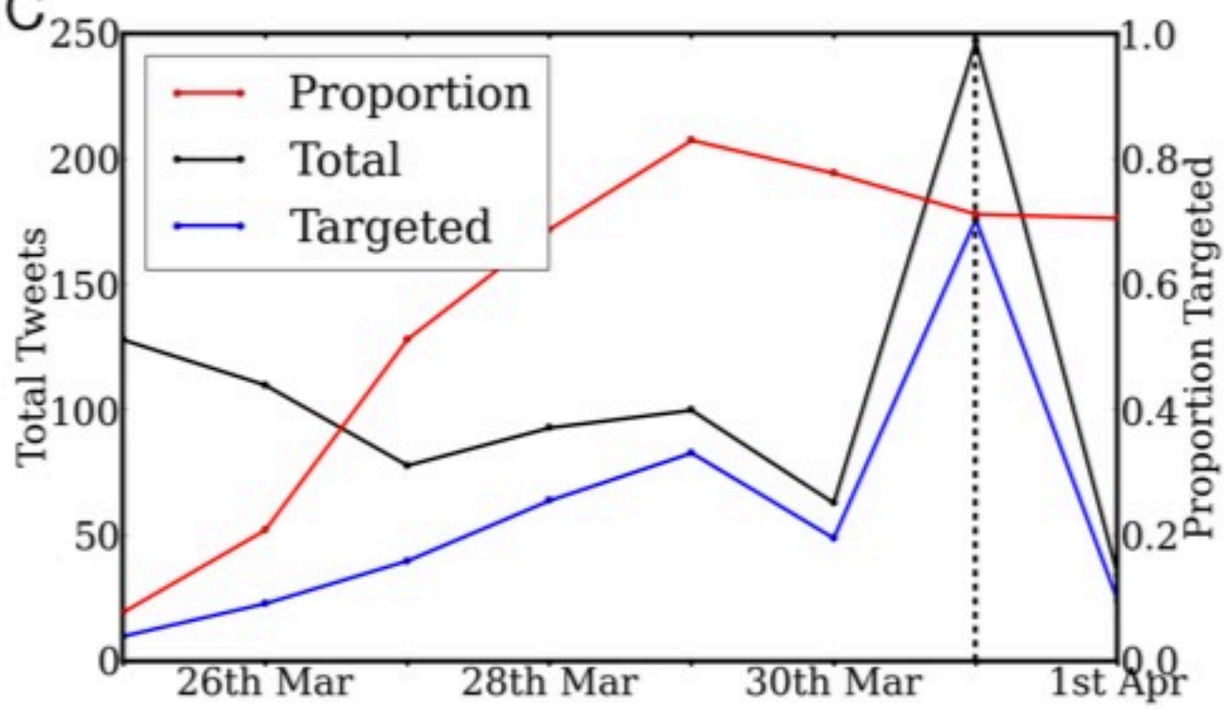

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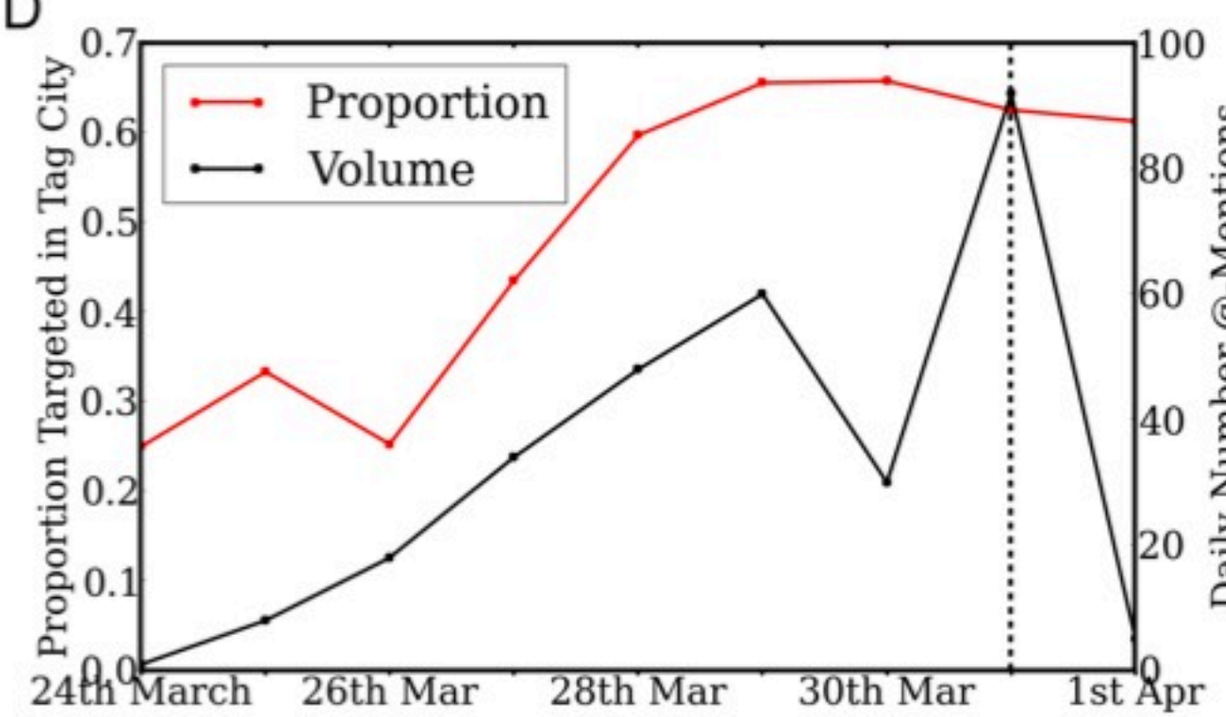

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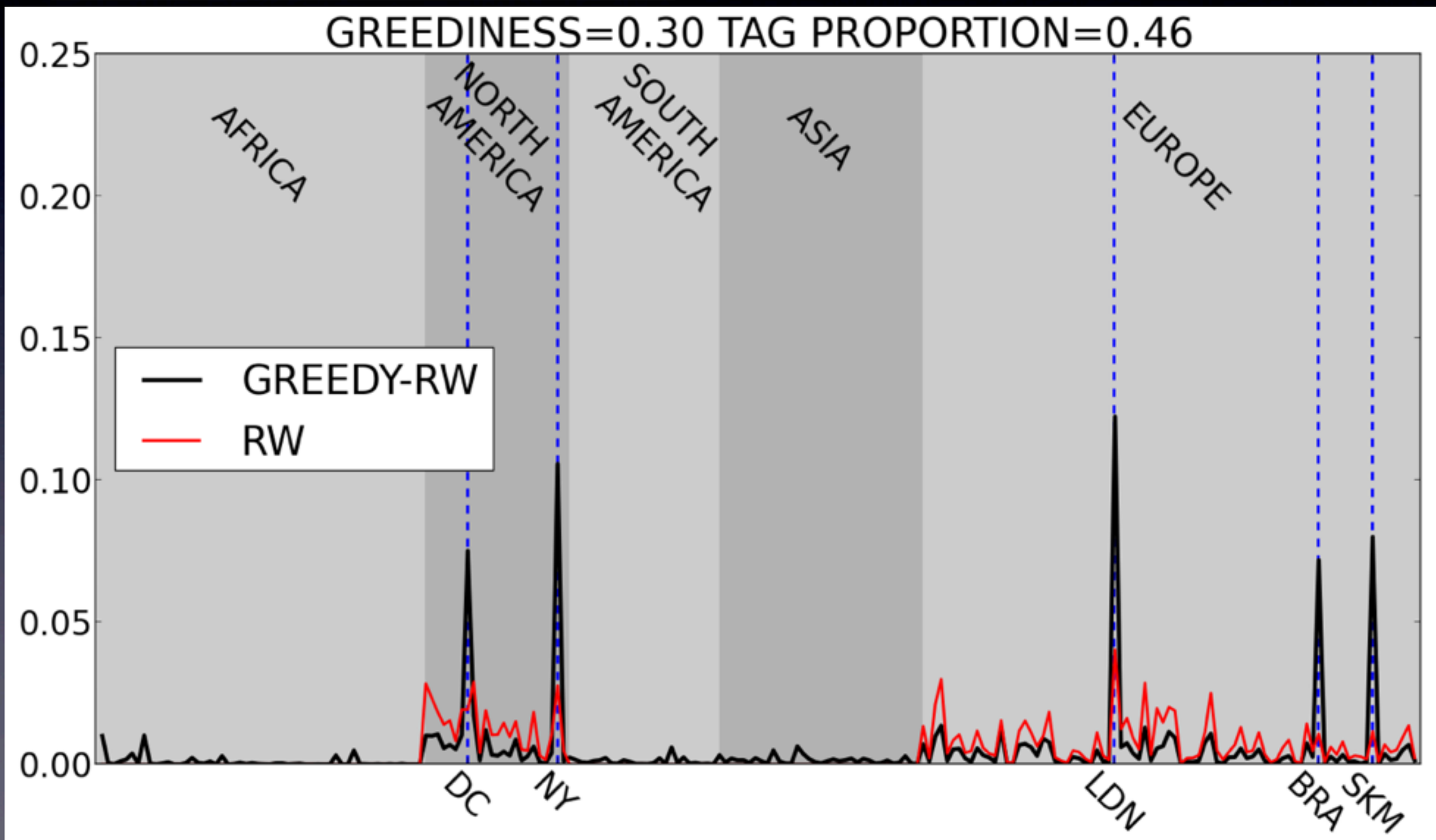
London
New York
Bratislava
Washington DC

Stockholm
London
New York
Bratislava
Washington DC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AFRICA
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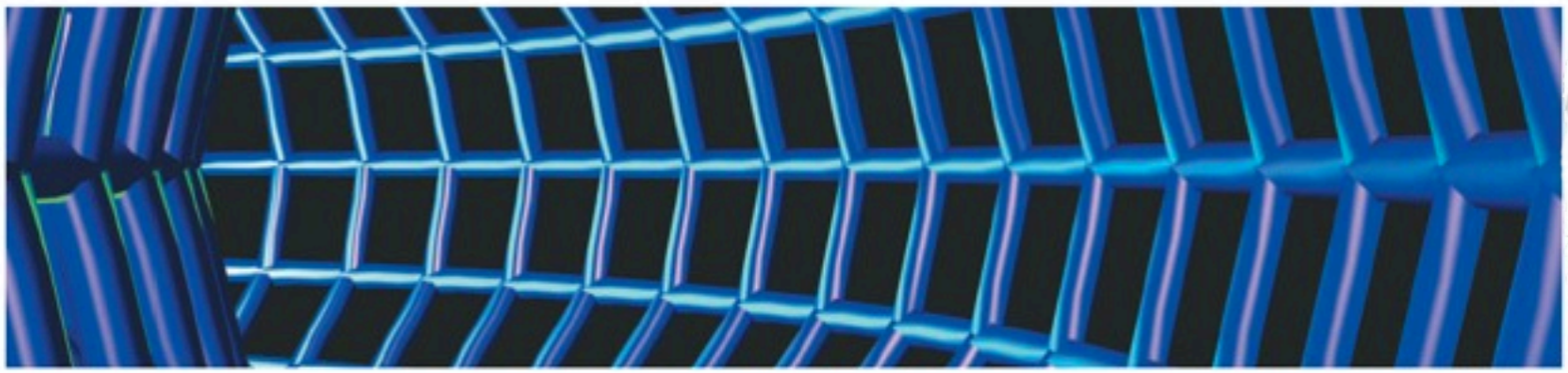
EUROPE
GREEDY-RW
RW
DC
NY
LDN
BRA
SKM

TAGTEAM

PERSPECTIVES



Global Manhunt Pushes the Limits of Social Mobilization

Iyad Rahwan, Sohan Dsouza, and Alex Rutherford, *Masdar Institute of Science & Technology, UAE*

Victor Naroditskiy, James McInerney, Matteo Venanzi, and Nicholas R. Jennings
University of Southampton, UK

Manuel Cebrian, *National ICT Australia and Massachusetts Institute of Technology*

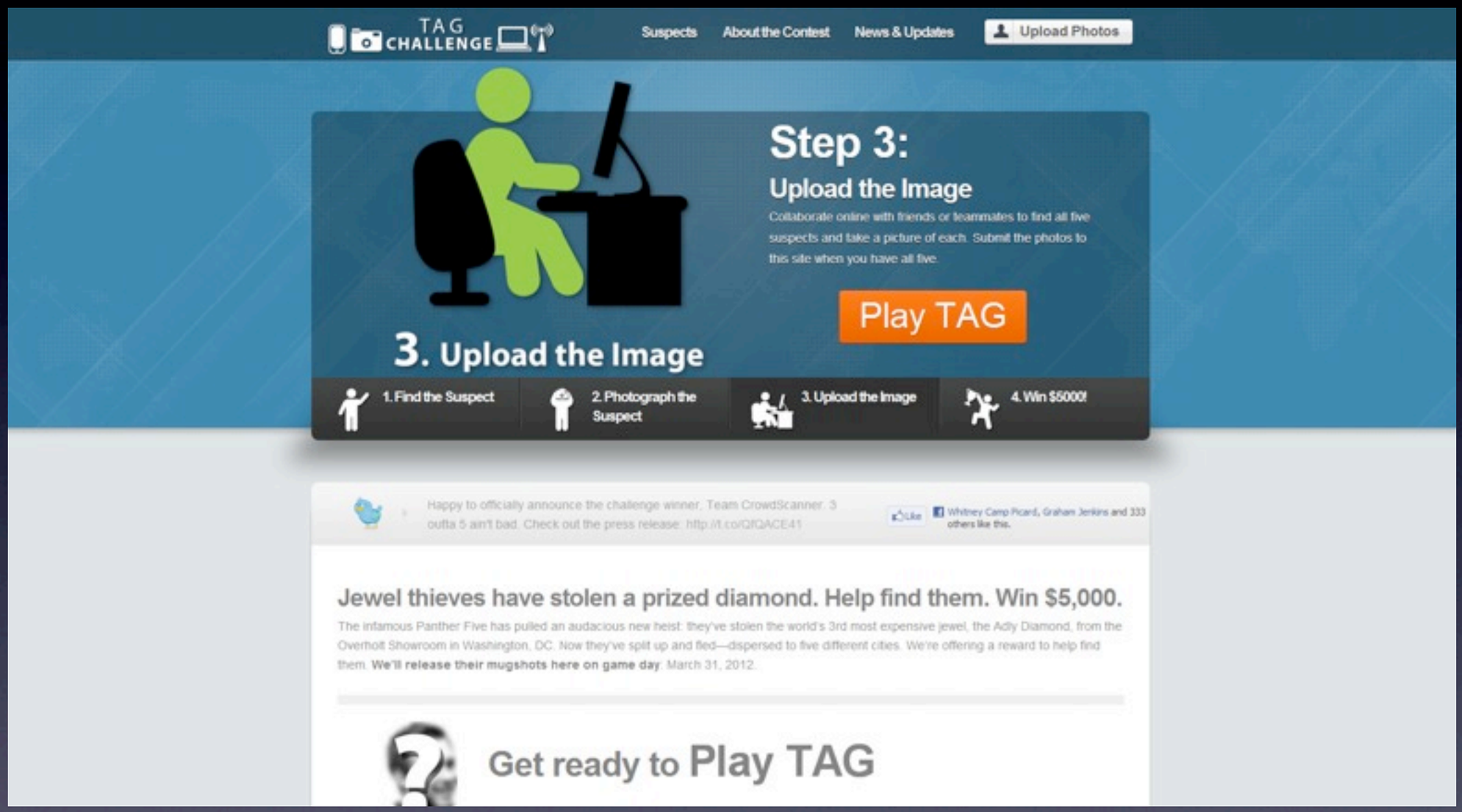
Mighty enemies!
Zachary Rabold
Gilbert Watson

Institute for Defense Analyses

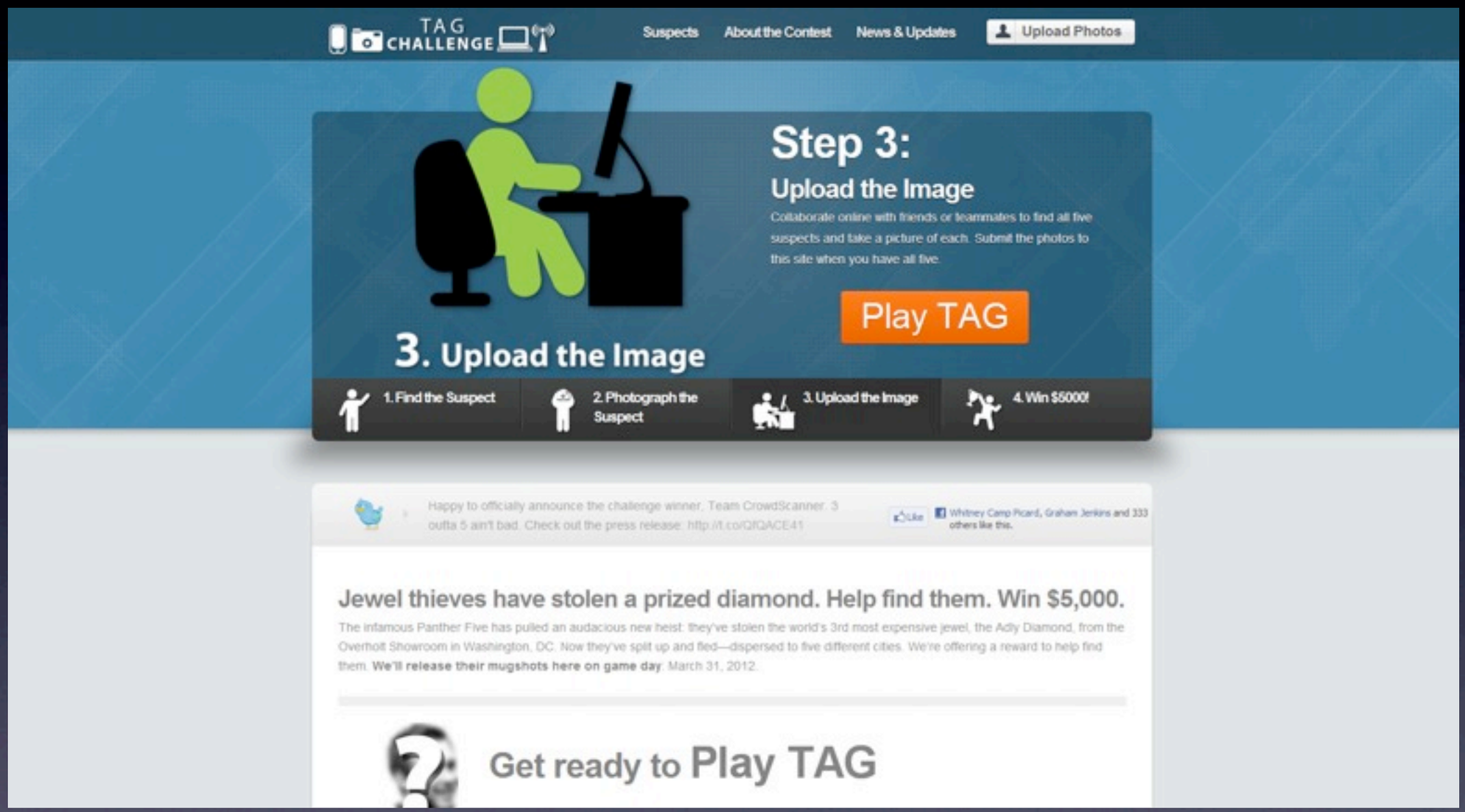
V2_v3

Addressing National Security Issues Since 1956

Official Website: www.tag-challenge.com



Our Website: www.tag-challenge.org



Twitter Spoofing

TAG Challenge
@TAG_challenge

A contest to test social media in international public safety: Find 5 jewel thieves in 5 cities, win $5,000. March 31, 2012. DC-NYC-London-Stockholm-Bratislava.
http://tag-challenge.com

Followed by TagTeam (Back Again) and Graham Jenkins .

143	204	37
TWEETS	FOLLOWING	FOLLOWERS

TAG Challenge @TAG_challenge 4 Apr
Happy to officially announce the challenge winner, Team CrowdScanner. 3 outta 5 ain't bad. Check out the press release: ow.ly/a55l5

TAG Challenge @TAG_challenge 3 Apr
RT @dagrier: Pop Sci has has nice summary of @TAGChallenge #crowdsourcing contest of last Saturday at bit.ly/HRy7mA

TAG Challenge @TAG_challenge 1 Apr
With three suspects found and photographed by 7:17pm EST, Team Crowdscanner has won TAG Challenge! Congratulations!

