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CASE STUDY

Ethical Challenges in Analyzing and Mapping Historical Demographic Changes and Migration Using Population-Scale Family Trees

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Despite the progress made toward generating and utilizing population-scale family trees to study historical population dynamics, little is known about their representativeness for the entire population. In this article, we confront the inherent complexities and biases in historical data collection and shed light on the extensive areas of history that remain unknown, unrecorded, or inaccurately portrayed. Although we do not provide definitive solutions for these data gaps, we aim to initiate a dialogue on these critical issues, contributing to the discourse on ethical data collection and representation in historical research. We first report on the preliminary results of a record linkage experiment between family tree records and a historical census, emphasizing the need for methods that integrate historical data from multiple sources to systematically evaluate representativeness. The experiment reveals significant underrepresentation of certain groups in the United States, notably Native American, Black, and Mexican persons, as well as those from eastern Europe, southern Europe, and Ireland. These findings underscore the ethical responsibilities that should guide historical research, including the need to address underrepresentation and improve methodologies to better reflect the diversity of population dynamics and migration patterns. To complement these efforts, we advocate for the use of interactive story maps to amplify the qualitative narratives of underrepresented populations and integrate them into the broader historical narrative. Our endeavor to map migration and demographic changes is not just about tracing the past; it's about shaping a more equitable and comprehensive understanding of history that honors the diversity of all its participants.

KEYWORDS: mapping historical migration; population-scale family trees; representativeness; bias in crowd-sourced data; bias in historical census data

INTRODUCTION

Population-scale kinship networks are large-scale social networks that describe kinship connections among a significant number of individuals within a given population. These networks offer insights into the complex network of relations established through biological ties, marriages, and extended kinship connections over many generations (Koylu and Kasakoff 2024). Constructing models of these networks, connecting individuals and families across geographic space and time, is enabled by family tree records generated by amateur and professional genealogists. These records offer a wealth of data including kinship ties (parents, children, spouses), names of individuals, and their dates and places of birth and death.

In our previous work, we cleaned, connected, and deduplicated crowd-sourced family tree data to generate the largest population-scale and longitudinal kinship network to date, containing about 40 million individuals in a single family tree spanning across centuries and continents (Koylu et al. 2021). Utilizing the child-ladder approach, which traces changes in birthplaces between consecutive siblings, we mapped interstate migration flows in the US between 1789 and 1924, uncovering the long-term changes in migration patterns in the US history (Koylu and Kasakoff 2022).

Despite the progress made toward generating and utilizing population-scale family trees to study historical

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population dynamics, we struggle with a critical limitation: significant underrepresentation of certain groups in the United States, notably Native American, Black, and Mexican persons, as well as those from eastern Europe, southern Europe, and Ireland. This raises serious ethical concerns, highlighting our responsibilities as researchers to avoid perpetuating biases, to include marginalized groups in historical narratives, and to accurately interpret population dynamics without oversimplification.

These concerns challenge the reliability of our data and the validity of our findings, particularly when addressing questions about migration patterns, social mobility, and historical trends that may differ significantly across groups. Moreover, these challenges are also valid for other historical data, raising questions about their reliability for studying the social and demographic history of the entire population. Addressing these limitations requires not only methods to better evaluate the representativeness of population groups but also strategies to bridge data gaps by incorporating alternative historical sources and improving linkage techniques.

The discussion presented in this article aims to unpack these ethical challenges, explore the biases embedded in historical data collection, and examine the vast swathes of unknown, unrecorded, or misrepresented histories. While we do not offer a comprehensive solution to these issues, we seek to initiate a conversation and propose approaches for acknowledging and addressing these gaps in future research.

EMPIRICAL EVALUATION OF REPRESENTATIVENESS

Previous studies of population-scale family trees have consistently highlighted significant biases and limitations in representativeness. For instance, genealogical and genetic datasets have consistently shown a lack of African Americans and a skew toward the White population (Price et al. 2021; Erlich et al. 2018; Kaplanis et al. 2018). By comparing state-level statistics of individuals likely alive in 1880 with the 1880 United States Census, Koylu et al. (2021) revealed notable biases in family tree data, particularly favoring native-born White Americans and farmers while underrepresenting Black, Native American, and Mexican persons. They also found consistent biases toward men and older individuals across states. While these studies compared aggregate statistics from population-scale family trees with census data, a thorough comparison of representativeness requires linking individual records in family trees with those in historical census records.

