

Ph.D Dissertation Defense



Technology-Facilitated Crowdsourcing Systems

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College of Engineering

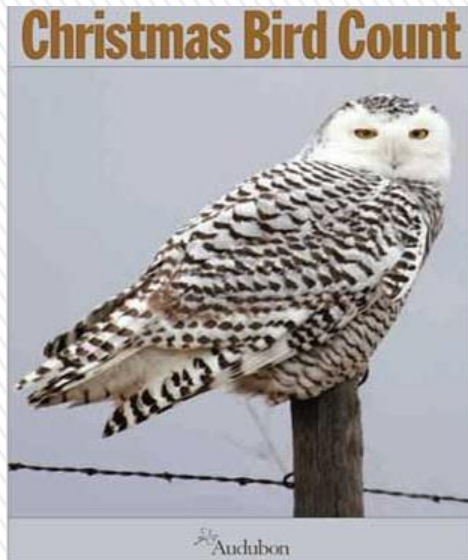
University of Notre Dame

April 4th , 2013



Crowdsourcing

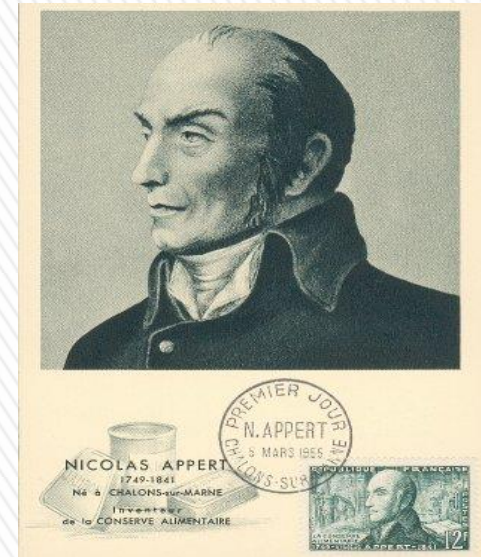
– Not an Entirely New Idea



Data Collection:

Christmas Bird Count

Counting Started: 1899



Idea Competition:

Nicolas Appert's Food Canning

Competition started: 1795

Awards Won: 1810

New Information Technologies Brought in New Opportunities

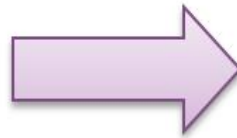
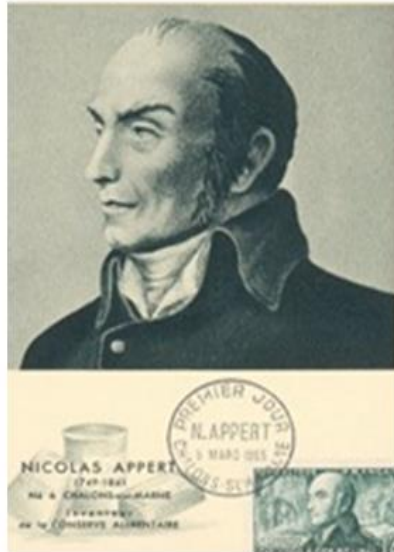


Christmas Bird Count
(since 1900)



eBird Counting
(since 2002)

New Information Technologies Brought in New Opportunities



Open Competition for Food Preservation

Competition Started: 1795
Prize Won: 12,000 Franc, 1810
Winner: Nicolas Appert

Netflix Grand Competition For Collaborative Filtering Algorithm

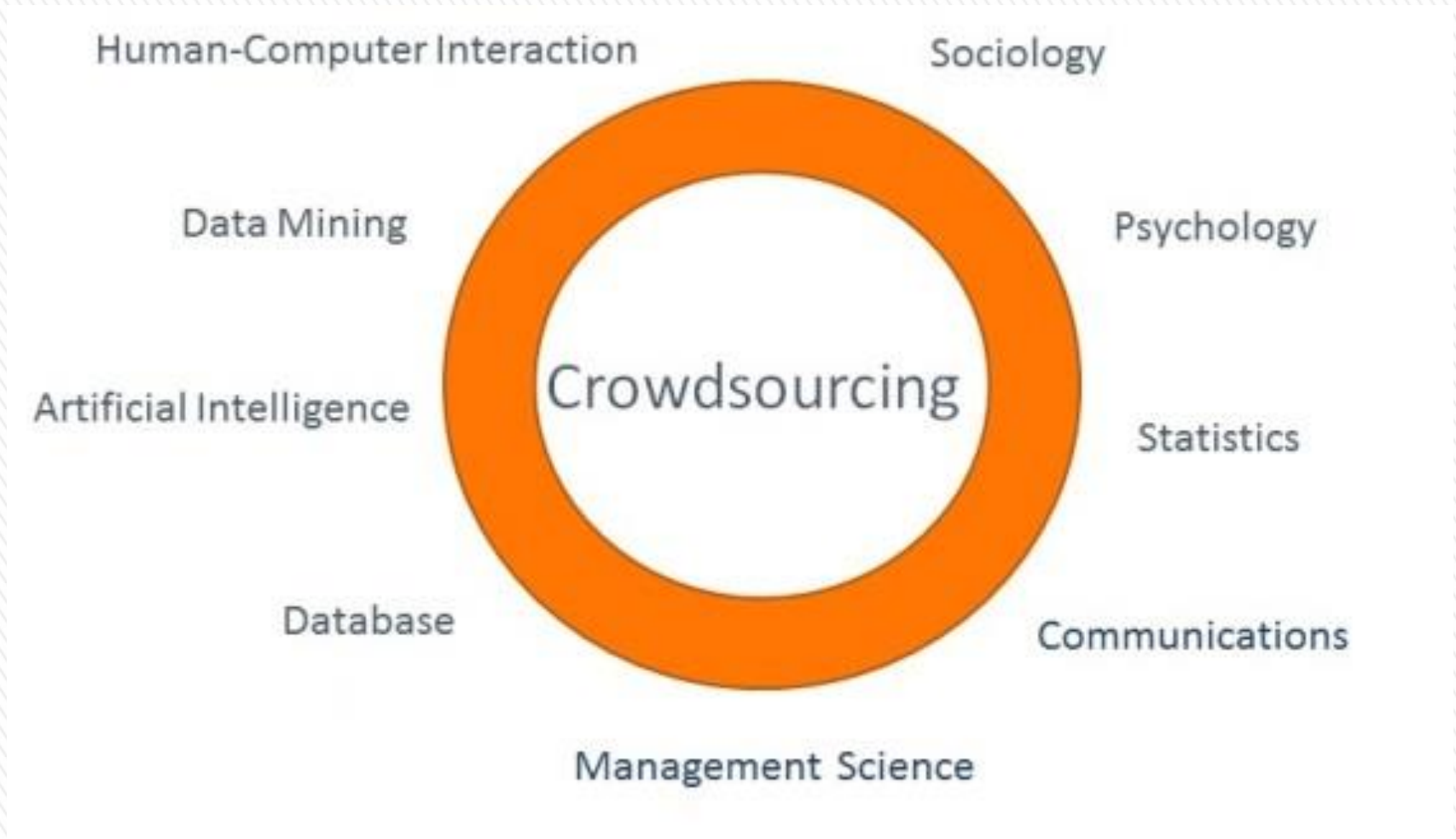
Competition Started: 2006
Prize Won: \$1M, 2009
Winner: BellKor's Pragmatic Chaos team

What is *Crowdsourcing*?



Crowdsourcing –

An Interdisciplinary Research



Applications of Crowdsourcing

E.g. Sorting Algorithms: Many sorting algorithms available,
 Bubble Sort, Quick Sort, Merge Sort...

But, what would it be if we want to sort
the trustworthiness of websites or
the attractiveness of celebrities?

» 3 categories of applications:

- 1 Perceptual Skills: e.g. audio/video classifications
- 2 Cognitive Skills: e.g. comprehensive planning and reasoning.
- 3 Language Skills: e.g. natural language translation.

Our View: 4 Roles that Crowds Can Play

Crowds can be leveraged as:

» Information Collectors.

e.g.

 CNNiReport

 examiner

 DIGITAL JOURNAL

» Human Processors.

e.g.

 amazonmechanical turk
Artificial Artificial Intelligence

 clickworker

 RapidWorkers

» Content Contributors.

e.g.