TAG Challenge
@TAGchallenge FOLLOWS YOU

A contest to test social media in international public safety: Find 5 jewel thieves in 5 cities, win $5,000. March 31, 2012. DC-NYC-London-Stockholm-Bratislava.
http://tag-challenge.com

Followed by TagTeam (Back Again) , EM Simpson , Graham Jenkins and Danger Room .

229	189	119
TWEETS	FOLLOWING	FOLLOWERS

TAG Challenge @TAGchallenge 4 Apr
Happy to officially announce the challenge winner, Team CrowdScanner. 3 outta 5 ain't bad. Check out the press release: ow.ly/a55l5
Details

TAG Challenge @TAGchallenge 1 Apr
With three suspects found and photographed by 7:17pm EST, Team Crowdscanner has won TAG Challenge! Congratulations!
Details

TAG Challenge @TAGchallenge 1 Apr
Suspects were located in NYC, DC, and Bratislava. Thanks to all those who participated. Official press release to follow.
Details

Discredit

TagTeam (Back Again) @TagTeam_ 27 Mar

Don't help amateur comedians, help @TagTeam_ win @TAG_challenge this weekend. tagteambackagain.com cc:@sohandsouza #buschleague

Expand

TagTeam (Back Again) @TagTeam_ 28 Mar

@abdulapopoola #buschleague refers to the former second tier of the great American sport of NASCAR. Join @TagTeam_ for the @TAG_challenge

View conversation

TagTeam (Back Again) @TagTeam_ 31 Mar

@TeamRave Why would I care about tweets to your whopping 16 followers - #posers #DARPAleftovers

View conversation

Discredit

Zack Rabold @ThisIsTheZemix 31 Mar

Help upset the #"pros" @CrowdScannerHQ by finding this girl @Starbucks #NationalMall #DC #CherryBlossoms @TagTeam_ pic.twitter.com/UBC7xd7x

View photo

Zack Rabold @ThisIsTheZemix 31 Mar

It's still #MarchMadness - help @TagTeam_ upset the #NuttyProfessors at @CrowdScannerHQ find her and DM us pic.twitter.com/ss84Tn2A

View photo Reply Retweet Favorite

Zack Rabold @ThisIsTheZemix 31 Mar

Hey #DC - help @TagTeam_ defend our hometurf and defeat the #NuttyProfessors at @CrowdscanningHQ #99percent pic.twitter.com/EazpRy7j

View photo

Zack Rabold @ThisIsTheZemix 31 Mar

I thought @CrowdScannerHQ was going to solve this in #onehour #BuschLeague

Expand

Discredit

TagTeam (Back Again) @TagTeam_ 27 Mar

Don't help amateur comedians, help @TagTeam_ win @TAG_challenge this weekend. tagteambackagain.com cc:@sohandsouza #buschleague

Expand

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@abdulapopoola #buschleague refers to the former second tier of the great American sport of NASCAR. Join @TagTeam_ for the @TAG_challenge

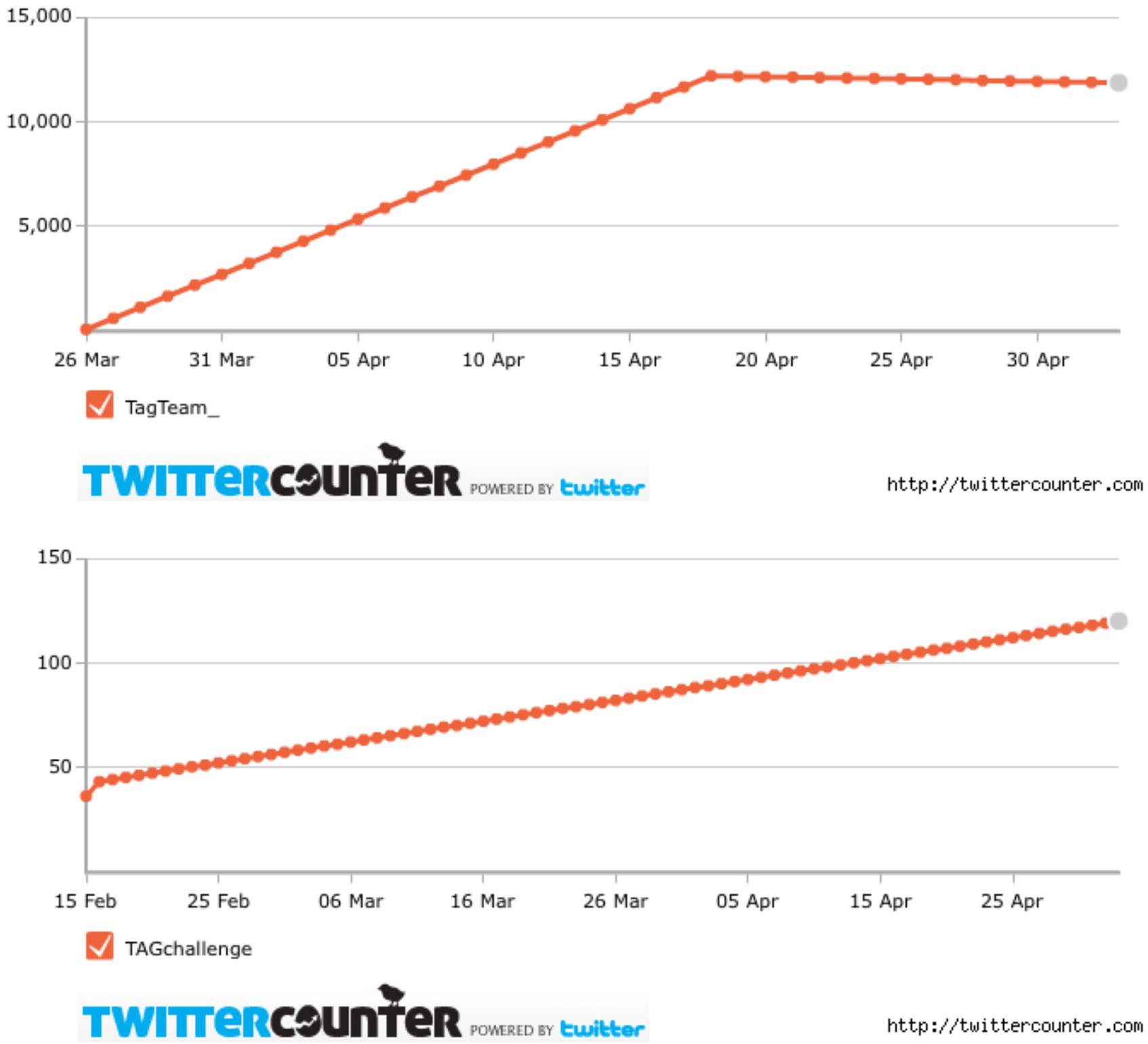
View conversation

TagTeam (Back Again) @TagTeam_ 31 Mar

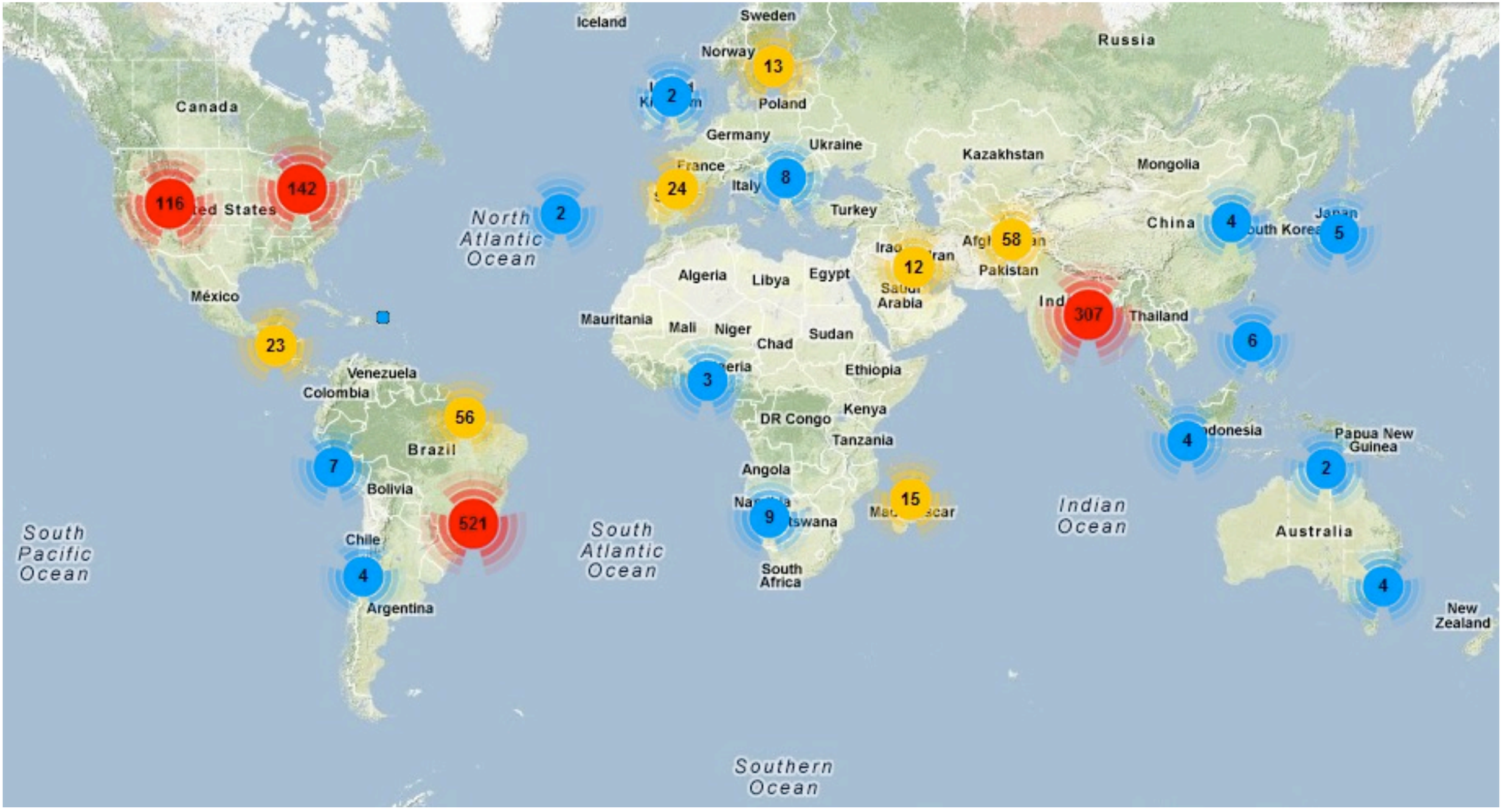
@TeamRave Why would I care about tweets to your whopping 16 followers - #posers #DARPAleftovers

View conversation

Fake followers?



Where Our Followers Were Located (Sample Size = 5000 Followers)



Allows people to perform a service call “Get Friends Fast” or GFF. We elected to buy this service to help create a “buzz” around our twitter profile.

From the Twitter glossary:

GFF [Get Followers Fast]: Sites that promise to get you more followers if you provide your username and password. After signing up, these sites send spam from your account. Don't use them.

Identified the *wrong* target!

Misidentified Target

Actual Stockholm Target

Body identified as student falsely implicated in Boston bombing

smh.com.au Apr 26th 2013

Credibility in the Age of Twitter: A Town Hall on the Marathon Bombing this Wednesday at the Nieman Foundation

by Seth Mnookin, blogs.plos.org April 30th 2013

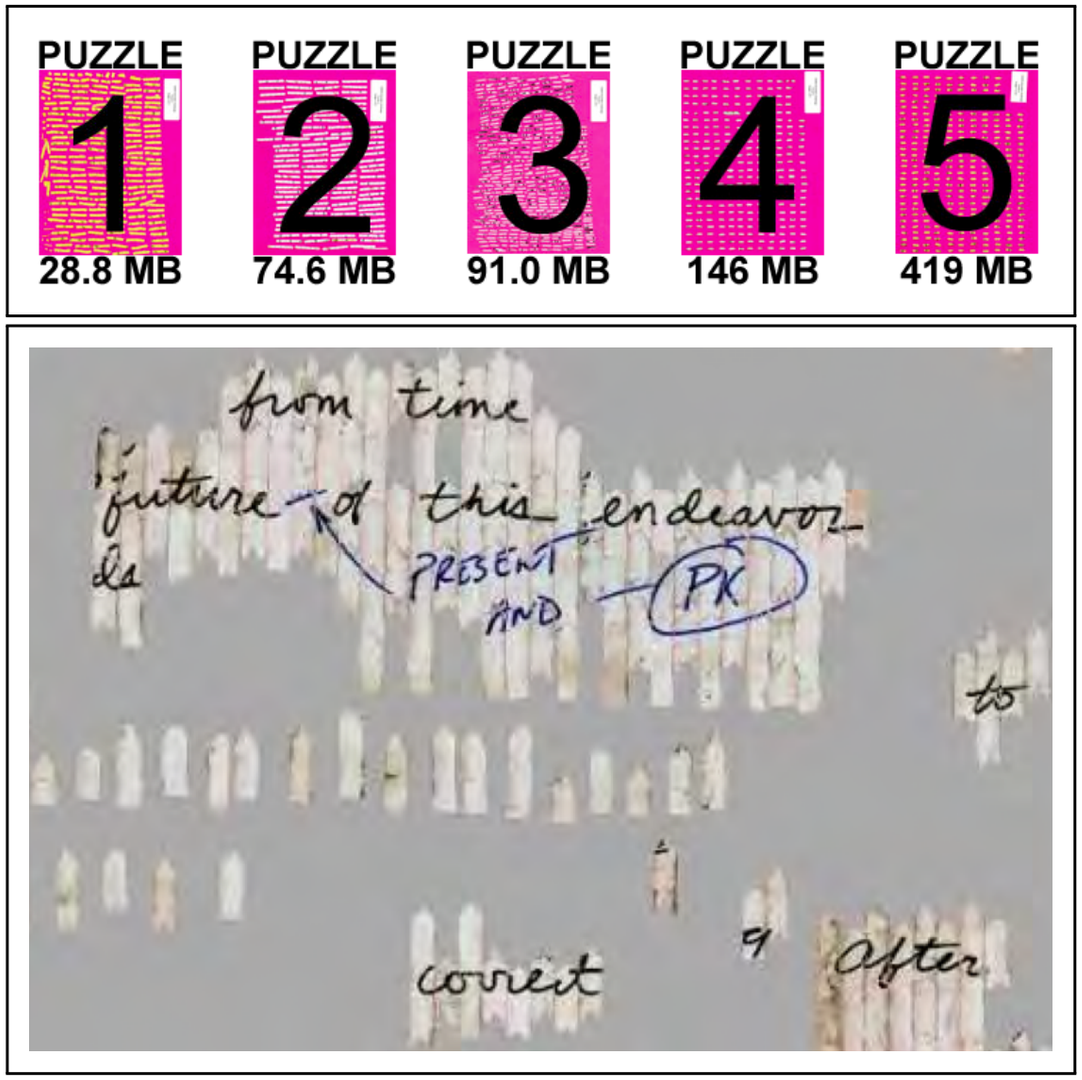
How the Internet Accused a High School Student of Terrorism

by Winston Ross, thedailybeast.com

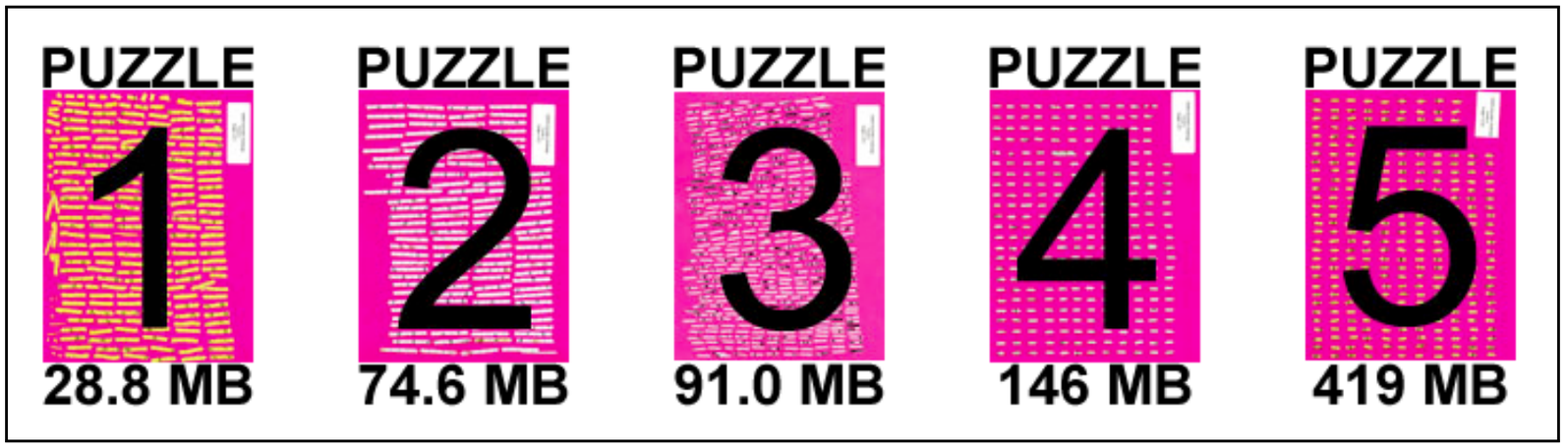
Reddit, Boston and the missing student

by Alex Hern, newstatesman.com April 19th 2013

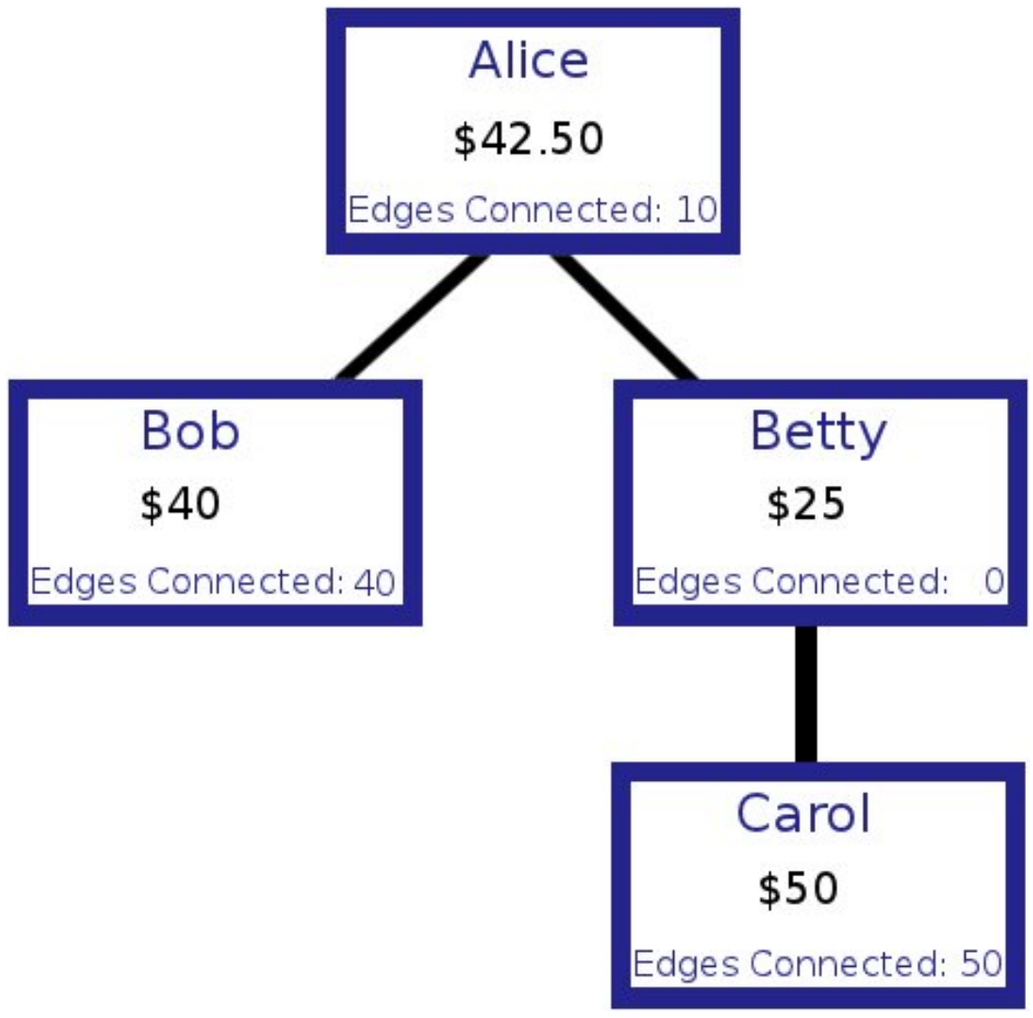
DARPA Shredder Challenge (2011)



- $50,000 reward.
- Why time-critical?
  - Assemble for 1 month.
  - Essentially no recruitment time.
- Why social?
  - NP-complete problem.
  - $224, 373, 1115, 2340, 6068$ pieces.
- Social mobilization for a combinatorial problem.

