Population Sized Record Linkage

Andee Kaplan and Rebecca C. Steorts

Department of Statistical Science, Duke University

Overview

Provide an estimate for population size from multiple noisy capture datasets and quantify uncertainty in that estimate using Bayesian methods.

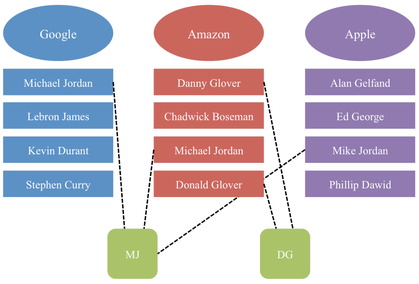
Motivating example

- "Historically, these numbers matter... because they can have a direct impact on policy, accountability and a global sense of urgency."[1]
- Duplicated information regarding information about who has died from multiple sources (NGOs)
- Messy overlapping datasets with errors
- String data (names) as identifiers

Goal: Count the (population of) casualties and *quantify the uncertainty* in the estimate.

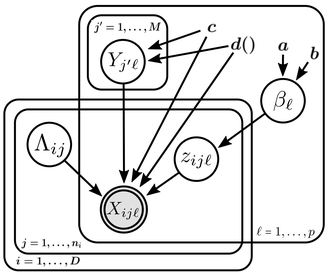
Graphical Record Linkage (RL)

Record linkage is merging together multiple datasets that have duplicate entries, often in the absence of a unique identifier.



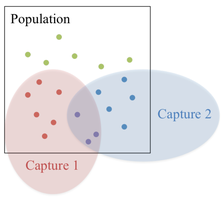
Bayesian Hierarchical Model

Latent clustering approach[2] with a package on CRAN (`blink`)[3]



Capture-recapture Methods (CRC)

Capture-recapture (CRC) is a method used to estimate a closed population's size through the use of mark-release-recapture.



List 2

List 1 \ List 2	Yes	No
No	5	6
Yes	3	6

Bayesian Model Averaging (BMA)

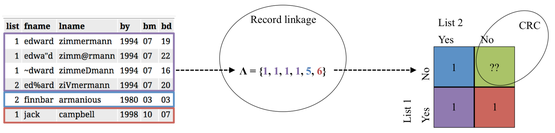
- Model averaging approach allows for various types of dependency between lists through the use of decomposable Bayesian graphical models[4] with a package on CRAN (`dga`)[5]
- **Likelihood** Bayesian hierarchical log-linear models given model with certain dependency between lists
- **Priors** t-distribution for log-linear parameters, $p(N) \propto N^{-1}$
- Models averaged over all decomposable Bayesian graphical models to obtain final posterior distribution
- For 3 lists, this corresponds to 8 models, 4 lists - 61 models, 5 lists - 822 models

Bayesian NP Latent Class Model (NPLCM)

- Assumes independence between lists, used to model heterogeneity in the capture probabilities[6] with a package on CRAN (`LCMCR`)[7]
- **Likelihood** Multinomial multiple-capture estimation with finite mixture models for probability of capture where each component in the mixture has stratum-specific parameters
- **Priors** Dirichlet process model for strata mixture weights, $\text{Beta}(1, 1)$ for stratum-specific capture probabilities
- No need to specify the number of strata
- Can handle large numbers of recapture with moderate sample size

RL + CRC

list	fname	lname	by	bm	bd
1	edward	zimmermann	1994	07	19
1	edwa"d	zimm@rmann	1994	07	22
1	~dward	zimmeDmann	1994	07	16
2	ed%ard	ziVmermann	1994	07	20
2	finnbar	armanious	1980	03	03
1	jack	campbell	1998	10	07



Simulated Data Example

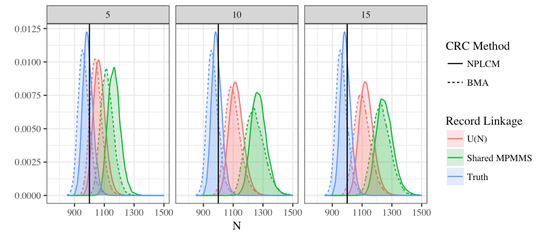
- Generated data in 5 lists according to the following stratified capture probabilities

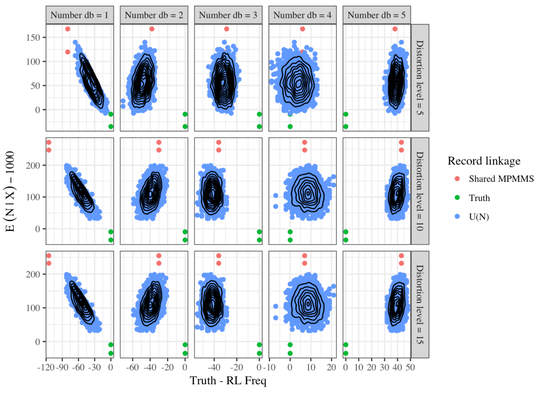
Strata	Proportion	List 1	List 2	List 3	List 4	List 5
1	0.75	0.07	0.31	0.17	0.31	0.14
2	0.25	0.94	0.77	0.85	0.90	0.91

- Strata are (1) large & hard to capture and (2) small & easy to capture population
- Add additional duplicates within each database at a 5% level
- Distort the duplicates – strings are distorted at three levels: $5\%, 10\%, 15\%$ of characters

fname	lname	by	bm	bd
jacobie	annL	1981	12	02
jacobie	annK	1981	12	17
amaya	mcmellon	1985	08	17

Results and Performance





Discussion

Takeaways

- Full posterior estimation via MCMC is **computationally expensive**, point estimate from RL for CRC, less valid intervals
- NPLCM CRC method is for independent lists; works best for many lists (≥ 4)
- BMA CRC method does not scale beyond 5 lists easily because need to precompute valid dependencies
- Both CRC methods sensitive to errors from RL and become biased

To do

- Much more extensive simulation with different levels of duplication and list inclusion probabilities
- Alternative prior specification for Bayesian RL that prioritizes singletons
- Investigate CRC methods that are robust to misspecifications and incorporating additional information (duplication) from RL
- Do this on **real data**!

References

(1) Specia, M. How Syrian's Death Toll Is Lost in the Fog of War. *The New York Times* **2018**.
(2) Steorts, R. C. Entity Resolution with Empirically Motivated Priors. *Bayesian Analysis* **2015**, *10* (4), 849–875.
(3) Steorts, R. *Blink: Record Linkage for Empirically Motivated Priors*; 2017.
(4) Madigan, D.; York, J. C. Bayesian Methods for Estimation of the Size of a Closed Population. *Biometrika* **1997**, *84* (1), 19–31.
(5) Johndrow, J.; Lum, K.; Ball, P. *Dga: Capture-Recapture Estimation Using Bayesian Model Averaging*; 2015.
(6) Manrique-Vallier, D. Bayesian Population Size Estimation Using Dirichlet Process Mixtures. *Biometrics* **2016**, *72* (4), 1246–1254.
(7) Manrique-Vallier, D. *LCMCR: Bayesian Non-Parametric Latent-Class Capture-Recapture*; 2017.
(8) Australian Bureau of Statistics. *Eber: Empirical Bayes Entity Resolution*.