

On the Outlier Detection for Standardized Tests

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- $\geq 230,000$ applicants per year (Chile's population is almost 20 million)
- Some of the obtained scores may not be truthful (or correct)
E.g.:
 - Correction was performed with the wrong answer key
 - Operational issue (pencil did not mark well)
 - Cheating
 - Other

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E.g. (scores between 0 and 100):
 - ① LANG/MATH/HIST = $84/80/90$ 
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Research Question:

How can we **identify outliers** for standardized tests while providing a way to **interpret and classify** the type of outlier?

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For this presentation we consider:

- Applicants who took the tests **LANG/MATH/HIST** in December 2021.
 - $\geq 103,000$ applicants on this group.

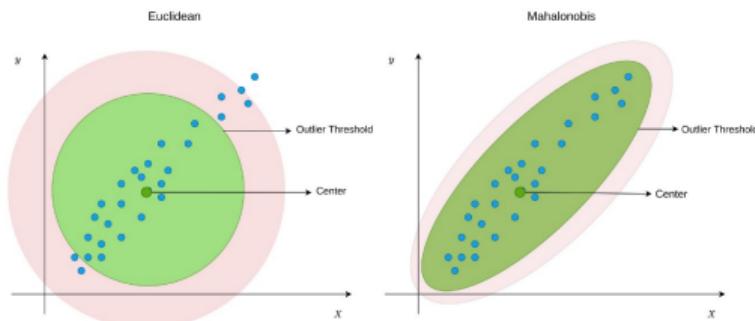
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- Applicants who took the tests **LANG/MATH/HIST** in December 2021.
 - $\geq 103,000$ applicants on this group.
- Test scores are the **percentages of correct answers** for each test.
 - Scores between 0 and 100.

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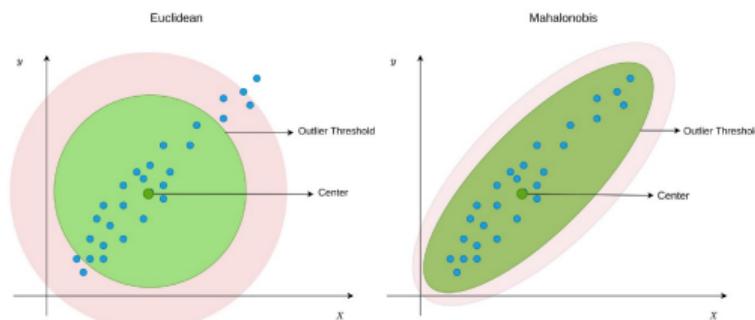
Multivariate Outlier Detection Methods:

1 Mahalanobis Distance



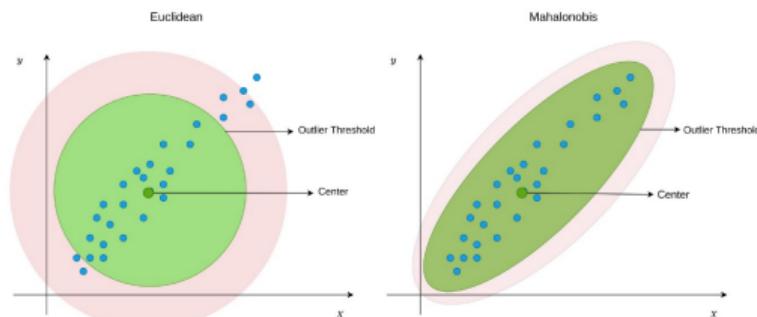
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- ① Mahalanobis Distance
- ② Robust Mahalanobis Distance

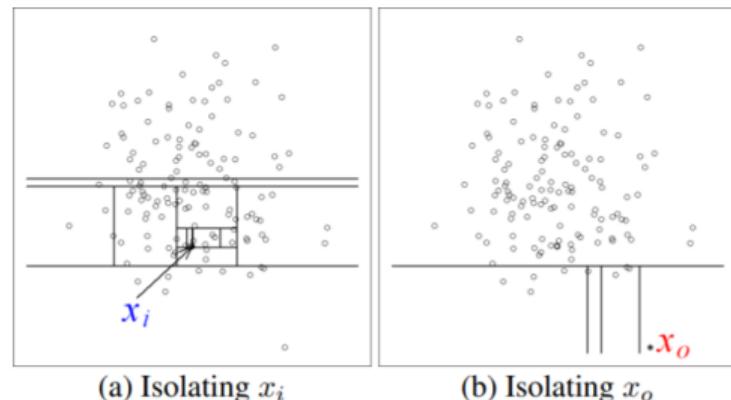


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- ③ Isolation Forest (iForest)

