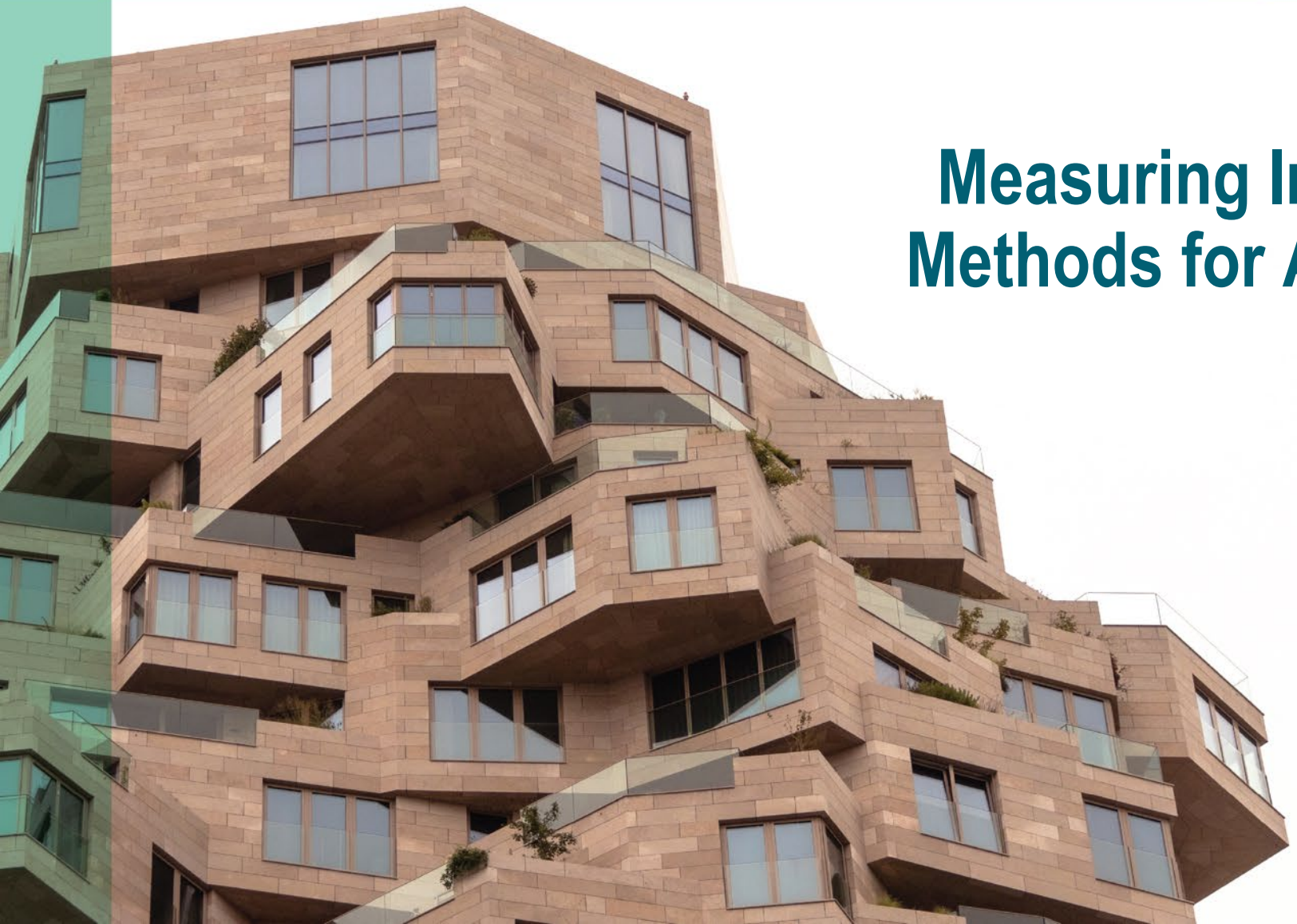
INTERNATIONAL RESEARCH SYMPOSIUM
Amsterdam, The Netherlands · December 4 - 5, 2024
ASSESSMENT INNOVATION & COLLABORATION WITH A FOCUS ON AI



Measuring Impact: New Statistical Methods for Assessment Accuracy and Transparency

Nicole Jardine, PhD
Cook County, Illinois, USA

IAAO

IIFI IPTI
International Property Tax Institute

Hello!

WOZ up?

3 Challenges

Data and Modeling

Outlier sales exist. How should we identify and exclude them?

Past ratio stats have room for improvement. Does a non-linear model help?

Transparency problems

We've improved the data and modeling. **How can we earn trust** after years of public mistrust and documented assessment inequities?

This follows up on work I presented with Jean Cochrane, Senior Data Scientist, at the IAAO Annual Conference in 2024.

Today's Agenda

Outlier sales	• Analytic approaches
A new model	• Linear vs. tree-based model: does it matter?
Explainability	• A new sale comps algorithm

Cook County

- Cook County, Illinois, USA:
  - Largest market-based assessment jurisdiction in the United States
  - 1.9M parcels (2024), 2450 km^2
  - Population: 5.1M (2022)
- Tax Facts:
  - Over 130 municipalities
  - 941 taxing agencies (like schools, parks) for roughly 800 units of government\]

Cook County Property Taxes: By the Numbers

- Property values and tax bills vary throughout Cook County.
  - Chicago $220k home → $4k bill (1.8% effective tax rate)
  - Winnetka $1.08M home → $24k bill (2.2% effective tax rate)
  - Dixmoor $66k home → $2.2k bill (3.3% effective tax rate)

- Property assessments are zero-sum: if my neighbor's home is under-assessed (and under-taxed), my property is over-taxed.

The New York Times OPINION

Chicago Tribune

PROPUBLICA

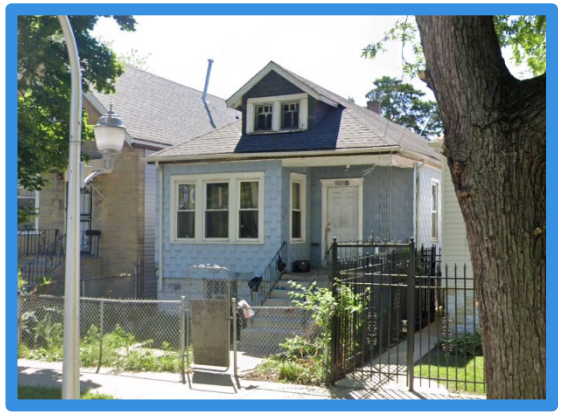
THE UNIVERSITY OF CHICAGO Harris Public Policy

How Lower-Income Americans Get Cheated on Property Taxes

Many homeowners are paying a total of billions of dollars extra because of inequities in assessing property values.

April 3, 2021

Chicago



$100K sale

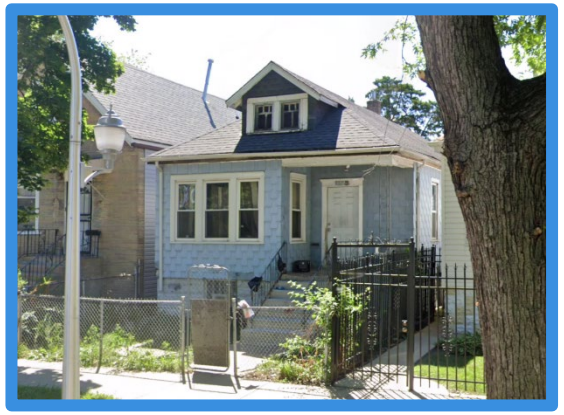
$1M sale

Bottom 10%

Top 10%

Highest price →

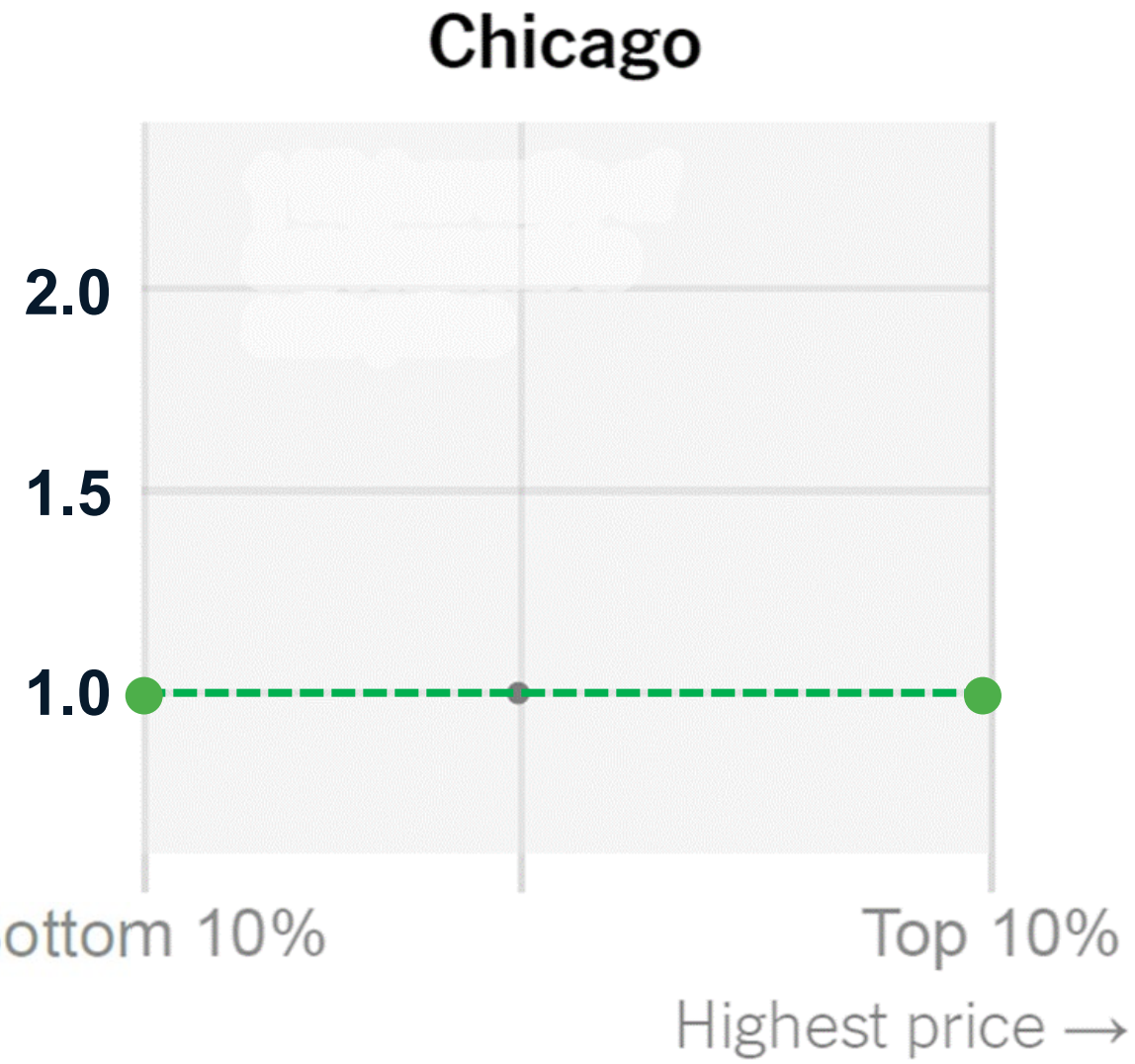
Source: **Chris Berry/NYT,** using assessments from prior years



