Computational thinking

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Rice University

Outline

- Computational thinking – what is it?
- Learning about computational thinking
  - comp140: a freshman course on computational thinking at Rice
- Practicing computational thinking
  - The Houston Storm Risk Calculator

Examples of problems in computational thinking

- Finding a book on your bookshelf
  - Google's index of Web documents
- Deciding on which line to stand in at a bank, supermarket
  - Queuing theory/task scheduling for Google's servers
- Packing items in your backpack
  - Knapsack problem for Fedex trucks
- Scheduling day/week activities (or cooking dinner)
  - Traveling salesman problem for Fedex/UPS

Challenges of scaling up

- The number of potential solutions is so large that even a fast computer cannot evaluate all these solutions.
  - How many ways to make a tour of 10 cities? 100 cities?
    - 3 million options for 10 cities, 10^{365} options for 100 cities
- Some solutions are cheap, and others may be expensive or undesirable.
- How can we find these good solutions?
  - Computational thinking tells us how!

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Module 0

- Problem: the devil and Daniel Webster
- Mathematics: recurrences
- Computation: computing recurrences, root finding by interval halving
- Python: lists, iteration, functions and recursion
- Project: compute a counteroffer for Webster, polynomial root finding, iterated function systems.

- The devil made a proposition to Daniel Webster. The devil proposed paying Daniel for services in the following way:"On the first day, I will pay you $1,000 early in the morning. At the end of the day, you must pay me a commission of $100. At the end of the day, we will both determine your next day's salary and my commission. I will double what you have earned at the end of the day, but you must double the amount that you pay me. Will you work for me for a month?"

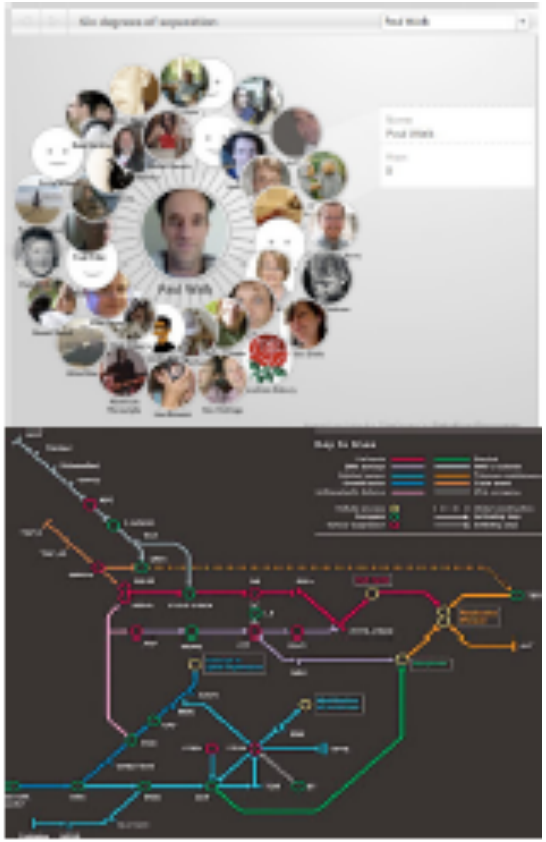
Module 1

- Problem: solving the curious case of Mark V. Shaney
- Mathematics: probability theory, generative models, Markov models
- Computation: text representation, strings, dictionaries, conditionals and iteration
- Python: string, dictionaries, file I/O, modules (random), if, for, while, functions
- Project: build a text riffer, analyze Twitter feeds from Houston

- Mr. Chairman, delegates, fellow citizens, I'm honored to aid the rise of democracy in Germany and Japan, Nicaragua and Central Europe and the freedom of knowing you can take them. Tonight, I remind every parent and every school must teach, so we do to improve health care and a more hopeful America. I am in their days of worry. We see that character in our future. We will build a safer world today. The progress we and our friends and allies seek in the life of our work. The terrorists are fighting freedom with all their cunning and cruelty because freedom is not America's gift to every man and woman in this place, that dream is renewed. Now we go forward, grateful for our older workers. With the huge baby boom generation approaching retirement, many of our work. About 40 nations stand beside us in the next four years.
- Riff on Bush's 2004 speech

Module 2

- Problem: modeling complex systems as networks and analyzing their properties
- Mathematics: graph theory, hubs and authorities, paths, cycles, connected components, six degrees of separation
- Computation: PageRank computation, graph visualizations, path computation
- Python: the networkx module, pylab, recursive functions (findpath), fixpoint computations (page rank)
- Project: analyze Rice facebook network, Enron email network, airline route maps



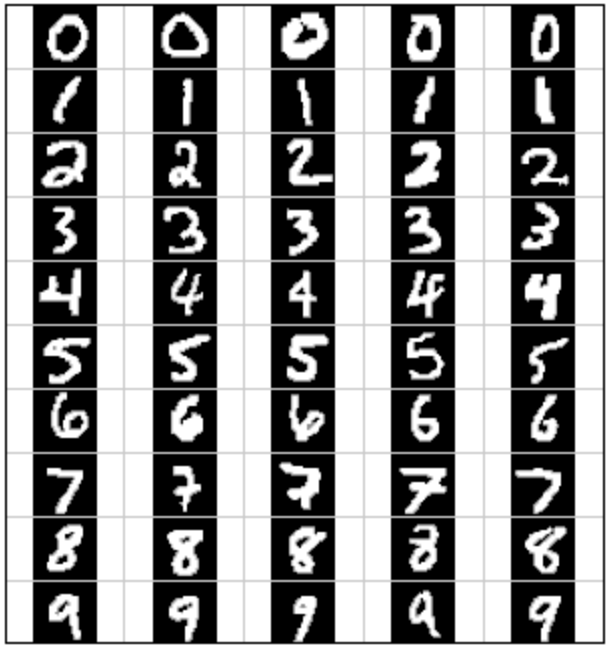
Rice is a tighter world than the world outside the hedges.

Characterization of Rice colleges

Entity	#comp	Size of comp 1	Global clust	Avg degree	dia	Pop deg	Pop bc
comp140	13	77	0.427	4.52	13	Mengqi Jia	Connie Feng
Baker	3	140	0.544	35.67	4	Christine Cooper	Avinash Ravishankar
Brown	2	169	0.527	47.30	4	John Mendell	John Mendell
Duncan	3	181	0.491	40.75	5	Kelvin Pho	Kelvin Pho
Hanszen	2	169	0.545	56.45	4	Megan Johnson	Megan Johnson
Lovett	2	188	0.558	54.22	4	Max Chester	Michael Tilghman
Jones	3	156	0.535	47.58	4	Steven Boswell	Steven Boswell
Martel	1	175	0.531	46.14	4	Claire Morice	Kevin Tran
McMurtry	3	152	0.500	33.61	4	Emily Pyle	Emily Pyle
SidRich	3	131	0.563	41.76	4	Gustavo Herrera	Gustavo Herrera
Wiess	3	178	0.510	44.42	4	Alice Fa	Tiffany Ho
WillRice	5	145	0.540	44.70	3	Nicholas Feltman	Justin Lin

Module 3

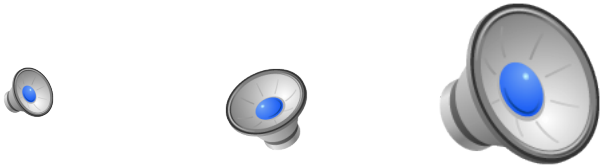
- Problem: understanding how spam filters, handwritten digit recognizers work
- Mathematics: recognition by inverting generative models, Bayes' Theorem
- Computation: recipes with randomization, image representations, multi-level dictionaries, objects (counters), functions, methods
- Python: lists, dictionaries, more file I/O, math and random modules
- Project: build recognizer for handwritten digits from NIST database, extension to face recognizers



Which digit?