We performed an empirical assessment of crowd-sourced family tree records compared to historical census records to evaluate the extent of their alignment, with the census data serving as a proxy for the actual population. We began by identifying potential connections between the family tree data—focusing on individuals likely alive in 1880 in the tree data—and those listed in the 1880 United States Census. For each record in the tree data, up to 100 potential census links were reviewed by trained research assistants who evaluated the correspondence of information between a single entry in the tree data and a possible census record for the same individual and decided whether a match could be made. Links made by the research assistants were reviewed for consistency, and instances where different research assistants selected different census records for the same tree record were flagged. The set of several hundred decisions about links and the characteristics of the tree and census records were used as training data for out-of-sample prediction of links between tree and census records. The training data were stratified by sex and marriage status to evaluate the potential ability of family trees to link women with maiden names. Utilizing the training data composed of manually linked records between family trees and the 1880 census, we developed a machine learning model (specifically, a probit regression model) to identify matches among millions of records from both the family tree and the 1880 census datasets. The initial linkage result showed an 18% linkage rate, corresponding to approximately 3% of the entire census. Our preliminary analysis of the census linkage indicates a significant representation of European-descended white populations across various sex and age groups, but a stark underrepresentation of critical demographic groups, including Black populations in the South, where they are scarcely represented in the family tree records, and Native Americans, who are mostly absent in family tree records. However, this underrepresentation is not limited to family tree data; historical census records themselves fail to accurately capture these groups due to systemic biases and

inconsistent documentation. We discuss historical biases in census-taking to explain the reasons for underrepresentation in the following section.

The major source of the problem in crowd-sourced family trees is the absence of records for historically underrepresented groups. This results largely from several ways these populations have been "discounted," making data for personal research harder to decode: inconsistent recording of names and lack of sources which included named individuals, lack of written records recording life events, passing (where individuals change their names and racial identities to gain social or economic benefits), and changing racial designations in historical sources. For some groups, common surnames within large cities made it difficult to disentangle different individuals with the same names. Moreover, the lack of crowd-sourced trees in certain populations also results from varying interest in genealogy by ancestry. For example, there is a notably low interest among individuals identified as Latino/a and a high interest among those identified as Black (Horowitz et al. 2019). This suggests that different racial or ethnic groups may have varying motivations or access to resources for exploring their genealogical backgrounds, potentially influenced by historical, cultural, or socioeconomic factors (Greely 2008; Roth et al. 2018).

All US datasets based upon crowd-sourced family trees, and many of those using DNA, have the same problem. Even those that link individuals between censuses have much less success linking together Black populations or recent immigrants, and they do not have any Native Americans (Helgertz et al. 2022). Records containing information on the slave trade including transatlantic ship records (Eltis 2020), slave biographies (Freedom Narratives 2024), runaway slave advertisements (Waldstreicher 1999), slave sales, and wills naming Black slaves bequeathed to others could be used to reconstruct Black trees and slave movement (Streets 2008). These records could also be linked with post-emancipation records such as censuses. However, generating such trees at a population scale would be a massive effort and may not yield a sample as representative as the one we have created for the European-descended white population. If generalized to the entire enslaved population, this technique might also lead to an overestimate of migration, as many of the potential datasets specifically focus on slaves known to have moved rather than a random sample of all slaves. Even if these holes in the crowd-sourced tree data were filled to better represent census population, most historical censuses fall short in accurately representing Black, Mexican, and Native American populations (Hochschild and Powell 2008). Compounding the problem, our analysis and mapping of migration over time is iterative and dependent on chains of data, so biases in population statistics propagate beyond their individual sources. Recognizing these biases is part of our ethical responsibility to ensure that our analyses do not inadvertently reinforce historical inaccuracies or exclude significant portions of the population.

REPRESENTATIVENESS IN HISTORICAL CENSUS

It is important to understand the complexities involved in census-taking, particularly concerning Native American populations. During the nineteenth century, Native Americans were often censused separately, especially those who were recognized as members of particular tribes that had signed treaties with the United States (Census Bureau 2024). These tribes were administered by the Department of Indian Affairs; tribal rolls were kept by Indian Agents, and did not always align directly with the general census process. Furthermore, the history of Native American censusing reveals that many Native American groups, especially those in the eastern portion of the United States, or those not recognized under treaties, may have been omitted or undercounted due to their unique socio-political status and the challenges of documenting populations that were, in some cases, actively hiding to avoid removal. The complexity of tribal recognition, eligibility for roll inclusion, and the impact of the Indian Reorganization Act of 1934 all further complicate how Native American populations were recorded.