$100K estimate

ÿ **$100K** sale

= 1.0 ratio

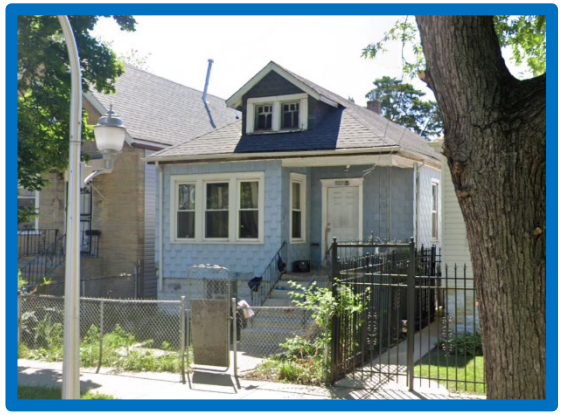


$1M estimate

ÿ **$1M** sale

= 1.0 ratio

Source: **Chris Berry/NYT,** using assessments from prior years



$100K sale

Dixmoor

$1

W

Source: **Chris Berry/NYT,** using assessments from prior years

Sales & characteristics → The Model → High-quality assessments

Outlier Sales: In an ideal world

A.4.1 Sales Generally Invalid for Ratio Studies

4. *Sales between relatives or corporate affiliates.* Sales between relatives are usually non-open-market transactions and tend to occur at prices lower than would otherwise be expected.
5. *Sales settling an estate.* A conveyance by an executor or trustee under powers granted in a will may not represent fair market value, particularly if the sale takes place soon after the will has been filed and admitted to probate in order to satisfy the decedent's debts or the wishes of an heir.
6. *Forced sales.* Such sales include those resulting from a judicial order. The seller in such cases is usually a sheriff, receiver, or other court officer.
7. *Sales of doubtful title.* Sales in which title is in doubt tend to be below market value. When a sale is made on other than a warranty deed, there is a question of whether the title is merchantable. Quit claim deeds and trustees' deeds are examples.

The IAAO Standard on Ratio Studies contains guidelines for sales that are invalid for ratio studies.

In theory, these sales would also be invalid for training the valuation model.

In practice, excluding these sales would exclude approximately **1 in 10 sales**.

In Cook County, we have a larger problem.

Problem: Characteristics errors

DESCRIPTION	One story residence, any age, up to 999 square feet
RESIDENCE TYPE	One Story
USE	Single Family
APARTMENTS	0
EXTERIOR CONSTRUCTION	Frame
FULL BATHS	1
HALF BATHS	0
BASEMENT[1]	Crawl Space
ATTIC	None
CENTRAL AIR	No
NUMBER OF FIREPLACES	0
GARAGE SIZE/TYPE[2]	None
AGE	101
BUILDING SQUARE FOOTAGE	854

Sale price:
$775k

Problem: Characteristics errors

DESCRIPTION	One story residence, any age, up to 999 square feet
RESIDENCE TYPE	One Story
USE	Single Family
APARTMENTS	0
EXTERIOR CONSTRUCTION	Frame
FULL BATHS	1
HALF BATHS	0
BASEMENT[1]	Crawl Space
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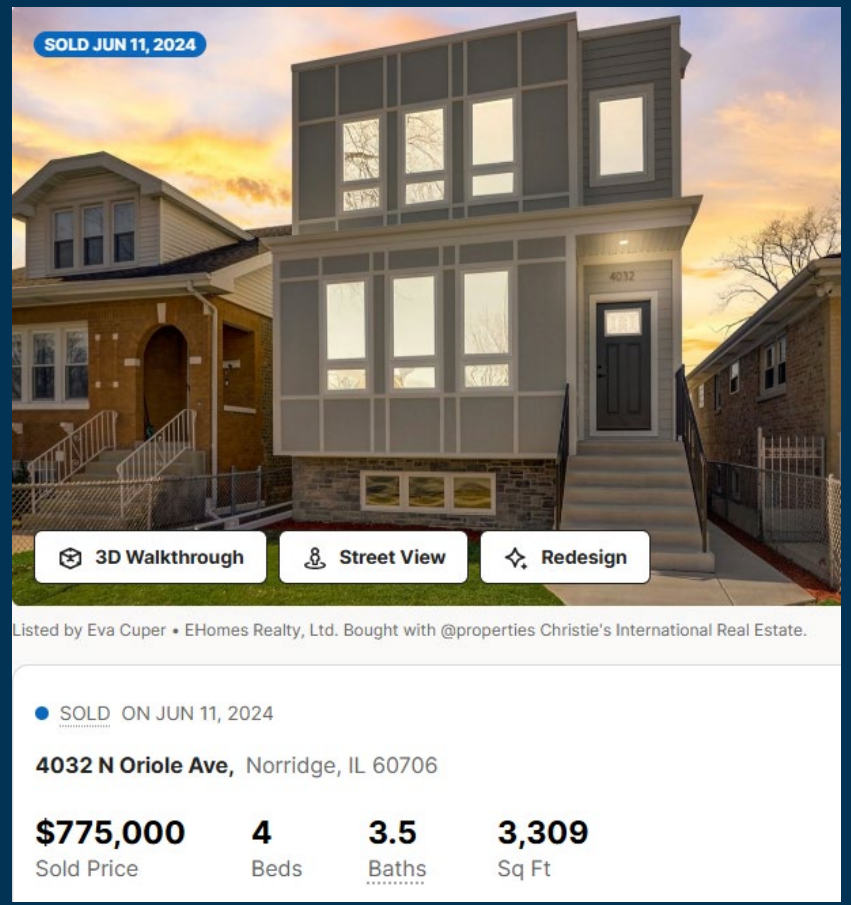


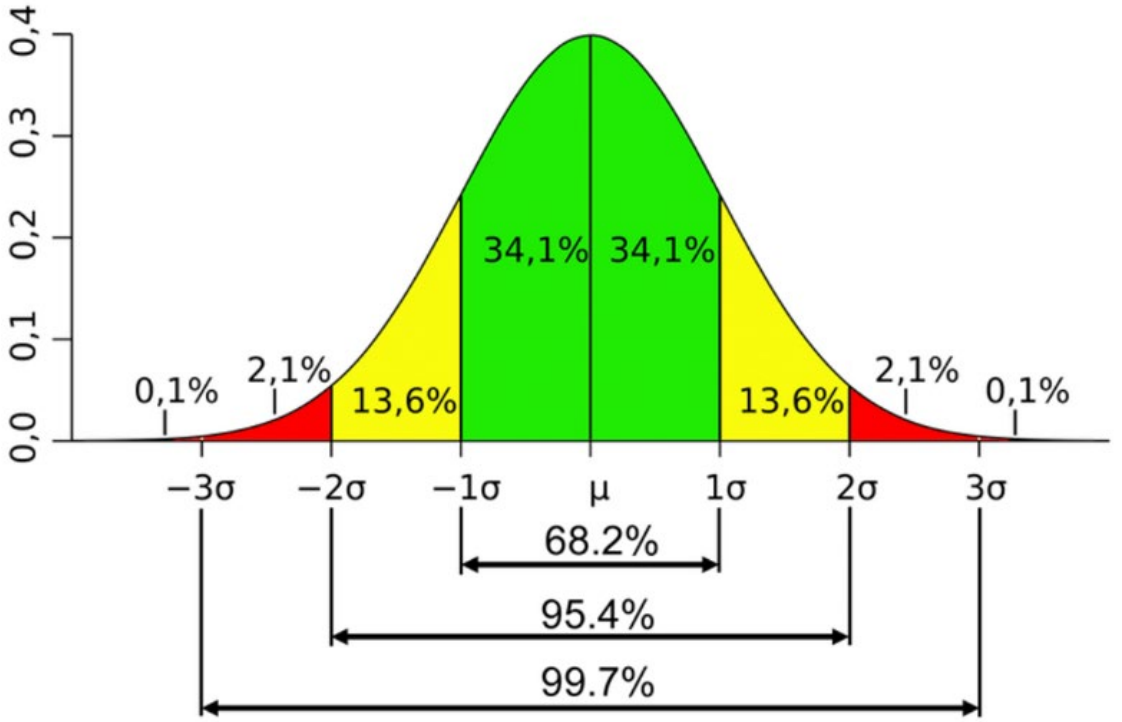
Outlier Sales

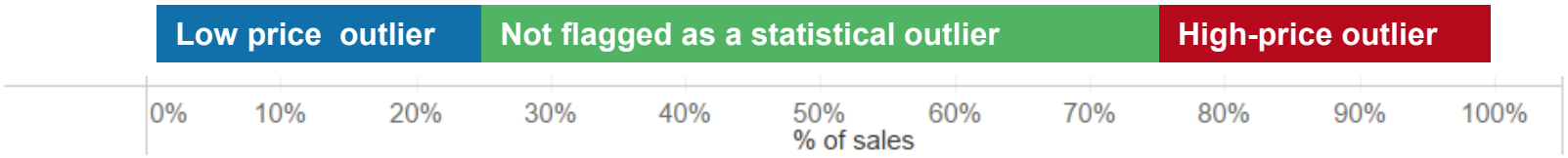
@ccao-data/**model-sales-val**

🚩 *Problem:* some sales are **outliers** (e.g, a home that sells for 50% higher than similar homes.)