Module 4

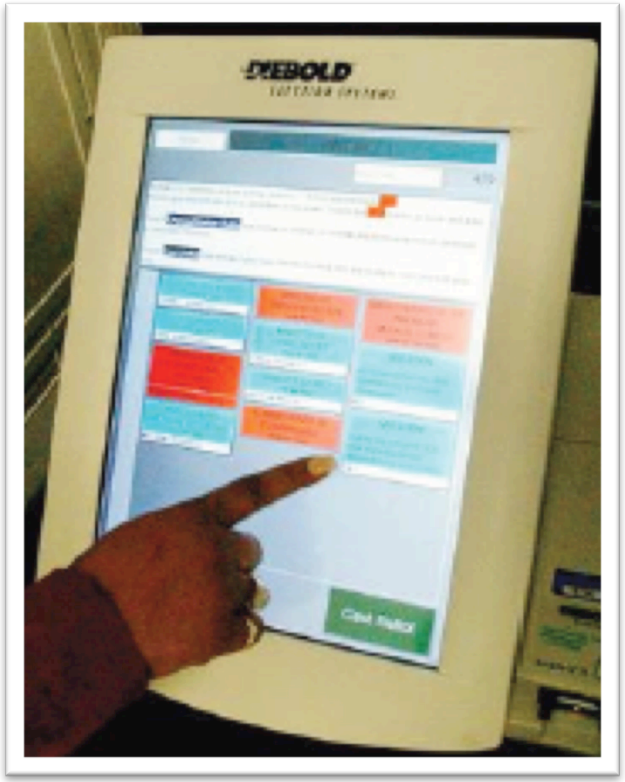
- Problem: build-a-DJ
- Mathematics: digitization of sound by sampling, Nyquist theorem, Fourier analysis, physics of sound
- Computation: representations of digitally sampled sound as lists, manipulating digital sounds (fading, mirroring, blending) by list computations, algorithmic composition
- Python: reading and writing sound files, map/reduce, elements of functional programming, pyaudio module
- Project: build your own ringtone, compose a piece of classical/choral music



Algorithmic composition
by Manan Mehta, F08
DJ sounds by Adrian Pellerin F09

Module 5

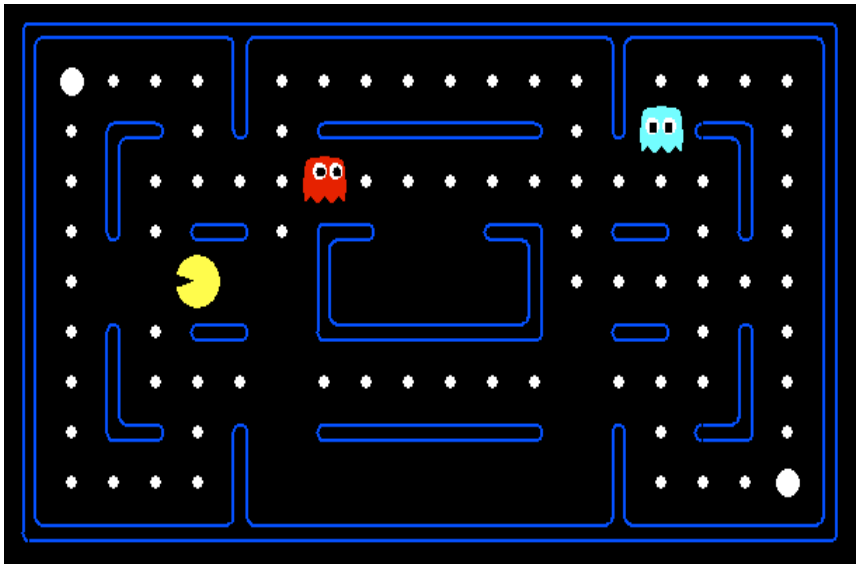
- Problem: End-to-end cryptographically verifiable elections
- Mathematics: homomorphic public key cryptography, modular arithmetic, zero-knowledge proofs
- Computation: Diffie-Helman, Elgamal crypto algorithms, Chaum-Pederson proofs
- Python: modular arithmetic, dictionaries, hash functions
- Project: Verifying the Helios election



Module developed with Professor Dan Wallach

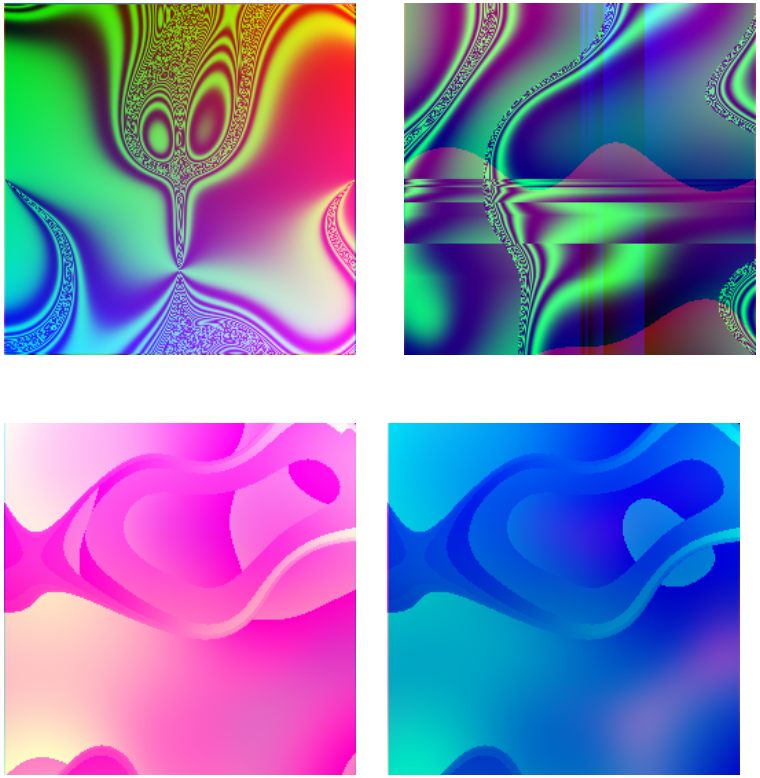
Module 6

- Problem: understanding how AI bots for interactive games are designed
- Mathematics: graphs, path finding in graphs, random walks, decision-making
- Computation: search algorithms on graphs, minimax, intelligent agents
- Python: module (graphs, search), queues, recursive functions, OOP
- Project: build a pacman playing AI bot



Module 6.5

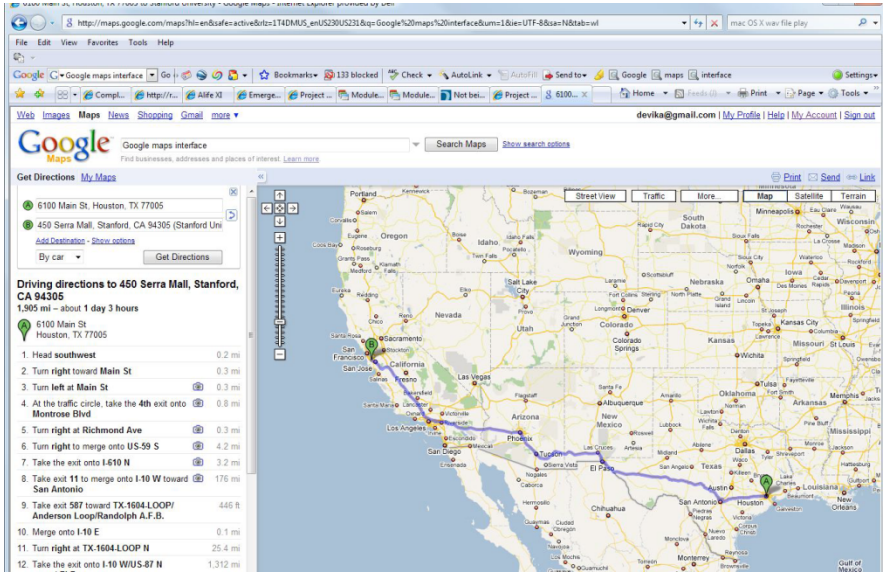
- Problem: evolving art
- Mathematics:
- Computation: the genetic algorithm, tree representations of mathematical functions
- Python: working with tree data structures
- Project: building your own computational art generator



Images generated by Ian Arnold, comp140 Fall2010

Module 7

- Problem: understand how GoogleMaps calculates routes
- Mathematics: path finding algorithms in graphs (Djikstra, Bellman-Ford, A*)
- Computation: graph representations, implementing A*, big O analysis of complexity, scaling
- Python: modules (networkx), Javascript, web services, mashups
- Project: building a web service to find routes between favorite haunts in Houston



http://www.google.com/help/maps/tour

Module built by my student Mitchell Koch, Rice CS alum, May 2011

comp140

You could have fun and learn about problem solving, computation and Python!

Come play and discover with us!