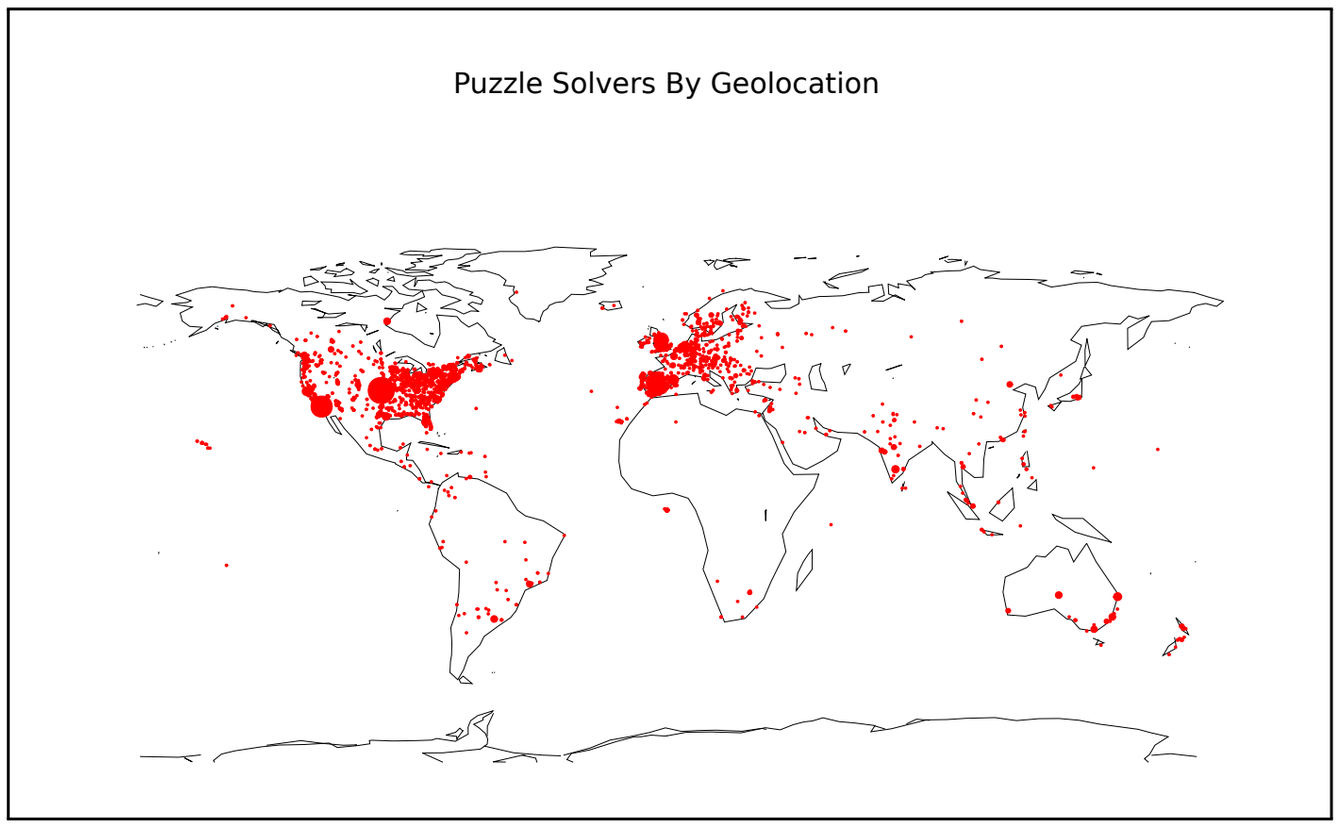


(a) $224, 373, 1115, 2340, 6068$ pieces $\approx$ 25000 connections.

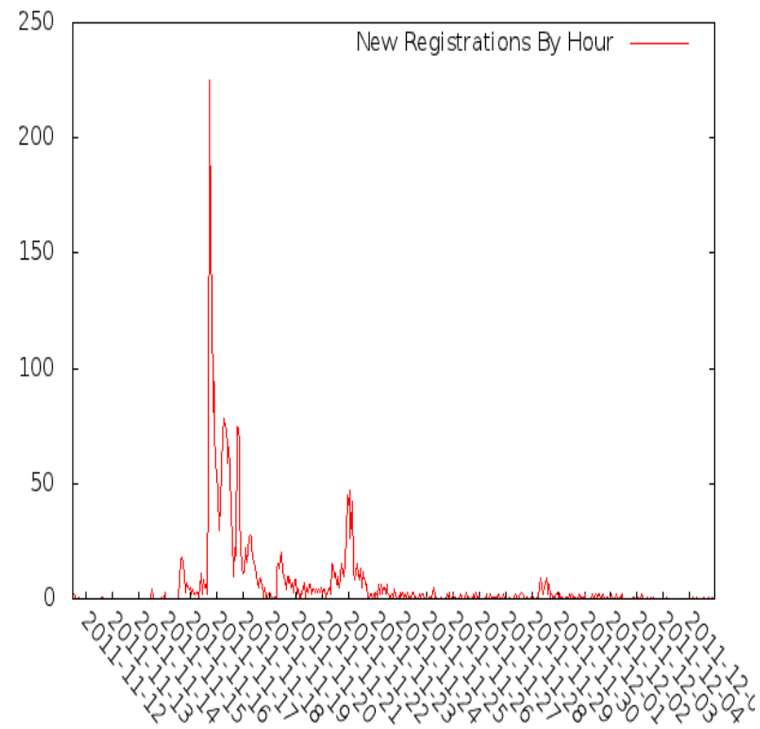


(b) Query incentive networks, again.

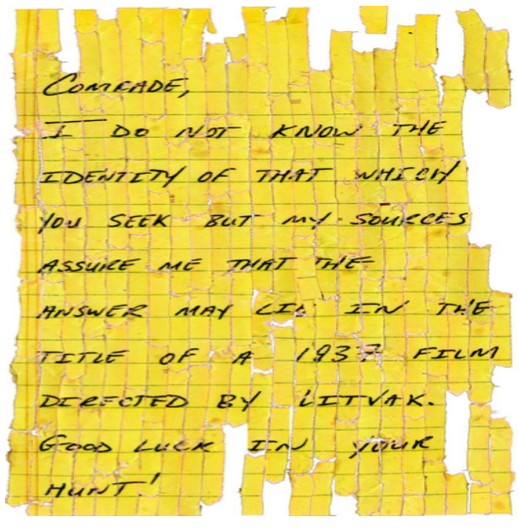
3,667 recruits.



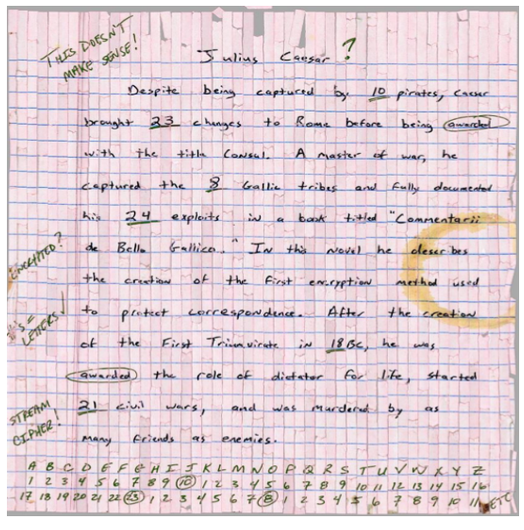
(a)



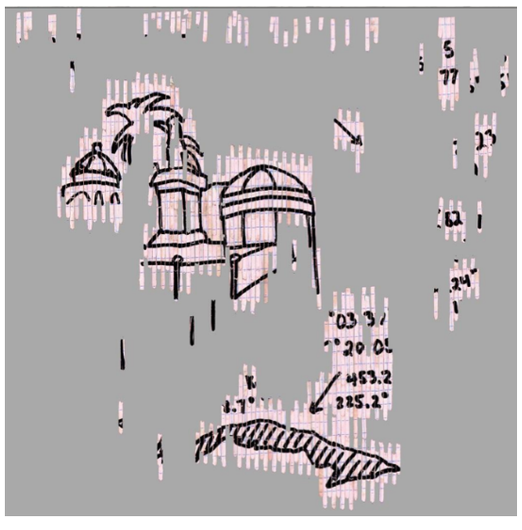
(b)



(c) #1



(d) #2

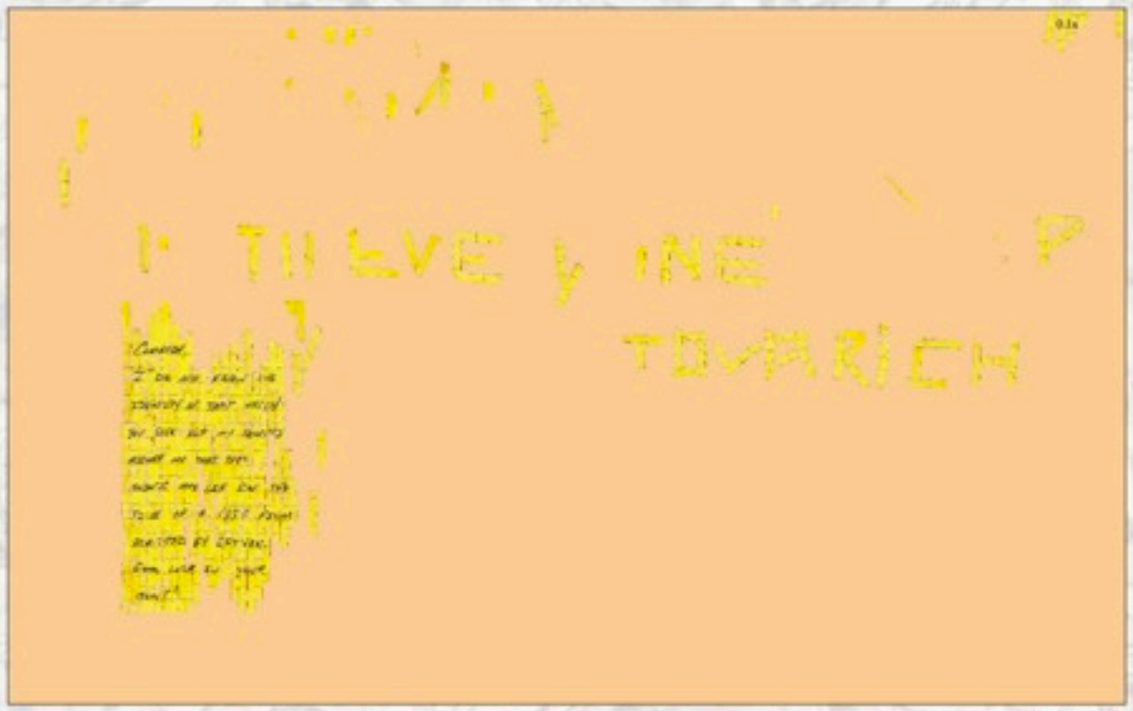


(e) #3

Honorable Mention Submissions

The following page contains spoiler information.

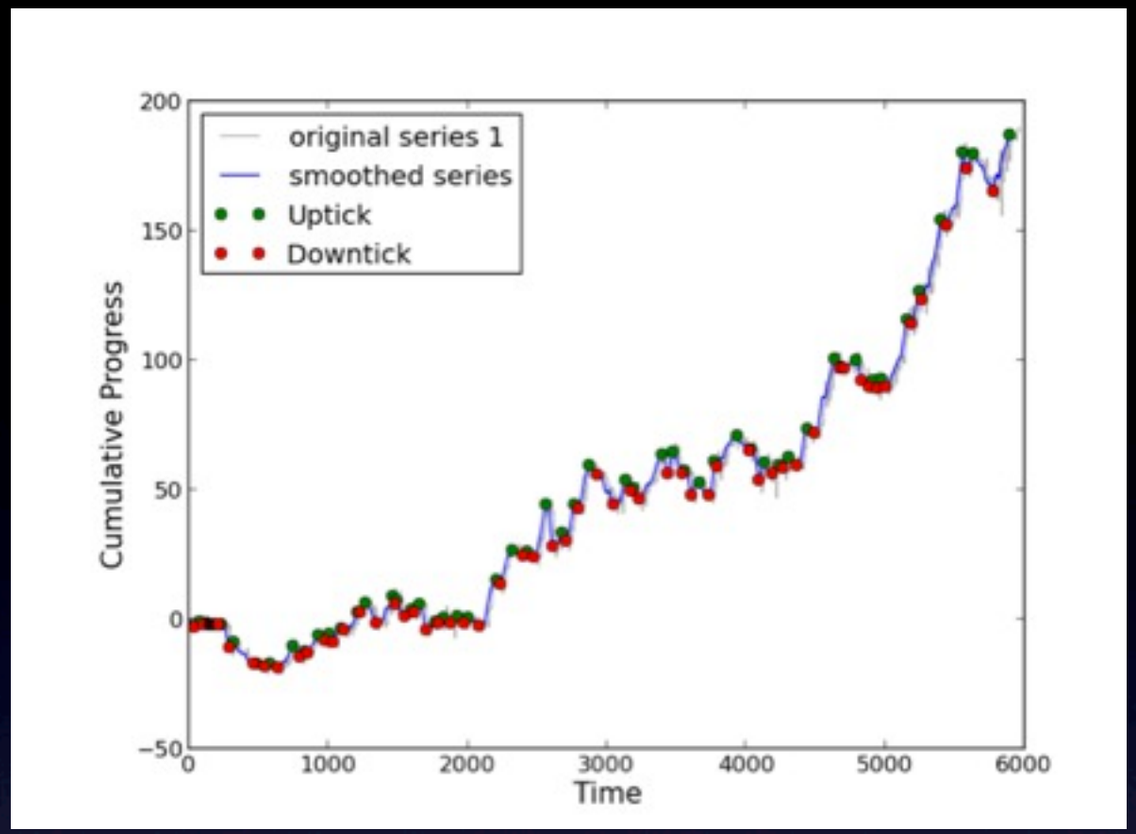
Puzzle 1



UCSD
(16 Nov)

