Artificial Intelligence as a driver for Innovation in Official Statistics

Francesco Pugliese, Central Directorate for Methodology and Design of Statistical Processes, **Istat**

ARTIFICIAL INTELLIGENCE AND OFFICIAL STATISTICS: THE NEW FRONTIER OF INNOVATION

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QUINDICESIMA GIORNATA ITALIANA DELLA STATISTICA

AI for Land Cover

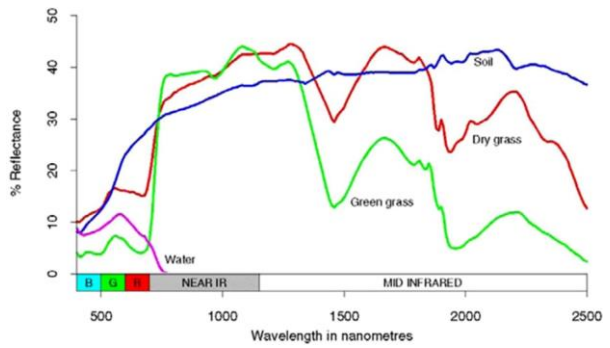
GOALS

Land Cover (LC) statistics and maps are a very important statistical product. As they require a big effort to be created, the idea is to build an automatic system that processes satellite images in order to generate:

- Automatic Land Cover Estimates
- Automatic Land Cover Maps

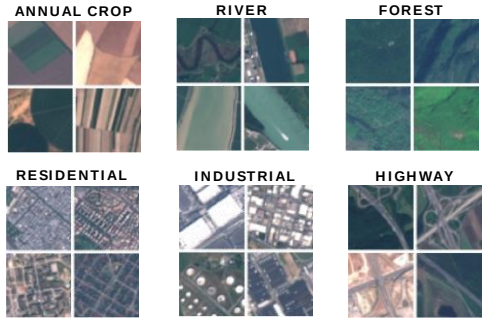
ML Approaches to LC from Images

Standard approach: Spectral Signature



- Different LC classes have different reflectance spectra
  - ✓ Variation of reflectance with EM frequency can be used to predict LC class
  - ✓ Trained ML algo predicts the LC class of image pixels independently
  - ✓ Decision on each pixel does not depend on neighboring pixels

New approach: Computer Vision (Deep Learning)



- Different LC classes have different visual/spatial patterns
  - ✓ Variation of visual/spatial patterns can be used to predict LC class
  - ✓ Trained ML algo (CNN/U-net) predicts LC class of image pixels based on information from neighboring pixels
  - ✓ Decision on each pixel depends on the whole sub-image (tile) the pixel belongs to