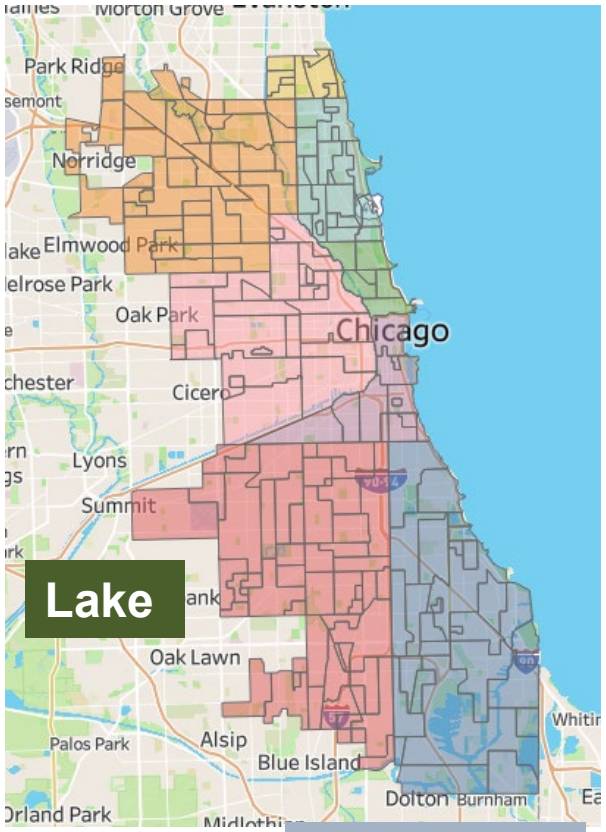
♻️ *Why it matters*: Garbage in, garbage out.

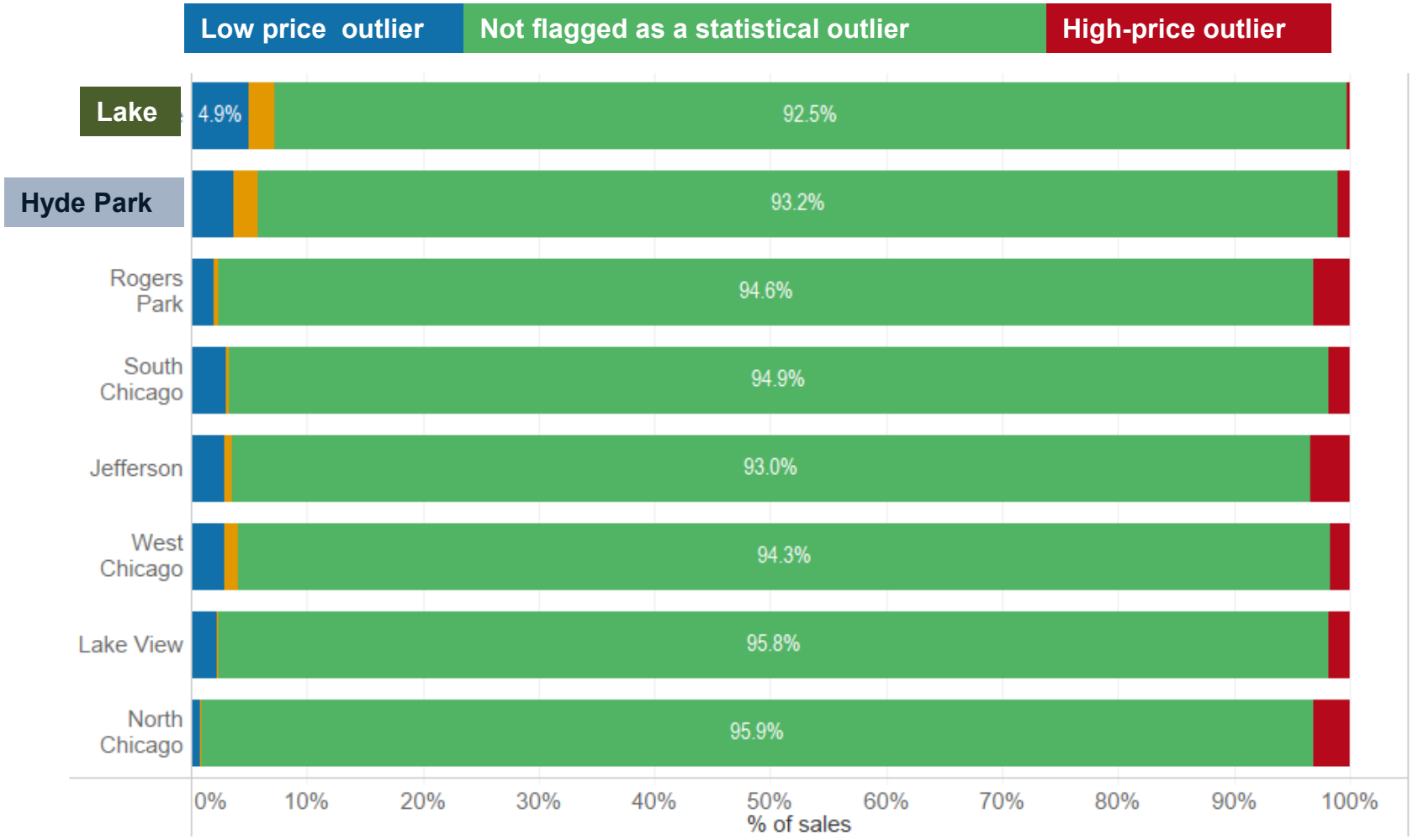
⚙️ *Solution*: build a pipeline to identify and exclude statistical outlier sales (~7% of sample).