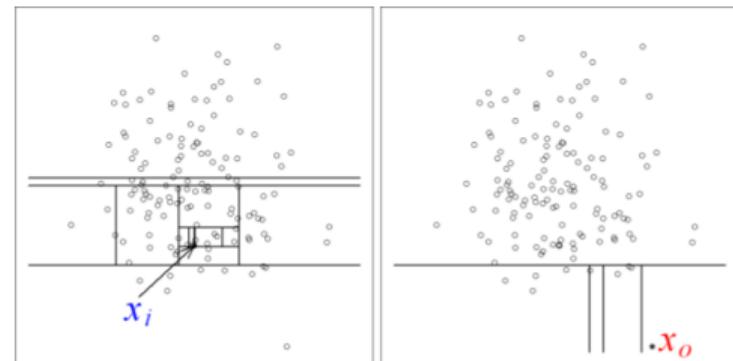
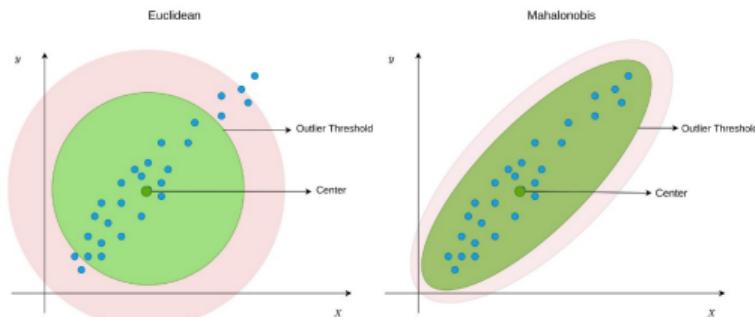


Outlier Detection Methods - Methodology

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- ③ Isolation Forest (iForest)
- ④ Extended iForest

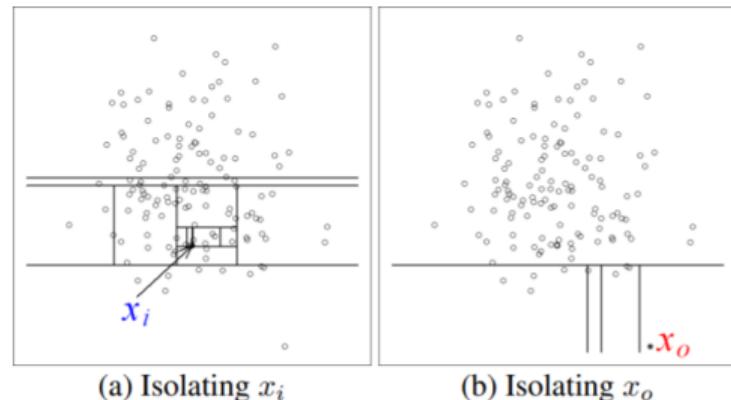
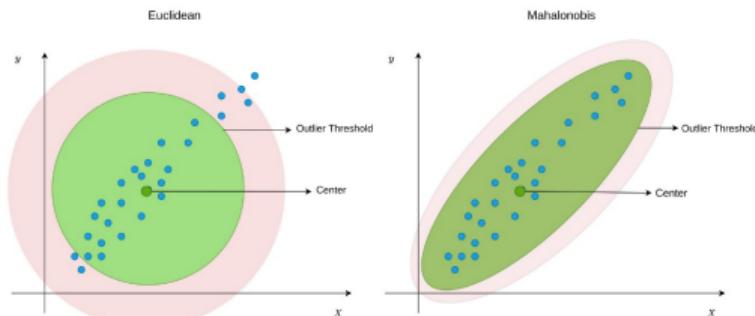


