Evaluation of Data Augmentation for Tabular Data

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Problem Statement

- The effective use of machine learning is challenging due to the substantial amount of data required for accuracy.
- To address data limitations, an existing solution is to turn to data augmentation techniques to artificially increase the size of data sets and improve model performance [1].
- Most research has focused on data augmentation methods alone; instead, we focused on evaluating if these methods were effective.

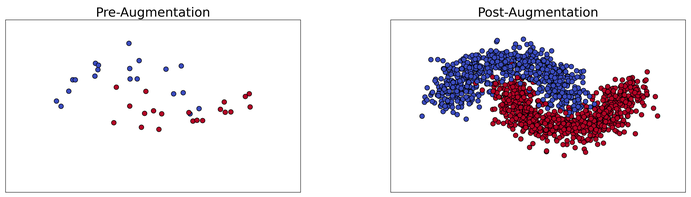
Research Question: Do current data augmentation methods effectively augment tabular data while maintaining original data patterns?

Our project goals are:

- Create evaluation metrics for augmenting tabular data
- Using evaluation metrics, compare: Feature Distributions, Features to Features and Features to Label

What is Data Augmentation?

The process of **generating new data** from existing data while **maintaining patterns** without collecting new data.

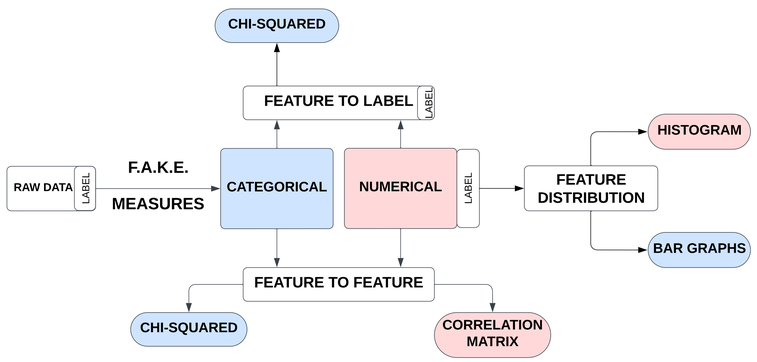


Augmentation Methods Used:

- **modPMOne:** chooses an observation (row) and adds or subtracts one unit from random variables [2]
- **randSwap:** randomly swaps a value from the augmented row with values of the same column from the original data set [2]
- **HAT:** generates a data set whose distribution is similar to that of the original data set [3]

Methods

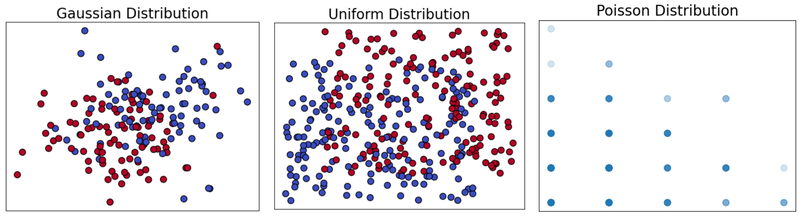
Our Process for Evaluating Patterns



Measuring Tools

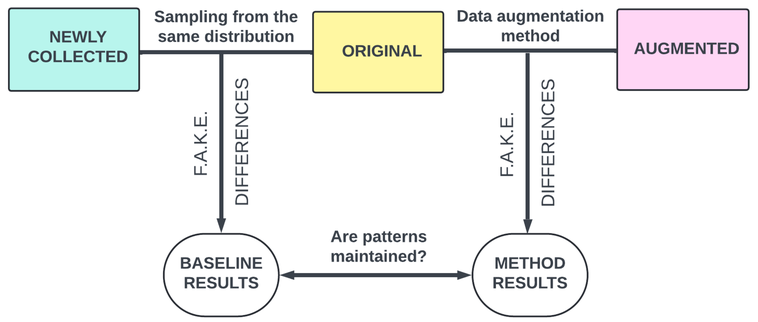
- **Correlation Matrix:** table that shows how strongly pairs of numerical columns are related
- **Frobenius Norm:** measure of the size or distance between matrices
- **Histogram:** displays the bin edges and the proportions of numerical columns in a data set
- **Mann-Whitney U Test:** measures differences between two numerical distributions [4]
- **Bar Graph:** displays the proportions of subcategories within categorical columns, illustrating the frequency or count of each subcategory
- **Euclidean Norm:** measure of the size or distance between vectors
- **Chi-Squared Test:** finds dependence between two categorical columns or between categorical columns and the label column