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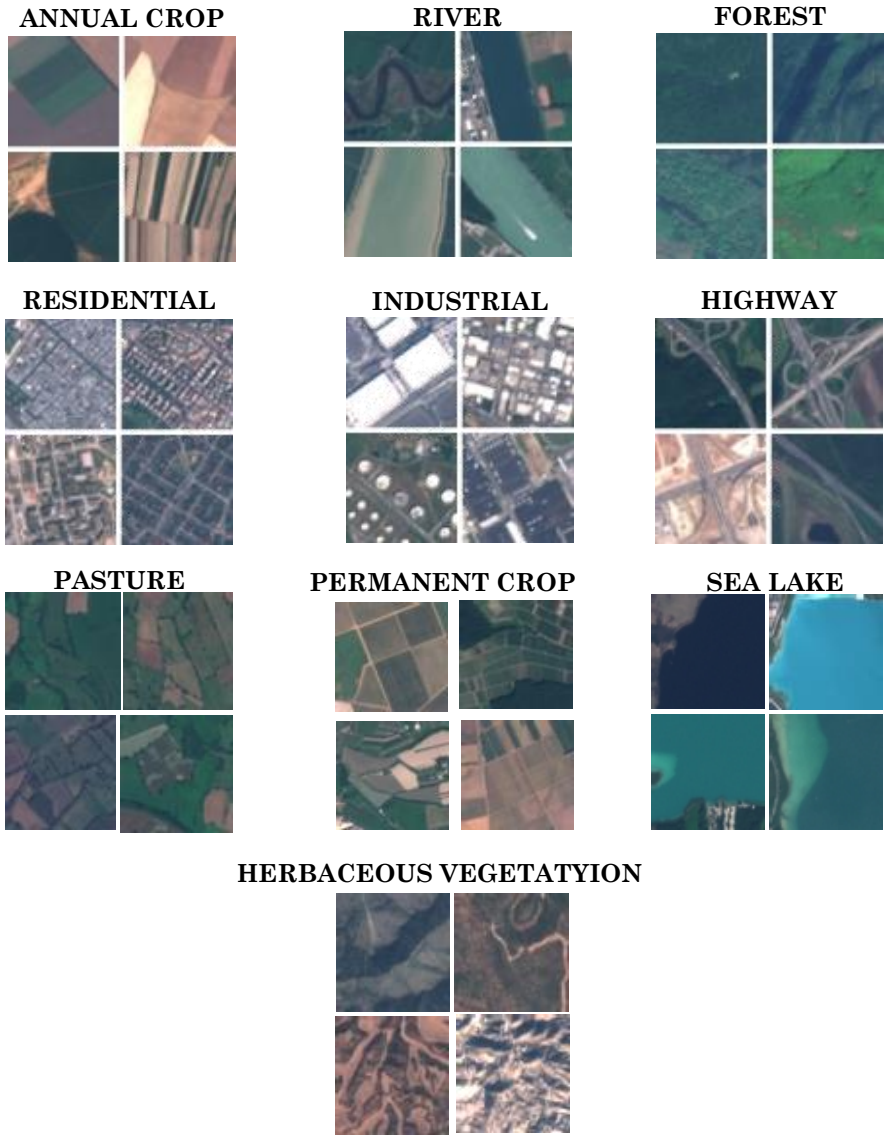

EuroSAT dataset (https://github.com/phelber/eurosat):

- Based on Sentinel-2 satellite images
- 27000 geo-referenced and labeled image patches (each one of 64x64 pixels)
- 10 different Land Use and Land Cover classes, with 2000-3000 images per class
- RGB (8-bit) and Multi-Spectral (13 spectral bands, 16-bit) versions available

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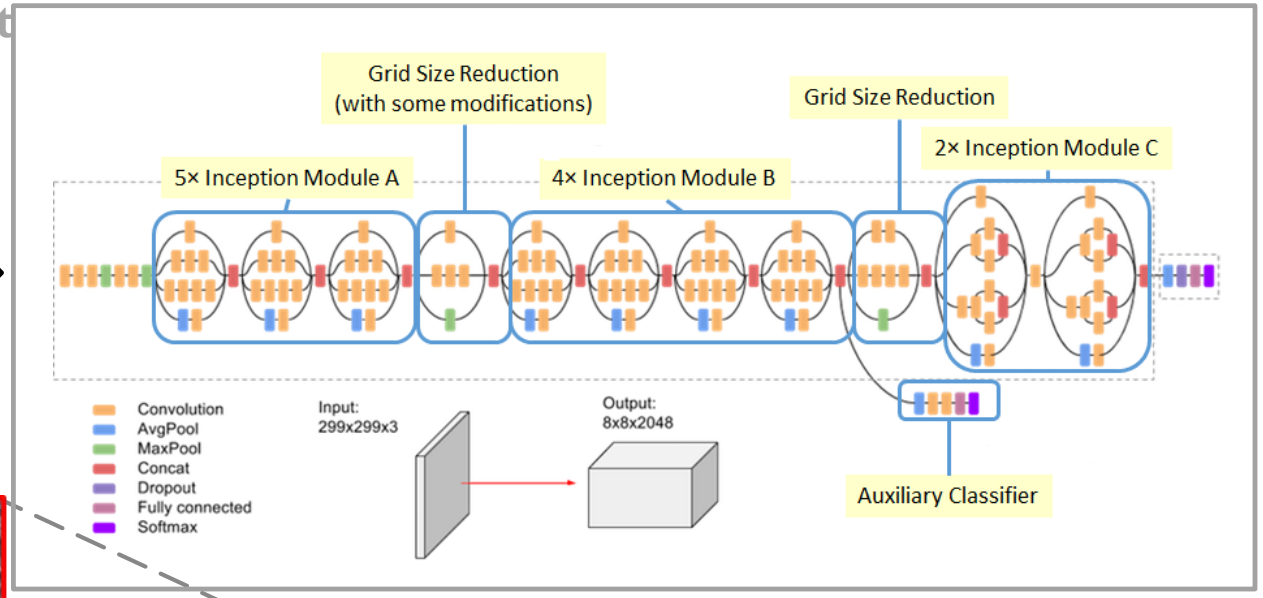
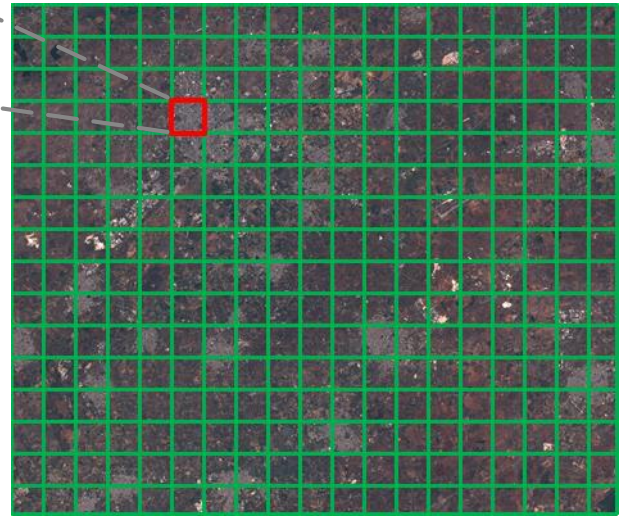
Classify-and-Count Approach