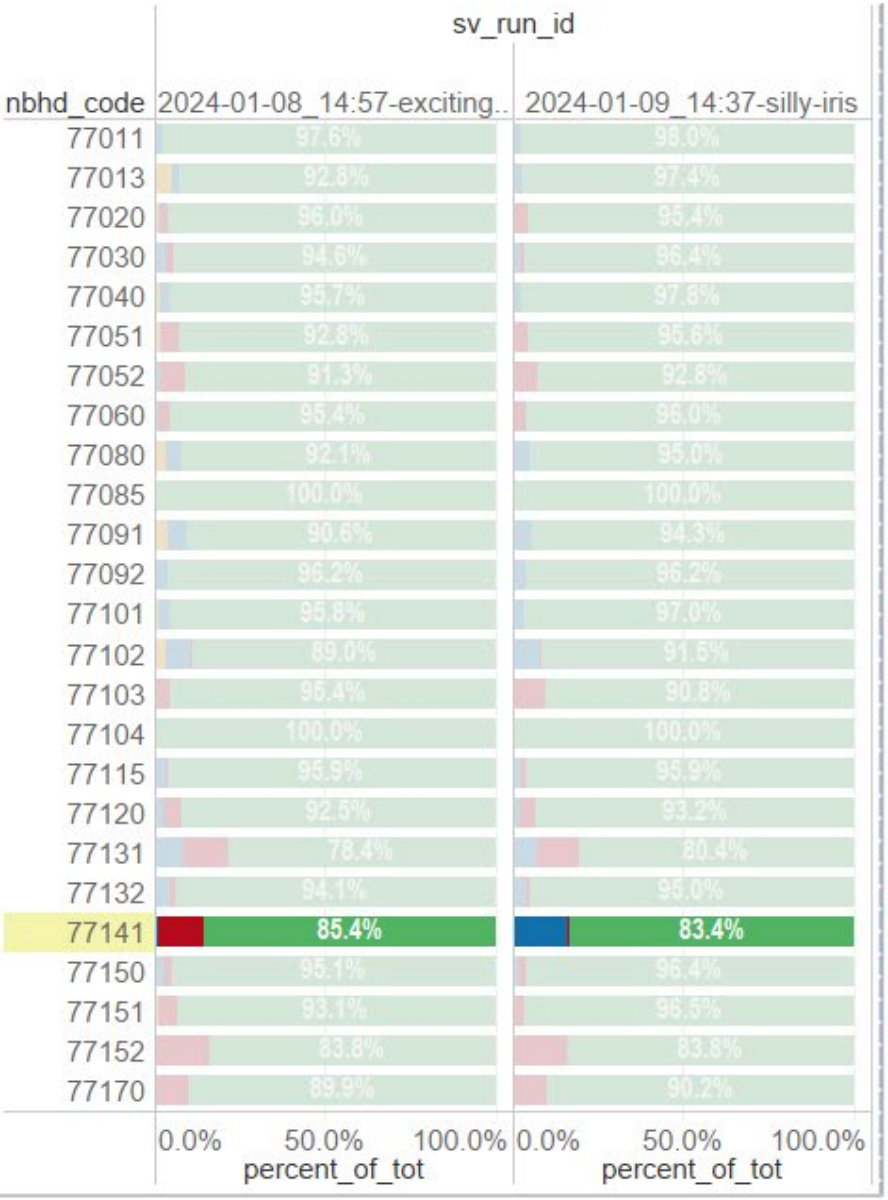


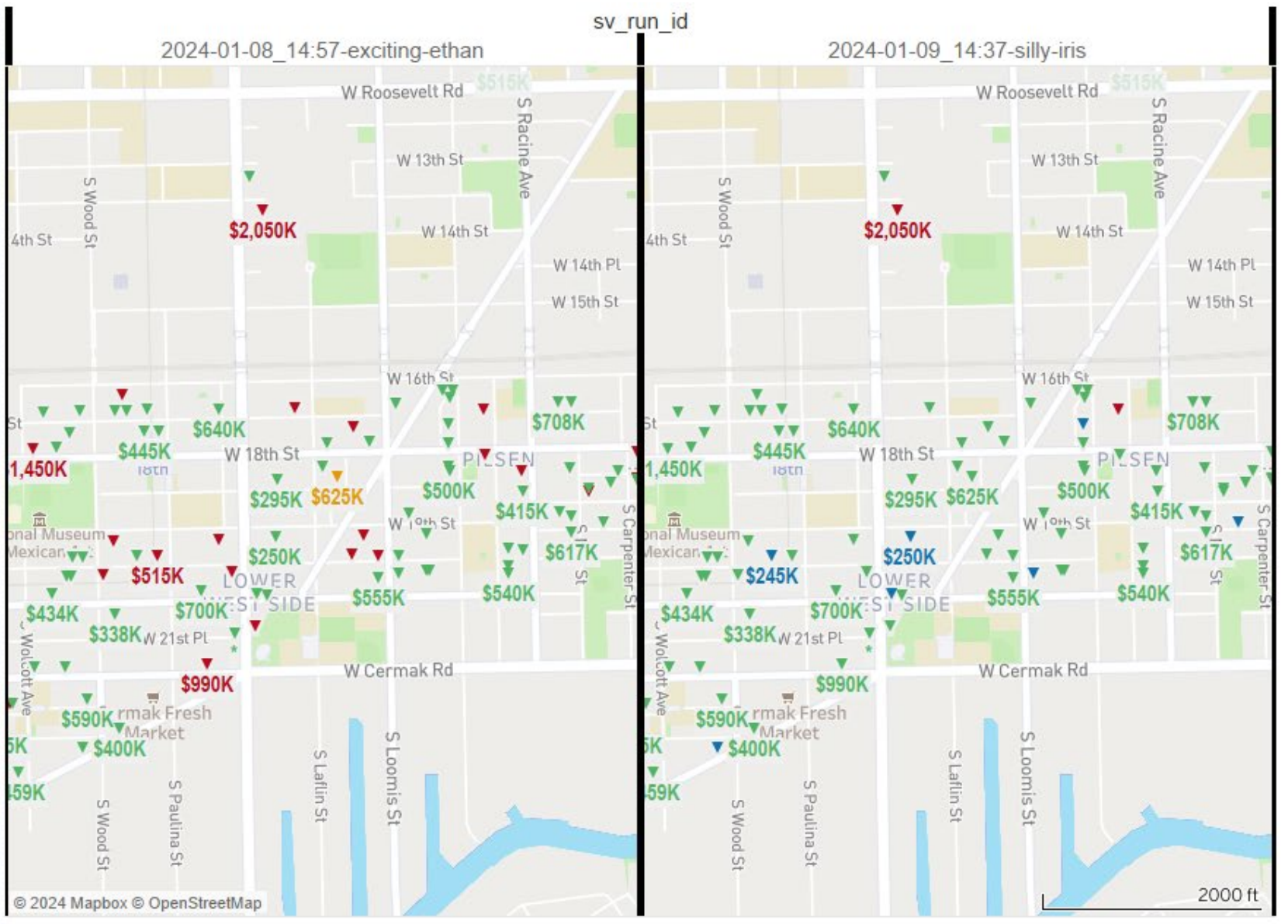

Low price outlier
Not flagged as a statistical outlier
High-price outlier
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of sales

Analysis: the first iteration flagged many **Low-Price outliers** on Chicago's very heterogeneous south side.






sv_run_id
nbhd_code
2024-01-08_14:57-exciting..
2024-01-09_14:37-silly-iris
77011 97.6% 98.0%
77013 92.8% 97.4%
77020 96.0% 95.4%
77030 94.6% 96.4%
77040 95.7% 97.8%
77051 92.8% 95.6%
77052 91.3% 92.6%
77060 95.4% 96.0%
77080 92.1% 95.0%
77085 100.0% 100.0%
77091 90.6% 94.3%
77092 96.2% 96.2%
77101 95.8% 97.0%
77102 89.0% 91.5%
77103 95.4% 90.8%
77104 100.0% 100.0%
77115 95.9% 95.9%
77120 92.5% 93.2%
77131 78.4% 80.4%
77132 94.1% 95.0%
77141 85.4% 83.4%
77150 95.1% 96.4%
77151 93.1% 96.5%
77152 83.8% 83.8%
77170 89.9% 90.2%
0.0% 50.0% 100.0% 0.0% 50.0% 100.0%
percent_of_tot
percent_of_tot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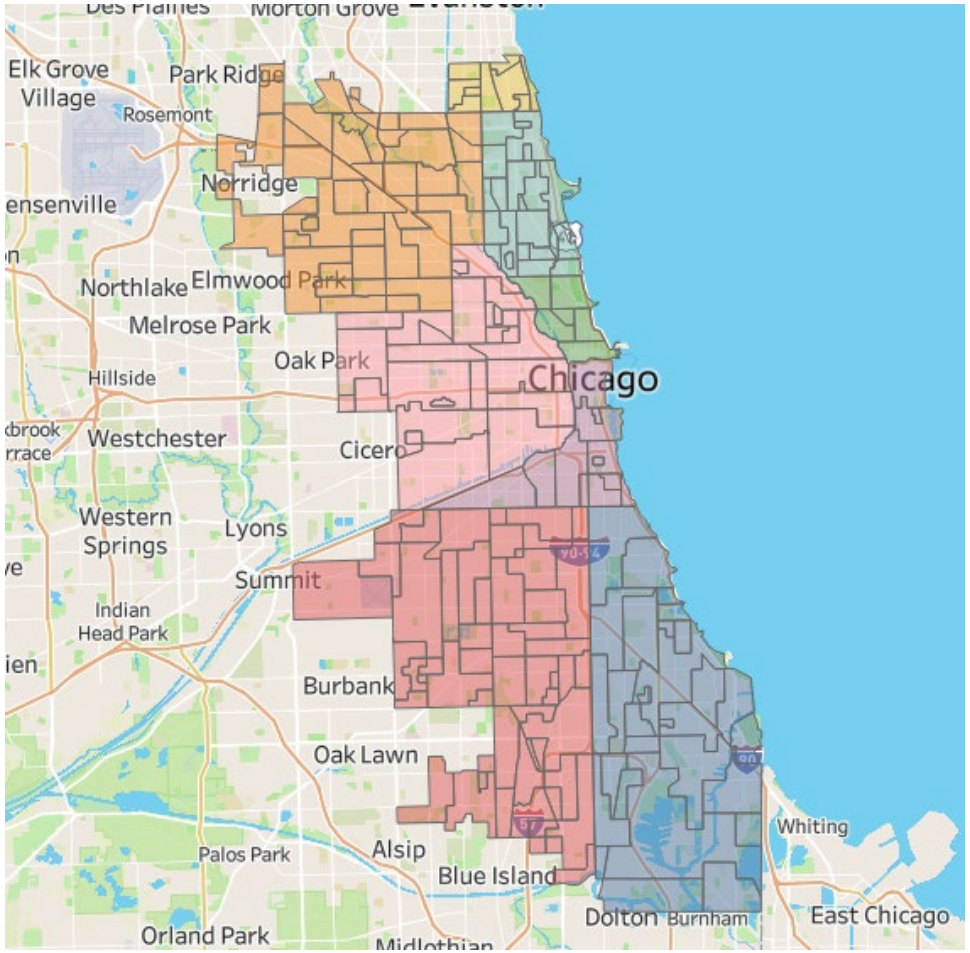
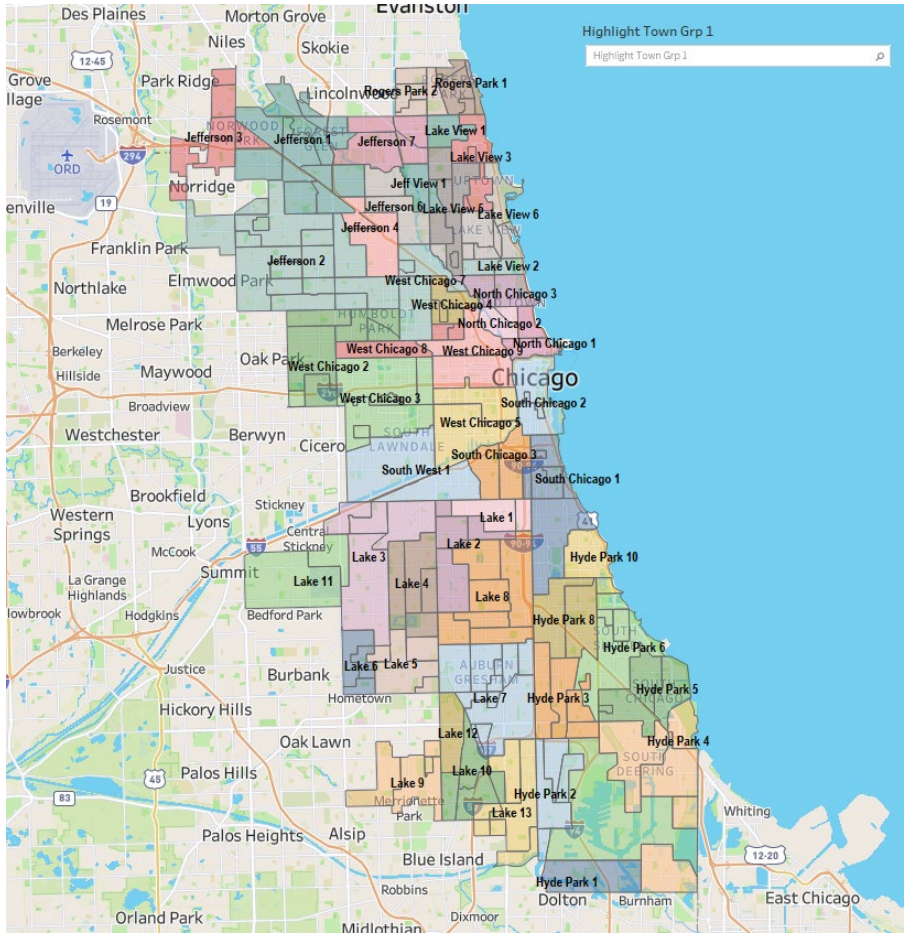
2024-01-08_14:57-exciting-ethan
2024-01-09_14:37-silly-iris
W Roosevelt Rd
W 13th St
W 14th St
W 14th Pl
W 15th St
W 16th St
W 18th St
W 21st Pl
W Cermak Rd
S Racine Ave
S Wood St
S Laflin St
S Loomis St
S Paulina St
S Carpenter St
S Wolcott Ave
PILSEN
LOWER WEST SIDE
$2,050K
$1,450K
$640K
$445K
$708K
$295K
$625K
$500K
$415K
$617K
$250K
$515K
$555K
$540K
$434K
$700K
$338K
$990K
$590K
$400K
$245K
Market
© 2024 Mapbox © OpenStreetMap
2000 ft