Data Sets



- Gaussian Data Set: 172 x 13
- Uniform Data Set: 343 x 25
- Mixed Distribution Data Set (Gaussian, uniform, and Poisson distributions horizontally mixed, respectively): 240 x 25

Experimental Design



Preliminary Results

Table 1. Relative Error of Correlation Matrices using Frobenius Norm (Feature-to-Feature)

	Gaussian Original	Uniform Original	Mixed Original
Original + New	**0.099**	**0.105**	**0.114**
Augmented with modPMOne	0.151	0.134	0.145
Augmented with randSwap	0.225	0.274	0.341
Augmented with HAT	0.082	0.124	0.116

Table 2. Count of Numerical Columns with Significant p-values using Mann-Whitney U Test

	Gaussian Original	Uniform Original	Mixed Original
Original + New	**0**	**0**	**0**
Augmented with modPMOne	0	0	0
Augmented with randSwap	0	0	0
Augmented with HAT	0	0	0

Table 3. Relative Error of Categorical Proportions using Euclidean Norm

	Gaussian Original	Uniform Original	Mixed Original
Original + New	**0.138**	**0.029**	**0.100**
Augmented with modPMOne	0.387	0.046	0.283
Augmented with randSwap	0.107	0.058	0.098
Augmented with HAT	0.106	0.060	0.102

Table 4. Count of Changes in Chi-Squared Significance (Feature-to-Label)

	Gaussian Original	Uniform Original	Mixed Original
Original + New	**0**	**0**	**0**
Augmented with modPMOne	0	5	9
Augmented with randSwap	0	0	2
Augmented with HAT	0	0	9

Table 5. Count of Changes in Chi-Squared Significance (Feature-to-Feature)

	Gaussian Original	Uniform Original	Mixed Original
Original + New	**0**	**0**	**2**
Augmented with modPMOne	8	6	28
Augmented with randSwap	0	6	8
Augmented with HAT	10	10	60

Conclusions

- Previously, no comprehensive methodology existed to test whether the patterns of a data set are maintained during data augmentation.
- We implemented our methodology through two functions, F.A.K.E. Measures and F.A.K.E. Differences, to ensure the original patterns are preserved.
- We designed experiments with synthetic data to test pattern retention after augmentation.

Future Work

- It would be beneficial for a variety of real-life data sets to be tested with our methods in order to determine their efficacy.
- A measuring tool could be added to our framework that compares numerical and categorical variables.
- Further work could focus more on the details of augmentation and how to optimize the process.

Acknowledgments

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References

[1] Pedro Filipe Costa Machado. *Conception and evaluation of data augmentation techniques for tabular data*. PhD thesis, Universidade do Minho, 2022.

[2] Christina Dietrich, Jeffrey Roberts, Jason White, and Marilyn Vazquez. Data augmentation for tabular data sets. 2022.

[3] Balachander Sathianarayanan, Yogesh Chandra Singh Samant, Prahalad S Conjeepuram Guruprasad, Varshin B Hariharan, and Nirmala Devi Manickam. Feature-based augmentation and classification for tabular data. *CAAI Transactions on Intelligence Technology*, 7(3):481–491, 2022.

[4] K. Perry. Determine if two distributions are significantly different using the mann-whitney u test. 2019.

GitHub Link for Our Code

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