Estimating the number of Modigliani sleepers

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Amedeo Modigliani (1884–1902) was an Italian artist whose work is now among the most sought after in modern art. Such works would usually be expected to be recorded in a catalogue raisoneé (CR), which – as those familiar with the UK television show *Fake or Fortune?* are likely to know – is a complete list of an artist's works.

There is often one CR per artist, compiled by a leading authority, but in the case of Modigliani there are five CRs. One reason for this is that Modigliani's popularity surged after his death. During his lifetime, he was known to sell his paintings cheaply, with his landlord even reporting of him using them to patch-up old mattresses, making it difficult to document his works. Box 1 gives a brief biography of Modigliani.

When an artist has only one CR, there is no way – using this list alone – to estimate the number of works that might have been missed. Such works are known as sleepers, and include unattributed works as well as those wrongly attributed to another artist. The premise of *Fake or Fortune?*, for example, is to uncover sleepers of renowned artists such as Modigliani.

Although the existence of multiple Modigliani CRs means there is no official figure for the total number of Modigliani works, it allows the more intriguing figure of the number of sleepers to be estimated via multiple systems estimation (MSE).

Box 1 Amedeo Modigliani: A brief biography

Amedeo Clemente Modigliani was born on the 12th of July 1884, in Livorno, Italy. As a boy he worked in the studio of Livorno painter, Guglielmo Micheli. In 1902 he moved to Florence, then to Naples, and then to Paris, where he lived in Montparnasse near to artists such as Pablo Picasso. During his lifetime he was never particularly well regarded as an artist. He was also an alcoholic and was refused entry into the army during World War I because of poor health. It was from 1914 onwards that Modigliani produced most of his paintings, which were mainly portraits.

Modigliani died, aged 35, on the 24th of January 1920, of tubercular meningitis. Two days later, Jeanne Hébuturne, his common law wife, took her own life and they are buried together in the Père Lachaise Cemetery in Paris.

As with other big names in art, including Vincent van Gogh, interest in Modigliani's work surged posthumously, and his works are now among those that fetch the highest prices in the art world. His painting "Nu couché", for example, sold for 170 million US dollars at Christie's, New York in 2015.

For a complete biography of Modigliani, see [1,2].

MSE and its rich history

MSE is closely related to capture-recapture. While the former tends to use administrative lists, the latter often has a longitudinal component and is usually used in an experimental context, often in ecology. The objective is to estimate the size N of a finite population from at least two incomplete lists of the population's subjects.

The textbook example is estimating the number of fish in a lake. A sample of fish of sample size $k \leq N$ is caught, marked and released. Later, a second sample is caught, and the proportion of marked fish in this second sample can be used to produce an estimate for N. This two-list estimator is known as the Petersen estimator, named after the Danish scientist C.G. Johannes Petersen (1860–1928), who indeed used this estimator in a fisheries application. The same idea holds when there are more than two lists.

Even earlier examples of MSE applications include that of John Graunt (1620–1674; see previous *Significance* article [3]), who used it to quantify the impact of the plague, and Pierre-Simon Laplace (1749–1827), who used it to estimate the population of France.

More recent applications of MSE include estimating the number of drug users [4], victims of human trafficking and modern slavery [5], and the number of deaths in Norway in the Middle Ages [6].

Creating a dataset from the Modigliani CRs

The Modigliani CRs can be treated as MSE lists. That is, Modigliani produced N paintings (only paintings are considered here, not drawings and sculptures). The five CR authors, named in Box 2, attempted to list these, resulting in five lists $L_1,...,L_5$ of sizes $n_1,...,n_5$, where each $n_j \leq N$.

Each Modigliani painting will therefore observe one (and only one) of $2^5 = 32$ possible "capture patterns". For example, a painting could be included on, say, L_1 and L_3 and excluded from L_2, L_4 and L_5. Or a painting could be included on all five lists; one such example is the portrait of Jeanne Hébuturne reproduced in Figure 1. Or, importantly, a painting could be excluded from all five lists; it is the number of paintings belonging to this latter category – i.e. the number of sleepers – that we wish to estimate.