Before



After



Today's Agenda

Outlier sales

- We combine IAAO standards with price outlier status to exclude sales for model training.

A new model

- Linear vs. tree-based model: does it matter?

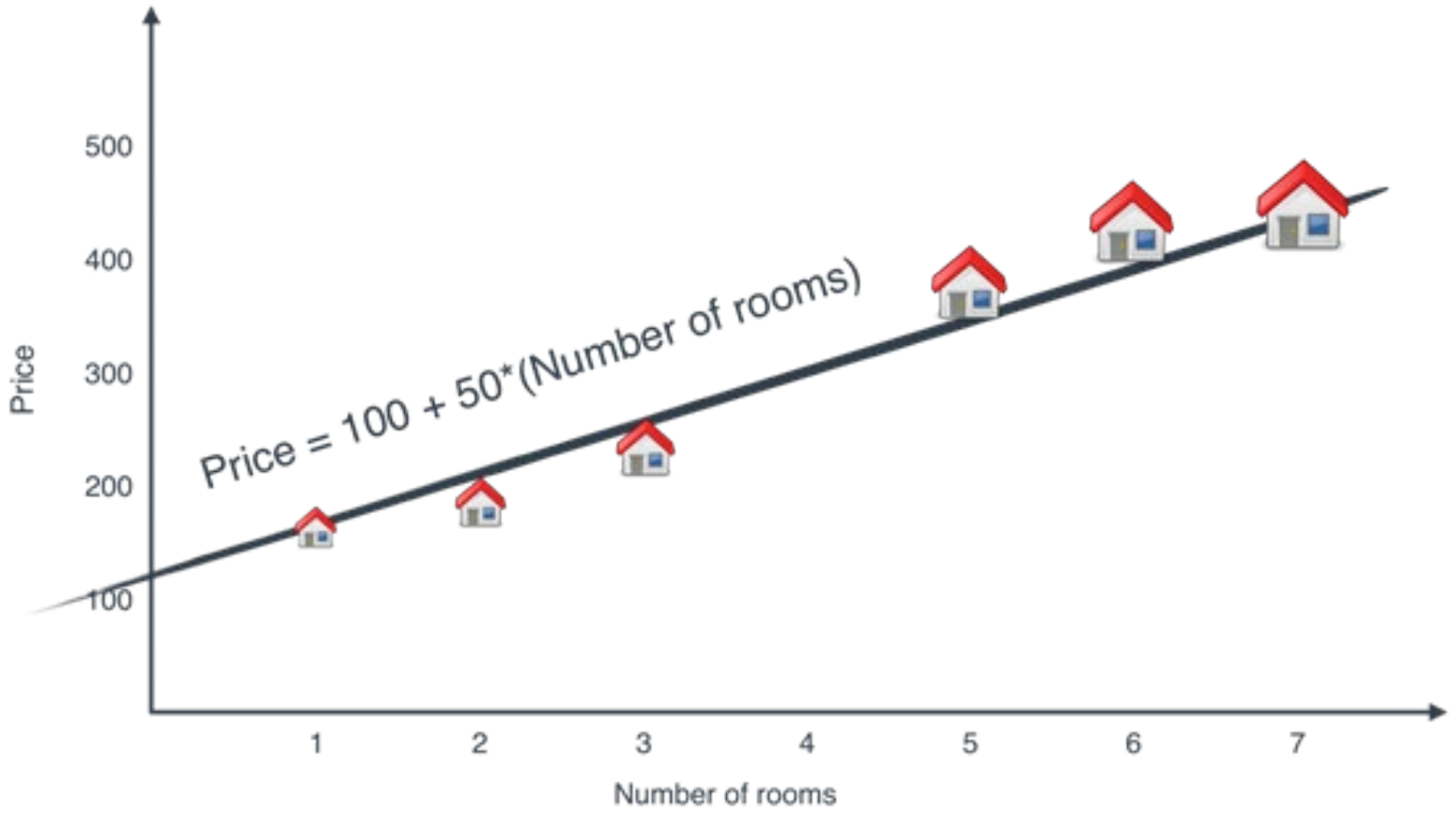
Explainability

- A new sale comps algorithm

Today's Agenda

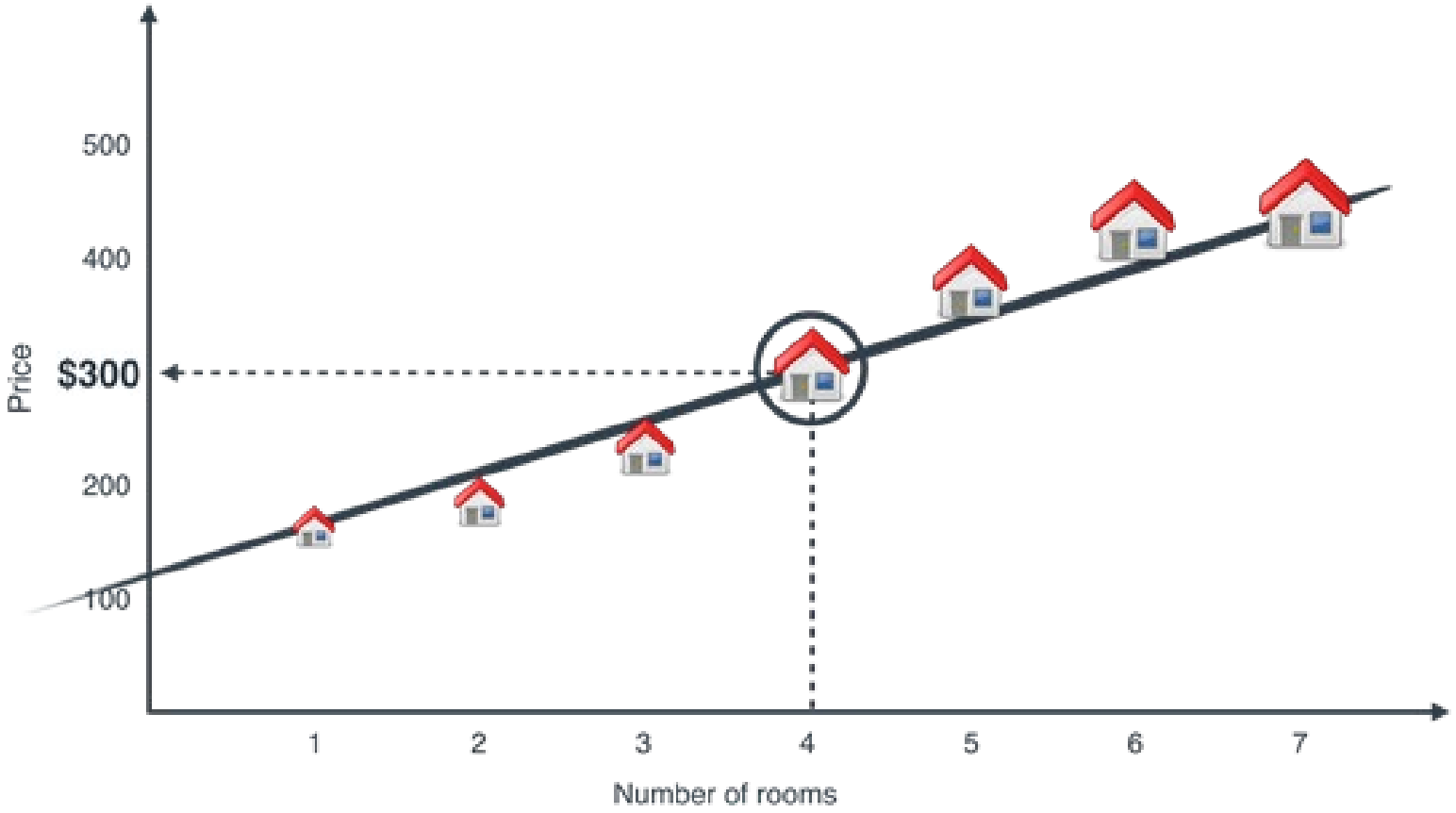
Outlier sales	• We combine IAAO standards with price outlier status to exclude sales for model training.
A new model	• Linear vs. tree-based model: does it matter?
Explainability	• A new sale comps algorithm