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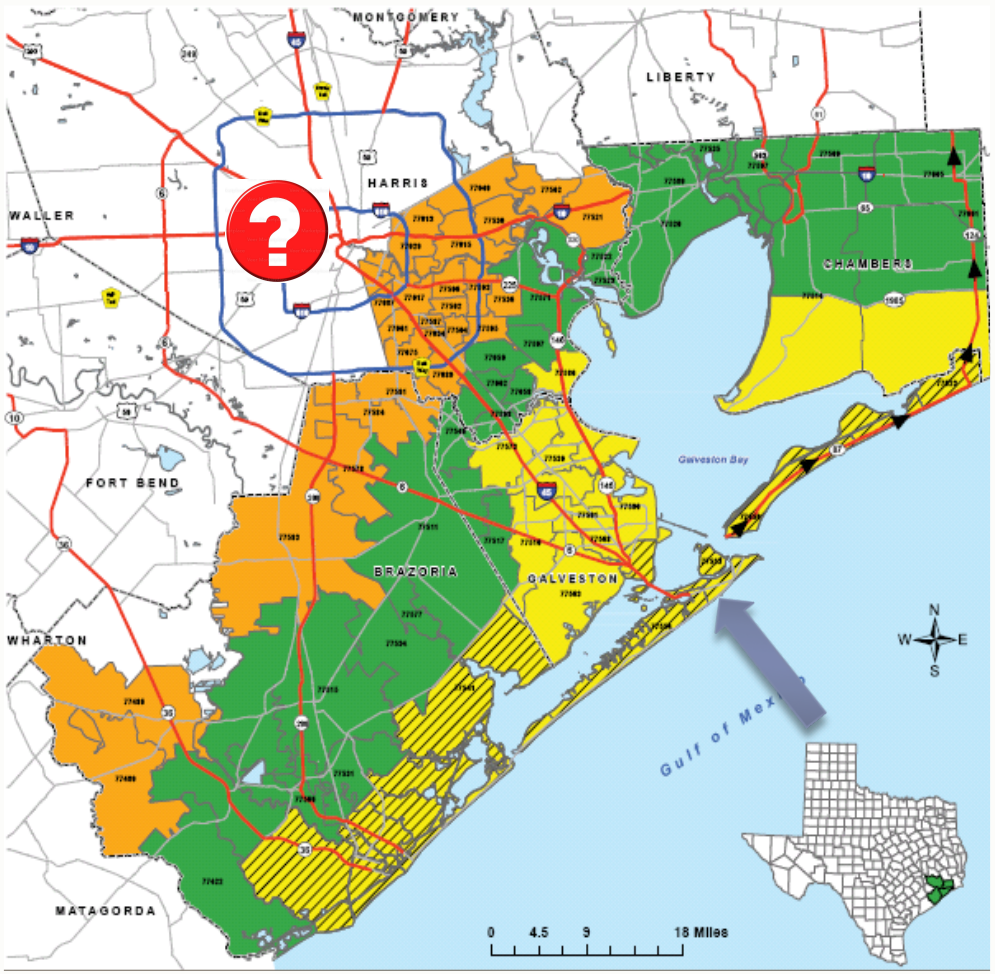
Building and validating geographically refined hurricane wind risk models for residential structures

- Devika Subramanian, Rice University
- Josue Salazar, Rice University
- Leonardo Duenas-Osorio, Rice University
- Bob Stein, Rice University

Building and validating geographically refined hurricane wind risk models for residential structures, Natural Hazards Review 10.1061/(ASCE)NH.1527-6996.0000130 (Sep. 12, 2013).

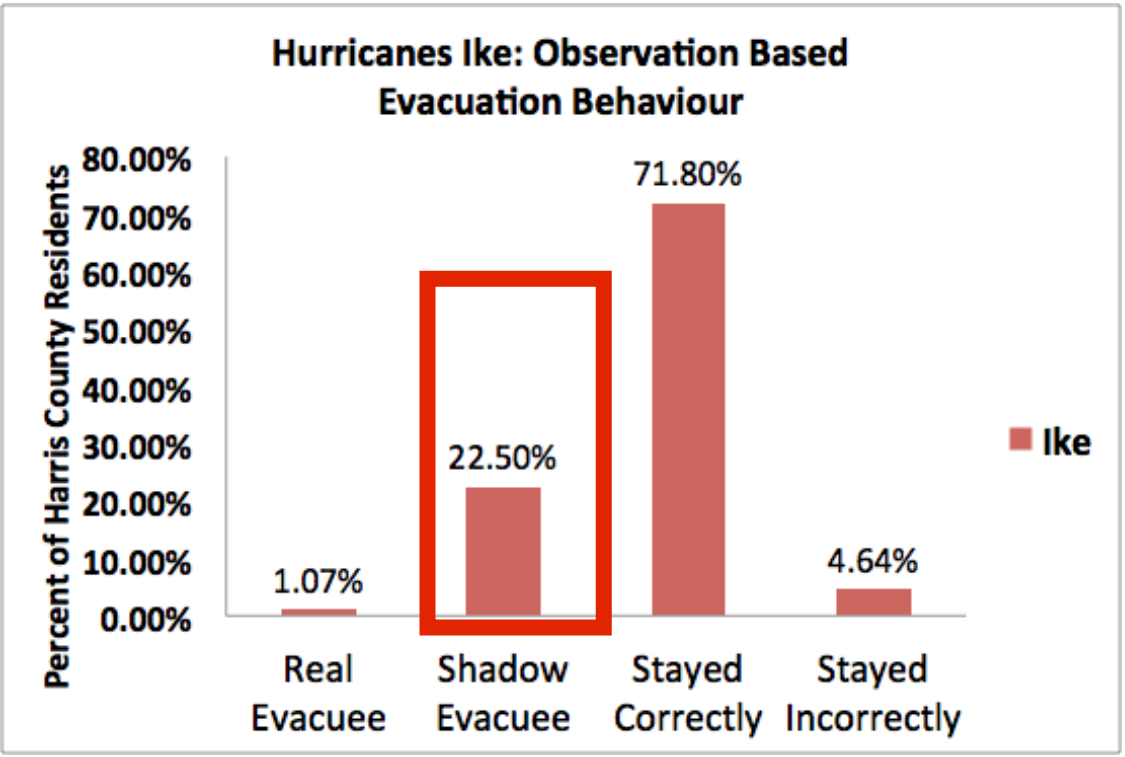
Motivation



- No information about hurricane induced risk is made available to people in the white zone.
- The white zone is where the bulk of the Harris County population resides.

http://www.hcoem.org/HCMap.aspx?P=Evacuation

Shadow evacuation (Ike, 2008)



- Real evacuee = at risk and decided to evacuate
- **Shadow evacuee** = not at risk and decided to evacuate
- Stayed correctly = not at risk and decided to shelter
- Stayed incorrectly = at risk and decided to shelter