 YouTube

 flickr

 iStockphoto

» Idea Creators.

e.g.

 InnoCentive

 IdeaScale

 spigit

Our Research: 4 Projects in 3 Categories

» Information Contributors.

① *Mobile Sensing Crumbling Infrastructure*

» Human Processors.

② *Haiti Earthquake Photo Classification*

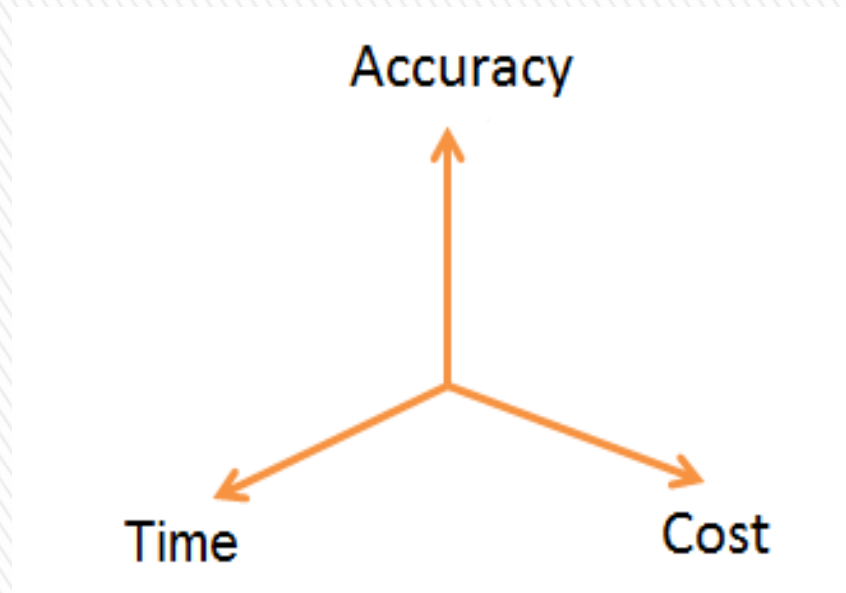
» Idea Contributors.

③ *Expert Citizens on Open Foam Simulation*

④ *Shelters For all Competition*

3 Dimensions

in Crowdsourcing Task Design



- » How much time do we want to allocate?
- » How accurate do we want our results to be?
- » How big is our budget to incentivize the workers?

1 Citizen Sensing Crumbling Infrastructure

- » According to *American Society of Civil Engineers* (ASCE), the general condition of civil infrastructure in the US is in a worrisome situation.
- » When evaluating the overall condition in 2009, the ASCE issued an alarming score of *D* as the GPA of America's infrastructure condition.
- » In 2013, the GPA of America's infrastructure condition is *D⁺*.

From 2009 to 2013 –

No Significant Improvement

TABLE A ★ 2009 Report Card for America's Infrastructure

Aviation	D
Bridges	C
Dams	D
Drinking Water	D-
Energy	D+
Hazardous Waste	D
Inland Waterways	D-
Levees	D-
Public Parks and Recreation	C-
Rail	C-
Roads	D-
Schools	D
Solid Waste	C+
Transit	D
Wastewater	D-

AMERICA'S INFRASTRUCTURE G.P.A. **D**

ESTIMATED 5 YEAR INVESTMENT NEED **\$2.2 TRILLION**

NOTES Each category was evaluated on the basis of capacity, condition, funding, future need, operation and maintenance, public safety and resilience

A = Exceptional
B = Good
C = Mediocre
D = Poor
F = Failing

2009

2013 REPORT CARD FOR AMERICA'S INFRASTRUCTURE **ASCE**

SHARE THIS PAGE

AMERICA'S INFRASTRUCTURE G.P.A. **D+**

Each category was evaluated on the basis of capacity, condition, funding, future need, operation and maintenance, public safety and resilience. [METHODOLOGY >](#)

AVIATION	D	PORTS	C
BRIDGES	C+	PUBLIC PARKS AND RECREATION	C-
DAMS	D	RAIL	C+
DRINKING WATER	D	ROADS	D
ENERGY	D+	SCHOOLS	D
HAZARDOUS WASTE	D	SOLID WASTE	B-
INLAND WATERWAYS	D-	TRANSIT	D
LEVEES	D-	WASTEWATER	D

A = Exceptional
B = Good
C = Mediocre
D = Poor
F = Failing

ESTIMATED INVESTMENT NEEDED BY 2020:

\$3.6 TRILLION

[LEARN MORE >](#)

2013



I-35W Bridge in Minneapolis, Minnesota suddenly collapsed during the evening rush hour, in 2007.

Challenges

- » The amount of infrastructure in countries that covers a broad area, such as that in the US, overwhelmingly exceeds the number of inspectors.
- » A more pervasive, efficient, and operable sensing mechanism empowering national level coverage is needed.

Citizen Engineering Solution



Digital Devices

GPS Tagging



Yahoo API

Address Translation Web Portal



Google API

Photo Aggregation



Google Global Map

Advantages

- » Hand-held digital devices have pervasive coverage.
- » As a basic personal communication tool, cell phones have a relatively reliable power supply.
- » Digital device carriers' assistance could be leveraged to achieve sophisticated application functionalities.

Sample Uploads

Minneapolis

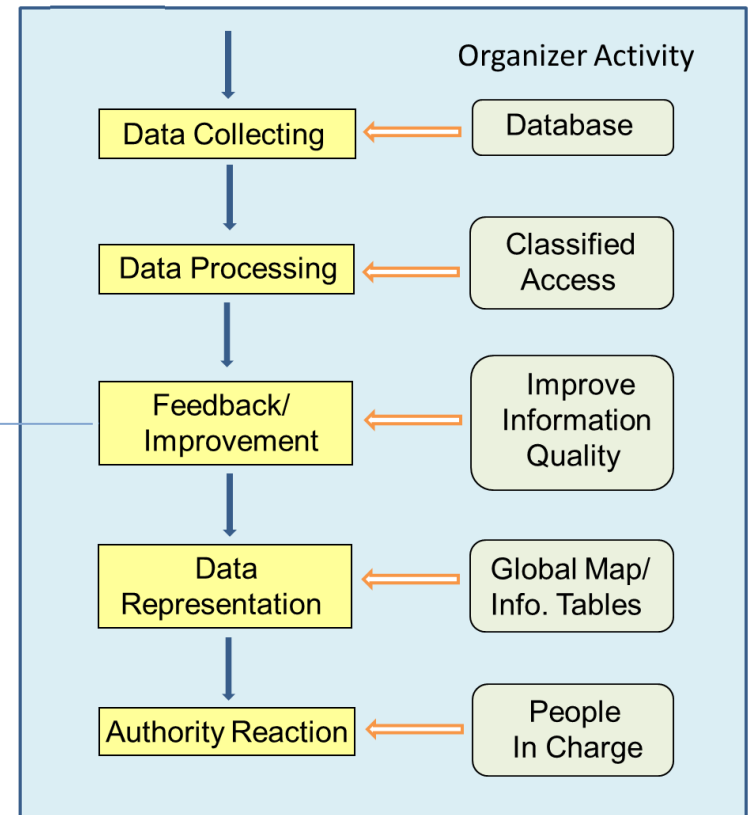
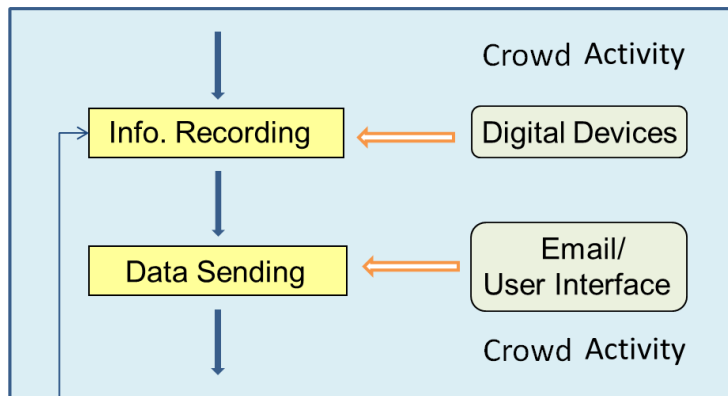
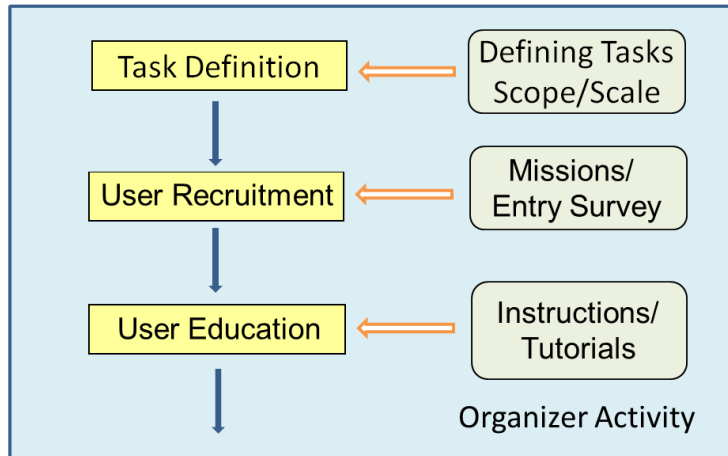