Leaderboard Summary
Final

Place	Display Name	Score
1	All Your Shreds Are Belong To U.S.	50
2	Schroddon	30
3	wasabi	26
4	MKI	22
5	mmvd	22
6	University of California, San Diego	22
7	Craig Landrum	19
8	mkelly	19
9	Icandoit	19
10	Goldsong	17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smoothed series
Uptick
Downtick
Cumulative Progress
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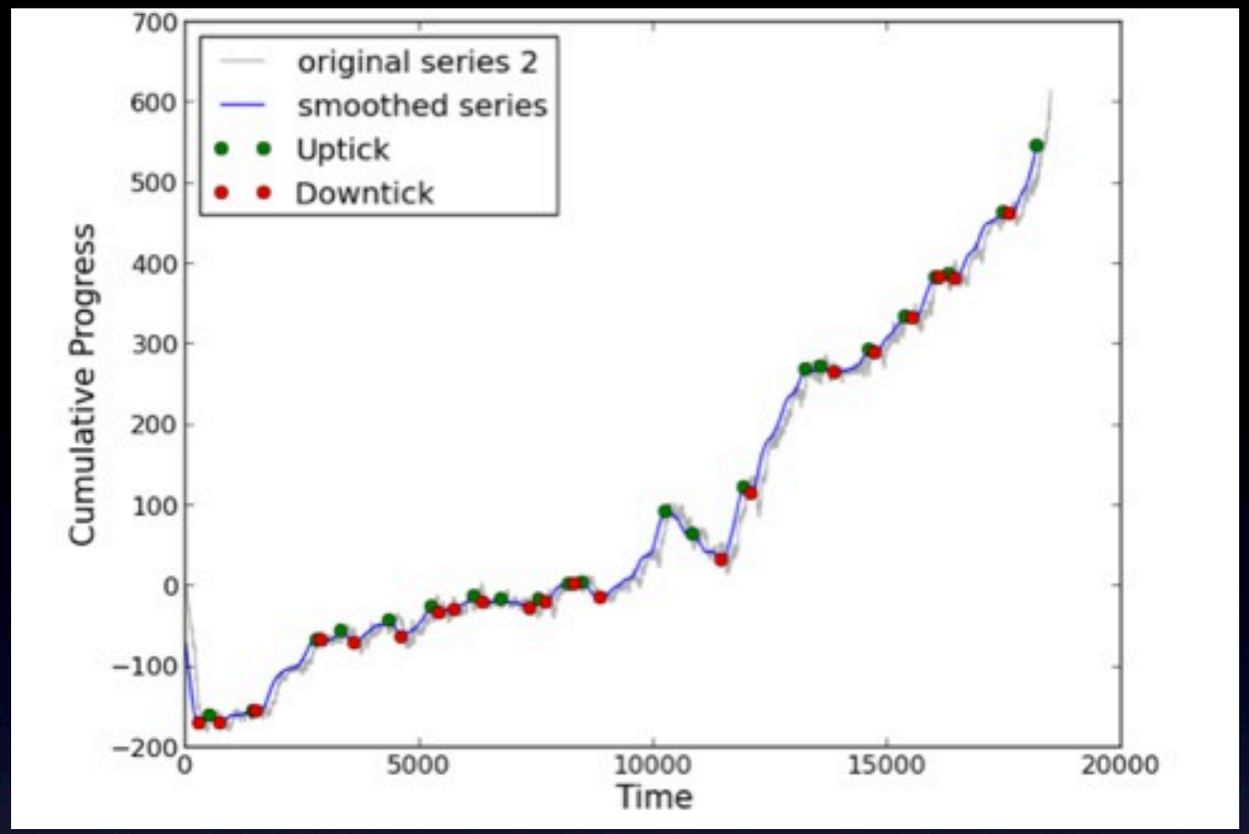
100
50
0
−50
0
1000
2000
3000
4000
5000
6000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smoothed series
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Downtick
Cumulative Progress
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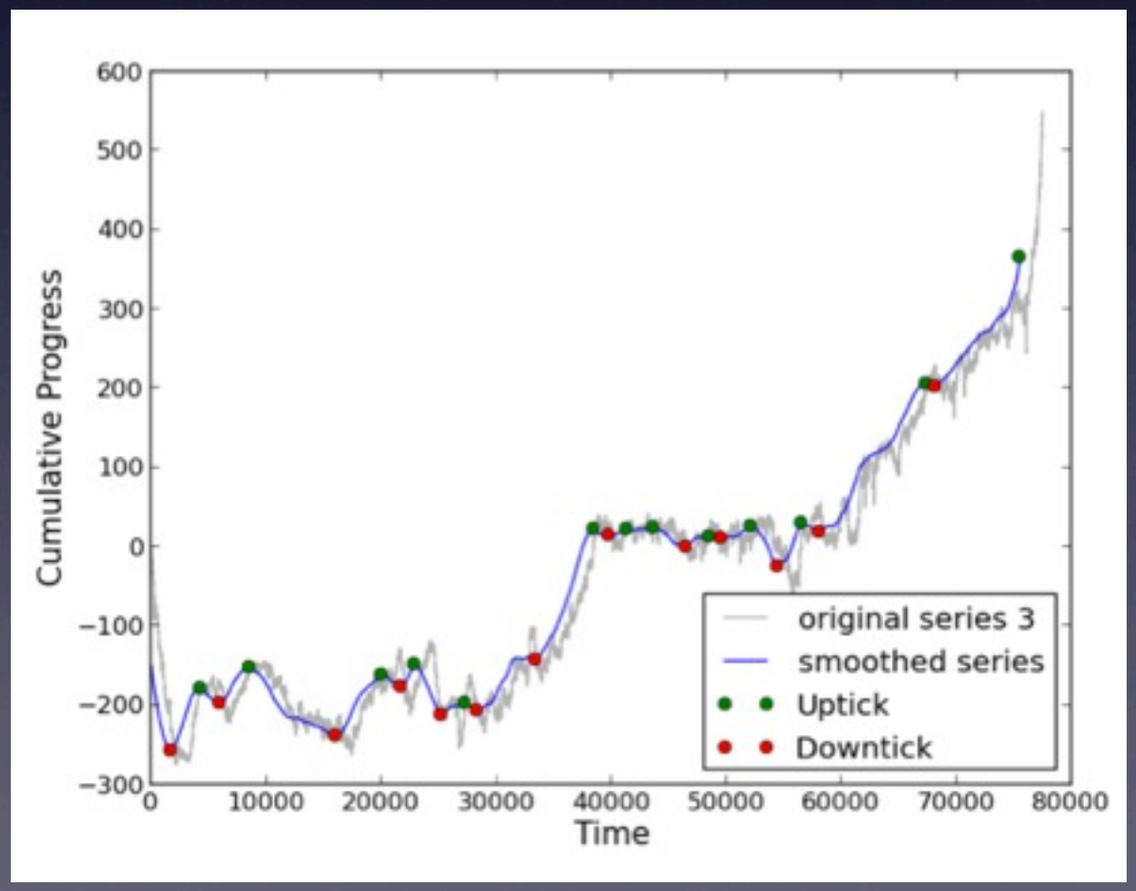
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Downtick
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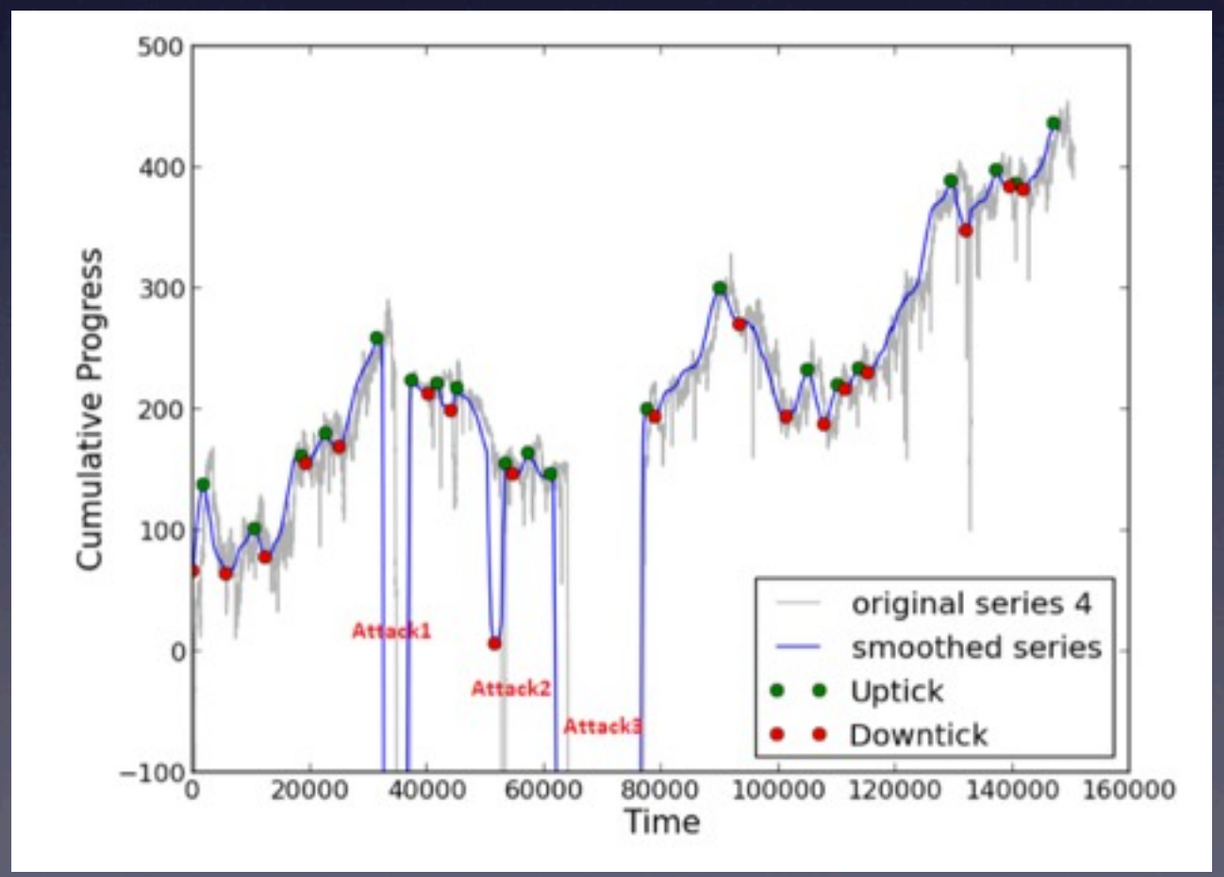
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smoothed series
Uptick
Downtick
Attack1
Attack2
Attack3
Cumulative Progress
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200
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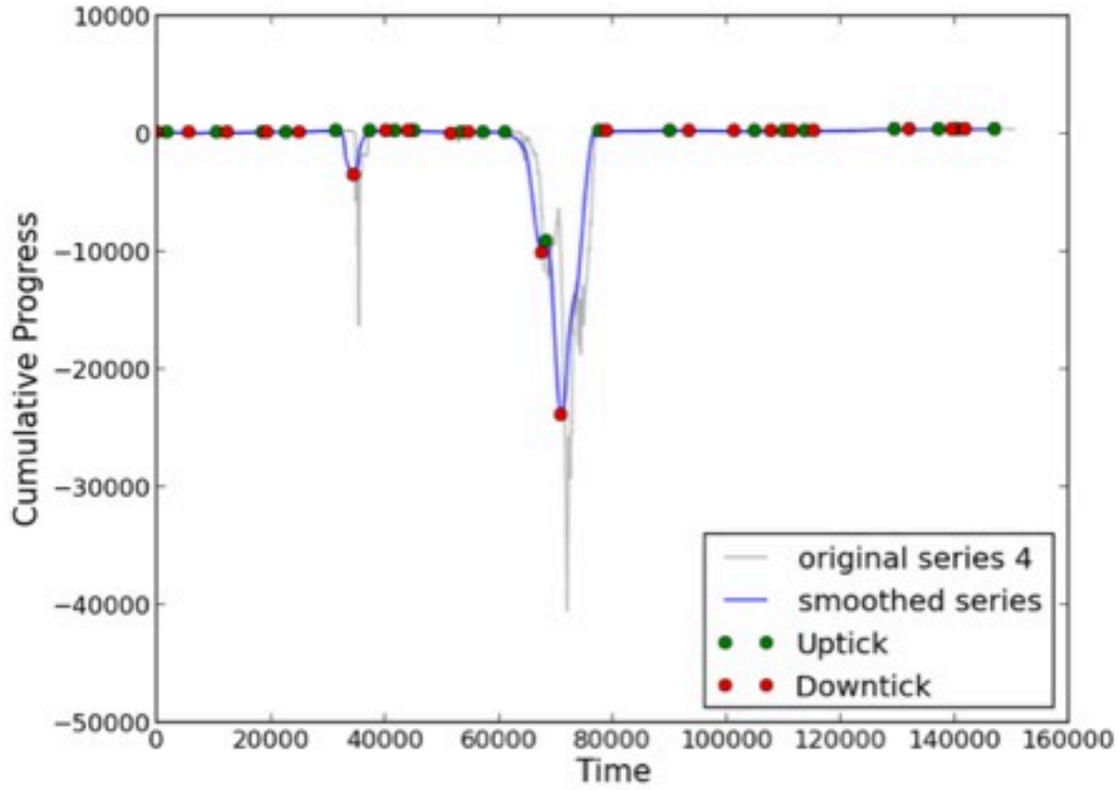
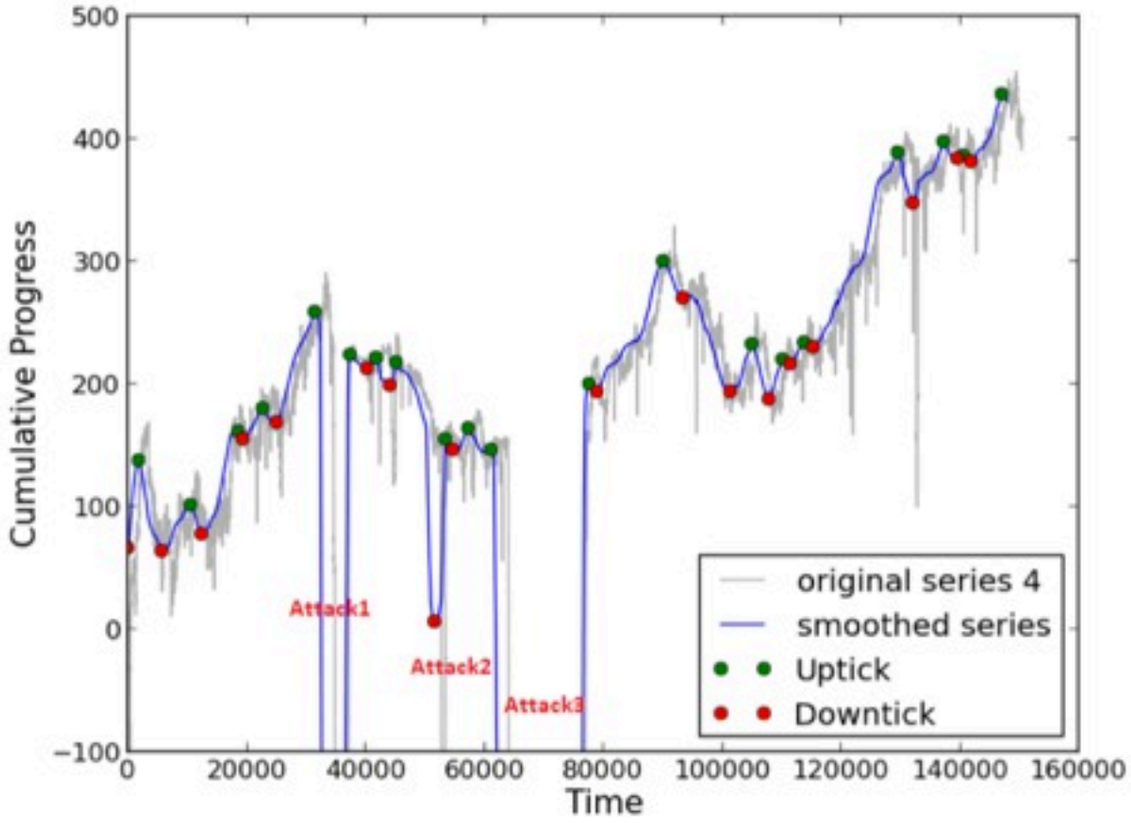
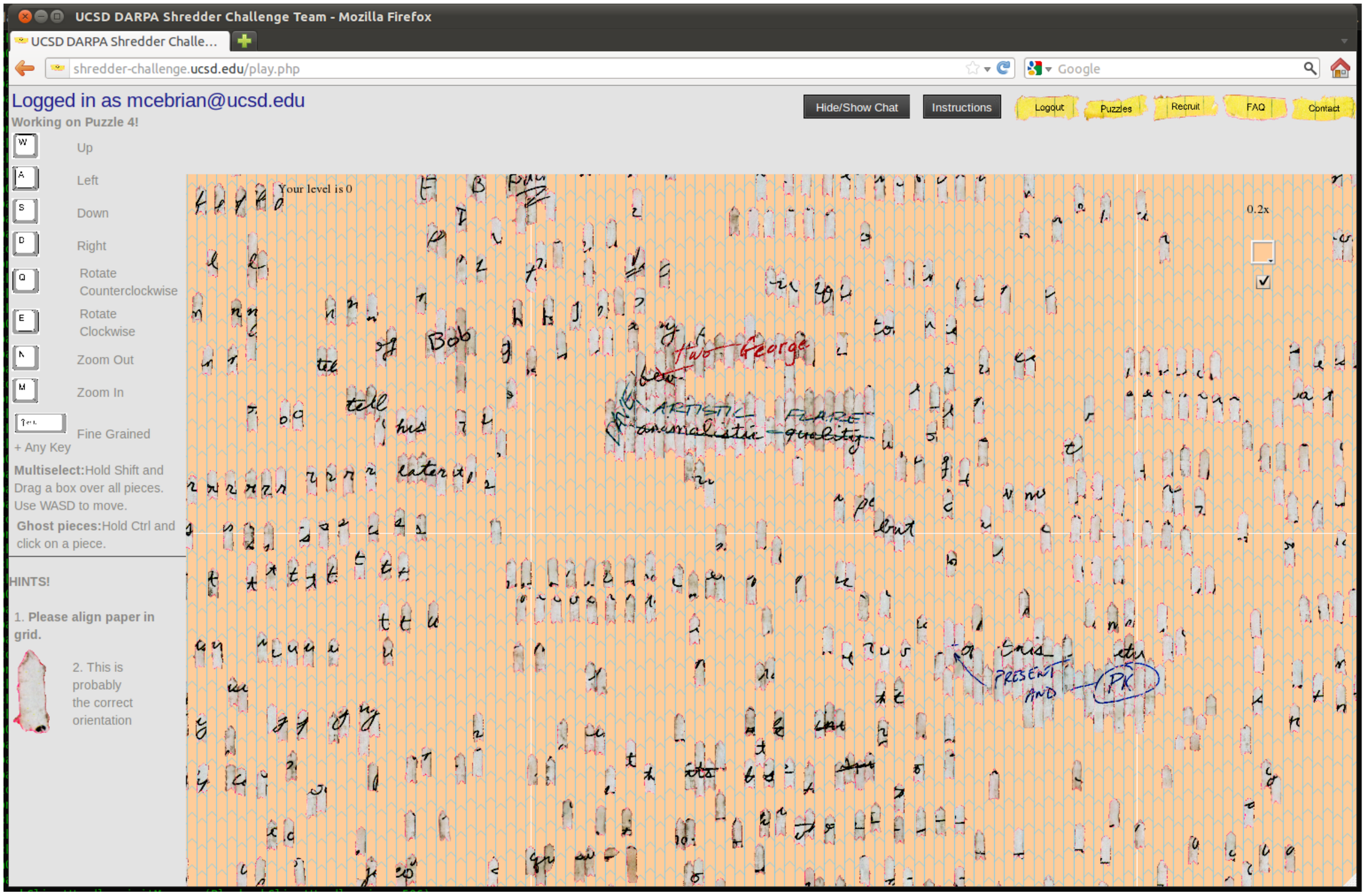
40000
60000
80000
100000
120000
140000
160000



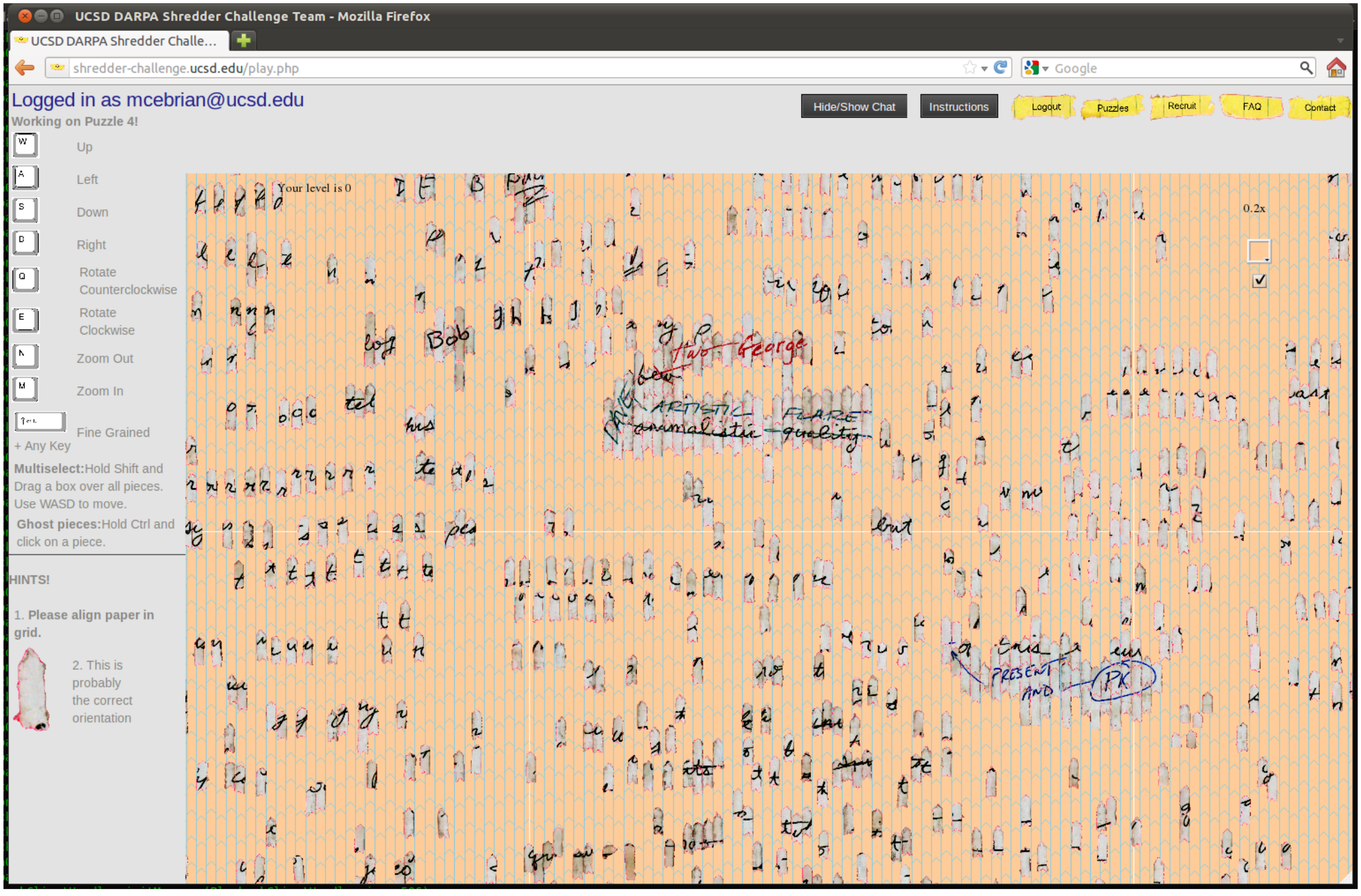
(a) Puzzle4



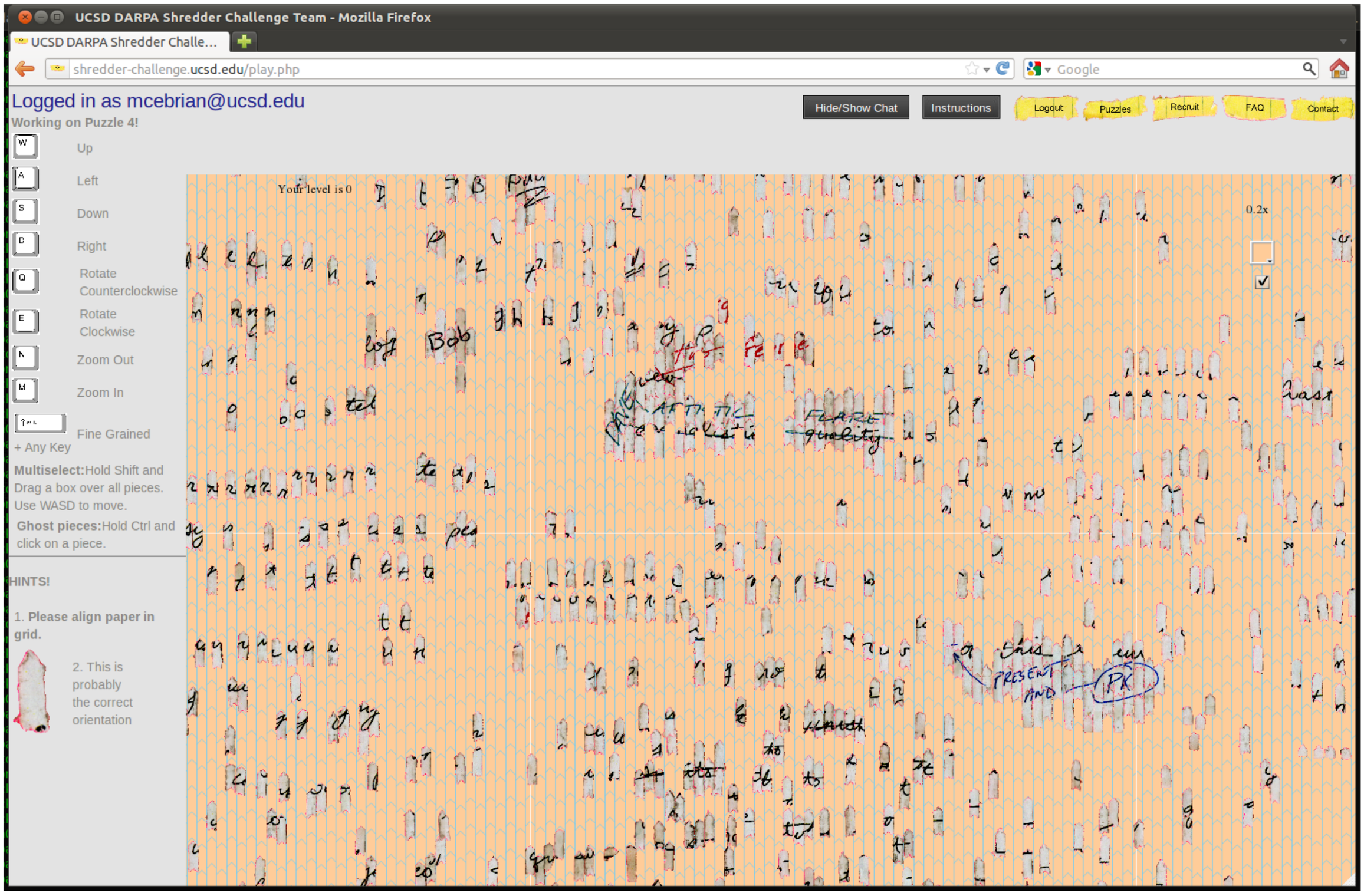
(b) Puzzle4 (Zoomed)