http://www.npr.org/templates/story/story.php?storyId=94546210

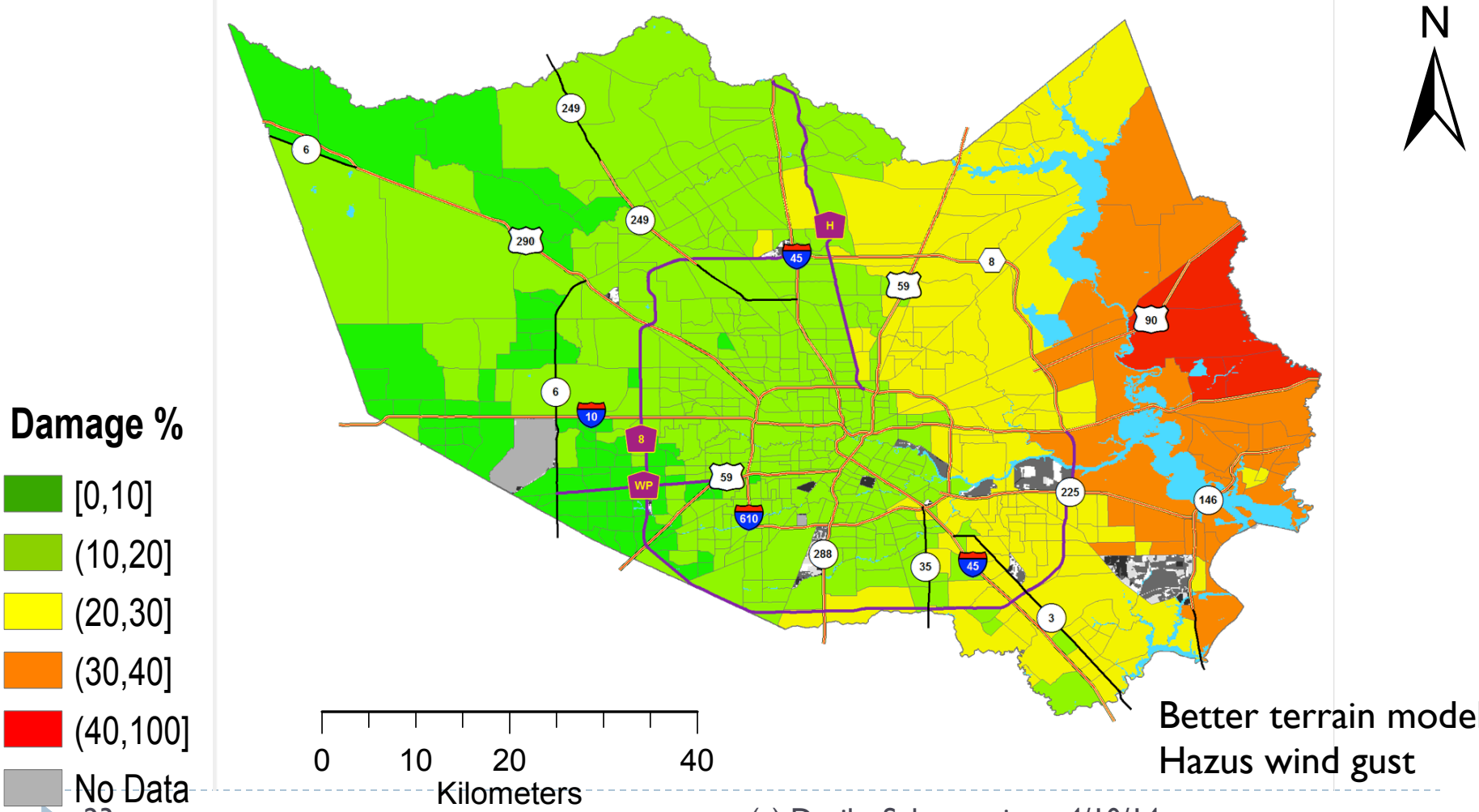
Perspective

- How do we exploit the massive amounts of data we gather, using new instrumentation and algorithms we have developed, to help answer questions that matter to us?
- Artificial intelligence and machine learning are the primary technological enablers for data-driven decision-making!

An information resource for Harris County

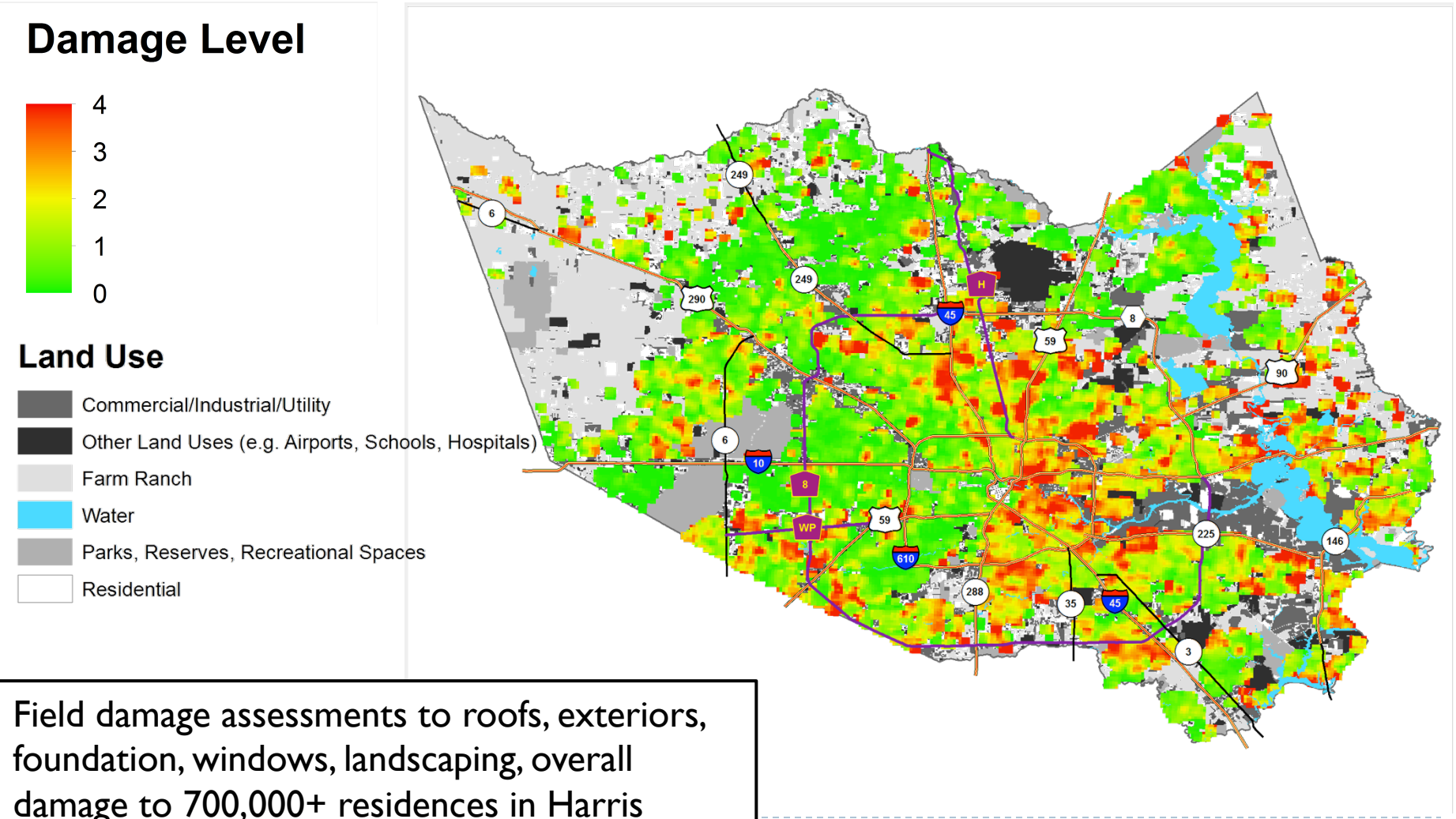
- What if we could
  - calculate risk of damage to residential structures due to surge, rainfall and wind at the level of city blocks?
  - effectively communicate that risk through a website?

State of the art prediction at the census tract level for Ike



Better terrain model
Hazus wind gust

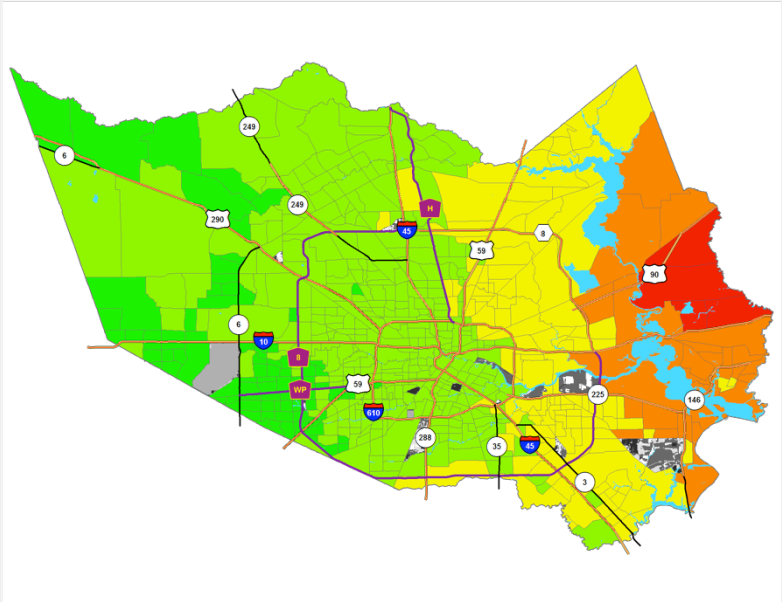
Observed Ike wind damage



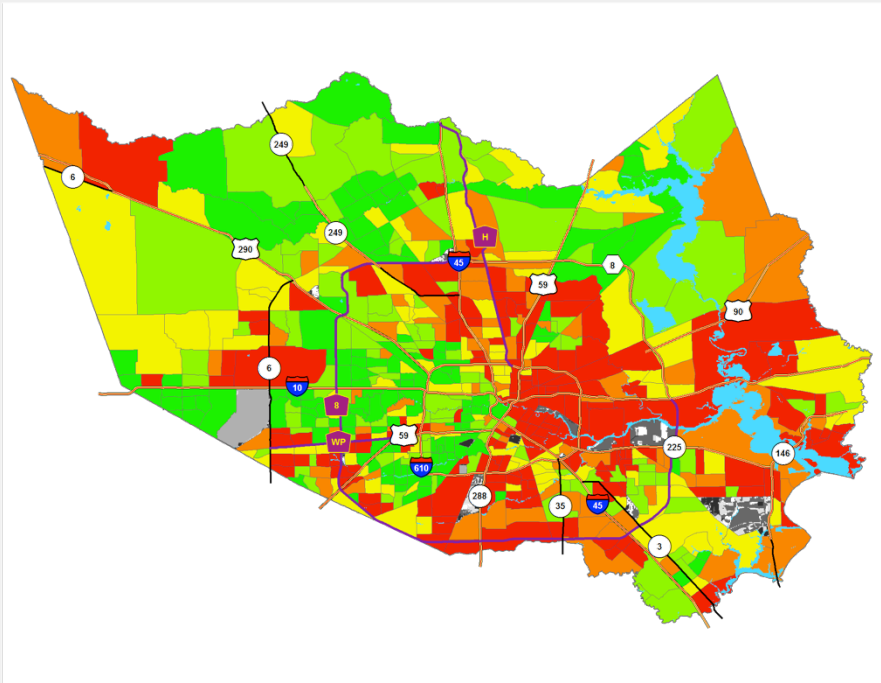
Field damage assessments to roofs, exteriors, foundation, windows, landscaping, overall damage to 700,000+ residences in Harris County