Linear Model: Training



https://livebook.manning.com/book/grokking-machine-learning/3-2-the-solution-building-a-regression-model-for-housing-prices/v-4/57

Linear Model: Prediction

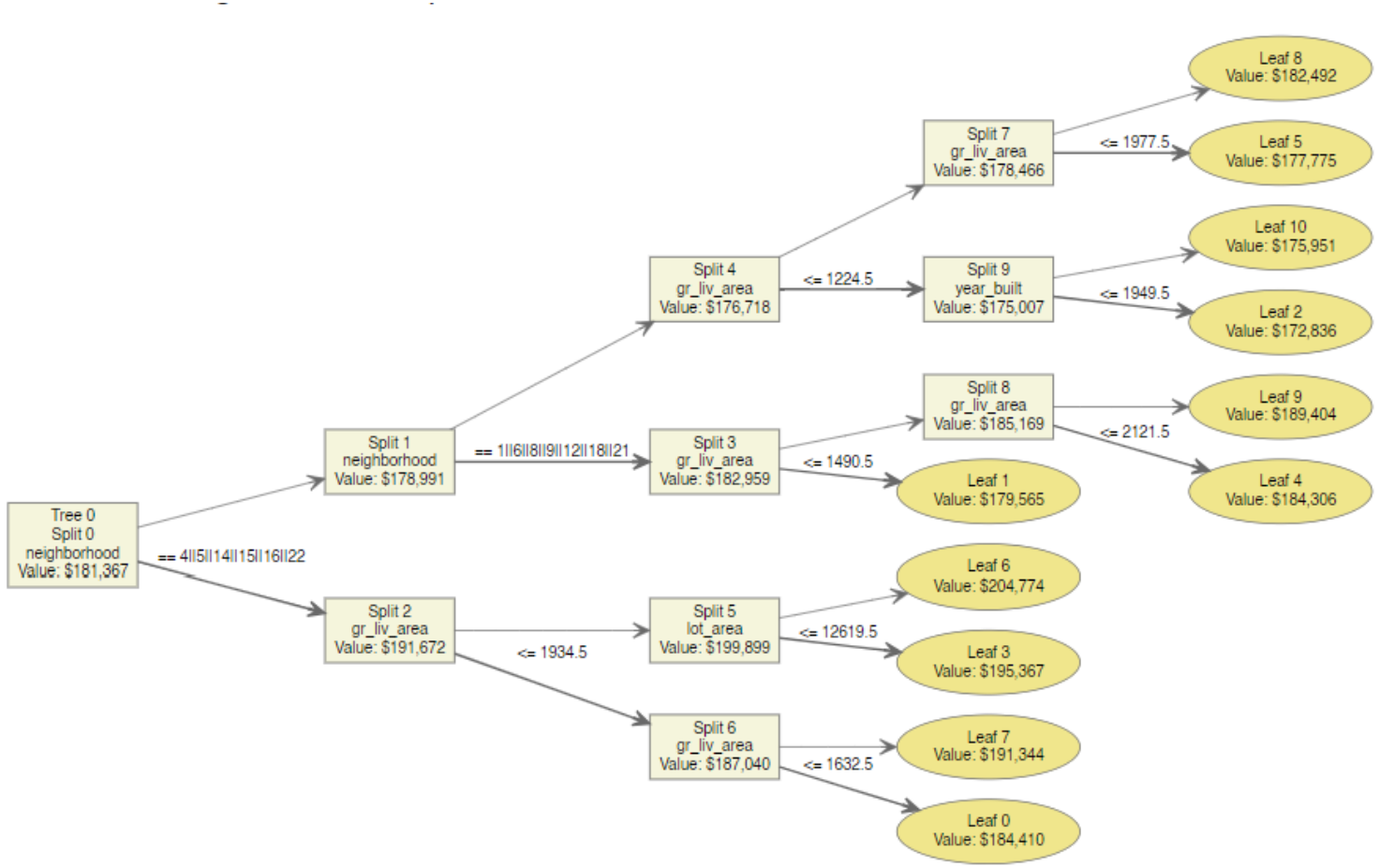


Pros: Highly interpretable and generalizable.

Cons: sometimes not as performant, and conditional averaging may introduce inequities

https://livebook.manning.com/book/grokking-machine-learning/3-2-the-solution-building-a-regression-model-for-housing-prices/v-4/57

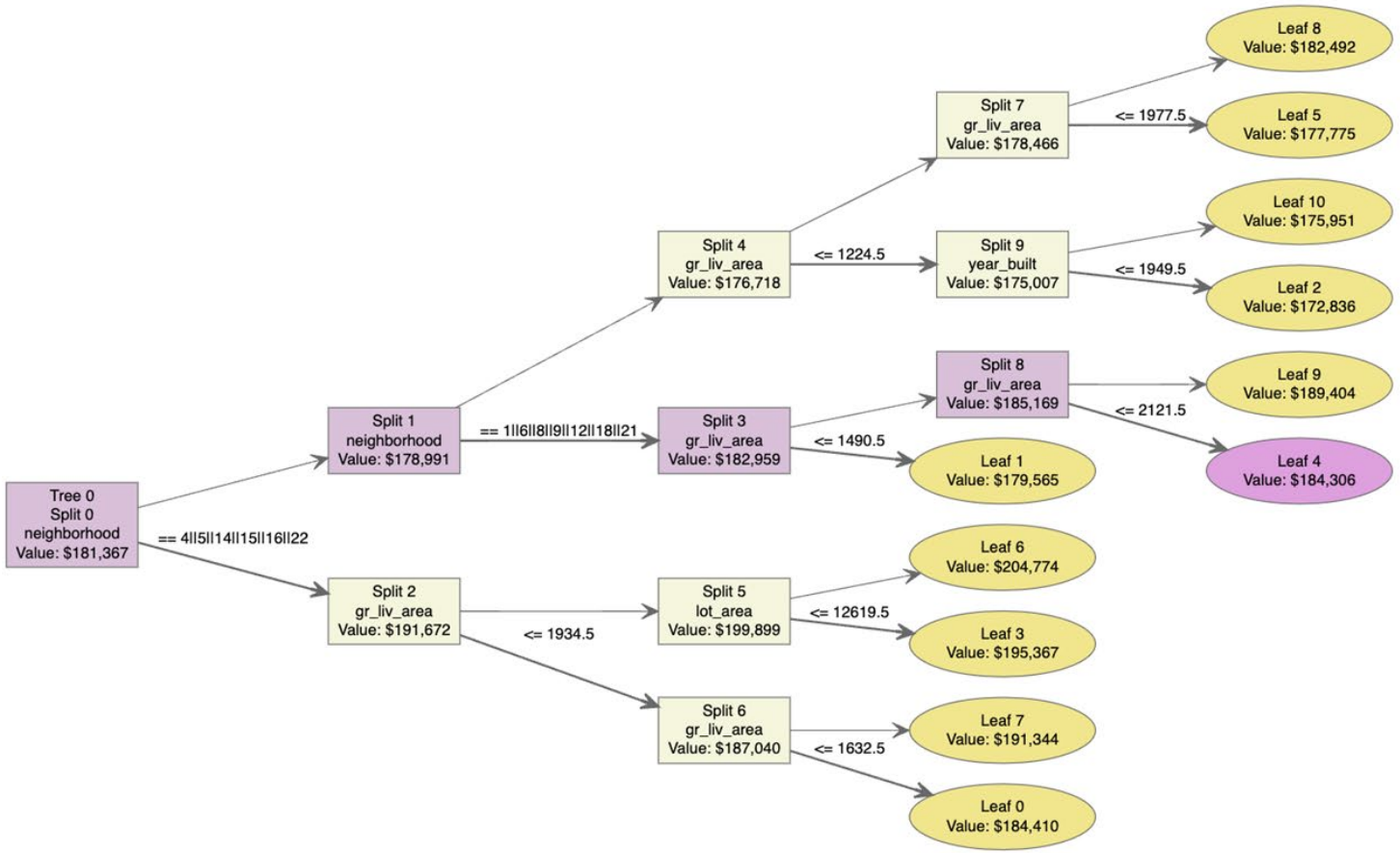
Non-Linear Model: Training



Decision tree models make **decisions** about where to **split** the data into two partitions using "if-then" rules.

Partitions are split into two again with more "if-then" rules until more partitions don't add much information.

Tree-Based Model: Prediction



Pros: Advantageous for non-linear relationships, handles categorical variables well, can outperform linear models.

Cons: requires careful tuning to avoid over-fitting.