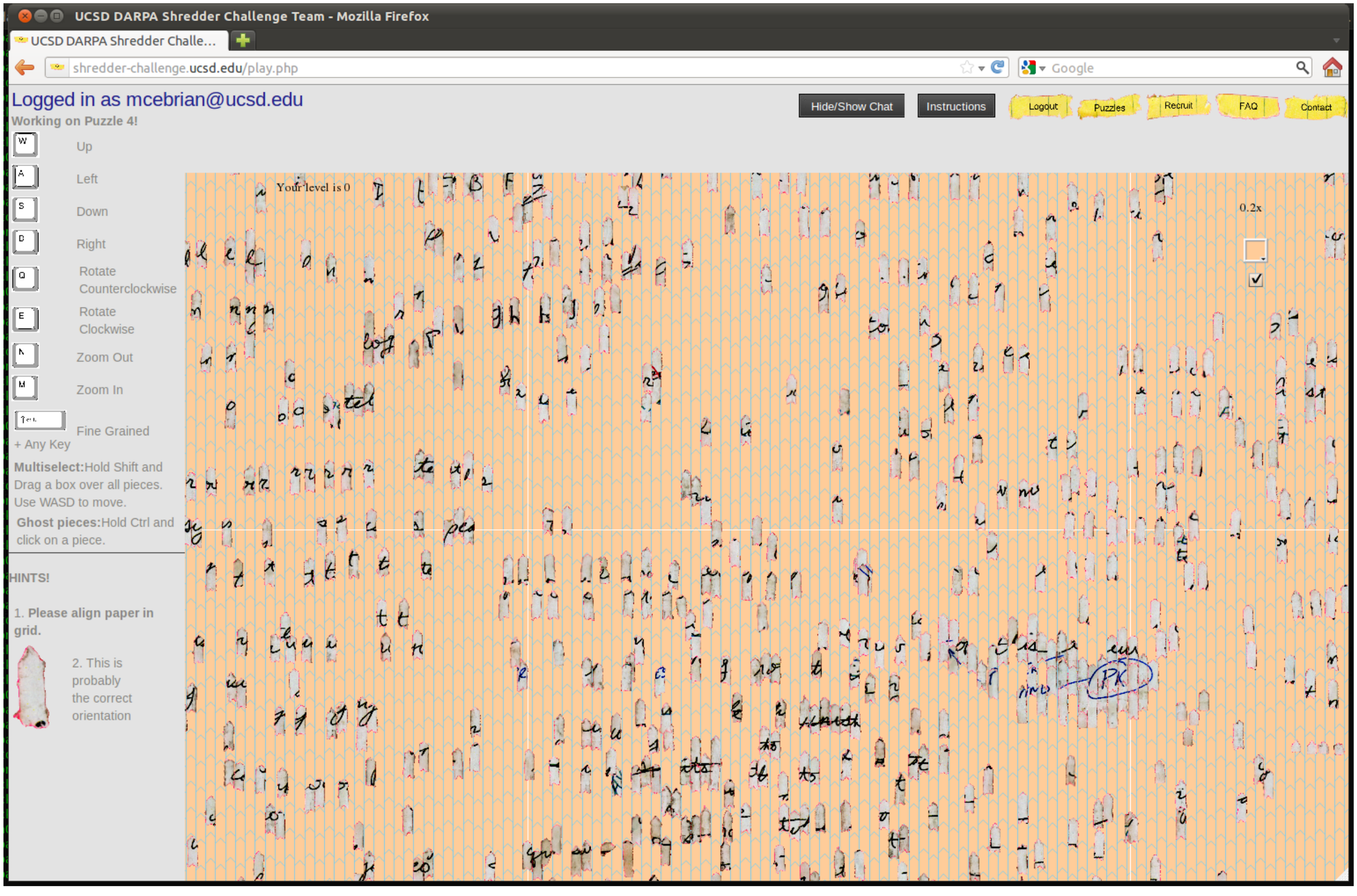
Before the attack.



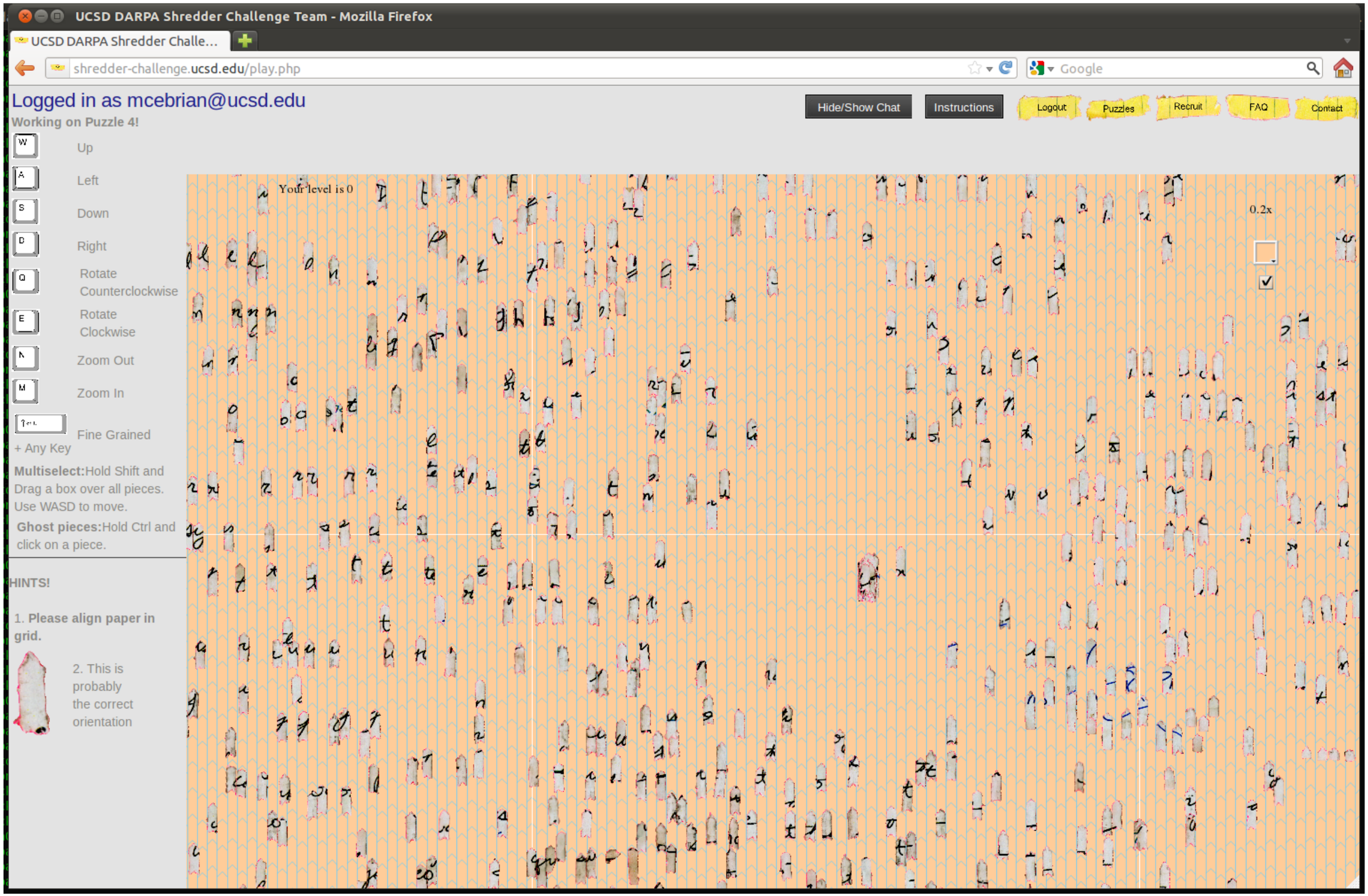
Probing with unconnected pieces.



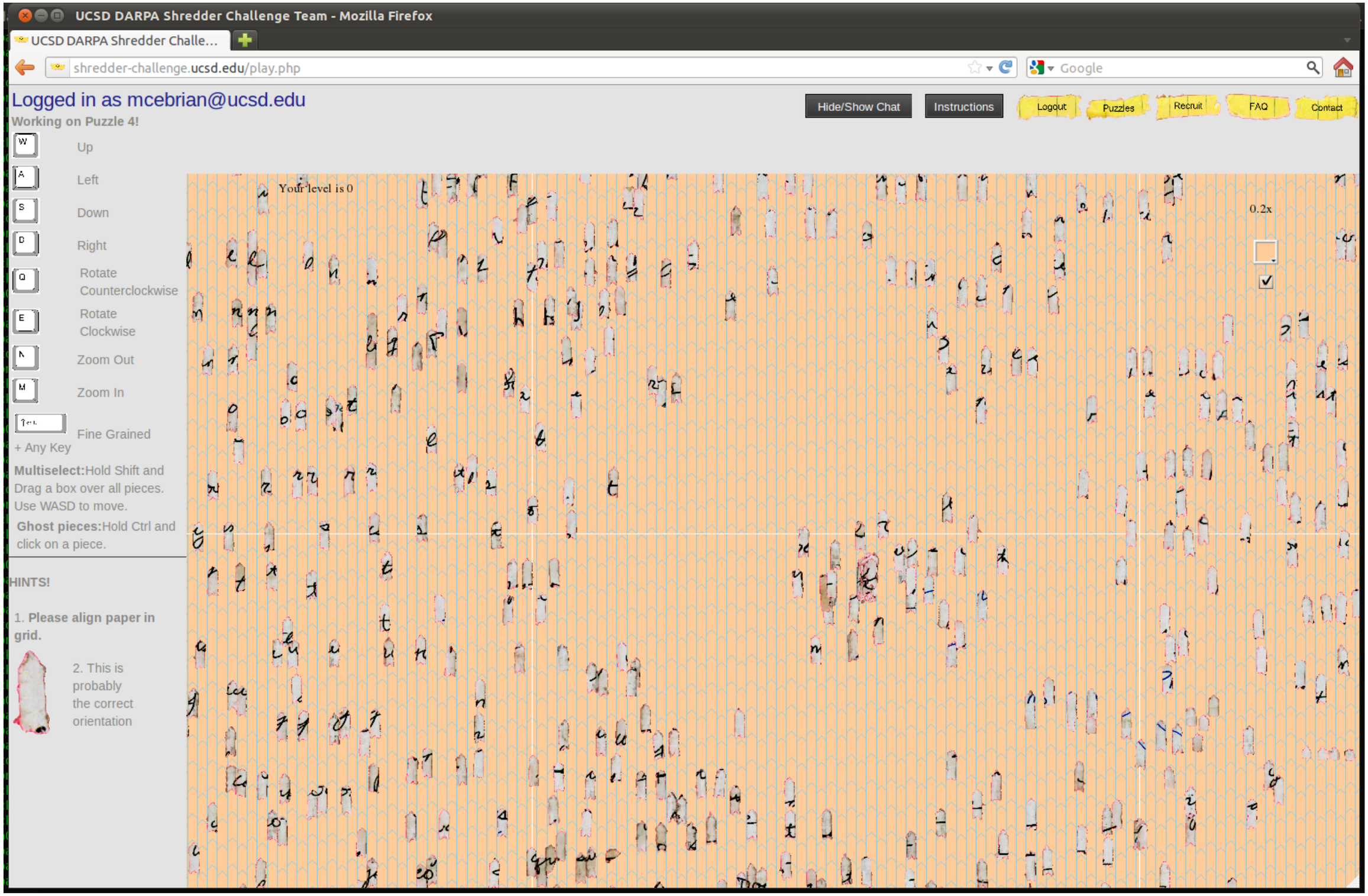
Small structures under attack.



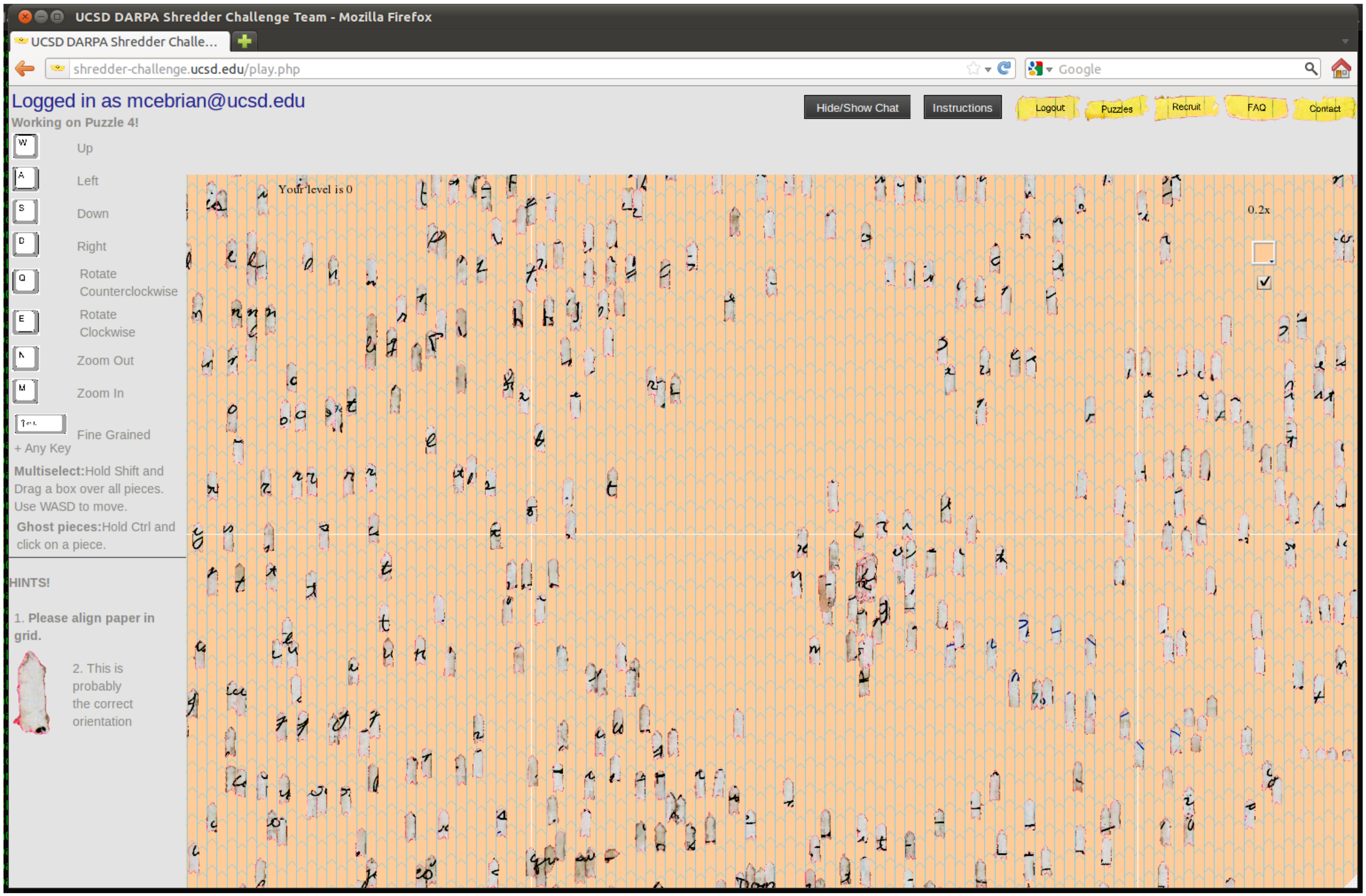
Main structure gone.



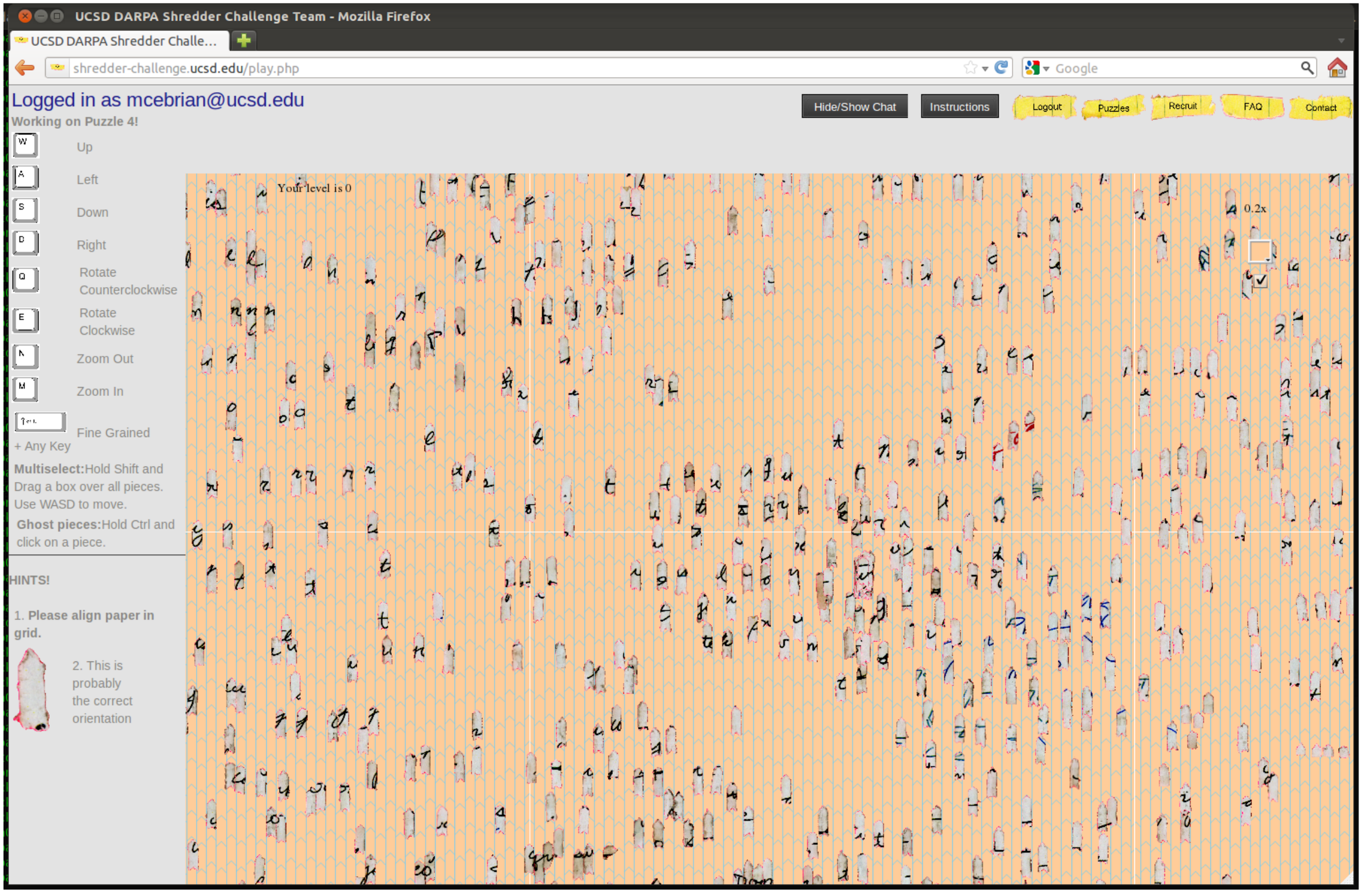
All progress gone.