Portland



Contribution

- 10-Module Framework




Case Study I - Summary

» Contributions:


- ❖ Established the cyber-Infrastructure.
- ❖ Demonstrated the concept of citizen sensing.
- ❖ 10-module citizen sensing framework.

2 Haiti Earthquake Photo Classification

Classify Photos

Number of Photos You Completed 

You've tagged 2 photos (1% of our database)

Your Standing in the Crowd 

You are in the 24th percentile (of all participants)



Is there damage in (any of) [the beam\(s\)](#)?

- Yes
- No

Is there damage in (any of) [the column\(s\)](#)?

- Yes
- No

Is there damage in (any of) [the slab\(s\)](#)?

- Yes
- No

Is there damage in (any of) [the wall\(s\)](#)?

- Yes
- No

[BACK](#)

[NEXT](#)

Clicking on links (underlined phrases in blue) will take you to the relevant page in the tutorial.

Questions Attached for Each Photo

Which **building** needs to be tagged?

- Tag entire photo
- Tag part of photo
- Cannot determine

BACK NEXT



What **primary elements** are visible and can be assessed in this photo?
(Check all that apply)

- Beam
- Column
- Slab
- Wall
- Cannot determine

BACK NEXT



Is there damage in (any of) **the beam(s)**?

- Yes
- No

Is there damage in (any of) **the column(s)**?

- Yes
- No

Is there damage in (any of) **the slab(s)**?

- Yes
- No

Is there damage in (any of) **the wall(s)**?

- Yes
- No

BACK NEXT



What **damage patterns** are visible in (any of) the beam(s)?
(Check all that apply)

- Flexure
- Shear
- Concrete Loss

What **damage patterns** are visible in (any of) the column(s)?
(Check all that apply)

- Flexure
- Shear
- Concrete Loss

What **damage patterns** are visible in (any of) the slab(s)?
(Check all that apply)

- Flexure
- Shear
- Concrete Loss

What **damage patterns** are visible in (any of) the wall(s)?
(Check all that apply)

- Sliding Shear
- Diagonal Shear
- Out-of-Plane



What is the **severity** of the worst damage pattern in (any of) the beam(s)?

- Yellow
- Red

What is the **severity** of the worst damage pattern in (any of) the column(s)?

- Yellow
- Red

What is the **severity** of the worst damage pattern in (any of) the slab(s)?

- Yellow
- Red

What is the **severity** of the worst damage pattern in (any of) the wall(s)?

- Yellow
- Red

BACK NEXT

Post Experiment Data Analysis

Step I: Data Cleansing

Data Preparation - Cleansing

Two approaches:

» Behavioral Analysis:

Subjects' behaviors in the process of performing tasks.

e.g. average tagging time.

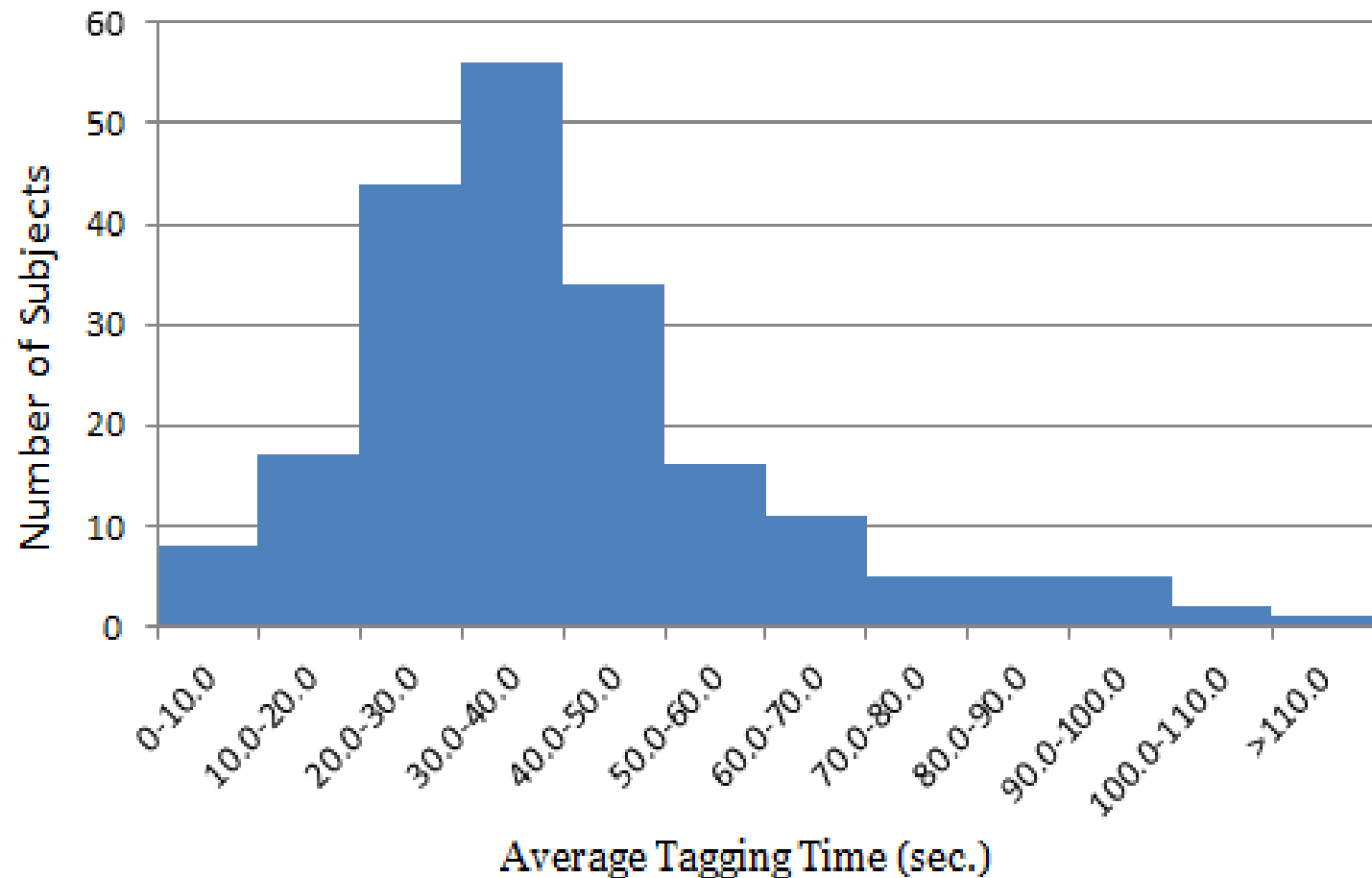
» Output Analysis:

Patterns embedded in subjects' answers.

e.g. consecutive appearances of "Cannot Determine."