CNN: Inception-V3 Archite

RESIDENTIAL

Input Satellite Image



LAND COVER CLASS	AREA SHARE
…	…
RESIDENTIAL	$\frac{45}{16 * 19} \cong 15\%$
…	…

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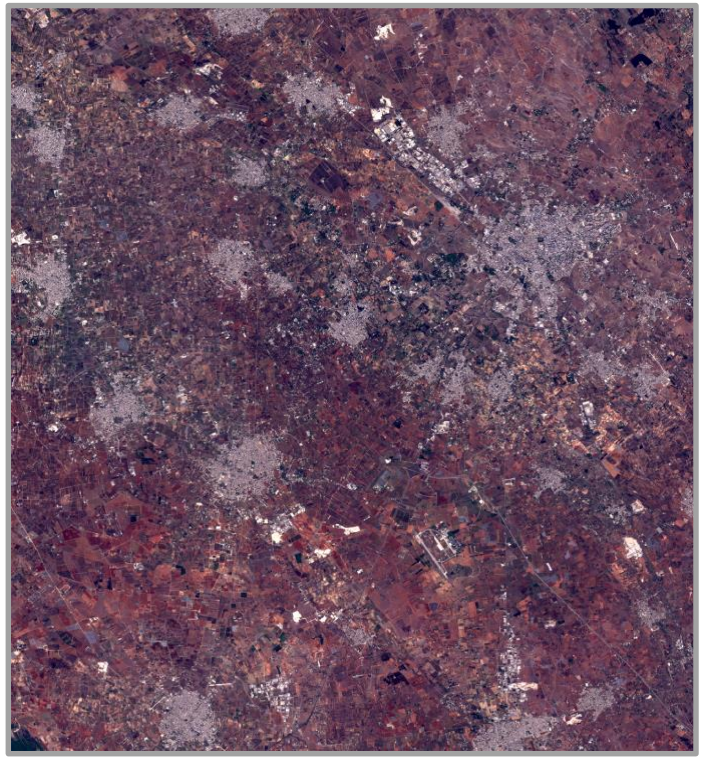
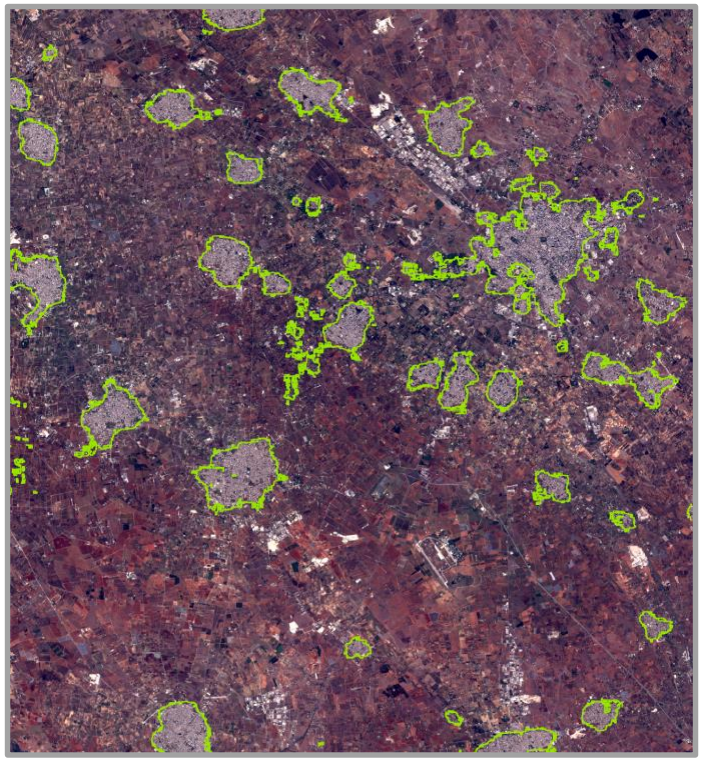