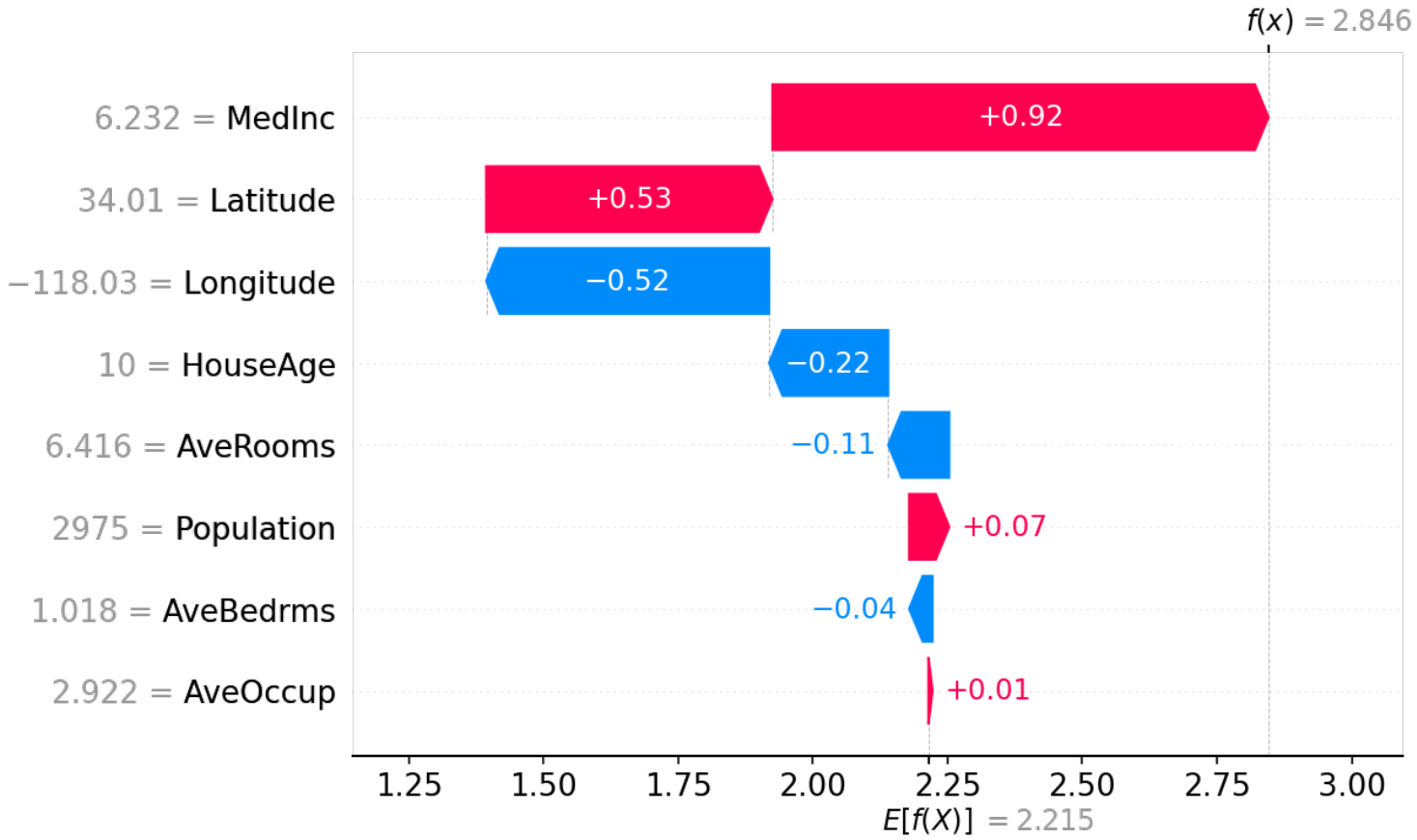
Outlier sales	• We combine IAAO standards with price outlier status to exclude sales for model training.
A new model	• Linear vs. tree-based model: tree-based model is more performant.
Explainability	• A new sale comps algorithm

“What sales did the model use to assess *my* home?”

Explainable AI (XAI): AI should be able to produce details that make its functions easy to understand for its intended audience.

"…the chatbot falsely suggested it is legal for an employer to fire a worker who complains about sexual harassment, doesn't disclose a pregnancy, or refuses to cut their dreadlocks."

SHAP values to the rescue?

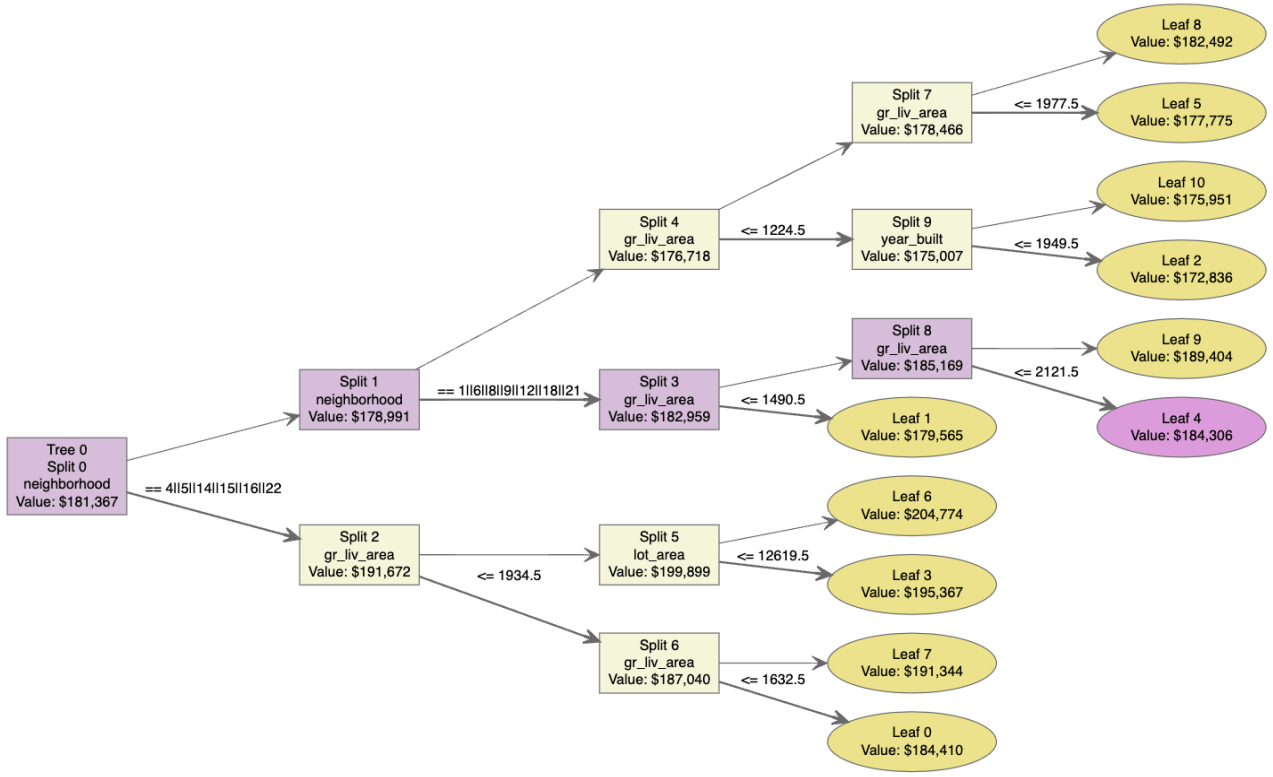


SHAP values confusing, require understanding the “baseline”

characteristic	char_value	shap_value
time_sale_day	3288	$40,340
loc_school_elementary_district_geoid	610046	$26,172
time_sale_year	2024	$9,959
loc_school_secondary_district_geoid	609732	$7,053
time_sale_post_covid	TRUE	$4,803
...	...	...
char_fbath	1	-$8,507
time_sale_day_of_year	1	-$9,920
char_yrblt	1915	-$10,213
meta_nbhd_code	71250	-$27,845
char_bldg_sf	1197	-$49,459

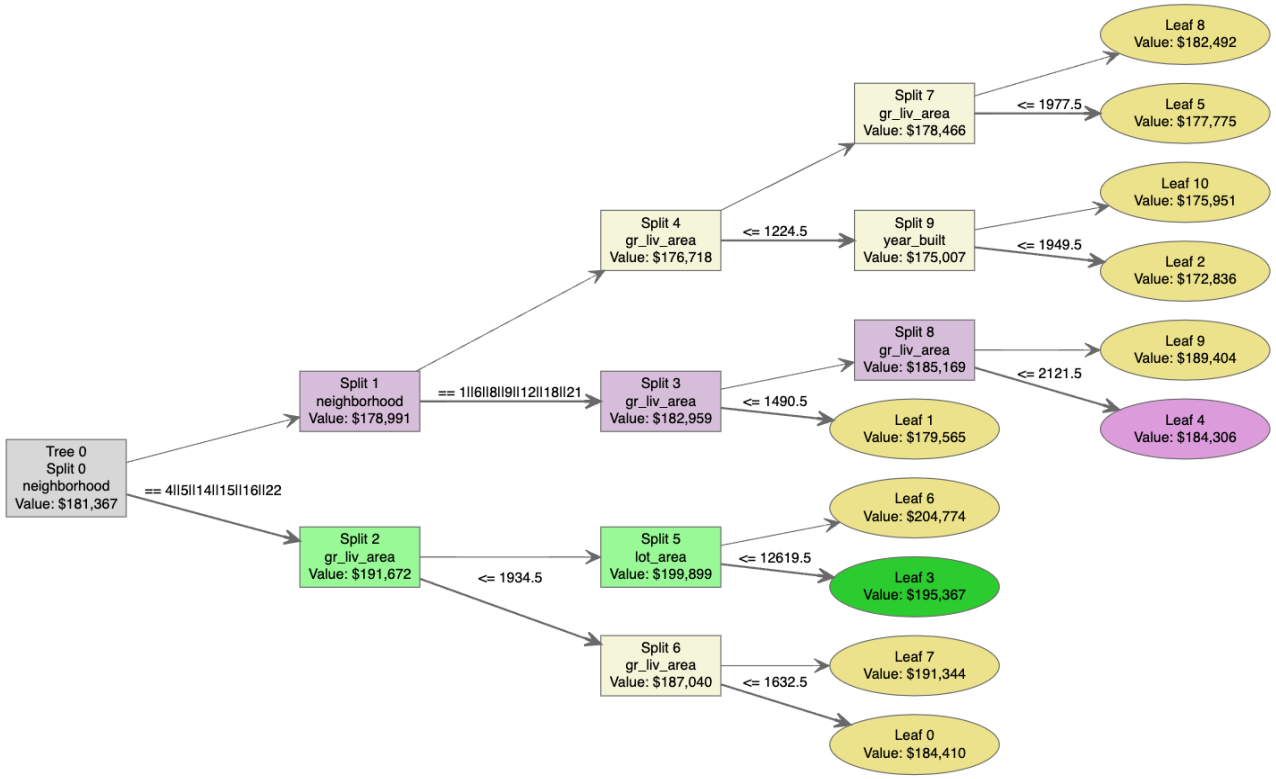
We created an algorithm to analyze our model's decision trees…