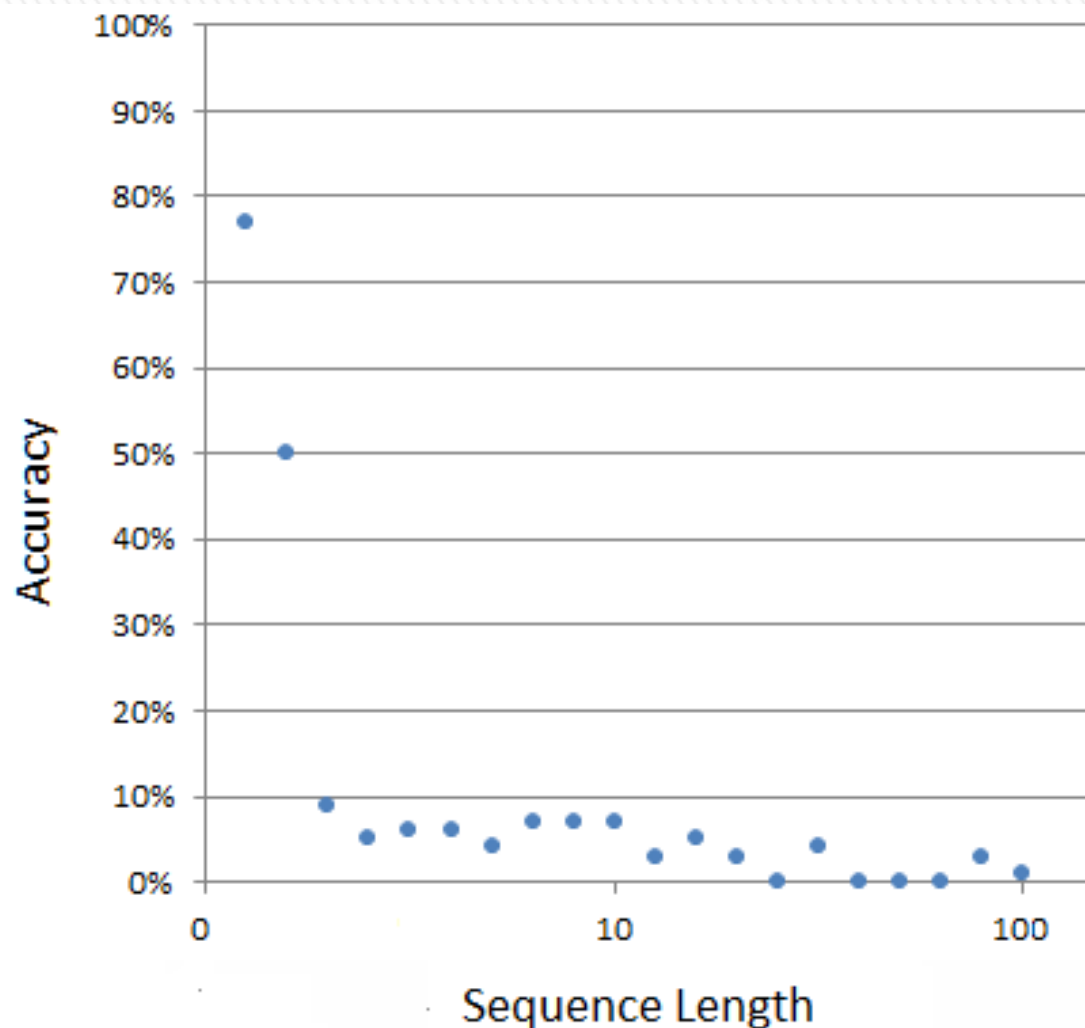
Method 1 - Behavioral Analysis

Freeloader: Average tagging time less than 13 sec.



Method 2 - Output Analysis

Freeloader: Long “Cannot Determine Sequences”



Data Preparation - Results

- » Before Data Cleaning
 - > 9318 user-image pairs (Classifications)
 - > 204 users

- » After Data Cleaning:
 - > 6186 user-image pairs (Classifications)
 - > 202 users

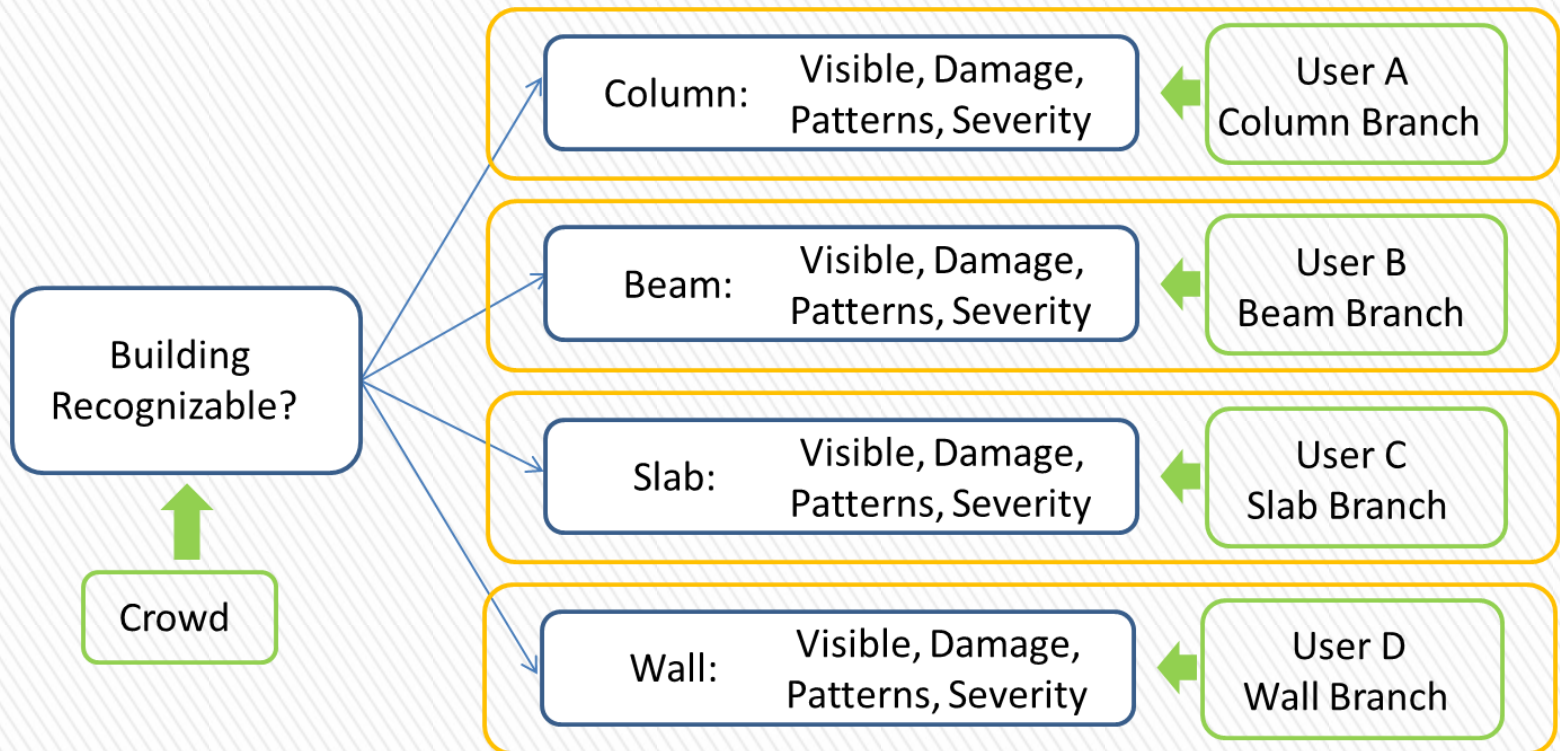
Post Experiment Data Analysis

Step II: Answer Retrieval

Algorithm I: Simple Voting

- » One Subject has One Vote.
All subjects have an equal weight.
- » The option that most subjects agreed upon is the crowd consensus.
- » Comparing the crowd consensus with the ground truth to evaluate the crowd performance.