Source: Harris County Housing Authority, 2008

Side by side comparison

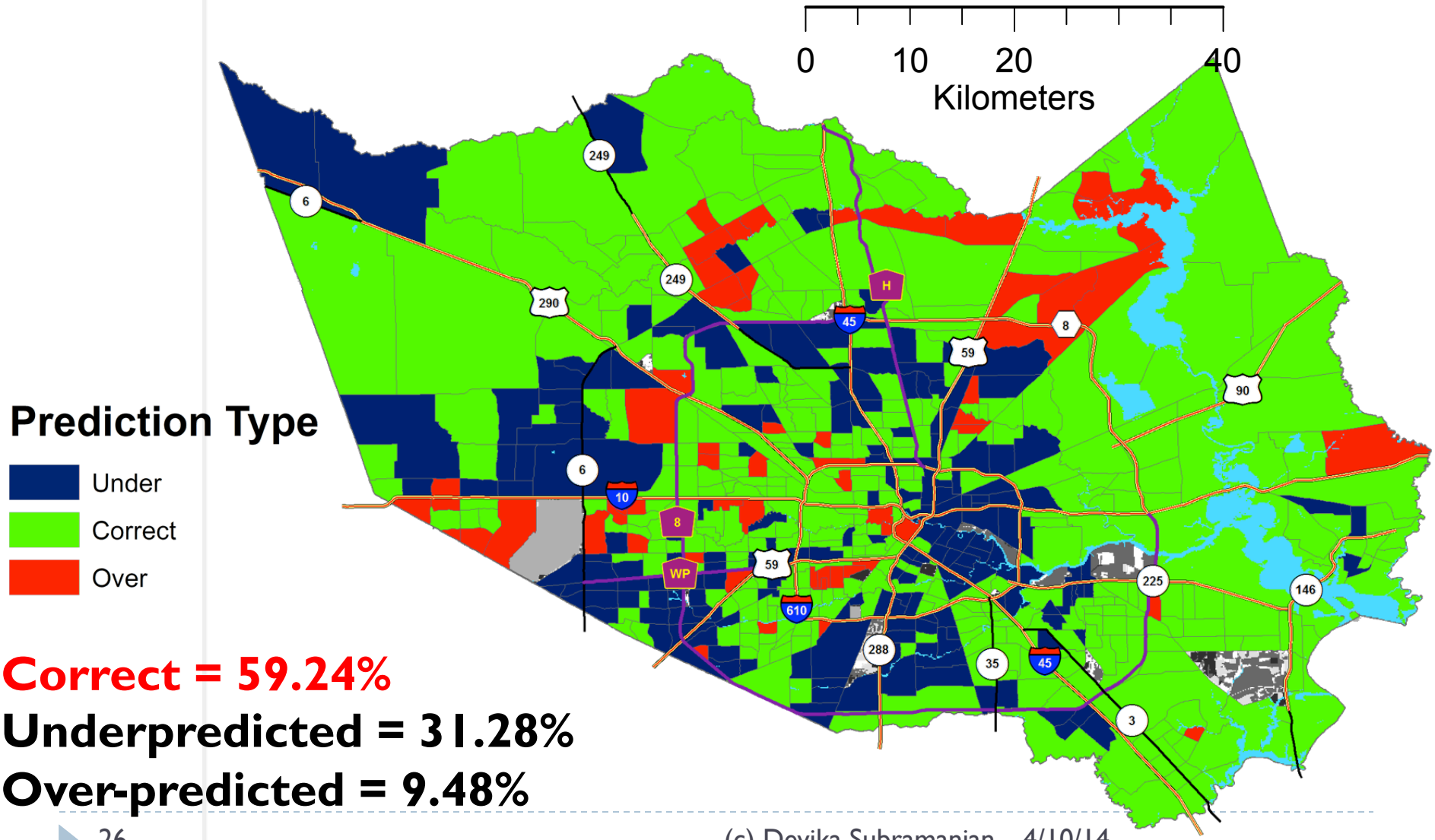


Predicted



Actual

Prediction errors at the tract level



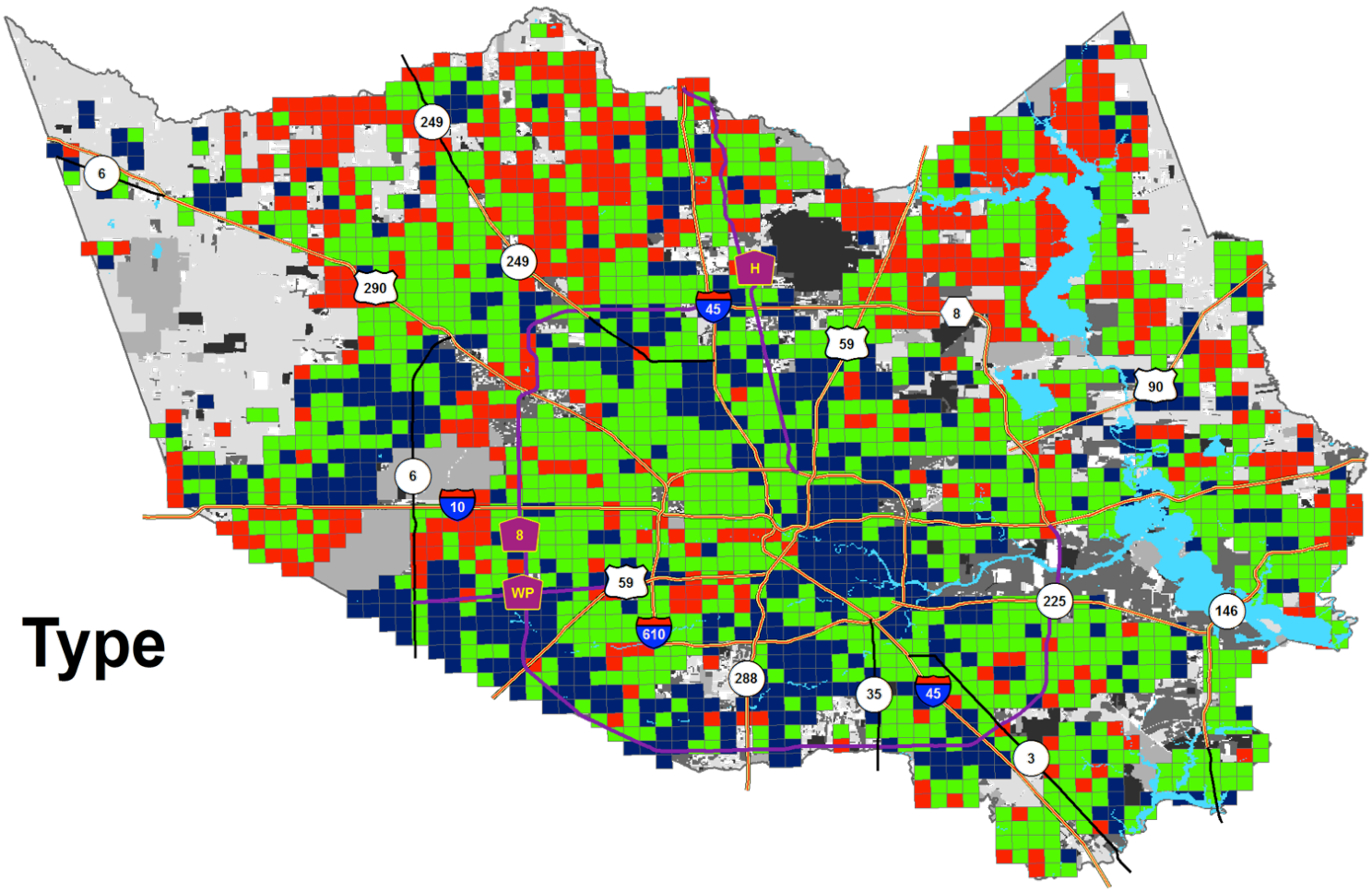
Correct = 59.24%

Underpredicted = 31.28%

Over-predicted = 9.48%

Prediction errors at 1 km^2 level

Correct = 51.03%
Under= 25.63%
Over = 23.34%

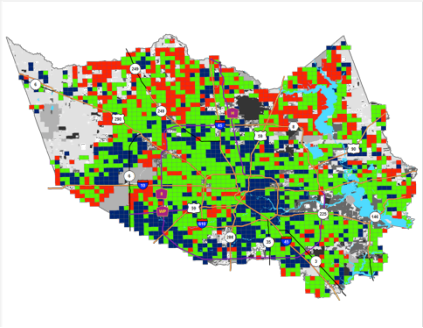


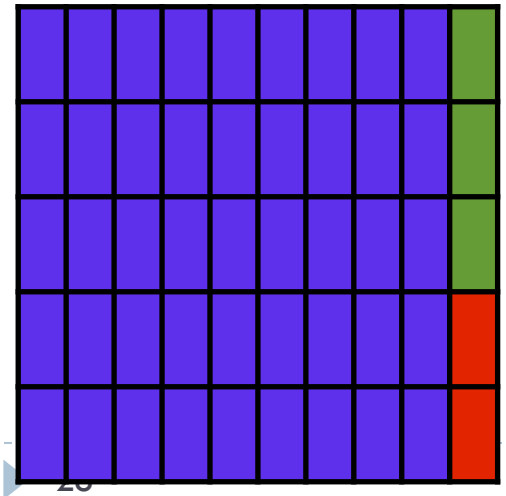
Prediction Type

- Under
- Correct
- Over

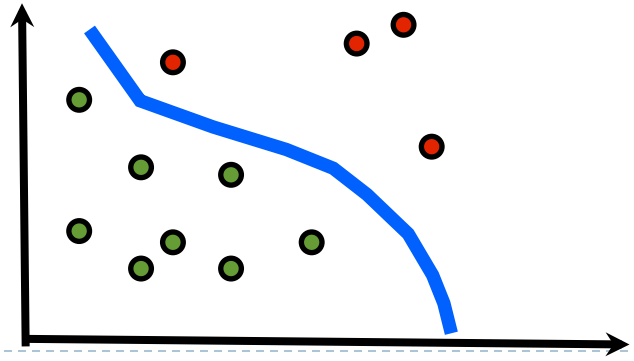
Error analysis using machine learning

What are the characteristics of the tracts/blocks where the fragility curve based model makes errors?





Training data



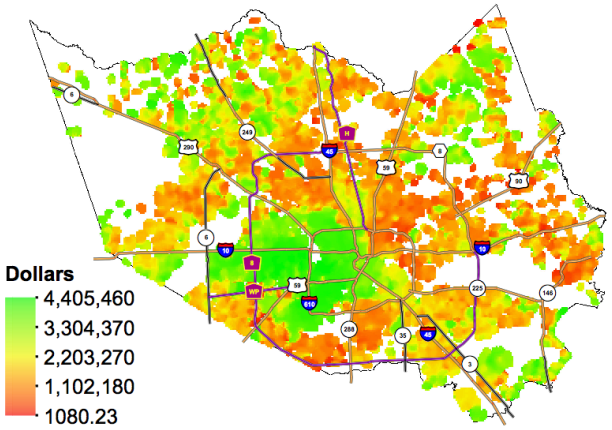
Structure of model

- Features averaged at census tract/block level
  - Terrain: Roughness length, HGAC landcover, tree100m, highway1km
  - Building properties: land value, building value, extra features value, exterior wall, floors, age, remodeled age, construction quality, garage type
  - Construction code enforcement: in an incorporated area, incorporation year, built after incorporation
  - Hazard characteristics: Max wind, wind swath, wind direction, wind duration, wind steadiness, hazus wind gust, hazus sustained wind