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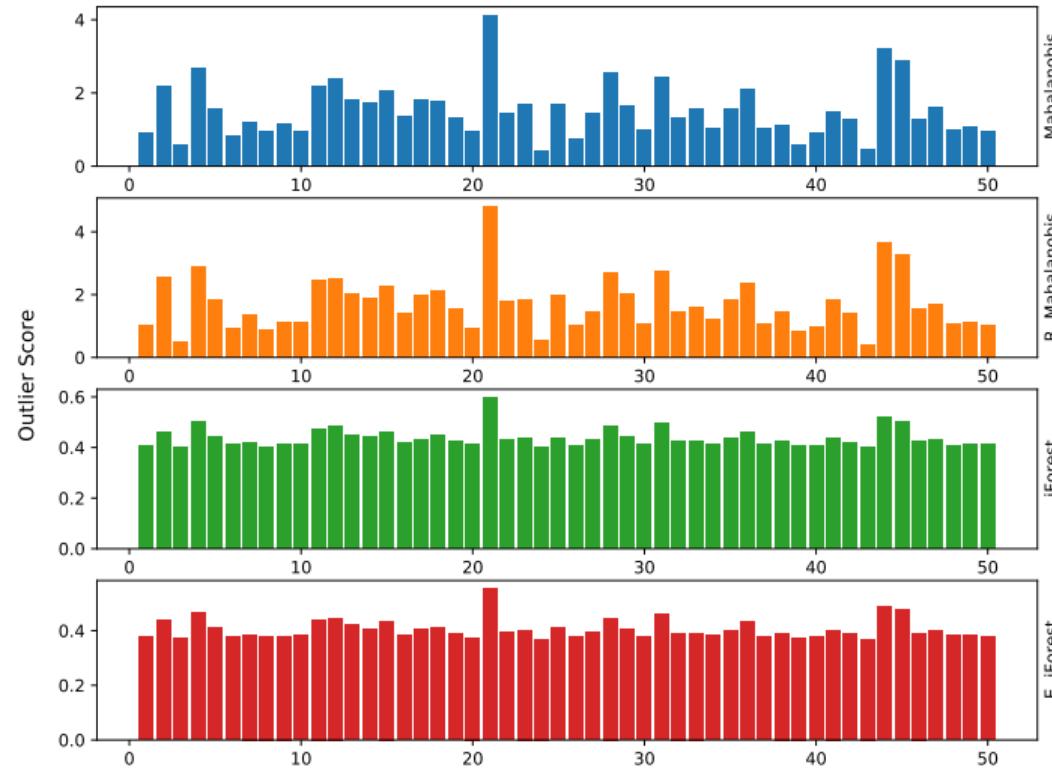
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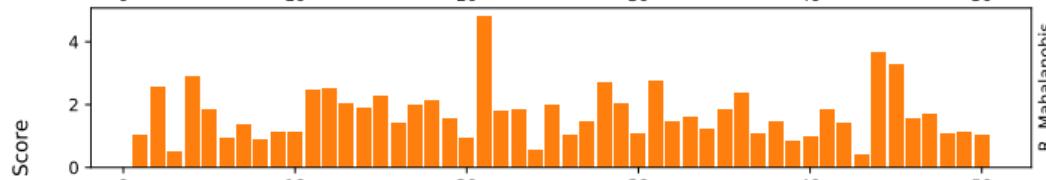
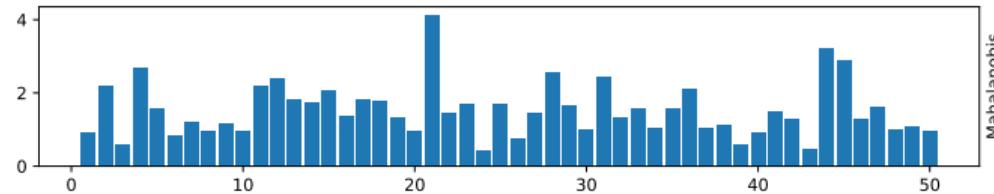


Every method gives us an **outlier score** (i.e. anomaly score) for all the applicants.