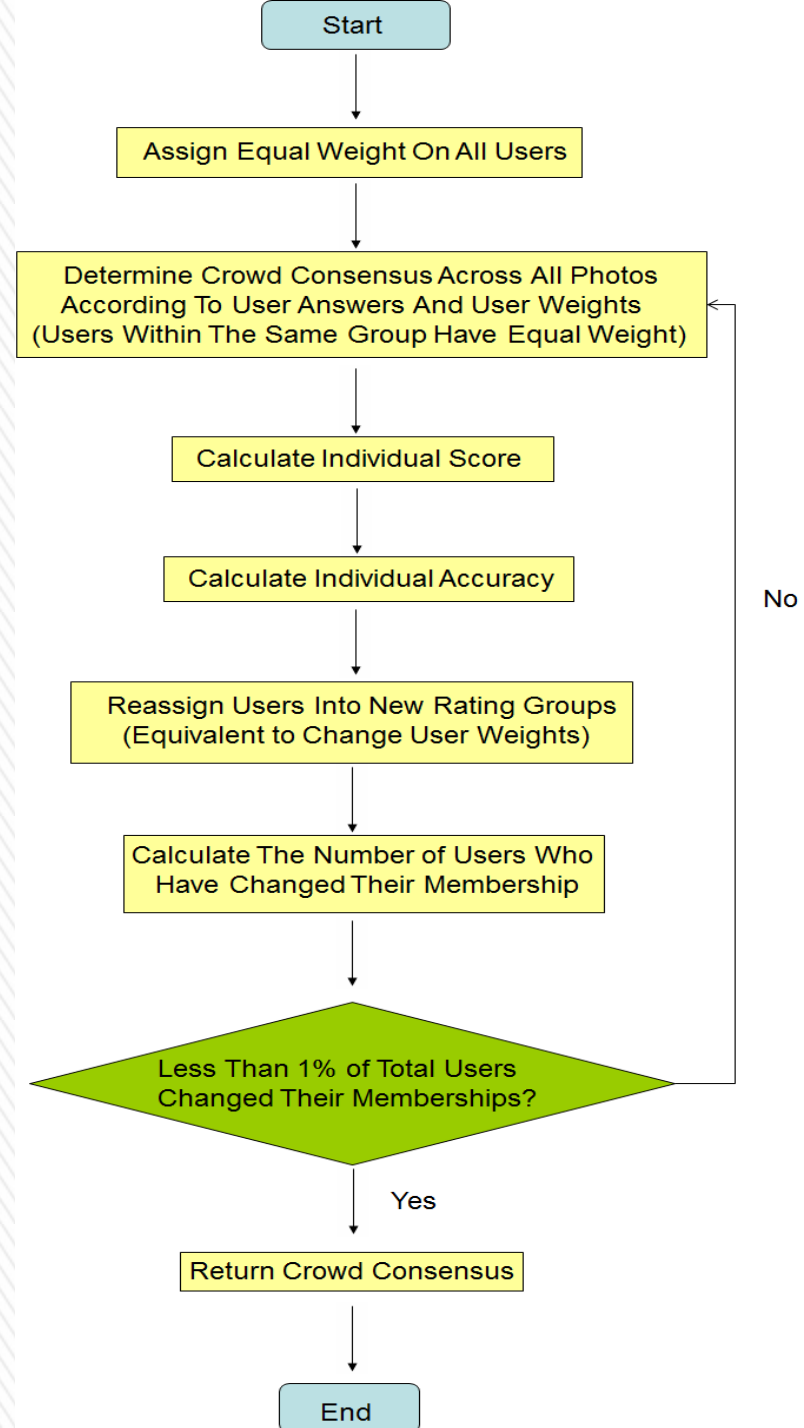
Algorithm II: Branch Composite



Algorithm III: Leader Verdict

	Is column visible?	Is column damaged?	Damage Pattern 1 Damage Pattern 2 Damage Pattern 3	How severe is the damage?
User I	✓ (L)	✓ (L)	✓ ✓ ✓	Yellow
User II	✓	✓	✗ ✓ ✓ (L)	Red
User III	✓	✓	✗ ✗ ✓	Yellow
User IV	✓	✗		
User V	✓	✗		
Crowd	✓	✓	✗ ✓ ✓	Red

Algorithm IV Dynamic Weight



Comparisons

	Algorithm 1 Simple Voting	Algorithm 2 Branch Composite	Algorithm 3 Leader Verdict	Algorithm 4 Dynamic Weight	Professionals' Average
Accuracy	74.0%	63.5%	79.0%	79.2%	78.6%
Effectiveness	$O(nm)$	$O(n)$	$O(n * m \log m)$	$O(\text{gen} * (nm + m \log m))$	
Note		Accuracy is averaged over 10 runs	Accuracy is averaged over 10 runs	<i>gen</i> denotes the generation, which depends on the stopping criteria.	3 Professionals
The number of photos is denoted as n , and the number of classifications that each photo received is denoted as m .					

Case Study II - Summary

» Contributions:

- ❖ Web portal architecture.
- ❖ 3 Data Cleansing Strategies.
- ❖ 4 Result Retrieval Algorithms.
- ❖ User motivation analysis.

(Data Support for sociologists)

3 Expert Citizen Engineering- CFD Simulation

OSD-CI Expert Citizen Engineer Experiment

[Home](#)

[Login](#)

Welcome to the OSD-CI Expert Experiment

You are invited to participate in an online experiment run by the OSD-CI. If you decide to participate, we will ask you to login to a secure website, answer a few questions and take a brief tutorial.

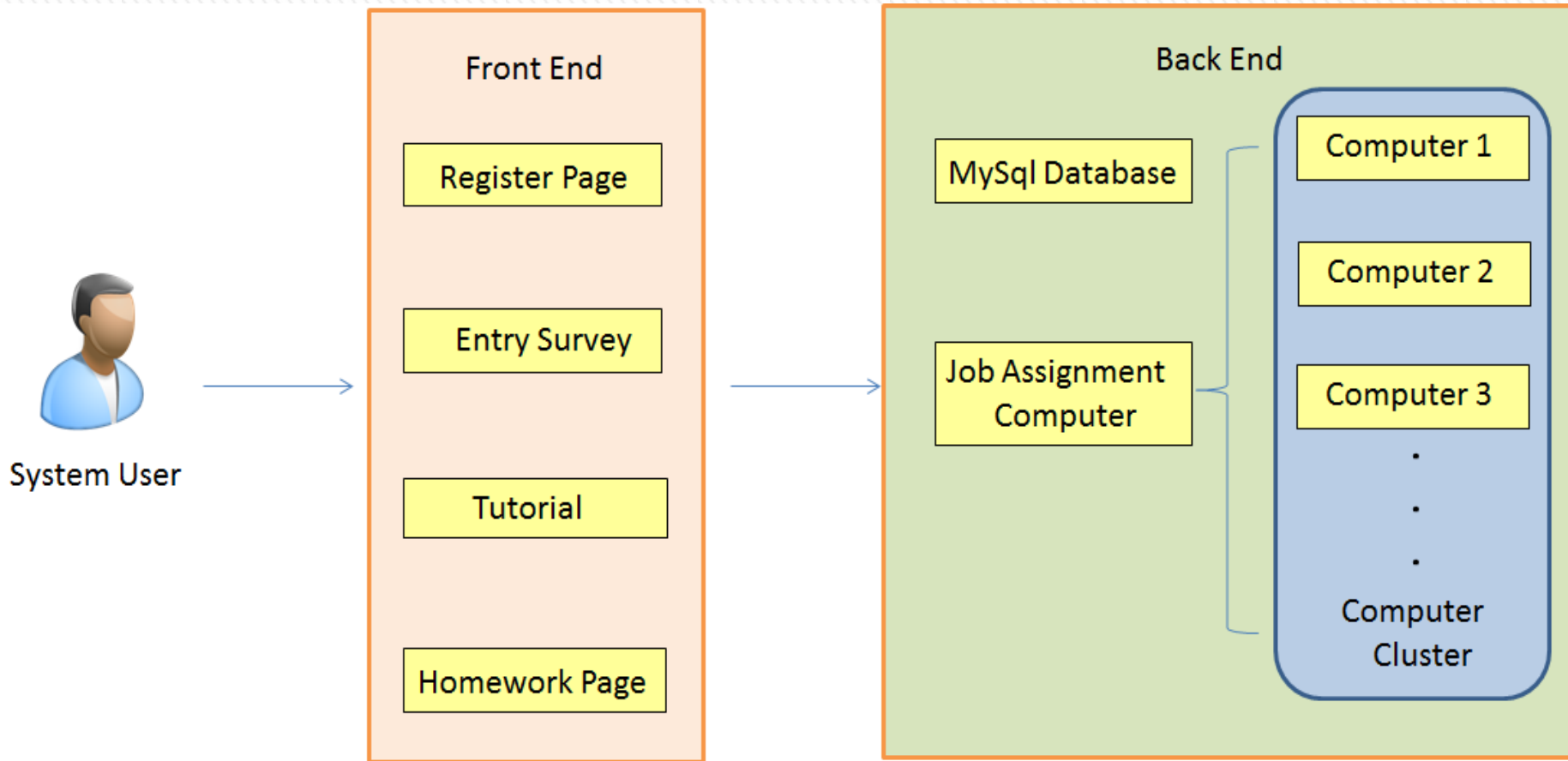
- **Prior to the tutorial, you will also receive information about additional benefits you may derive from participating in this experiment.**
- **If you choose to participate this experiment, it is important that you do not discuss the details of the study with others.**