Explanatory variables

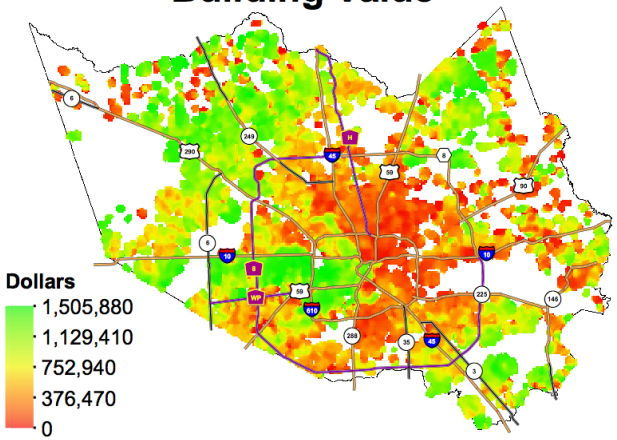
HCAD

Land Value



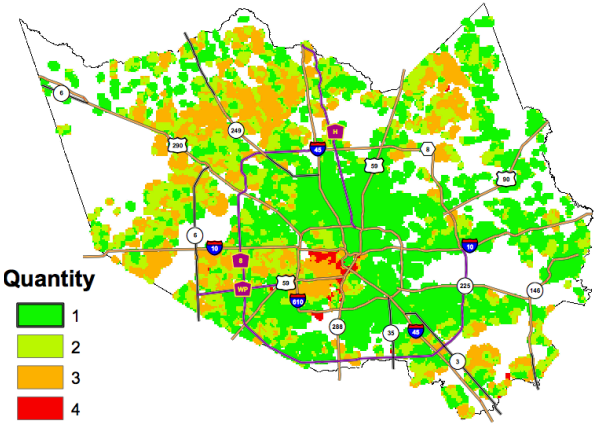
HCAD

Building Value

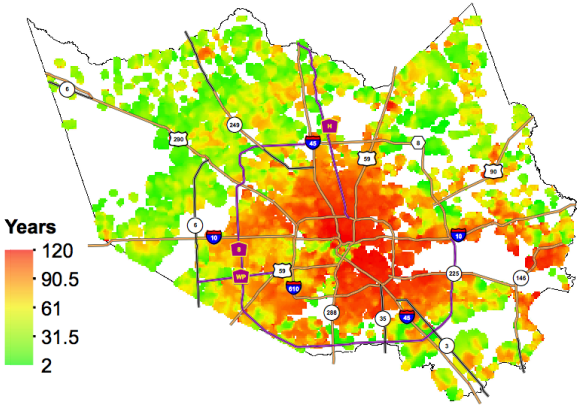


HCAD

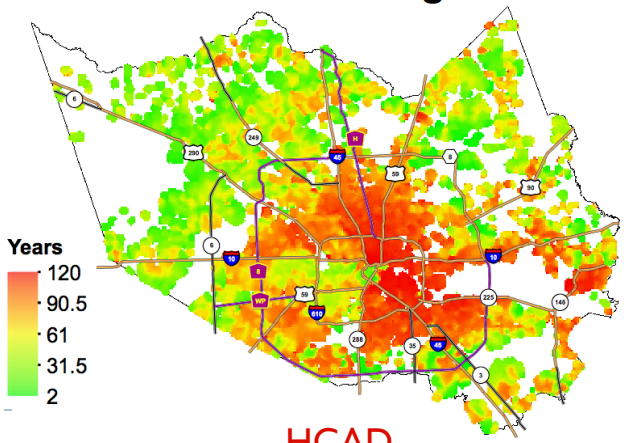
Number of Stories



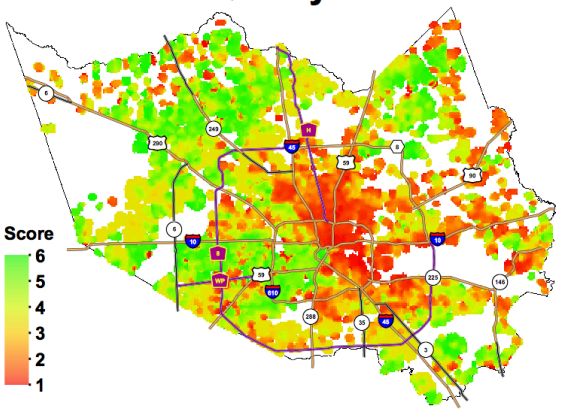
Age



Remodeled Age

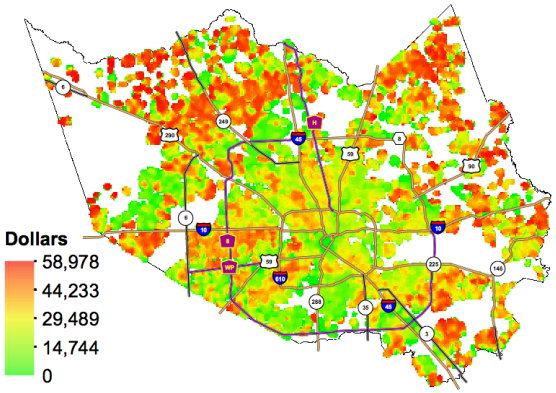


Quality



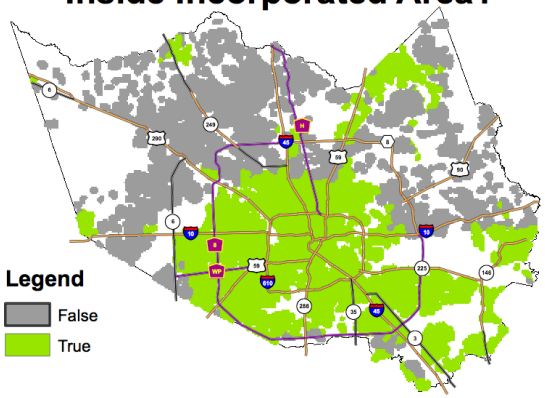
HCAD

Extra Features Value



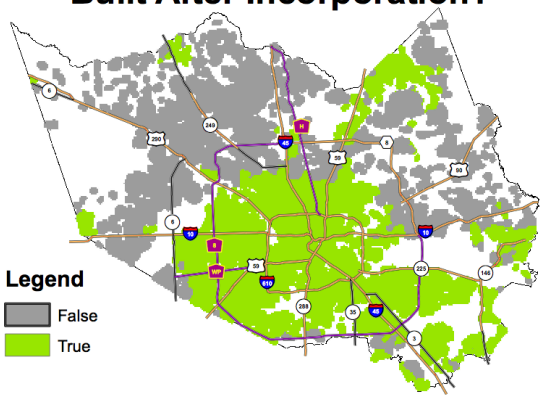
County

Inside Incorporated Area?

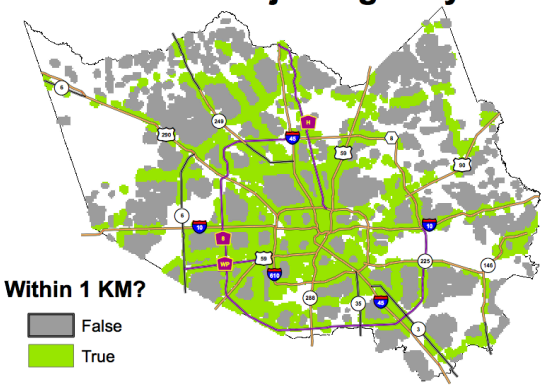


County

Built After Incorporation?