[A]
The 'Lecce image'
(751 km^2)

[B]
Automated LC map derived from the 'Lecce image'



[C]
Edge line of the 'Residential' class derived from [B] overlaid on [A]

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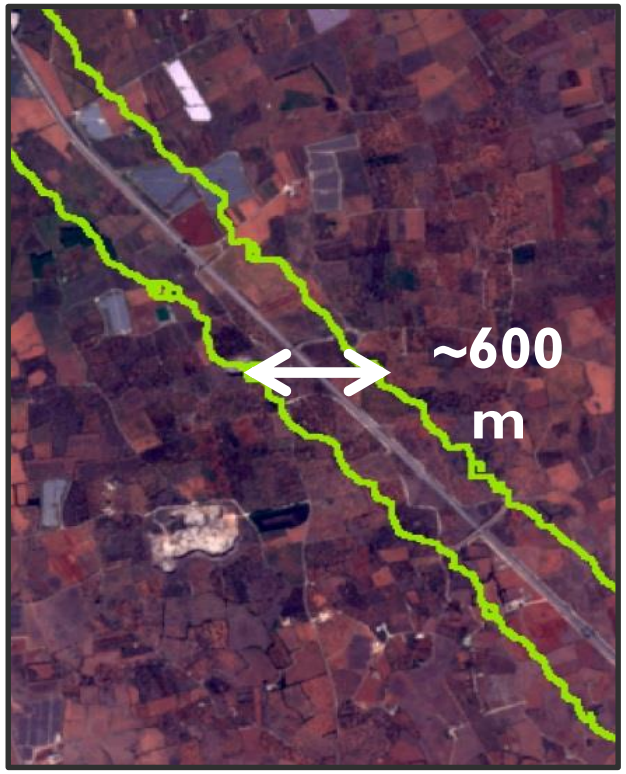
[D]
A detailed view of the course of the Arno River (cropped from the **'Pisa image'**, 443 km^2) overlaid with a semitransparent version of the corresponding automated LC map



[E]
A highway fragment from the **'Lecce image'** overlaid with the edge line of the 'Highway' class

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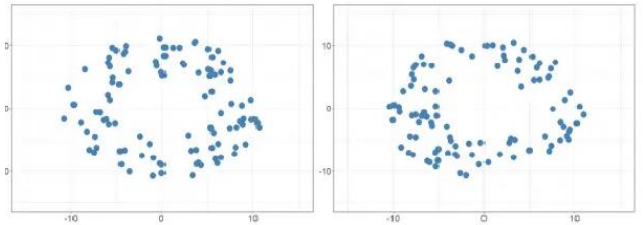
AI for the generation of Synthetic Data

- ✓ With the **digitalization of information** and the increasing accessibility of **administrative** data, the amount of data to be handled has grown substantially in recent years. This raises significant concerns about **data protection** and **privacy** since the disclosure of sensitive information can pose serious risks to individuals, institutions, and public administrations.

- ✓ **Synthetic data** are artificially created datasets intended to **replicate** the statistical characteristics and structure of real data, while preventing the exposure of **sensitive** or **personally identifiable** information.