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. BY CLICKING THE "I WOULD LIKE TO PARTICIPATE" OPTION YOU INDICATE THAT YOU ARE A NOTRE DAME STUDENT AND HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

 [I would like to participate.](#)

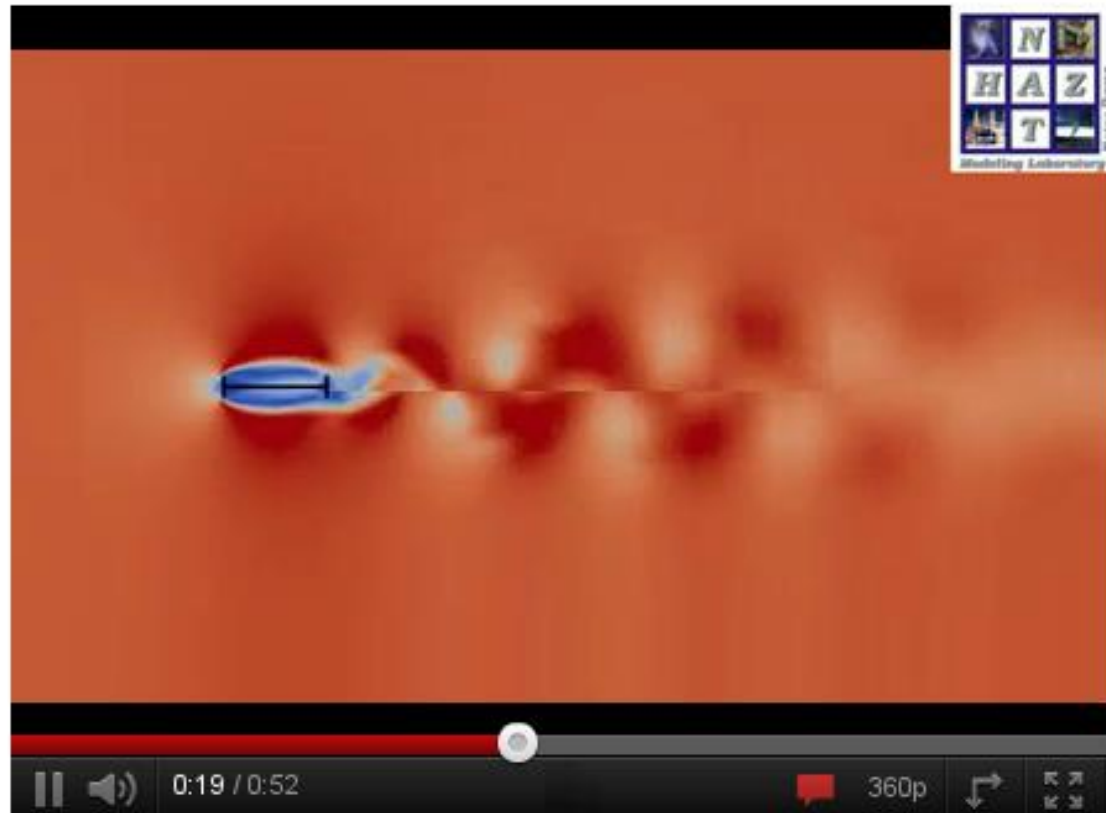
 [I would not like to participate.](#)