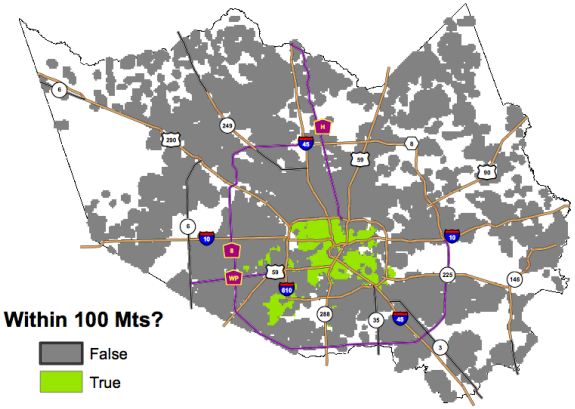


Next to Major Highway



County

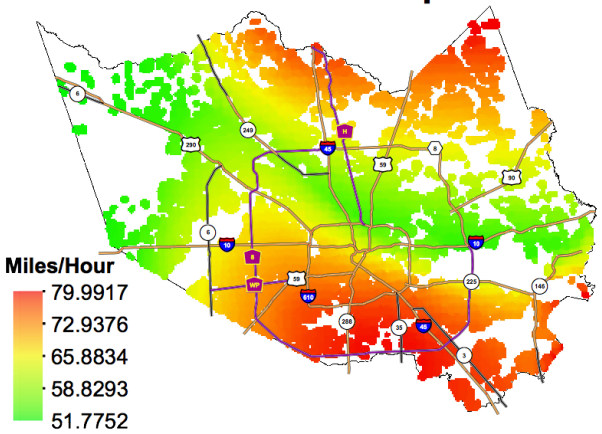
Next to Tree



County

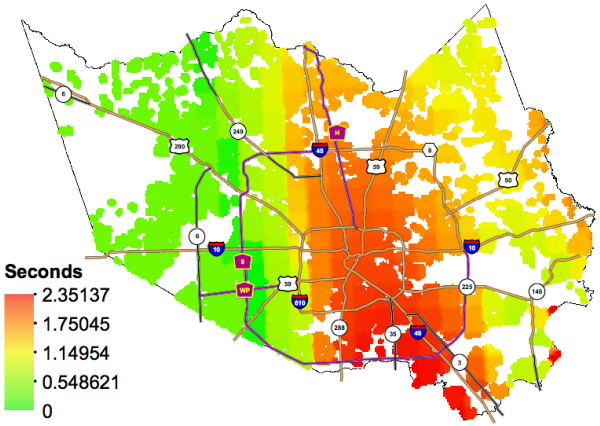
NOAA

Maximum Wind Speed



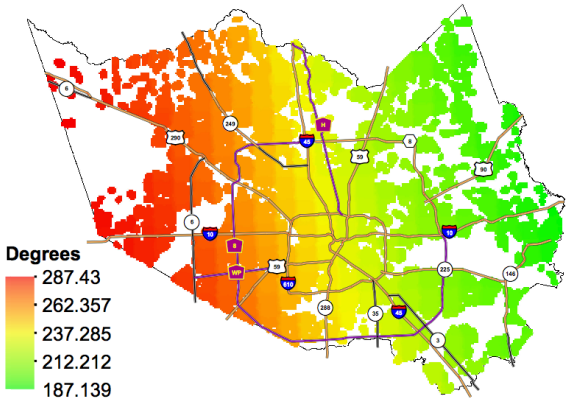
NOAA

Wind Duration

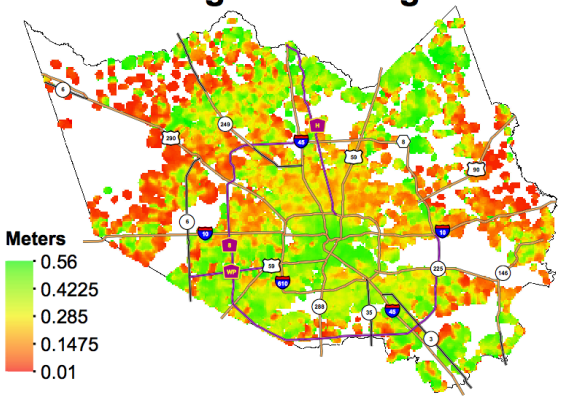


NOAA

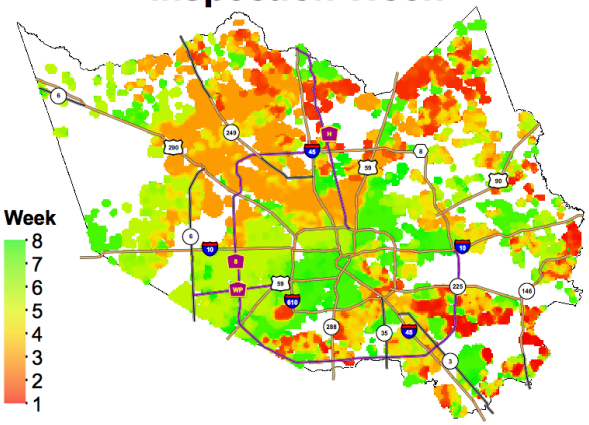
Wind Direction



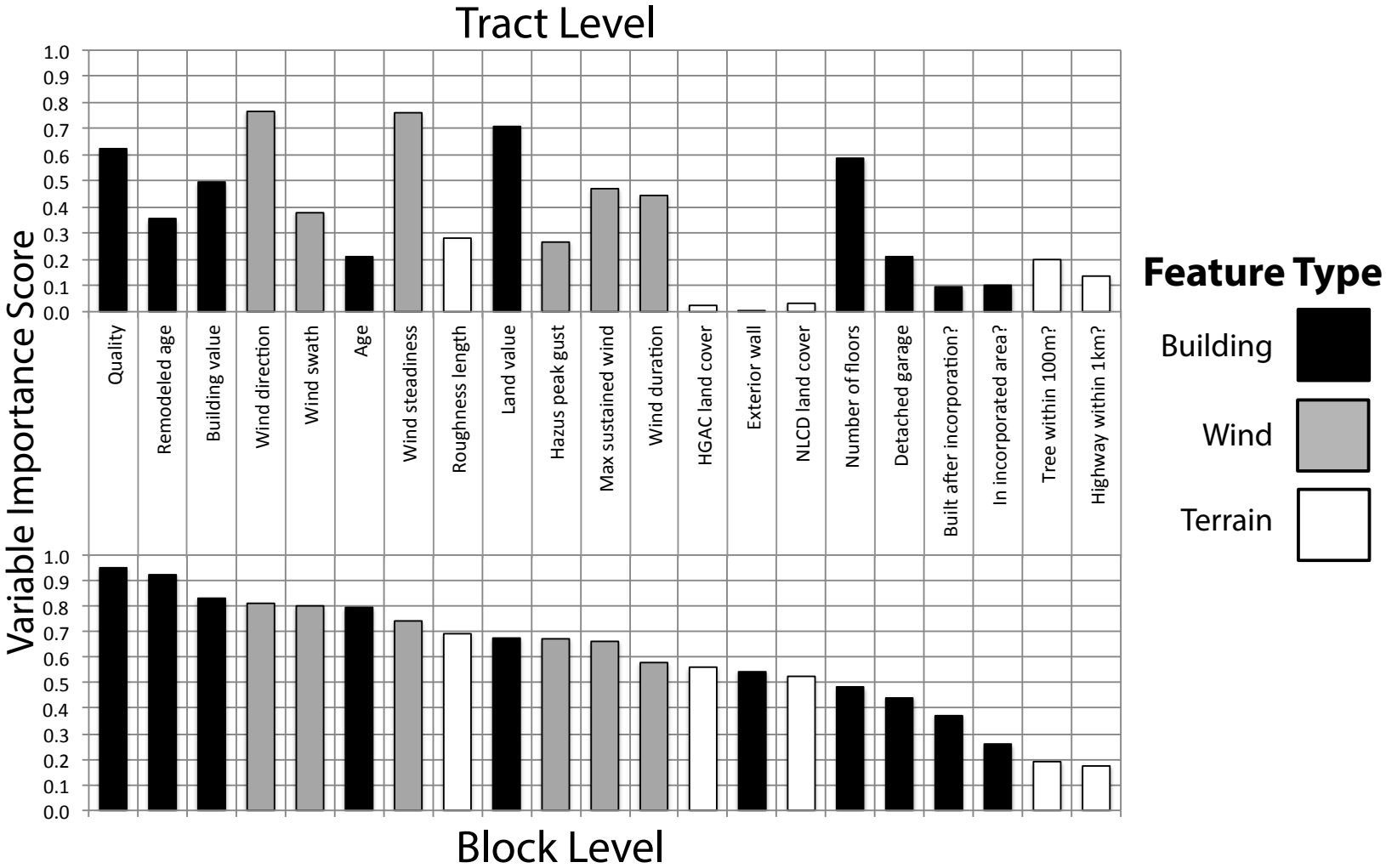
Roughness Length



Inspection Week



Results of analysis



Interpreting results

- Variable importance plots tell us which factors are critical in designing the next generation of risk prediction models.