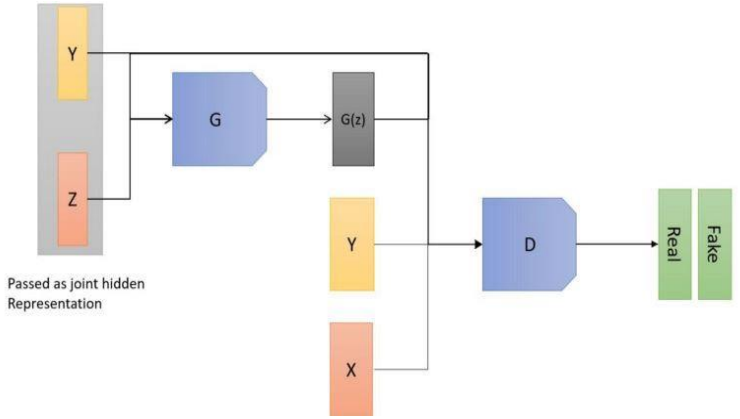


AI for the generation of Synthetic Data

- ✓ **Keep in mind!** Synthetic data do not necessarily reproduce the atomic data (categorical, numerical, etc) from the original source. **Synthesis** capability might rely rather on the **relationships** between different kind of **entities**, such as people and objects, school and neighborhoods, or users and cellular antennas.

- ✓ In this study, the **analyzed data** relate to the frequency and attributes of trips and vacations undertaken by residents of Italy. They originate from **the Istat Trips and Holidays survey**, as a module of the **Household Budget Survey (HBS)** which collects information on the tourism flows of residents. This information includes journeys made for leisure or work, both domestically and internationally.

- ✓ In the WP13's Istat PoC of AI/ML Essnet project, we compared different AI methods: **CT-GAN, VAEs, DP-CTGAN, SMOTENC, Random Forest, XGBoost**