Architecture

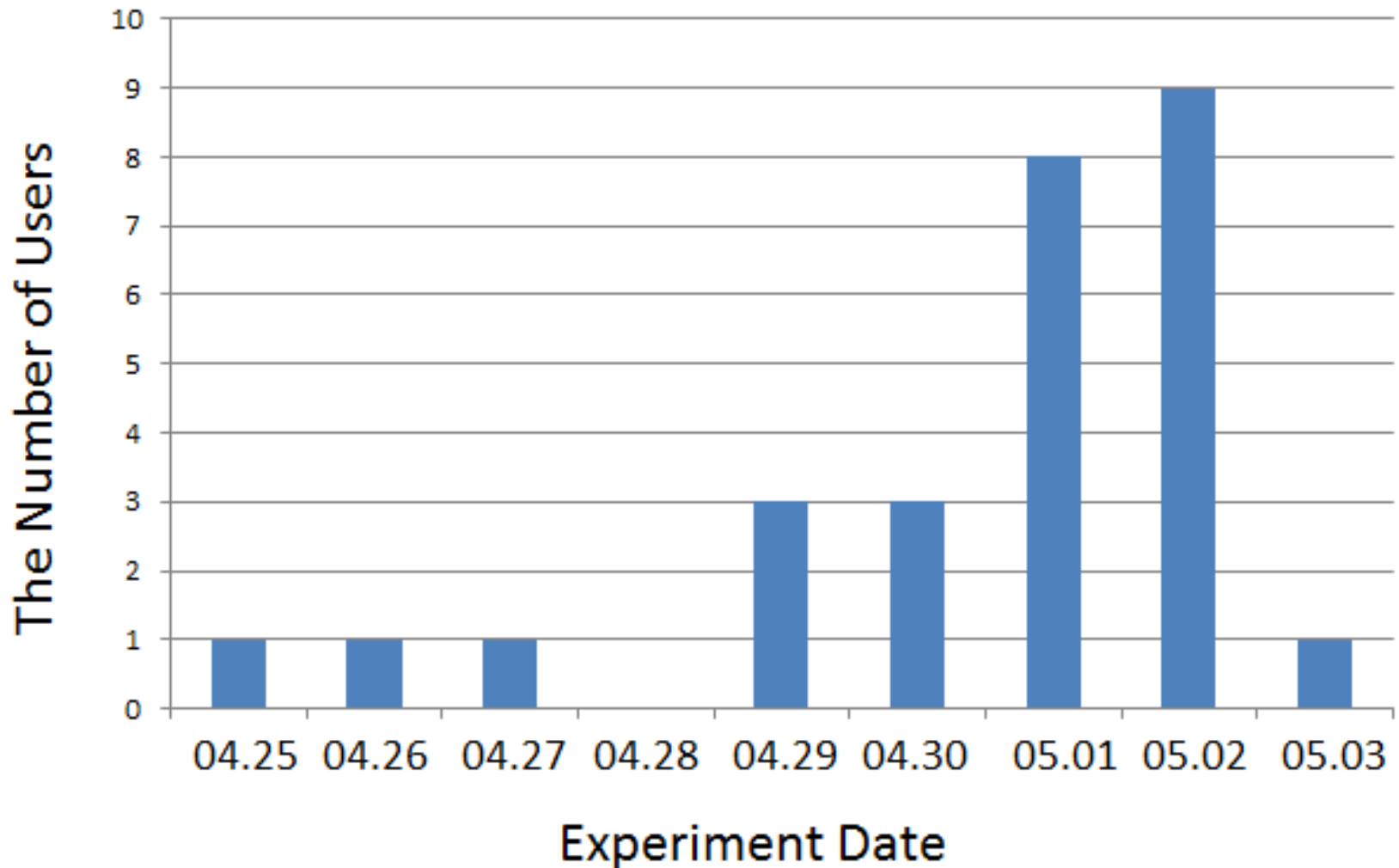


Tutorial

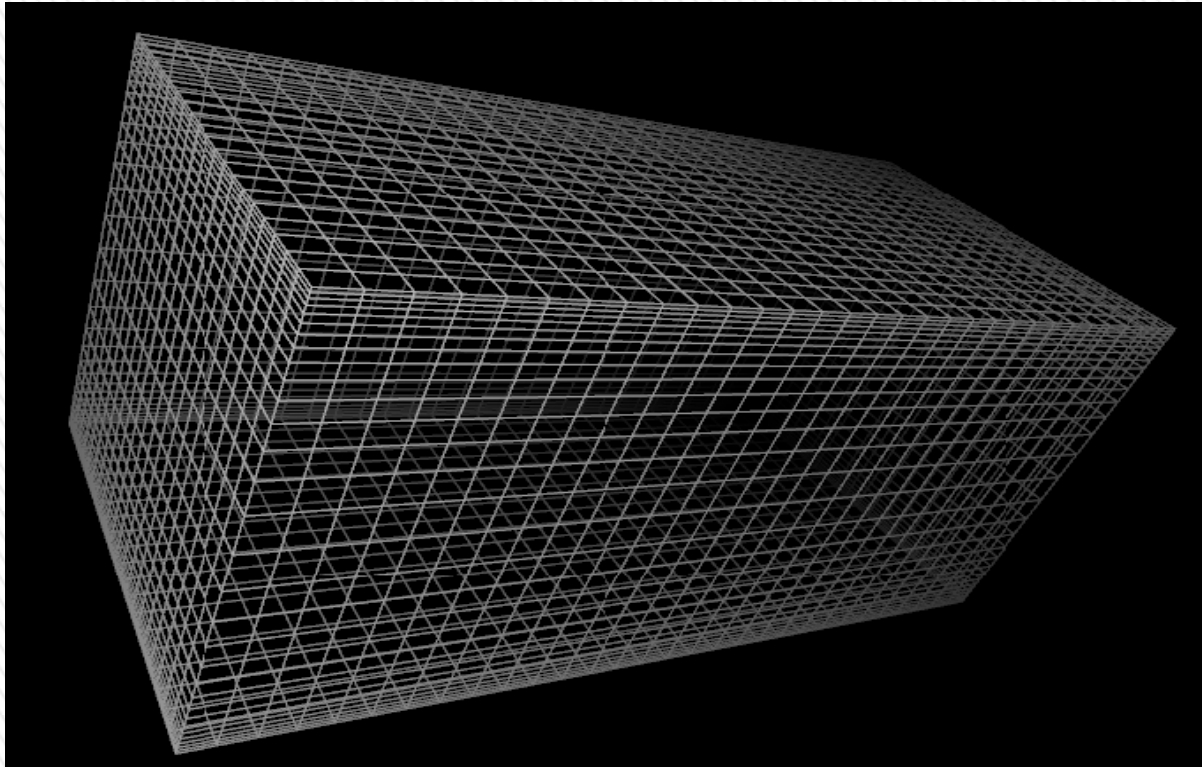
Expert Citizen Engineer Experiment

[Welcome](#)[Task](#)[Simulator](#)[Submission](#)[Profile](#)[Knowledge Base](#)[Logout](#)

User Statistics



Mesh Generation From Student Reports



Case Study III - Summary

- ❖ Established the front-end web portal.
- ❖ Demonstrated the concept of expert-citizen Engineering.
- ❖ Lessons learned:
 - 1 High-end users require high-performance computing facilities.
 - 2 Innovative ways need to be developed to evaluate high-skilled tasks. (An ongoing experiment on Mechanical Turk)
 - 3 The platform needs to be prepared to take burst requests.

4

Shelters For all Competition

Shelters for All
Harnessing the Wisdom of Crowds to Deliver Safe, Affordable Housing to the World's Urban Poor

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[About Us](#) [Blog](#) [FAQ](#)

1 in 7 worldwide live in substandard & unsafe urban housing...
but you can be the **ONE** to change their future!

Join the **Shelters for All Competition** and develop innovative solutions to the urban housing crisis in the developing world.

Winner Announcement:

First Place: "Earthen Dome Home" - Martin Mechtenberg (Application: Africa)
Second Place: "Flexible Homes" - Bowen Anderson (Application: Latin America/Caribbean)
Third place: "The Hempcrete Brickhaus" - Amad Uddin (Application: Bangladesh)
Popular vote (based on peer-review): Matt Oravec (Application: Africa)

		Sign up for our newsletter <input type="text"/> <input type="submit" value="Submit"/>		
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This material is based upon work supported by the [National Science Foundation](#) under Grant No. CISE-09-41585

The User Account Page

Shelters for All
Harnessing the Wisdom of Crowds to Deliver Safe, Affordable Housing to the World's Urban Poor

Home | Logout | Admin

My Account | Team | Documentation | About Us | Blog | FAQ

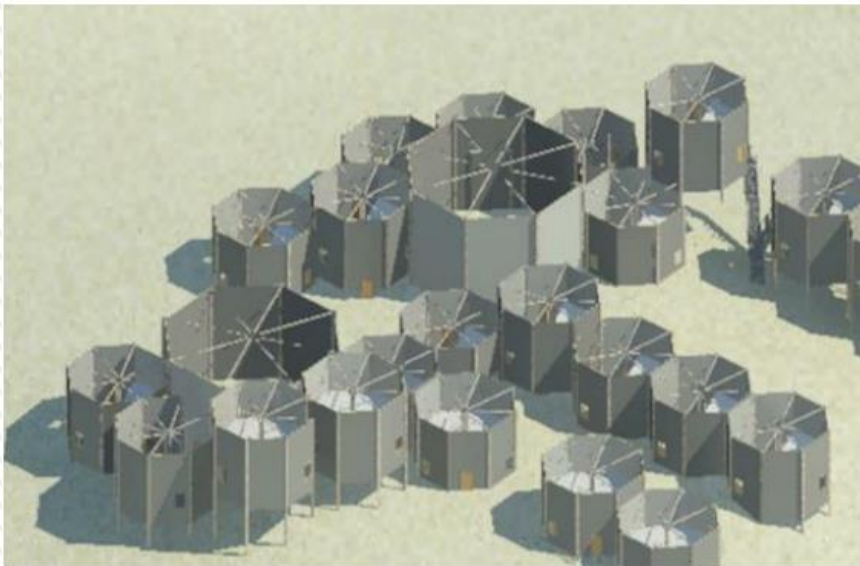
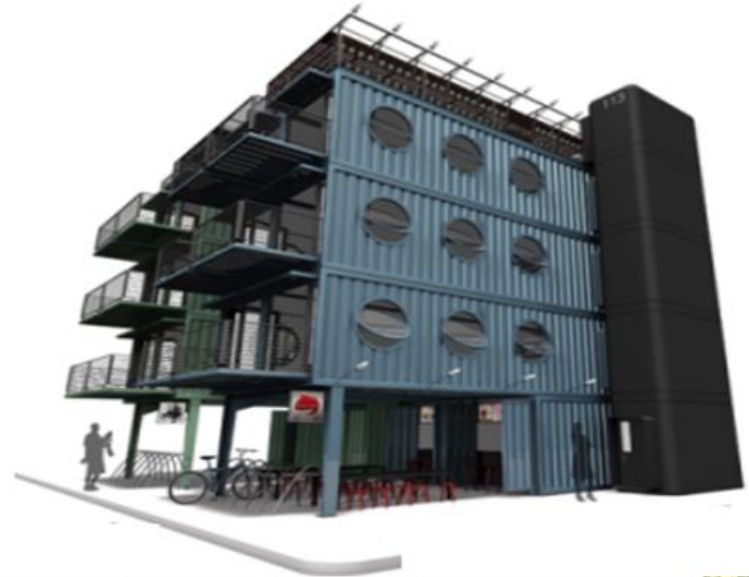
My Account

Account Progress

Entry Survey → Submission → Exit Survey → Peer Review → Submission Repository

* The green bar shows the user progress.