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Creating a dataset based on these CRs involves going through each one, recording which paintings appear in which CR. This brings several challenges. Even finding copies of the CRs is not easy, with few available in libraries across the UK. Moreover, determining which paintings appear in which CR is not trivial, since it involves matching similarly looking paintings across the CRs. A helpful resource was the Secret Modigliani website (*https://www.secretmodigliani.com*), compiled by Francisco Garcia, which has cross-classified the majority of Modigliani paintings.

The complete dataset is given in the "upset" plot in Figure 2. The counts for the observed capture patterns are given in the main bar chart in the centre/right of the plot. For example,

the right-most vertical bar gives the number of paintings (181), included on all five lists. In addition, the horizontal bars on the lower-left give the marginal counts for the numbers appearing on each list. In total, there are $n_{obs} = 488$ distinct paintings that appear on at least one of the lists, i.e. 488 known works, which is the sum of the individual bars in the main bar chart of Figure 2.

The number of sleepers is therefore given as the quantity $N - n_{obs}$, which is estimated by MSE by fitting Poisson log-linear models to this dataset.

Box 2. The Modigliani CRs

These are the five Modigliani CR authors.

1. Pfannstiel [7]
2. Lanthemann [8]
3. Ceroni [9]
4. Patani [10]
5. Parisot [11]

Figure 1: A Modigliani portrait of Jeanne Hébuturne dating from circa 1919. *Credit: The Metropolitan Museum of Art, New York. Gift of Mr. and Mrs. Nate B. Spingold, 1956.*