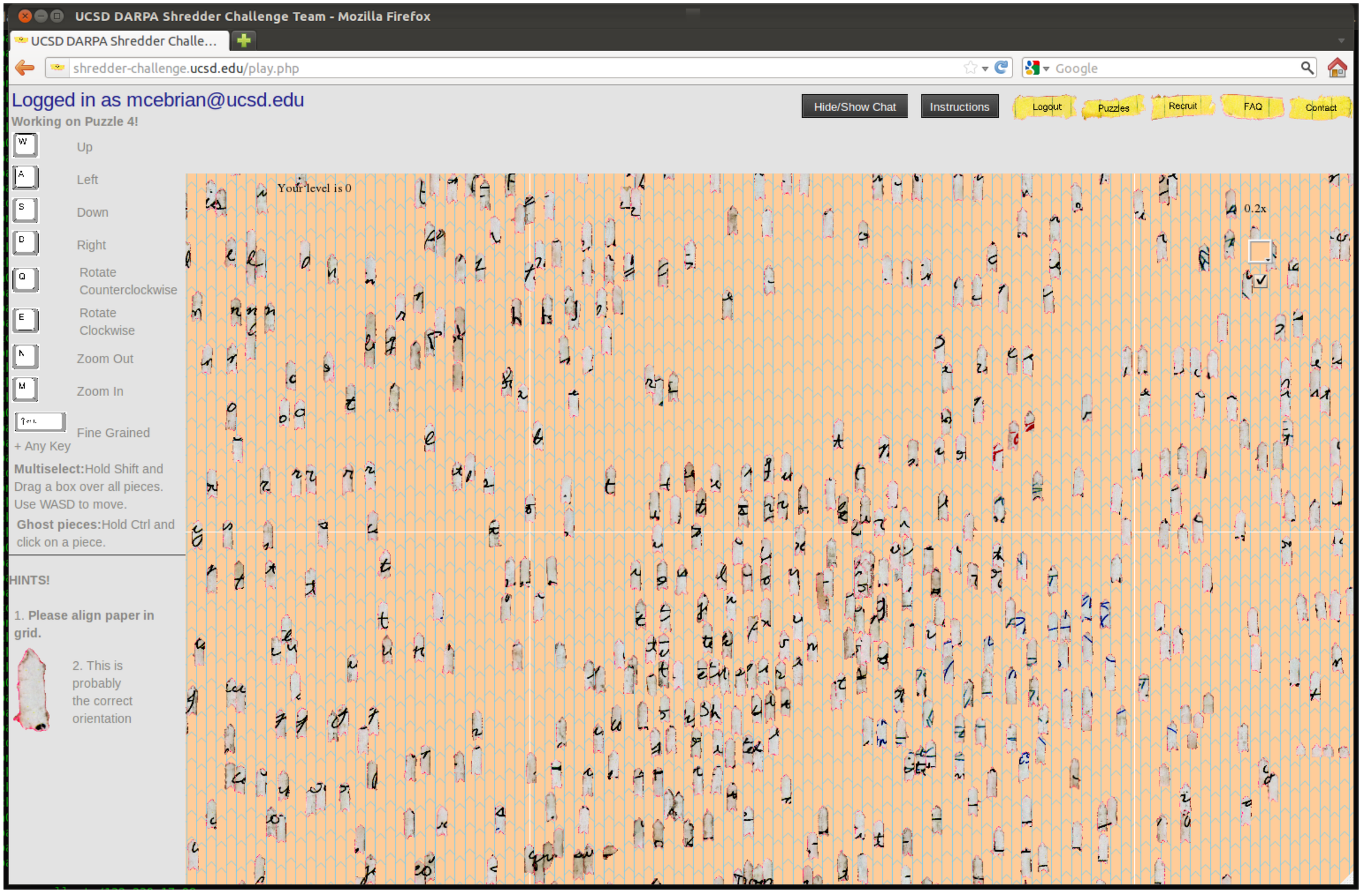
Participants trying to recover the progress.



Participants trying to recover the progress.

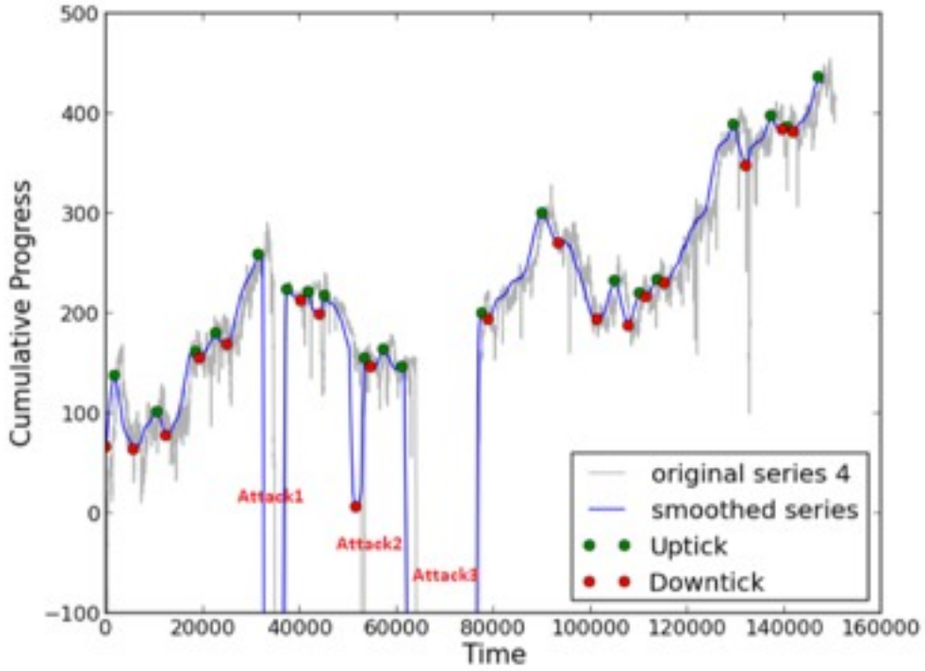


Participants trying to recover the progress.

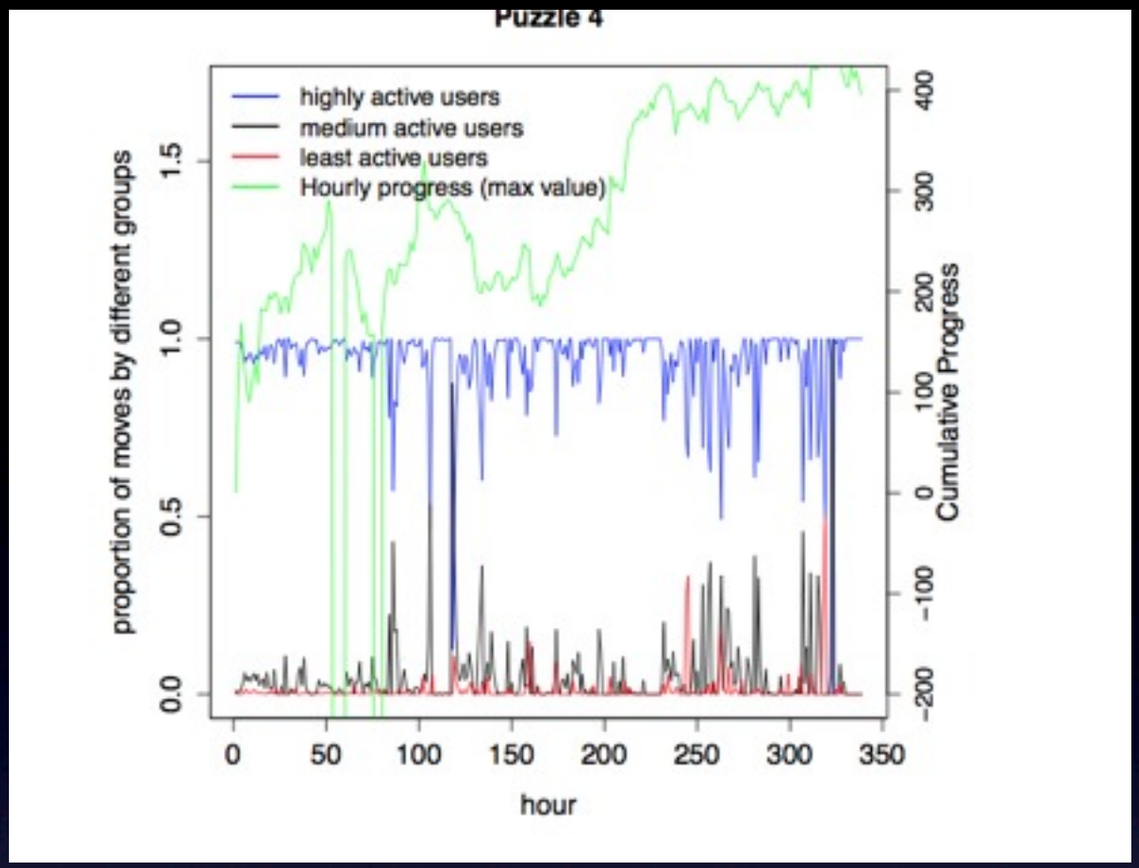


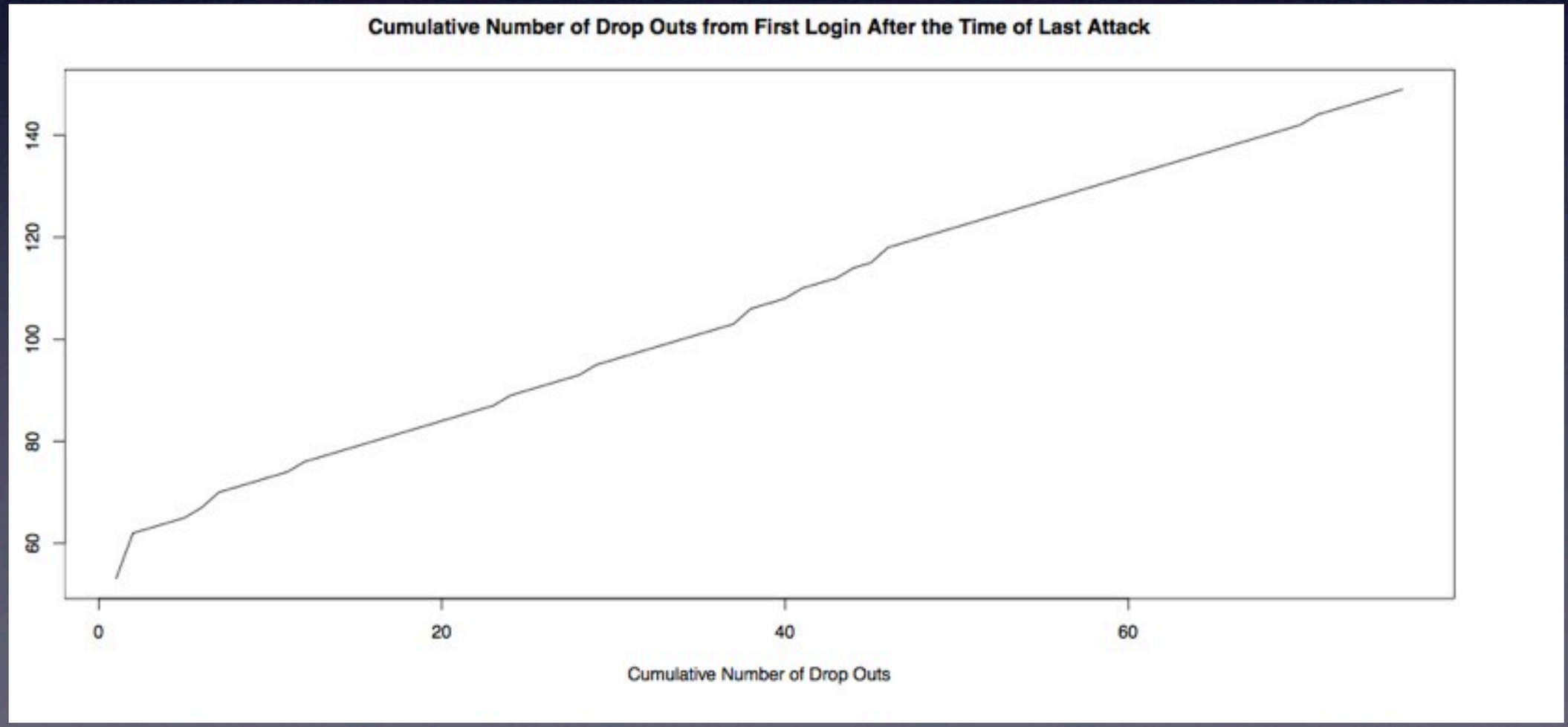
Participants trying to recover the progress.

(a) Puzzle4



(b) Puzzle4 (Zoomed)





from	**ucsdsaboteur@hushmail.com**
to	mcebrian@ucsd.edu
date	Thu, Nov 24, 2011 at 4:20 AM
subject	UCSD Shredder Challenge Sabotage

«I appreciate your acknowledging the cleverness of my exploitation of the weaknesses in your shredder challenge puzzle solving implementation.»

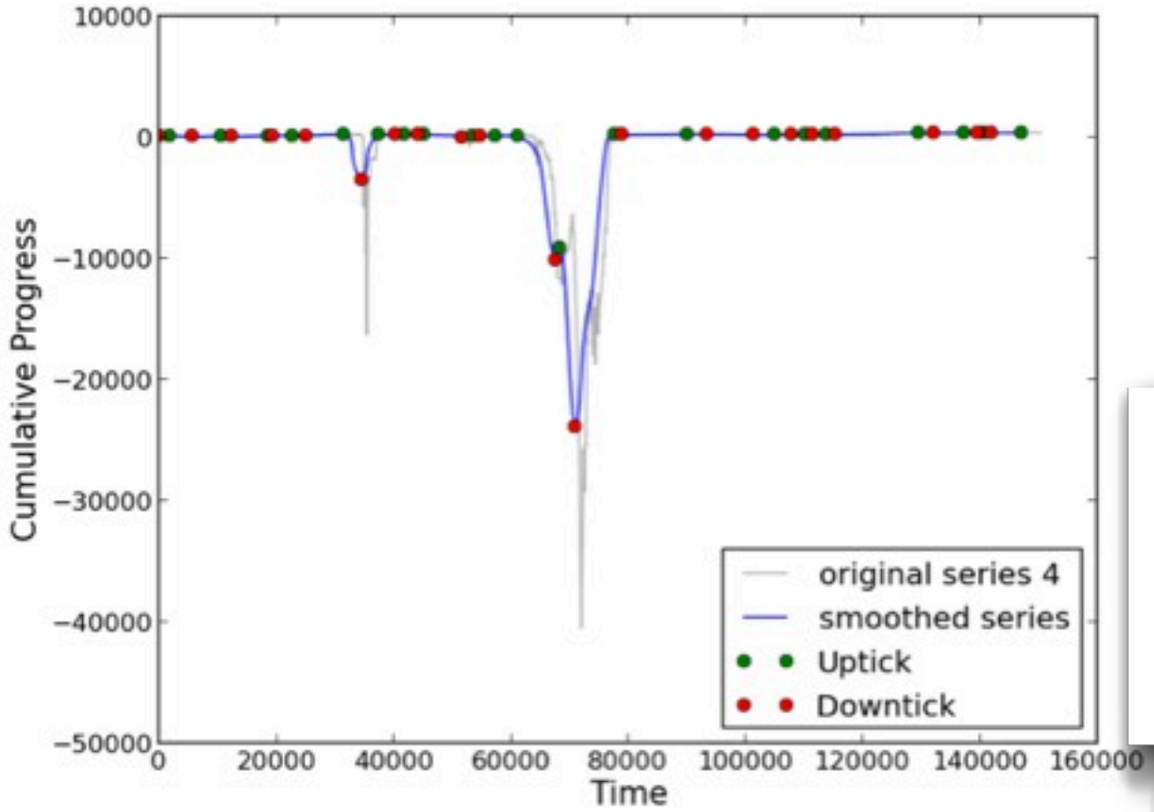
«For my first attack, everything was wide open. I made a post to 4chan to recruit people instructing them to disconnect any connected pieces and then start moving all the pieces into a single pile [...] However, it seemed all you did was lock the pieces together and ban my IP address.»

«Which led me to my second attack, using a VPN and a neighbors wireless for some new IP addresses, it was still very easy to just select all the pieces and place them on top of each other, but this got old soon and was too easily spotted by the puzzle solvers.»

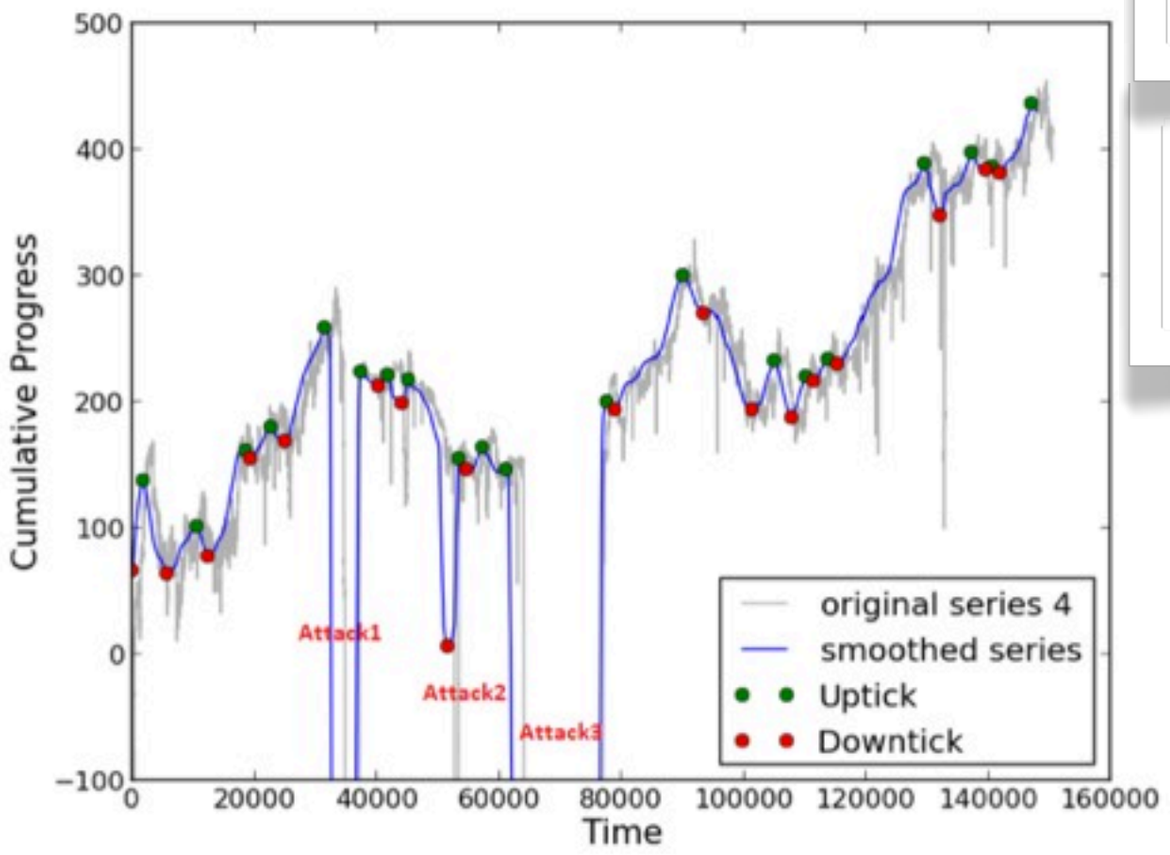
«So I decided to get a bit more sneaky when I realized your implementation didn't have any check on the bounds of the virtual table when moving pieces. I selected a number of pieces, enough to make solving the puzzle difficult with the missing pieces and not so much that people would immediately notice, and then just moved them off the top of the virtual table.»

«Anyways...I thoroughly enjoyed myself, and hope you all learned something about crowd sourcing and will give a bit more thought to security when considering your next implementation. Whatever and when ever that may be. »

«As for my motivation, I too am working on the puzzle and personally feel that crowd sourcing is basically cheating (and I'm not the only one that feels this way). Sure, if you get enough people together and working on it they will be able to solve nearly any puzzle. It's only a matter of time, however for what should be a programming challenge about computer vision algorithms, crowd sourcing really just seems like a brute force and ugly plan of attack, even if it is effective.»



(a) Puzzle4



(b) Puzzle4 (Zoomed)

$$\dot{P}(t) = \frac{\beta}{\alpha\gamma - 1} D(t).$$

$$D(t) = \frac{\alpha\gamma - 1}{\beta} \left(aP(t) + f(t) \right).$$

$$\dot{D}(t) = \frac{\alpha\gamma - 1}{\beta} \left(a\dot{P}(t) + bP(t) + f(t) \right).$$

$$\ddot{D}(t) = \frac{\alpha\gamma - 1}{\beta} \left(a\ddot{P}(t) + b\dot{P}(t) + cP(t) + f(t) \right).$$

$$\frac{d^2}{dx^2} P + a^2 P = A^2 e^{\sqrt{A^2 - a^2} x}$$

Cebrian, Amigo, Huerta, et al., 2013.