ID	Livable Area	Lot Area	Year Built	Condition	Neighborhood	Pred. Value
2	1,629	13,830	1997	4	6	$184,306



We created an algorithm to analyze our model's decision trees…

ID	Livable Area	Lot Area	Year Built	Condition	Neighborhood	Pred. Value
2	1,629	13,830	1997	4	6	$184,306
75	1,968	12,003	2009	4	14	$195,367



… to find sales that each decision tree thinks are similar…

ID	Livable Area	Lot Area	Year Built	Condition	Neighborhood	Pred. Value
3	1,604	9,978	1998	5	6	$184,306
14	1,960	7,851	2002	4	6	$184,306
21	2,110	8,880	1994	4	9	$184,306
48	1,675	15,263	1959	4	18	$184,306
55	1,694	10,475	2008	4	1	$184,306
60	1,978	10,389	2003	4	1	$184,306
61	2,098	9,375	1997	4	1	$184,306
62	1,661	12,137	1998	4	1	$184,306
70	1,652	19,645	1994	5	12	$184,306
84	1,571	7,837	1993	6	6	$184,306

… then make comparisons *between* decision trees…

ID	Tree 0	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Tree 6	Tree 7	Tree 8	Tree 9
2	$184,306	$3,322	$2,791	$1,779	$1,853	$1,928	$1,398	$1,483	-$450	$605

ID	Tree 0	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Tree 6	Tree 7	Tree 8	Tree 9
3	$184,306	$3,322	$2,791	$1,779	$1,853	$1,928	-$1,645	$1,483	-$450	$605
14	$184,306	$3,322	$9,008	$1,779	$4,435	$7,398	-$1,645	$1,483	$1,928	$1,288
21	$184,306	$3,322	$9,008	$1,779	$4,435	$7,398	$2,164	$6,202	$1,928	$605
48	$184,306	$3,322	-$2,739	$1,779	$1,853	-$2,057	$2,164	-$1,975	$3,036	$605
55	$184,306	$10,207	$7,507	$1,779	$1,853	$1,928	$2,164	$5,202	$5,038	$3,666
60	$184,306	$3,322	$9,008	$1,779	$4,435	$7,398	$2,164	$1,483	$3,036	$3,666
61	$184,306	$3,322	$9,008	$1,779	$4,435	$7,398	$2,164	$6,202	$3,036	$605
62	$184,306	$3,322	$2,791	$1,779	$1,853	$1,928	$2,164	$1,483	$3,036	$605
70	$184,306	$3,322	$2,791	$1,779	$1,853	$5,629	$2,164	$1,483	$3,036	$605
84	$184,306	-$1,044	$2,791	$1,779	$1,853	$1,928	-$1,645	$1,483	-$450	$605

… then make comparisons *between* decision trees…

ID	Tree 0	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Tree 6	Tree 7	Tree 8	Tree 9	Number	Percent
2	4	4	4	2	4	7	6	4	6	4		

ID	Tree 0	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Tree 6	Tree 7	Tree 8	Tree 9	Number	Percent
3	T	T	T	T	T	T	F	F	F	F	6 / 10	60%
14	T	T	F	F	F	F	F	F	F	F	2 / 10	20%
21	T	T	F	F	F	F	F	F	F	F	2 / 10	20%
48	T	T	F	F	F	F	F	F	F	F	2 / 10	20%
55	T	F	F	F	F	F	F	F	F	F	1 / 10	10%
60	T	T	F	F	F	F	F	F	F	F	2 / 10	20%
61	T	T	F	F	F	F	F	F	F	F	2 / 10	20%
62	T	T	T	T	T	T	F	F	F	F	6 / 10	60%
70	T	T	T	T	T	F	F	F	F	F	5 / 10	50%
84	T	F	T	T	T	T	F	F	F	F	6 / 10	60%

… then make comparisons *between* decision trees…

•	Tree 0	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Tree 6	Tree 7	Tree 8	Tree 9
Weight	71.2%	4.7%	4.2%	3.8%	3.4%	3.1%	2.8%	2.5%	2.2%	2.0%

ID	Tree 0	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Tree 6	Tree 7	Tree 8	Tree 9	Sim. Score
3	71.2%	4.7%	4.2%	3.8%	3.4%	3.1%	0.0%	0.0%	0.0%	0.0%	90.46%
14	71.2%	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.88%
21	71.2%	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.88%
48	71.2%	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.88%
55	71.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	71.18%
60	71.2%	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.88%
61	71.2%	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.88%
62	71.2%	4.7%	4.2%	3.8%	3.4%	3.1%	0.0%	0.0%	0.0%	0.0%	90.46%
70	71.2%	4.7%	4.2%	3.8%	3.4%	0.0%	0.0%	0.0%	0.0%	0.0%	87.37%
84	71.2%	0.0%	4.2%	3.8%	3.4%	3.1%	0.0%	0.0%	0.0%	0.0%	85.76%

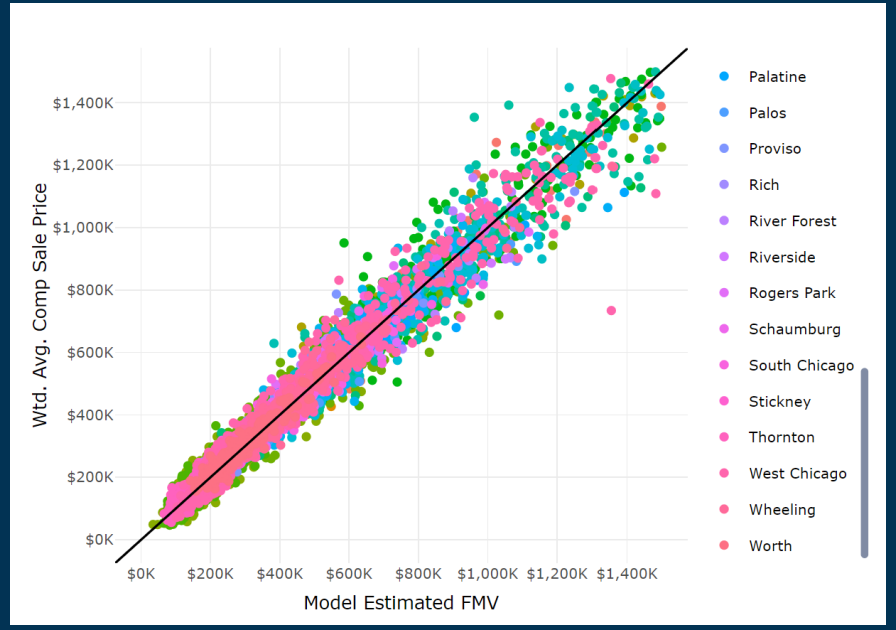
… and tell us which sales the model thinks are comparable

ID	Livable Area	Lot Area	Year Built	Condition	Neighborhood	Sale Price	Sim. Score
2	1,629	13,830	1997	4	6	$189,900	

ID	Livable Area	Lot Area	Year Built	Condition	Neighborhood	Sale Price	Sim. Score
3	1,604	9,978	1998	5	6	$195,500	90.46%
62	1,661	12,137	1998	4	1	$224,900	90.46%
70	1,652	19,645	1994	5	12	$203,135	87.37%
84	1,571	7,837	1993	6	6	$178,000	85.76%
14	1,960	7,851	2002	4	6	$216,500	75.88%
21	2,110	8,880	1994	4	9	$205,000	75.88%
48	1,675	15,263	1959	4	18	$173,000	75.88%
60	1,978	10,389	2003	4	1	$318,000	75.88%
61	2,098	9,375	1997	4	1	$240,000	75.88%
55	1,694	10,475	2008	4	1	$245,350	71.18%

Does it work?

- Our internal analysis of 113k sale comps found that these model sale comps are:
  - **Accurate.** Comps have a correlation of **0.98** with the PIN's predicted value.
  - **Well-behaved.** Highly-ranked comps are nearby the subject property; the median comp distance is **1,501 ft** from its subject.
  - **Typically consistent.** Comp patterns *typically* make sense within property groups.



These comps show us *how the model predicted value for a property*

Demo 1

Demo 2

Measuring Impact: New Statistical Methods for Assessment Accuracy and Transparency

Outlier sales

- We combine IAAO standards with price outlier status to exclude sales for model training.

A new model

- Linear vs. tree-based model: tree-based model is more performant.

Explainability

- A new sale comps algorithm

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