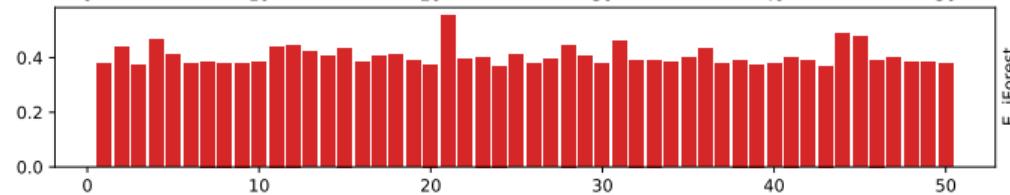
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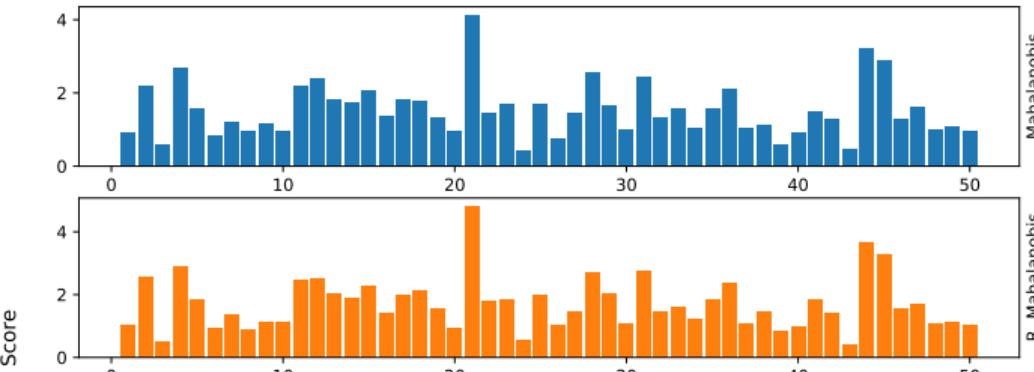


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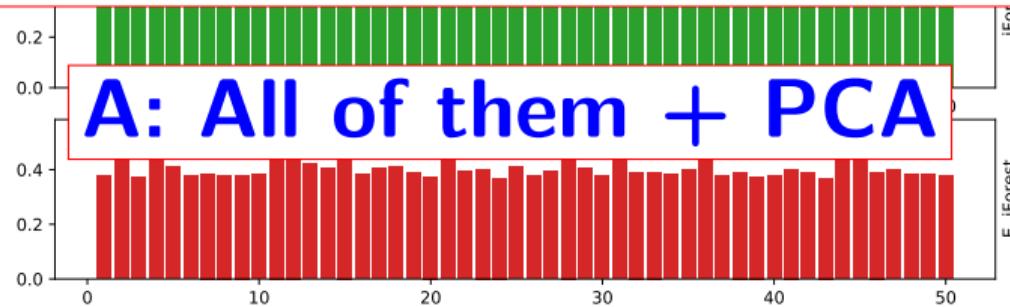


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① PDT Scores → ② Outlier Detection Methods → ③ **PCA** → ④ *k*-means

Applying PCA to the scores given by the 4 methods:

	PC1	PC2	PC3	PC4
Value	3.76	0.19	0.04	0.01
Percentage	94.07%	4.72%	1.00%	0.21%

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	Mahal.	R. Mahal.	iForest	E. iForest	PC1
Mahalanobis	1.00				
R. Mahalanobis	0.80	1.00			
iForest	0.70	0.74	1.00		
E. iForest	0.71	0.76	0.91	1.00	
PC1	0.83	0.86	0.85	0.87	1.00

Correlation Matrix with Kendall's τ coefficient

PCA - Results

Rank	LANG	MATH	HIST	SCI	PC1
1	13	20	98		17.76
2	7	20	72		14.90
3	28	22	95		14.63
4	67	2	93		13.49
5	38	27	97		13.32
6	88	100	48		13.23
7	55	97	50	28	12.87
8	67	82	18		12.83
9	58	97	45		12.79
10	28	68	67		12.66
11	55	97	67	61	12.64
12	38	80	70	26	12.54
13	18	58	7		12.52
14	70	90	30		12.49
15	37	82	60	60	12.47
16	62	73	13		12.35
17	68	12	98		12.21
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Results - Clustering

In order to group the different patterns, we:

- Took **1% of students with highest scores**
- **Clustered** according to their scores deviations from their applicants' average score

Cluster	LANG	MATH	HIST
1	6.96	15.08	-22.04
2	17.62	-42.01	24.39
3	-13.09	4.07	9.02
4	-7.78	-23.80	31.58
5	-5.91	16.53	-10.63
6	26.03	-4.23	-21.79
7	-2.27	2.82	-0.55

k-means centroids

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(Scores labeled as worth to investigate)