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DARPA NETWORK CHALLENGE
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Step 1:
Find the Suspect
A band of jewel thieves is on the run in five cities across the world. We need your help finding them. On March 31, 2012, we'll release their pictures to the public. Be on the lookout.
Play TAG
1. Find The Suspect
1. Find the Suspect
2. Photograph the Suspect
3. Upload the Image
4. Win $5000!

Real world activity
Terrorist
Recruiters
Members
Recruiters (stimuli)
Members
Members
Susceptible

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ECOLOGICAL NETWORKS

Received
24 August 2012

Violent extremist group ecologies under stress

Manuel Cebrian[1,2,3], Manuel R. Torres[4,5], Ramon Huerta[6] & James H. Fowler[7,8]

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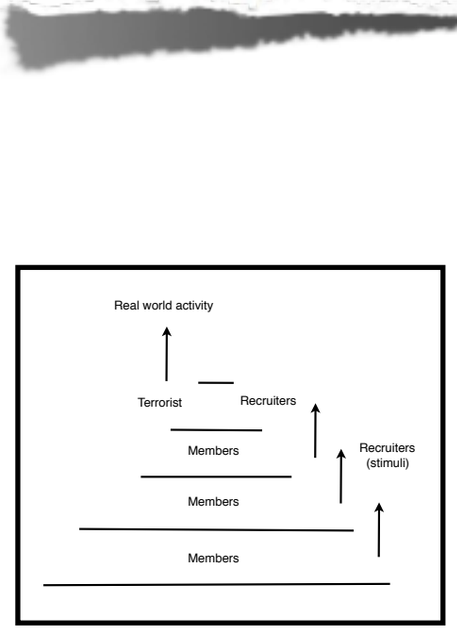
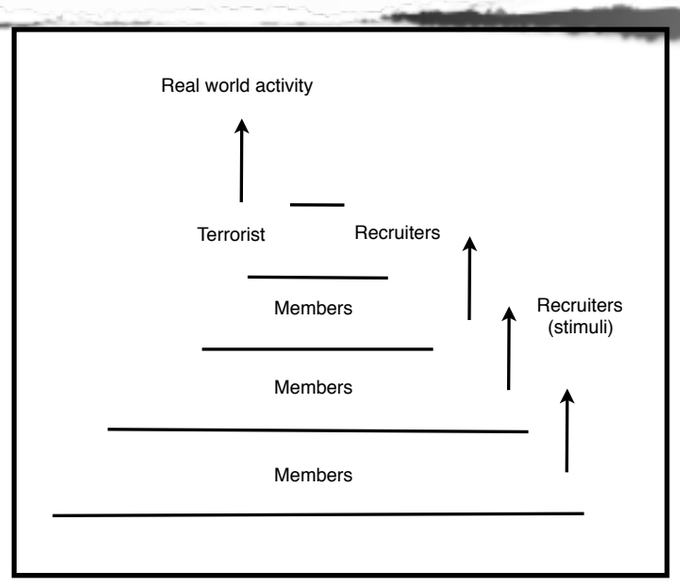
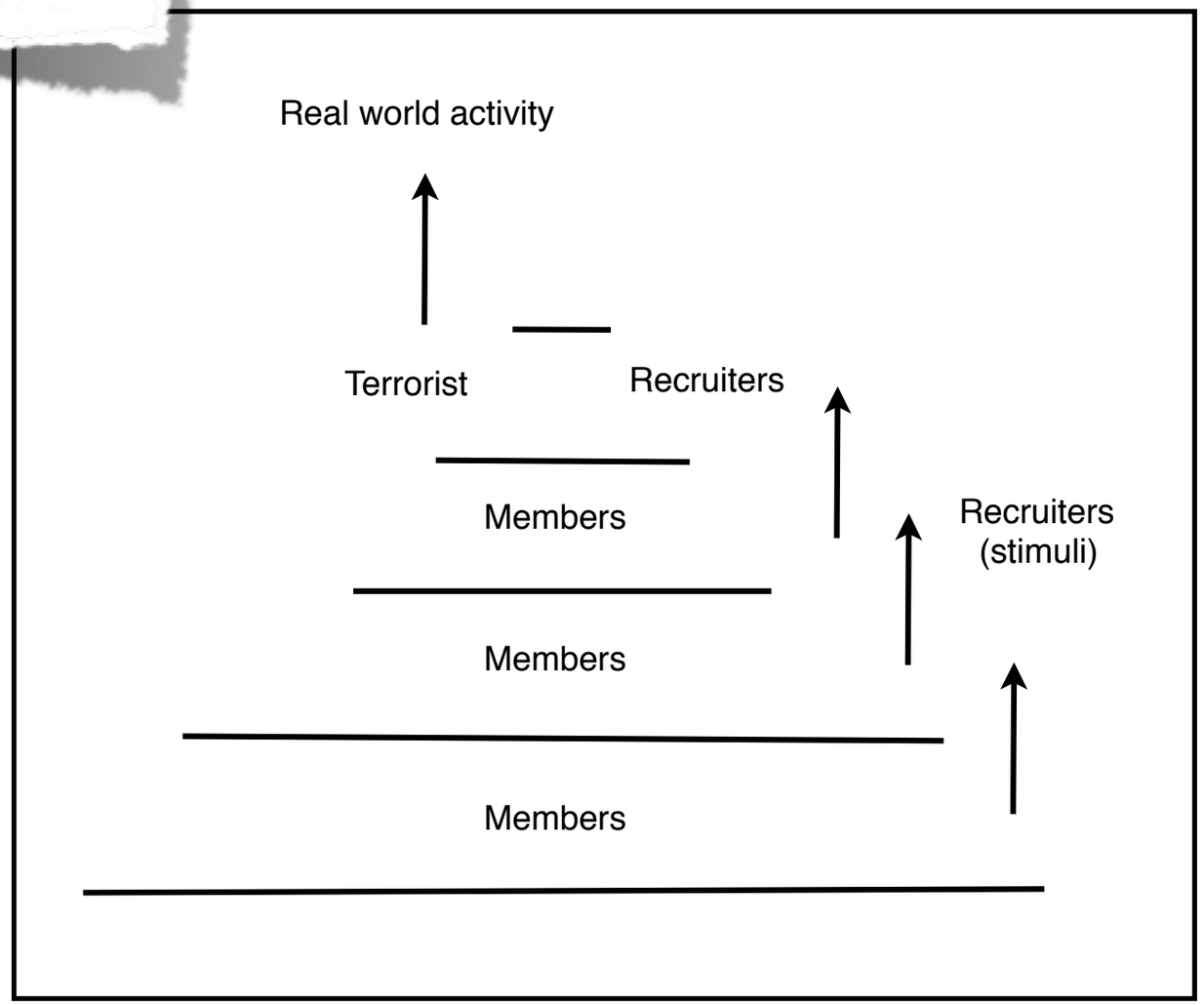
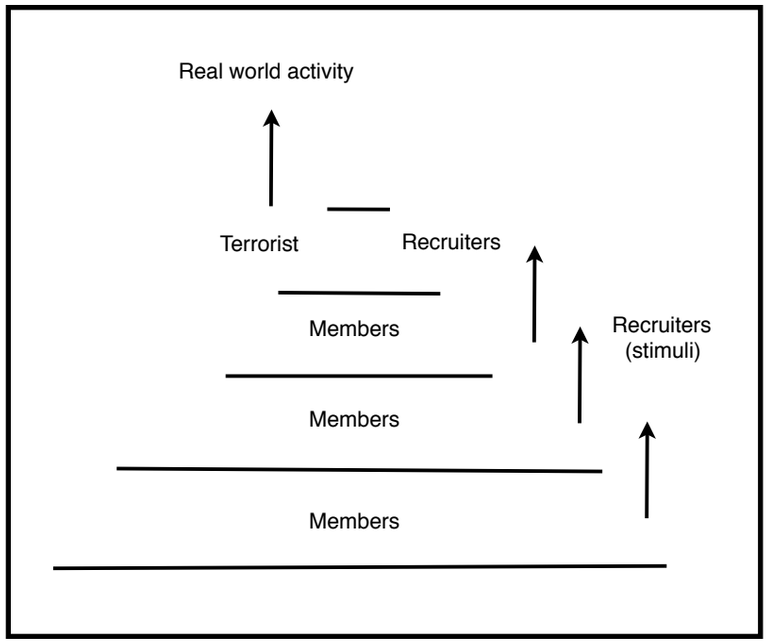
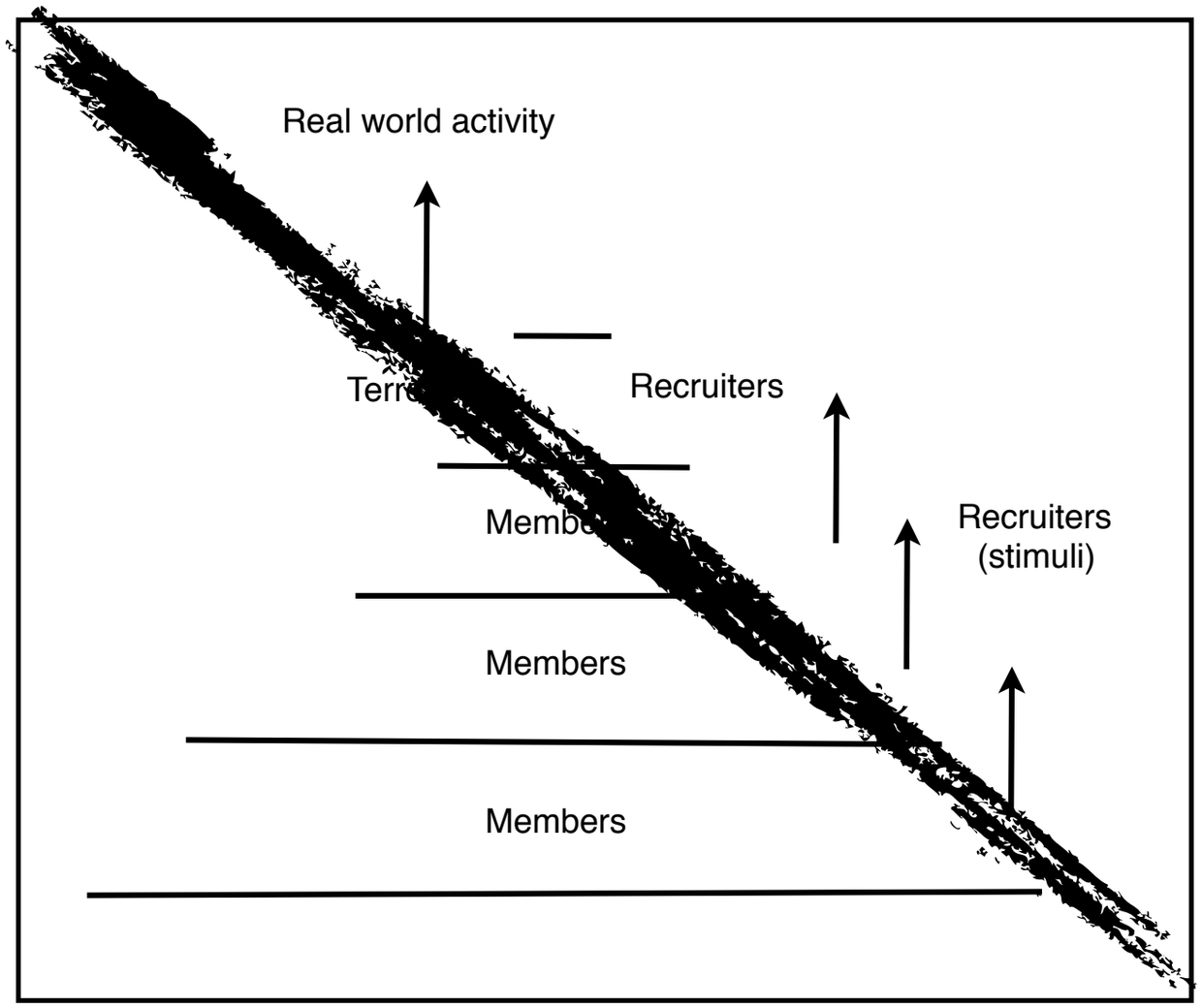




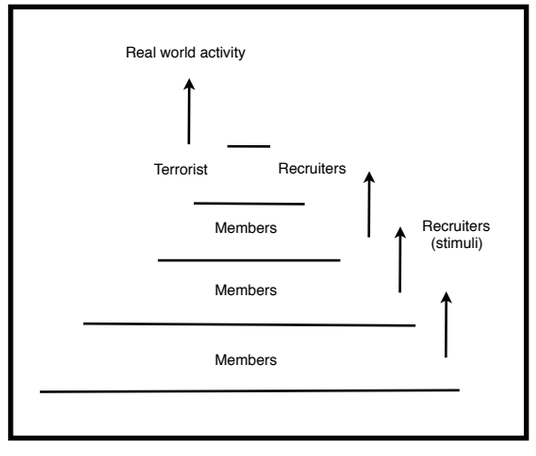
Susceptible

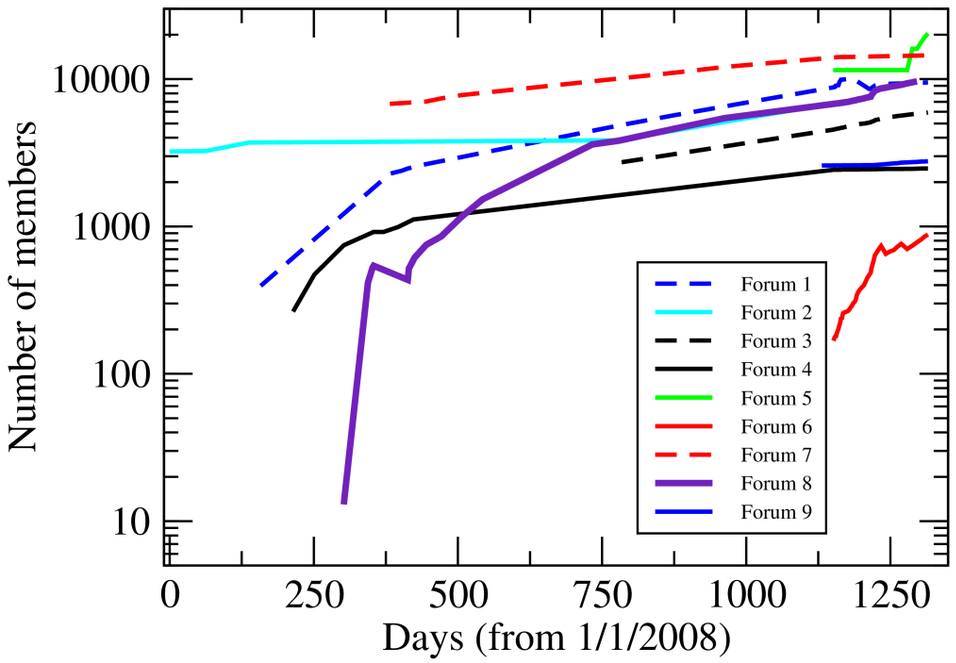






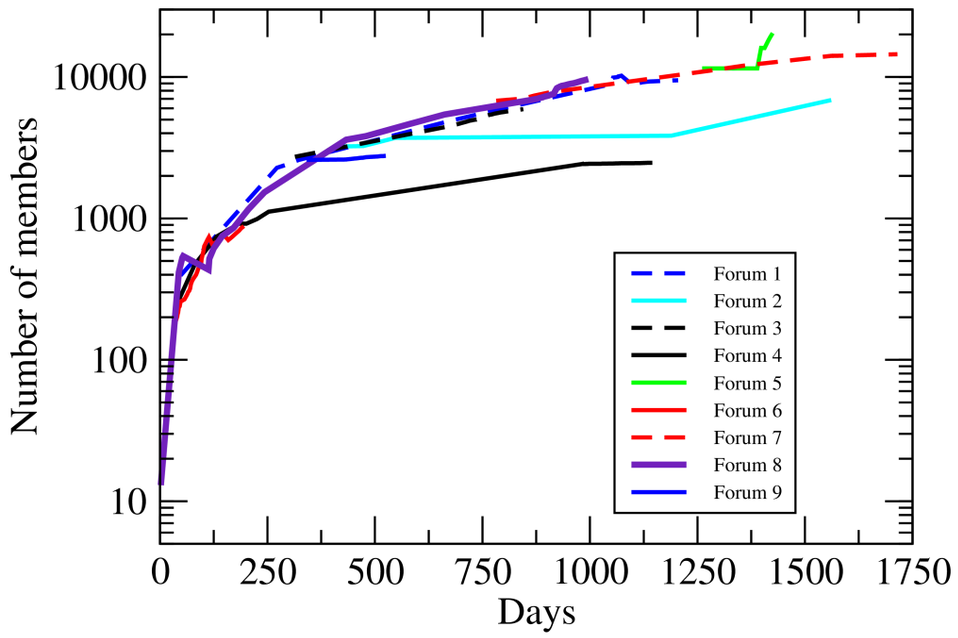
Susceptible





$$
\begin{aligned}
\frac{dX_1}{dt} &= \pi_{1,0}N - \pi_{21}X_1 \\
\frac{dX_i}{dt} &= \pi_{i,i-1}X_{i-1} - \pi_{i+1,i}X_i \\
\frac{dX_L}{dt} &= \pi_{L,L-1}X_{L-1} - p_{O,R}R - p_{R,R}R \\
\frac{dR}{dt} &= p_{R,R}R \\
\frac{dO}{dt} &= p_{O,R}R
\end{aligned}
$$

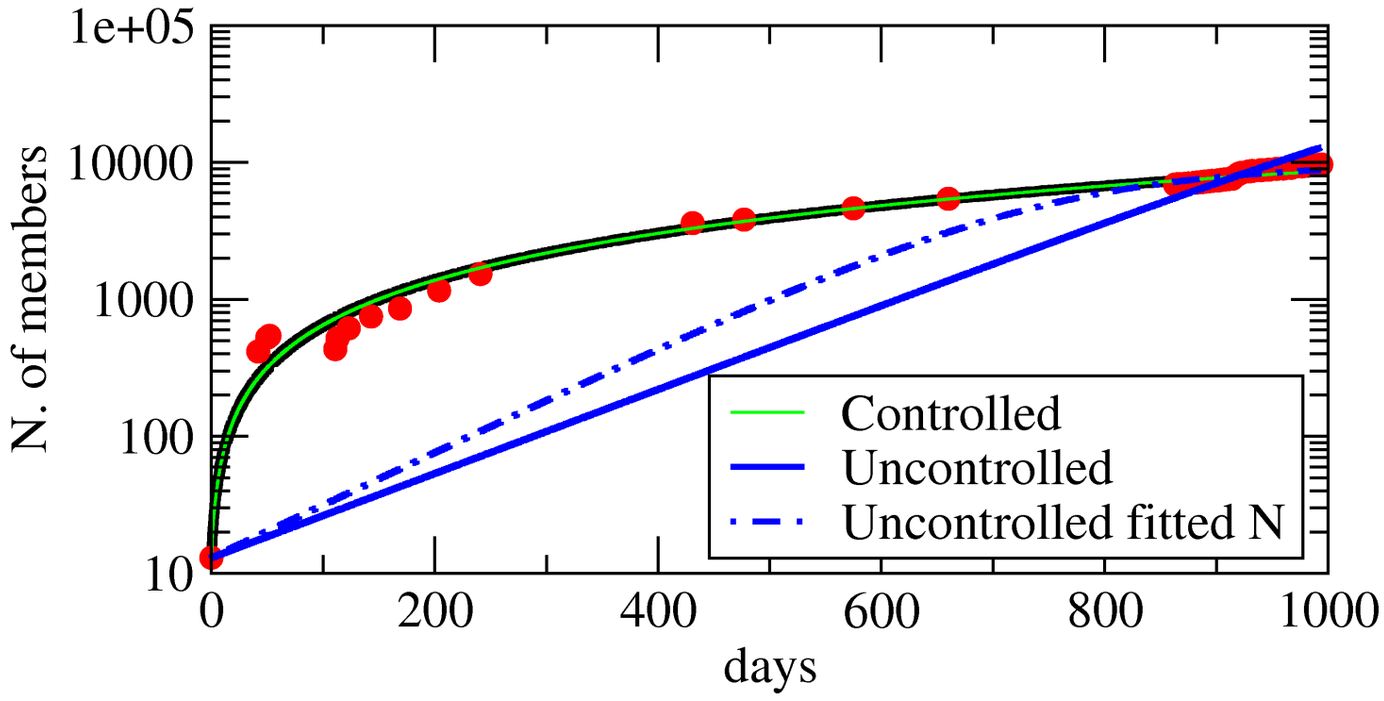
population dynamics



$$p_N(X^*) = \frac{(p_R^0 + p_O^0)R^*}{NX^*} =: p_N^*,$$

volume control

$$p_N(X,R) = \begin{cases} \frac{p_R^0+p_O^0}{NX^*}R + p_N^0(X^* - X), & \text{if} \quad X < X^* + \frac{p_N^*}{p_N^0} \\ 0, & \text{otherwise} \end{cases}$$