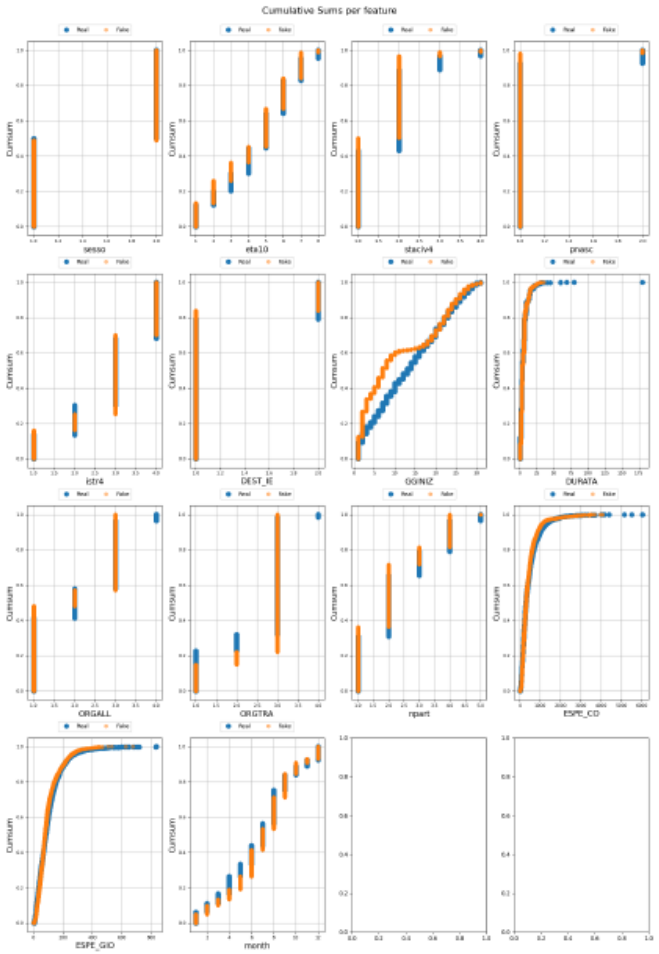


AI for the generation of Synthetic Data

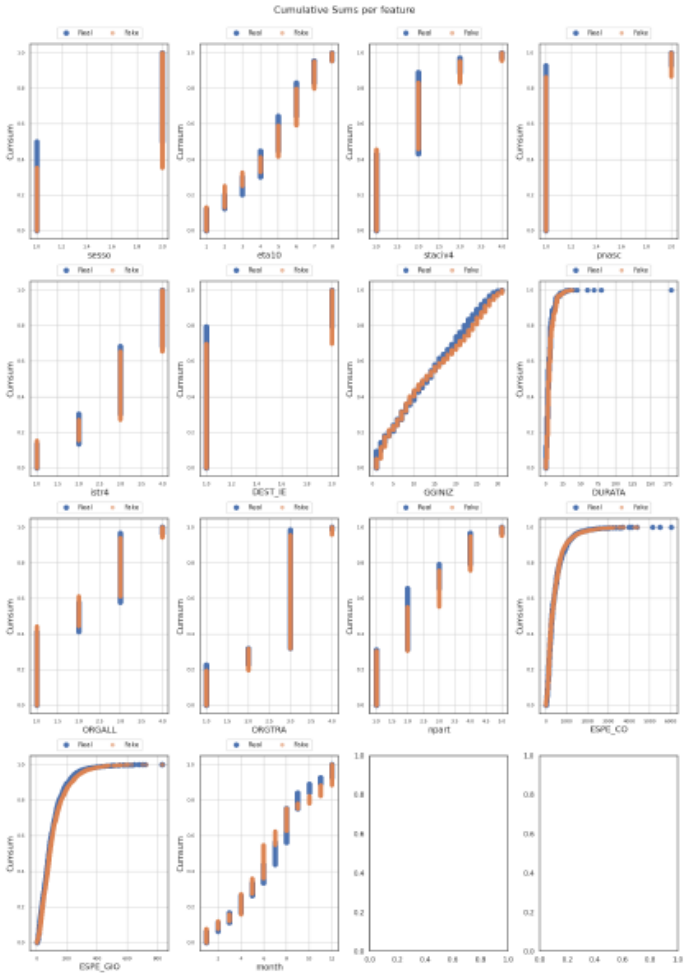
- ✓ Note: In the **original distribution itself**, the values are *not* sums of previous values. Only in the **cumulative sum version** do the values accumulate.

- ✓ It is **evident** from the **cumulative** distributions that the less effective methods, such as **Random Forest** or **XGBoost**, are **less** efficient on categorical variables, where they often **fail** to reproduce the categories, i.e. the domain values of these variables.

Variational Autoencoder (VAE)



CT-GAN



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AI for the generation of Synthetic Data

- ✓ As we can observe, apart from **SMOTENC** which tends to reproduce the data exactly, the best methods seem to be the deep learning–based ones such as CTGAN and VAE, as they achieve high accuracy but not identical to the original dataset, as expected. In fact, during the synthetic data generation process something is always **lost** in terms of the **properties** of the data being reproduced.

Model	Accuracy	F1-Score	Recall
Original Data	0.964516848	0.964516848	0.964516848
RF	0.660685592	0.660685592	0.660685592
XGB	4.46349e-05	4.46349e-05	4.46349e-05
SMOTENC	0.992813783	0.992813783	0.992813783
DPCTGAN	4.46349e-05	4.46349e-05	4.46349e-05
VAE	0.892385288	0.892385288	0.892385288
CTGAN	0.896134619	0.896134619	0.896134619

Conclusions and Next Steps

Conclusions

References

Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., ... & Bengio, Y. (2014). Generative adversarial nets. *Advances in neural information processing systems*, *27*.

Xu, Lei, et al. "Modeling tabular data using conditional gan." Advances in neural information processing systems 32 (2019).

Wu, J.; Plataniotis, K.; Liu, L.; Amjadian, E.; Lawryshyn, Y. Interpretation for Variational Autoencoder Used to Generate Financial Synthetic Tabular Data. *Algorithms* **2023**, *16*, 121. https://doi.org/10.3390/a16020121

Synthetic Data Vault: https://docs.sdv.dev/sdv

McHugh, Mary L. "The chi-square test of independence." *Biochemia medica* 23.2 (2013): 143-149.

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Thanks

FRANCESCO PUGLIESE | francesco.pugliese@istat.it

Istat | Istituto Nazionale di Statistica