Conclusions

- Outlier Detection methods + PCA enable the identification of suspicious **scores**
- **Clustering** methods allow us to interpret the groups according to the patterns
- Awaiting for the analysis of the last standardize PDT process

Future Work

- Analyze outliers at the level of **test rooms** and **test centers**
- Detection of **odd score patterns** in public schools

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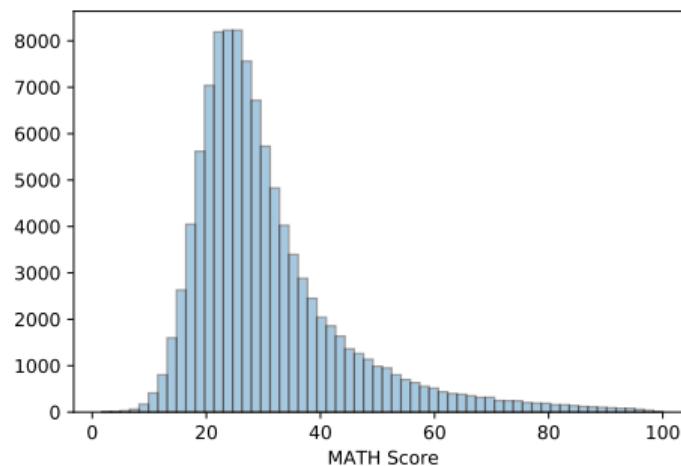
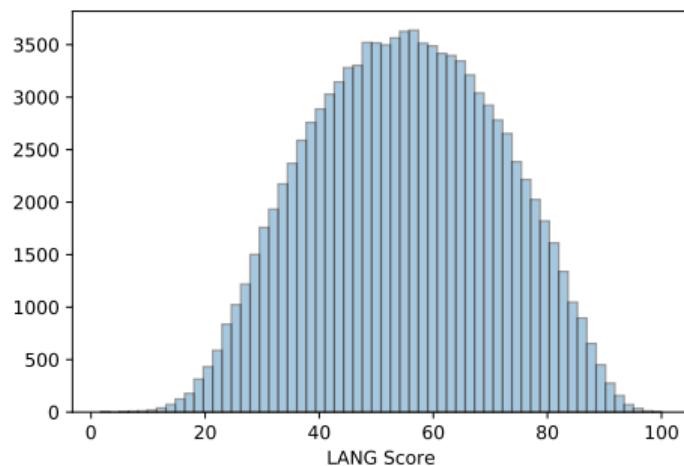
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Appendix: PDT Scores Distribution and Correlations



	LANG	MATH	HIST
LANG	1.00		
MATH	0.56	1.00	
HIST	0.74	0.61	1.00

Table: LANG/MATH/HIST test scores correlation

Appendix: Outlier Detection Methods Scoring

① Mahalanobis Distance:

$$d_M(X^{(i)}, \hat{\mu}) = \sqrt{(X^{(i)} - \hat{\mu})^\top \hat{\Sigma}^{-1} (X^{(i)} - \hat{\mu})}$$

② Robust Mahalanobis Distance:

$$\hat{\Sigma}_R = \sum_{i=1}^n \frac{K(d_M(X^{(i)}, \tilde{X})^2)(X^{(i)} - \tilde{X})(X^{(i)} - \tilde{X})^\top}{\sum_{j=1}^n K(d_M(X^{(j)}, \tilde{X})^2)}$$

where $K(u) = e^{-0.1u}$, and the distance then is computed as

$$d_{RM}(X^{(i)}, \tilde{X}) = \sqrt{(X^{(i)} - \tilde{X})^\top \hat{\Sigma}_R^{-1} (X^{(i)} - \tilde{X})}$$

③ iForest, and Extended iForest:

$$s(X^{(i)}, n) = 2^{-\frac{\mathbb{E}(h(X^{(i)}))}{c(n)}}$$

where $h()$ denotes the depth of the tree in which the i -th point is left as an outlier. $c(n)$ is the average path length of unsuccessful search in a Binary Search Tree with n elements.

Appendix: Anomaly Scores Correlation

Table: Correlation Matrix with Spearman's ρ coefficient

	Mahala.	R. Mahal.	iFor.	E. iFor	PC1
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R. Mahalanobis	0.99	1.00			
iForest	0.98	0.97	1.00		
E. iForest	0.97	0.98	0.98	1.00	
PC1	0.99	0.99	0.99	0.99	1.00