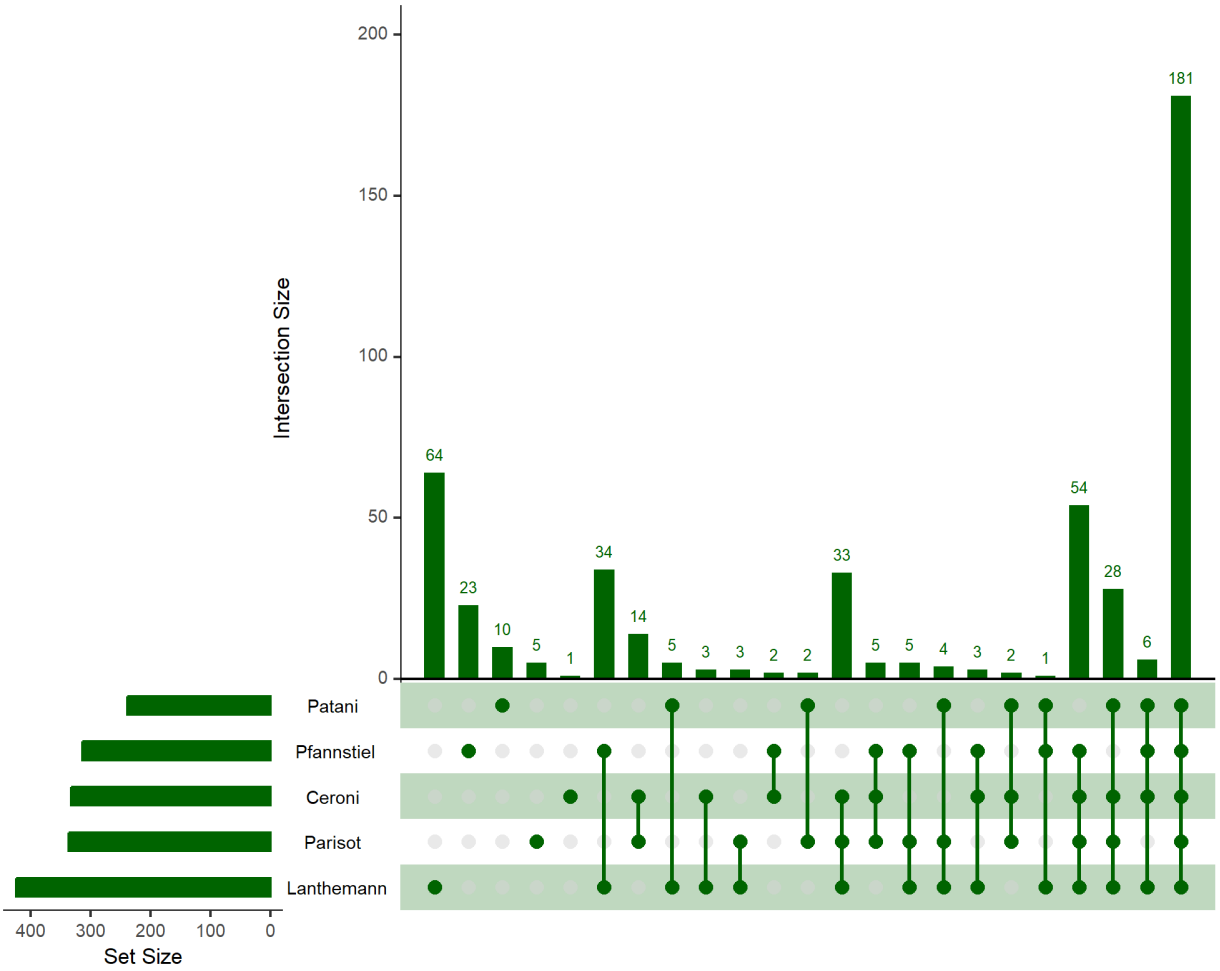

Figure 2: The Modigliani dataset as an “upset” plot, which is essentially an alternative way of displaying a frequency table. For example, the far-left vertical bar gives the number of paintings (64) included in the Lanthemann CR only.

The Results

A comprehensive summary of the results is given in [12]. Estimates are dependent on the interactions included in the log-linear model, and deciding which interactions to include, i.e. which model to fit, can be a contentious issue in MSE. For this reason, we consider all possible combinations of two-way interactions, i.e. all possible models involving two-way interactions. Figure 3 plots these estimates against models’ AIC values. Note that AIC assesses how well a model fits the data given the number of model parameters, with a lower AIC being preferable. The results appear to point towards a figure of between 20 and 120 for the number of sleepers. This suggests there are at least *some* unattributed Modigliani paintings out there, which is of interest to admirers of Modigliani’s work, as well as art to historians (and possibly even art dealers). Interestingly, the models giving the larger estimates tend have lower AIC values, possibly hinting at a greater number of sleepers, e.g. up to 500.

When computing these estimates, it has been assumed that each painting included on each list is genuine and there are no fakes or wrongly attributed works. Yet there are known to be Modigliani fakes. For example, an art exhibition in 2017 in Genoa exhibited 21 ‘Modiglianis’, but the vast majority were declared to be fakes. In this context, a fake painting is essentially a false positive and would impact the estimates for the number of sleepers. Simulations have indicated a complex relationship, though, between the number of fakes and the number of sleepers, e.g. more fakes does not necessarily imply fewer sleepers .