- The learning algorithms reveal how to modify decision criteria to predict wind risk better.

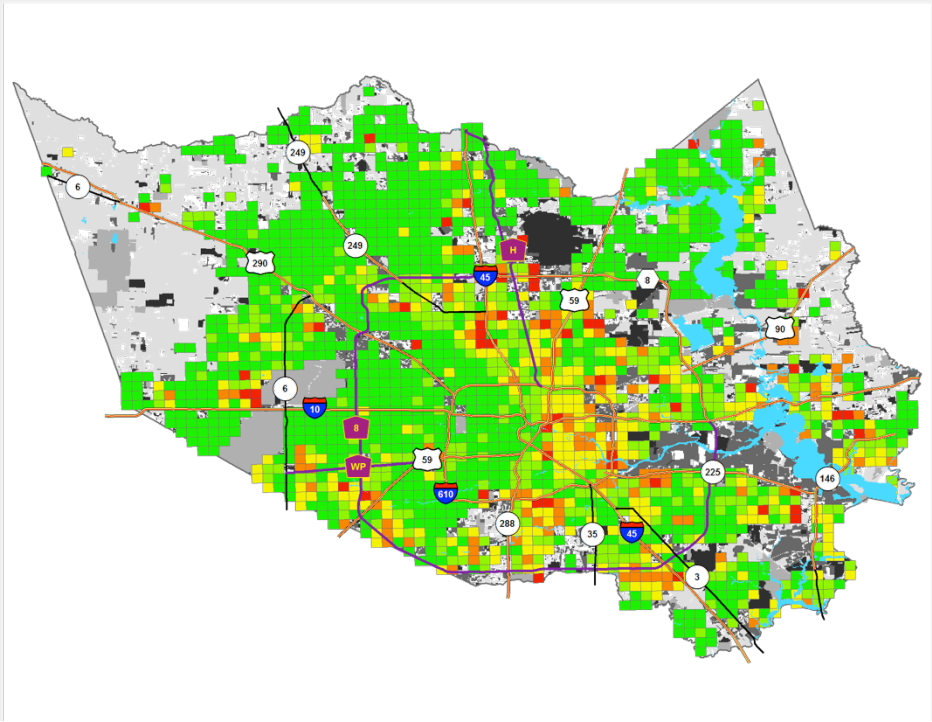
Old parameters

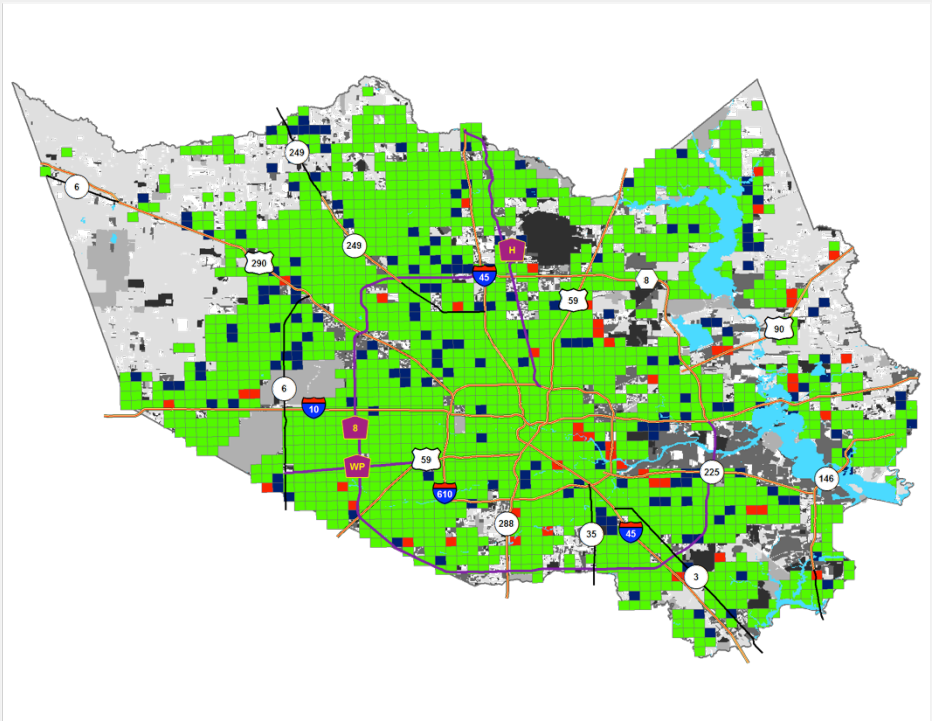
Frame
Floors
Roof shape
Roof-deck attachment
Nailing pattern
Garage type
Terrain
Wind speed

New parameters

Building value
Land value
Quality of construction
Age
Remodeled Age
Incorporation Year
Exterior wall

Direct prediction from data





Accuracy = 89%

Machine learning model

Prediction errors

http://houstonstormrisk..org

Houston Storm Risk Calculator

- http://houstonstormrisk.org/

Summary

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