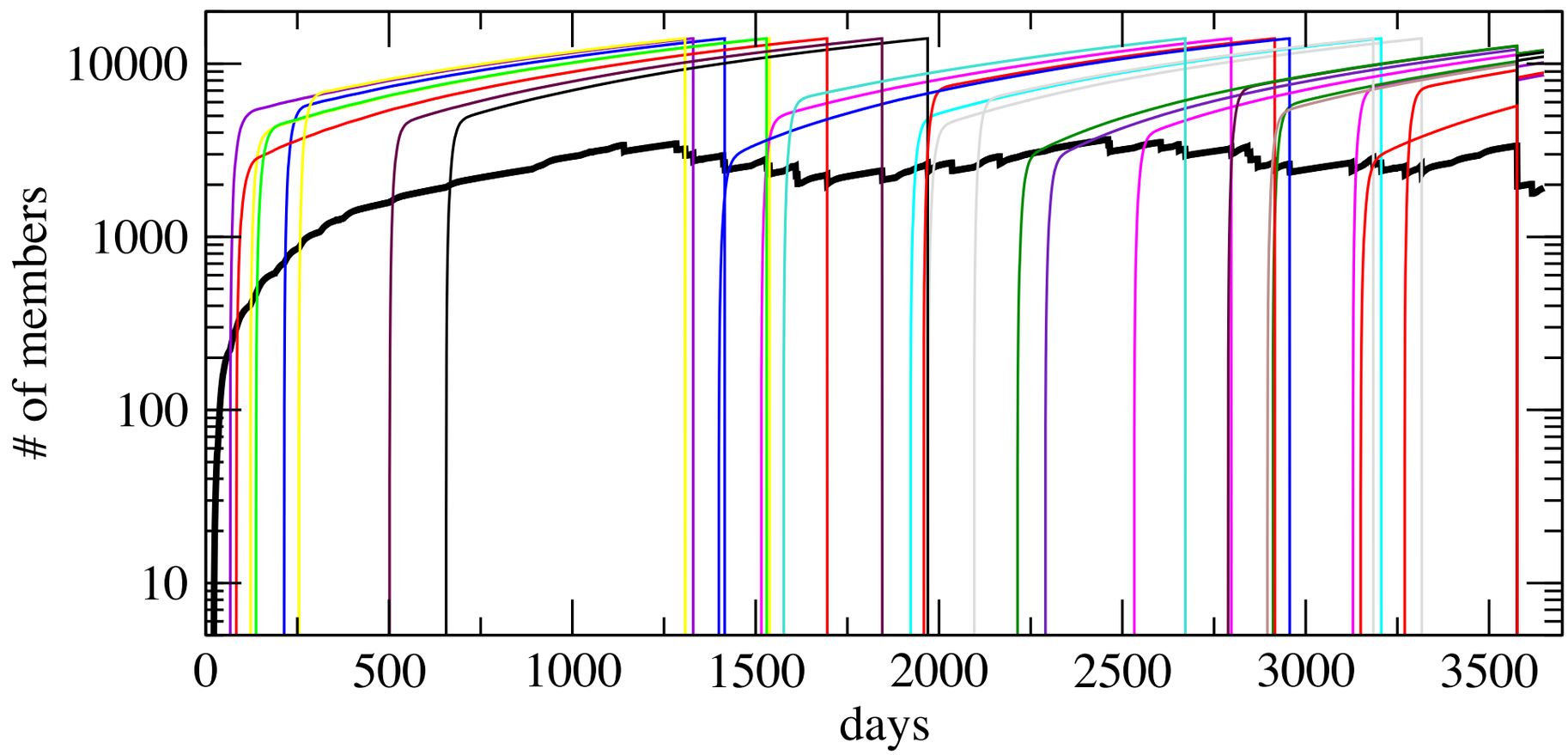
$$\frac{dX^i}{dt} = p_N(X^i(t-\tau), R^i(t-\tau), X^{i,*})X^i \times \left[I - \sum_{j=1}^{N_F} \left(X^j(t) + R^j(t) + O^j(t) \right) \right] +$$

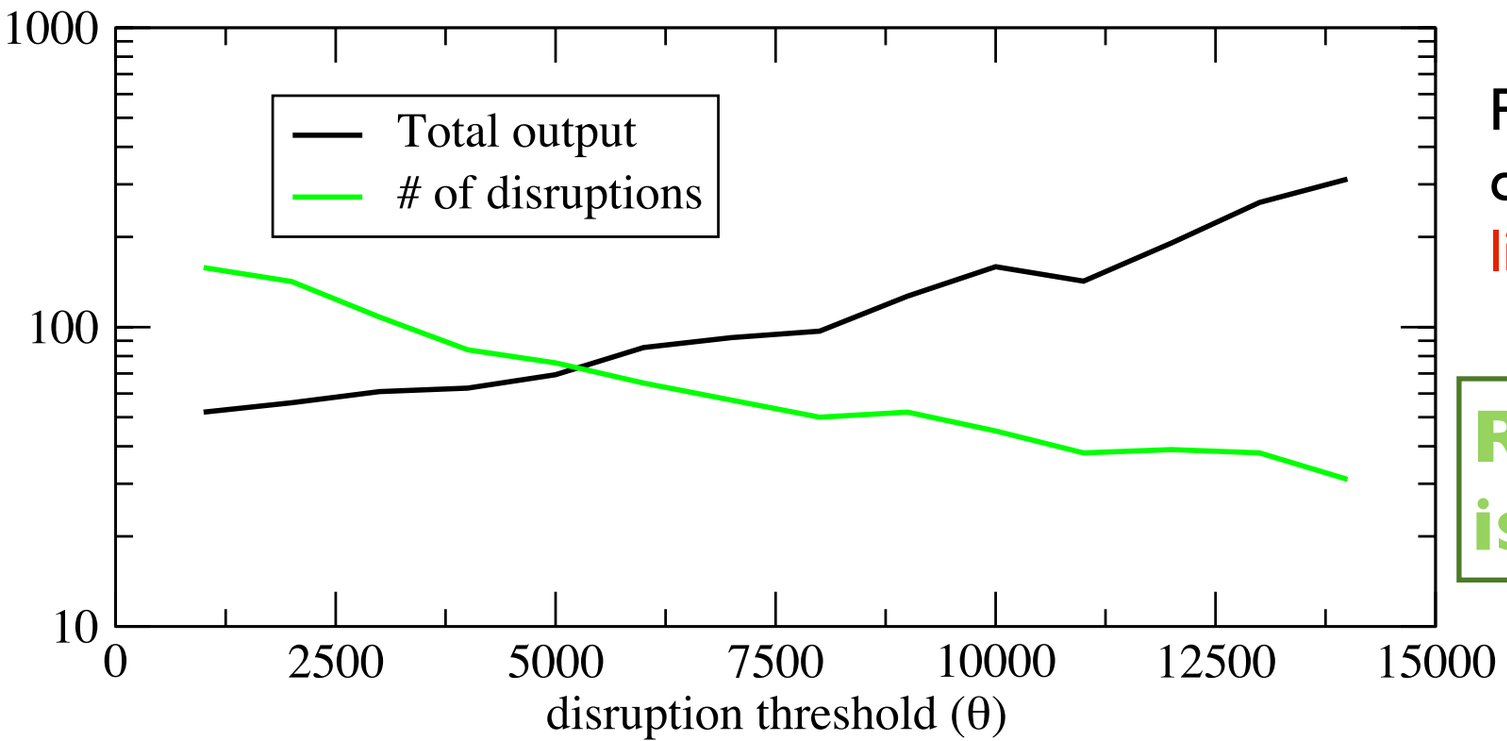
$$-(p_R + p_O^0)R^i$$

$$\frac{dR^i}{dt} = p_R^0 R^i,$$

$$\frac{dO^i}{dt} = p_O^0 R^i,$$

$$\frac{dX^{i,*}}{dt} = \lambda^i$$





Policy to attack large groups can be very efficient for limiting global recruitment.

Referral-based recruitment is externally controllable

Crowdsourcing Dilemma

Victor Naroditskiy [*], **Jennings** [*] , **Pascal Van Hentenryck** [†] [‡], **and Manuel Cebrian** [‡]

[*]University of Southampton, United Kingdom,[†]University of Melbourne, Australia, and [‡]National Information and Communications Technology Australia, Australia

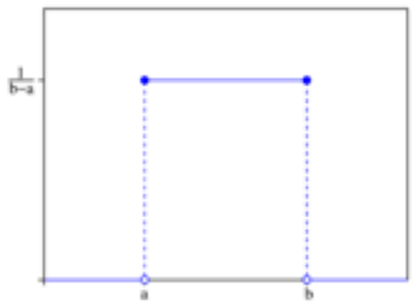
Submitted to Proceedings of the National Academy of Sciences of the United States of America

malicious?

strategy

productivity

CROWD



ATTACK

PEACE

IN-HOUSE

0

PEACE

ATTACK

2-player, 1 shot game

Wins!
1-0.4=0.6

IN-HOUSE

0

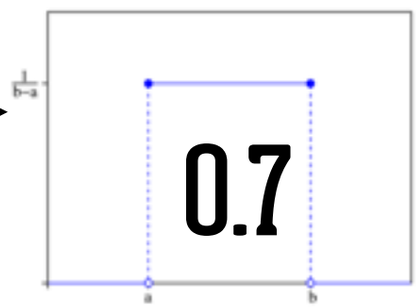
COST

0.4

ATTACK

0.8

CROWD



- 0.1

Cost of the attack $q \in [0, 1]$ [fraction of the total reward]

The damage inflicted by the attack $d \in [0, 1]$.

	C	S
C	$\frac{1}{2} - (d - \frac{d^2}{2})q, \frac{1}{2} - (d - \frac{d^2}{2})q$	$1 - d, d(1 - q)$
S	$d(1 - q), 1 - d$	$\frac{1}{2}, \frac{1}{2}$

Table 1: **Expected payoff matrix for the crowdsourcing game.**

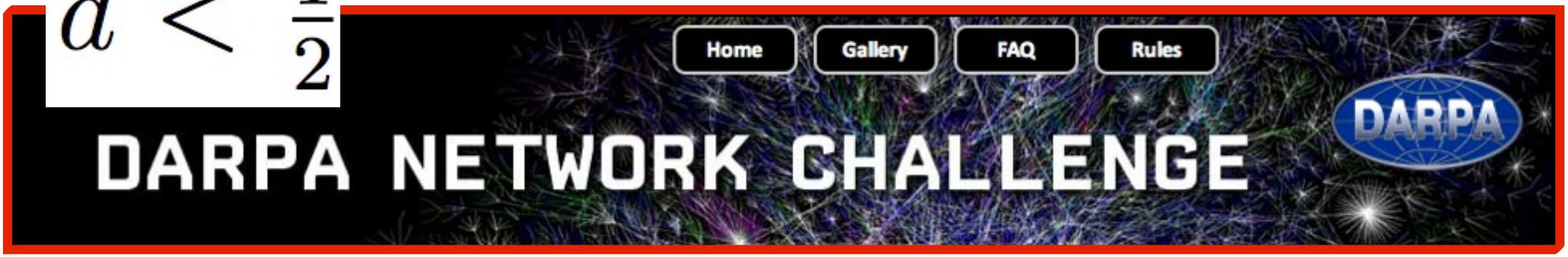
$d < \frac{1}{2}$ ⟶ Both CROWDSOURCE and ATTACK

$d > \frac{1}{2}$ and $q < \frac{2d-1}{d^2}$ ⟶ Both IN-HOUSE

$d \geq \frac{1}{2}$ and $q \geq \frac{2d-1}{d^2}$ ⟶ Both CROWDSOURCE + ATTACK & Both IN-HOUSE

Always attack (once) regardless of the cost of attack!

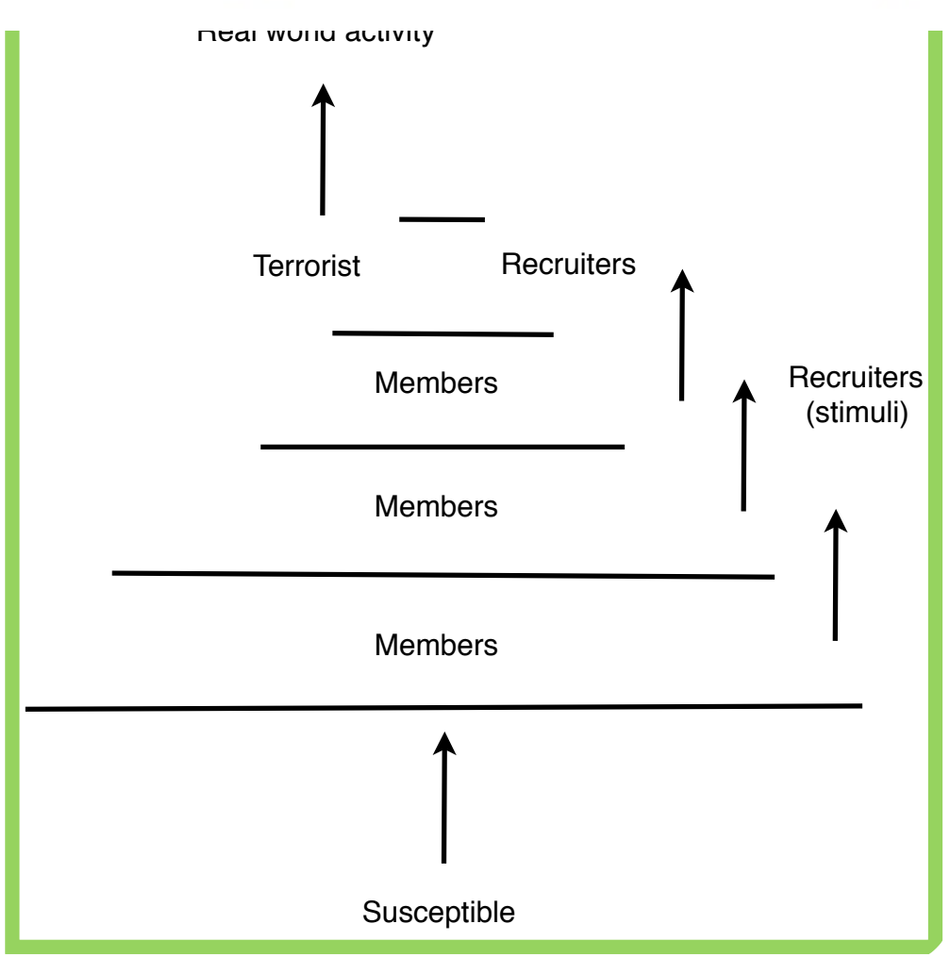
$$d < \frac{1}{2}$$



$$d \geq \frac{1}{2} \text{ and } q \geq \frac{2d-1}{d^2}$$

$$d > \frac{1}{2} \text{ and } q < \frac{2d-1}{d^2}$$

$$d < \frac{1}{2}$$



DARPA Network Challenge:
4 years, 4 lessons

I. Hierarchical, incentive-based mobilization can be fast, large, cheap.

II. Exhibits large variability (you have to be lucky, or try many times).

III. Can be made robust to misinformation, but not sabotage.

IV. Sabotage is the expected behavior.

nature COMMUNICATIONS

ARTICLE

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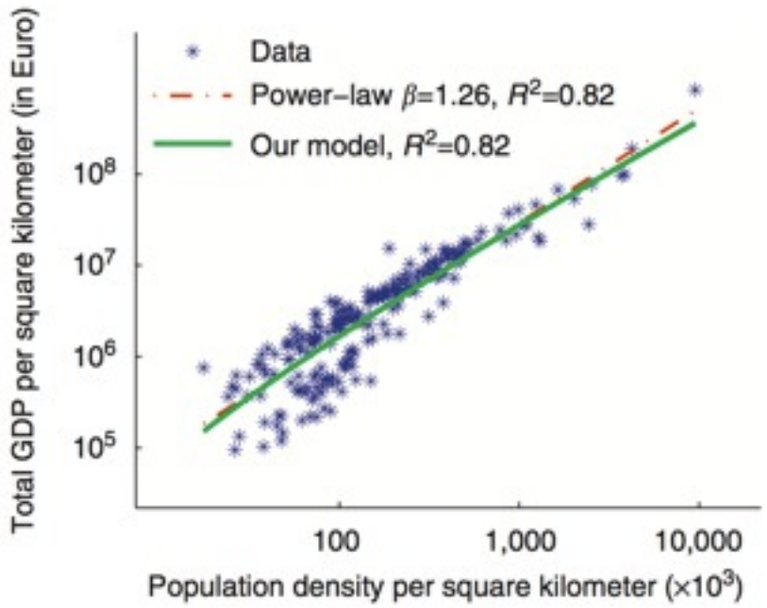
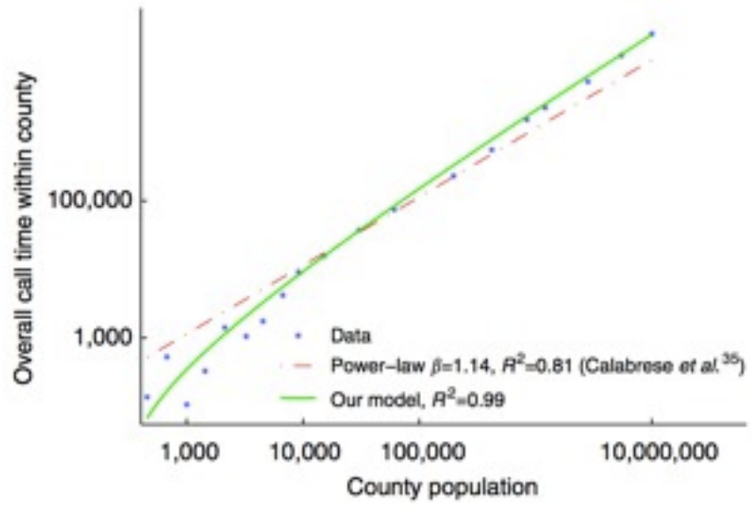
Urban characteristics attributable to density-driven tie formation

Wei Pan[1], Gourab Ghoshal[1,†], Coco Krumme[1], Manuel Cebrian[1,2,3] & Alex Pentland[1]

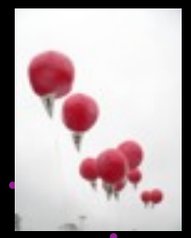
Motivated by empirical evidence on the interplay between geography, population density and societal interaction, we propose a generative process for the evolution of social structure in cities. Our analytical and simulation results predict both super-linear scaling of social-tie density and information contagion as a function of the population. Here we demonstrate that our model provides a robust and accurate fit for the dependency of city characteristics with city-size, ranging from individual-level dyadic interactions (number of acquaintances, volume of communication) to population level variables (contagious disease rates, patenting activity, economic productivity and crime) without the need to appeal to heterogeneity, modularity, specialization or hierarchy.



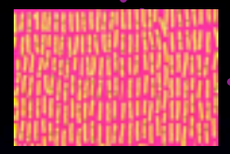


Why do cities ***super-scale?***

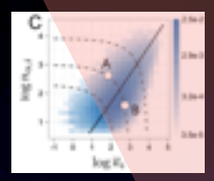
Why do only cities *super-scale?*

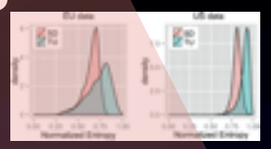


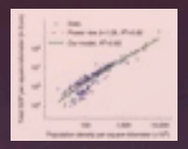
crowdsourcing



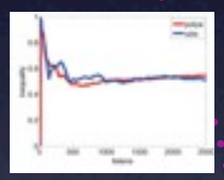
cities

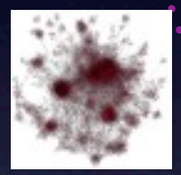


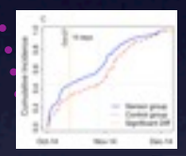




institutions







Harder

Faster

firms

social media