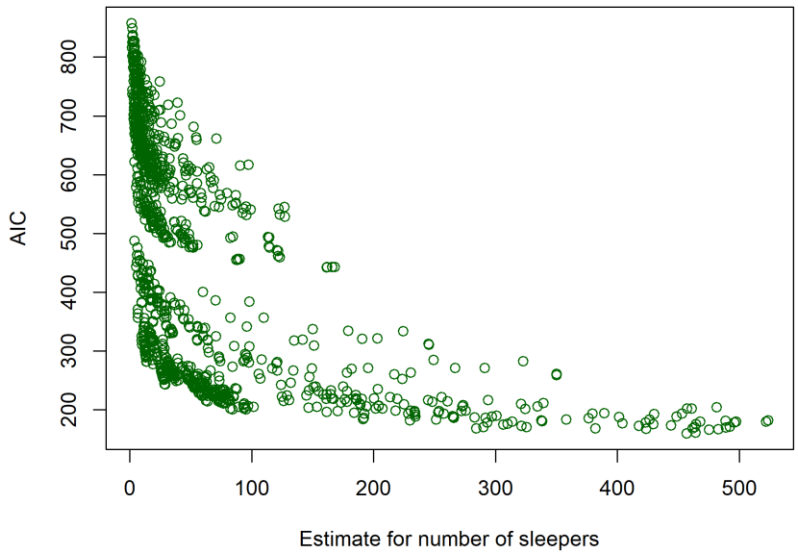

Figure 3: The estimates for the number of Modigliani sleepers plotted against AIC.

Summary

This is one of the few examples where statistics has been used to address a problem in art history. The results suggest there are likely to be some Modigliani sleepers out there, perhaps waiting to be the focus of a future episode of *Fake or Fortune?*

Work is also ongoing in the construction of two further Modigliani CRs, one by Marc Restellini and the other by Kenneth Wayne. Publication of these will allow these estimates to be further revised and provide an opportunity for further research.

As a concluding remark, Modigliani paintings that have been locked in a cupboard for 100 years, or which are stuffed in a mattress at the bottom of the Seine, have a zero probability of appearing on any CR and hence are not taken into account when applying MSE. Unfortunately, this is just an unavoidable limitation; one can instead view the estimates obtained as being a lower bound to the total number of sleepers. This also means that the sleepers estimated here are likely to be paintings that are in general circulation, but which each of the list authors decided to exclude.

Acknowledgments

This article is based on [12] . The dataset is available for download at https://doi.org/10.17635/lancaster/researchdata/696.

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References

[1] Gonzalo-Millan, d.e P. P. (1995), *Maldito: Novela basada en la vide de Modigliani*. Editorial Complutense, Madrid.

[2] Meyers, J. (2006) Modigliani: A life. Duckworth, London.

[3] Harkness, T. (2020) John Graunt at 400: Fighting Disease with Numbers. *Significance*, 17(4), 22–25. https://doi.org/10.1111/1740-9713.01421.

[4] King, R., Bird, S. M., Overstall, A. M., Hay, G., & Hutchinson, S. J. (2014). Estimating prevalence of injecting drug users and associated heroin-related death rates in England by using regional data and incorporating prior information. *Journal of the Royal Statistical Society Series A: Statistics in Society*, *177*(1), 209-236.

[5] Silverman, B. W. (2020). Multiple-systems analysis for the quantification of modern slavery: classical and Bayesian approaches. *Journal of the Royal Statistical Society Series A: Statistics in Society*, *183*(3), 691-736.

[6] Kadane, J. B. & Næshagen, F. L. (2013) The number of killings in southern rural Norway, 1300–1569, *The Annals of Applied Statistics*, 7(2), 846-859.

[7] Pfannstiel, A. (1956), *Modigliani et son œuvre : Étude critique et catalogue raisonné*, Bibliothèque Des Arts, Paris.

[8] Lanthemann, J. (1970), *Modigliani, 1884-1920: catalogue raisonné: sa vie, son œuvre complet, son art*, Gráficas Condal, Barcelona.

[9] Piccioni, L. & Ceroni, A. (1970), *I dipinti di Modigliani*, Rizzoli, Milano.

[10] Patani, O. (1991), *Amedeo Modigliani: catalogo generale*, Leonardo, Milano.

[11] Parisot, C. (1991), *Modigliani catalogue raisonné, Tome II*, Graphis Arte, Livorno.

[12] Jackson, J. & Francis, B. (2025), The use of multiple systems estimation to estimate the number of unattributed paintings by Modigliani. *Statistical Methods & Applications*, 34(1), 21–37. https://doi.org/10.1007/s10260-024-00774-w.

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