Submissions and Results



Proposal Gallery For Solution Seekers

Shelters for All

Harnessing the Wisdom of Crowds to Deliver Safe, Affordable Housing to the World's Urban Poor

[Home](#)[Gallery Tour](#)[Gallery Logout](#)[About Us](#)[Blog](#)[FAQ](#)

Honorable Mention 3: TARGET COUNTRY: Turkey. SUBMITTER: alexandros zomas.

Since the local population tends to built their own house, but they lack construction knowledge, our proposal aspires to combine the expert knowledge that can educate the local population. Our proposal is a combination of a pre - fabricated core that is provided at the beginning of the construction, which expands with a simple wooden system that can be developed by anyone in a very short time. [View This Design](#)

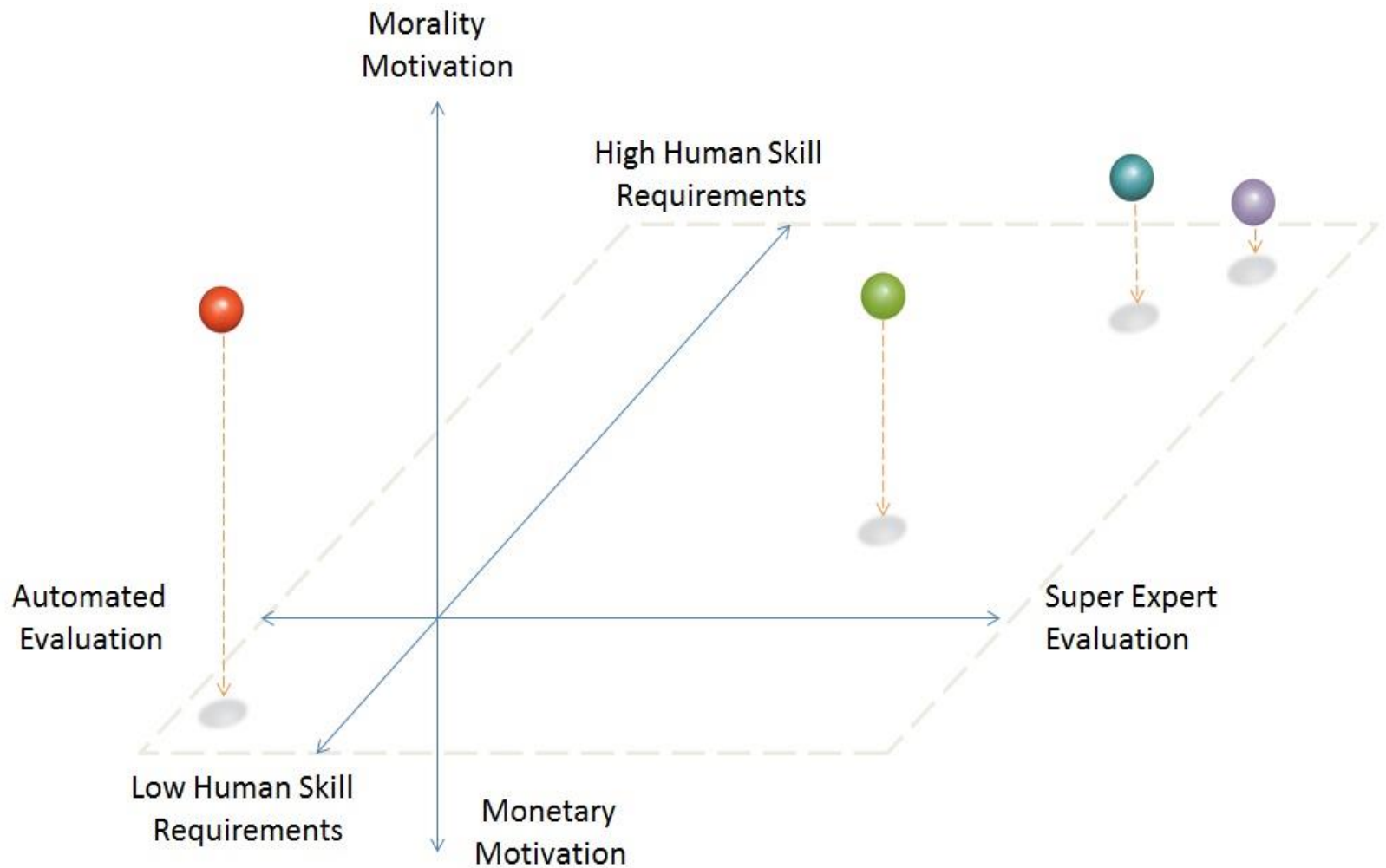
Case Study IV - Summary

- ❖ Established the cyber – infrastructure.
- ❖ Accomplished the platform Integration.
- ❖ 3 Directions for future research:
 - ① The efficiency of open competition model.
 - ② Competition level between participants.
 - ③ Investigate the potential opportunities for collaboration and networking among participants.

Research Summary

- » Case Study I: *Crumbling Infrastructure Photo Submission*
Crowds can be leveraged as information collectors.
- » Case Study II: *Haiti Earthquake Photo Tagging project*
Algorithms for Data Cleansing, and Results Retrieval.
- » Case Study III: *Expert Citizen Engineering*
System designs for high-skilled citizens.
- » Case Study IV: *Crumbling Infrastructure Photo*
Effective design processes for far-reaching and
large-scale innovative contests.





- Haiti Earthquake Photo Tagging : High Morality Motivation, Automated Evaluation, Low Human Skill Requirements.
- Smart Phone Infrastructure Monitoring: Medium Morality Motivation, High Expert Evaluation, Medium Human Skills.
- Shelters For All Competition : Mixed Motivation, Super Expert Evaluation, High Human Skill Requirements.
- OpenFOAM Simulation: Medium Morality Motivation, Super Expert Evaluation, High Human Skills Requirements.

Vision For the Future.

Stratified Citizen Engineering Systems

- » A whole spectrum of citizen engineers with variable backgrounds and expertise.
- » Our preliminary research focuses on low-end average citizen engineers and high-end expert engineers.
- » How about the ones in between? How to shepherd junior engineers to become experienced and thus be able to fulfill complicated tasks ?

Novel Crowd Sourcing System Design

- » What is the optimal number of workers per job?

Reliability vs. Efficiency

- » Teamwork: currently, most current platforms, including our photo tagging system, do not support teamwork.

How can we group users to achieve higher productivity?

The background is a solid orange color with several white line-art icons of lightbulbs scattered across it. Some lightbulbs have short lines radiating from them, suggesting they are lit. A horizontal white bar with a light purple gradient is positioned in the center of the slide, containing the text.

Thank you all.

Questions?

Publications

- » "Citizen Engineering: Evolving OSS Practices to Engineering Design and Analysis", *8th International Conference on Open Source Systems*, Hammamet, Tunisia – 10-13 September, 2012
- » "Haiti Earthquake Photo Tagging: Lessons on Crowdsourcing In-Depth Image Classifications", *Seventh International Conference on Digital Information Management (ICDIM 2012)*, August 22-24, 2012, Macau, China
- » "Crowdsourcing Highly Trustworthy Results", *45th Hawaii International Conference on System Science (HICSS)*, 2012
- » "Expert-Citizen Engineering: 'Crowdsourcing' Skilled Citizens" 2011 International Conference on Social Computing and its Applications (SCA2011) 12-14 December 2011, Sydney Australia
- » Timothy W. Schoenharl, Zhi Zhai, Ryan McCune, Alec Pawling, Gregory R. Madey: Design and implementation of an agent-based simulation for emergency response and crisis management. *SpringSim 2009*, San Diego, CA, March 2009
- » Francis Chen, Zhi Zhai and Greg Madey, "Dynamic Adaptive Disaster Simulation: Developing a Predictive Model of Emergency Behavior Using Cell Phones and GIS Data", *SpringSim 2011/ADS 2011*, Boston, April 2011

Many Thanks Go To...

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- » Committee Members:
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 - Prof. David Hachen
 - Prof. Douglas Thain
 - Prof. Tracy Kijewski-Correa
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 - Dr. Zack Kertcher
 - Dr. Jenny Vaydich
 - Ms. Ellen Childs
 - Mr. Peter Sempolinski
 - Mr. Andrew Weber
- » Sponsor: National Science Foundation

Backup Slides

Crowdsourcing –

An Interdisciplinary Research