Undercounting and inconsistent record-keeping of African-descended populations is also a major issue throughout the nineteenth century censuses, including the difficulties in documenting populations such as slaves, who lacked consistent naming conventions and whose records were not uniformly kept, and other marginalized groups whose presence in the census depended greatly on the fluctuating policies and practices of the time (Nix and Qian 2015). To uncover the ideological underpinnings

of racial categories, Lee (1993) provides a critical view of the methodologies employed in racial categorization, questioning the objective validity of these constructs and pointing towards a systemic reevaluation of racial data collection methods.

Similar problems of undercounting and inconsistent record-keeping also existed for Mexican populations (Parker et al. 2015). Between 1850 and 1920, the Census Bureau broadened its racial classification to include individuals of mixed race, identifying them under categories such as Mestizos and Mulattos. In this period, individuals of Mexican descent, including both Mexicans and Mexican Americans, were classified as "white" (Durand et al. 2001).

Even among the native-born white population, census records were far from complete, with notable variations across demographic groups and significant underenumeration in the nineteenth and early twentieth centuries. Hacker (2013) systematically examined this issue, utilizing back-projection methods, mortality estimates, and IPUMS samples to estimate age- and sex-specific underenumeration rates in the 1850–1930 censuses. His analysis showed that underenumeration rates ranged between 3.8 and 6.6 percent, with significant disparities across age and sex groups. Infants and older women were disproportionately undercounted. However, the undercounting of foreign-born populations is expected to be higher than the native-born persons. These findings highlight that while census data continue to be a reliable data source for historical research in the United States, it is our ethical responsibility to critically evaluate these data sources. This includes understanding their limitations, addressing underenumeration biases through appropriate corrections, and recognizing how these factors influence our interpretations.

REPRESENTATIVENESS OF MIGRATION PATTERNS FROM TREES

We use the child-ladder method to detect migration events from the tree data, dating these occurrences based on the midpoint of the birth years of two consecutive siblings born in different birthplaces. Given the relatively short intervals between the births of successive children—typically around two years within our study's timeframe of 1789 to 1924—this technique affords a more precise estimation of migration timing compared to broader decennial snapshots of household residences obtained from census data or parent-to-child or birth-to-death migration captured from birth and death events in family trees. However, the child-ladder method is inherently biased towards larger families and fails to capture the migration of single individuals or those with only one or no children. This approach also omits information on migration that may occur outside the childbearing period. Despite these limitations, the significance of this bias might be mitigated by the context of the US population during the study period, which was experiencing significant growth, with childless individuals constituting less than 10% of the population—a stark contrast to the higher proportions in the Northeast and Europe (Hacker 2016; Weir 1994). Therefore, while this method might not significantly underrepresent migration in a demographically expanding context like the US, especially at earlier dates, its effectiveness could diminish over time as the number of childless individuals increased. Nonetheless, the child-ladder method can detect multiple moves during the 10-year period between censuses.

Figure 1 illustrates a child-ladder migration flow map from 1850 to 1860 generated via **flowmapper.org** (Koylu et al. 2023). The curved flow lines illustrate the total number of families that moved between pairs of states; the point (node) symbols illustrate the gross volume of flows per state. Additionally, the choropleth base map represents migration efficiency, which is calculated by dividing the net flow of migration (the difference between the total inflow and outflow of migrants) by the sum of the total inflow and outflow. During this period, the child-ladder migration flows show a significant movement from east to west, with eastern states experiencing population declines and western states seeing increases. Major hubs of migration were identified in Ohio, Indiana, Illinois, Iowa, and Missouri.

To evaluate how closely the child-ladder migration from family trees reflects those from censused populations, we used the migration events derived from the IPUMS Multigenerational Longitudinal Panel (IPUMS-MLP) dataset (Helgertz et al. 2022) by leveraging changes in the state of residence for linked households across two consecutive censuses (i.e., 1850 to 1860). We should note that the MLP data set also introduces further bias into

the representation of population segments. For example, a comparative analysis with a sample from the 1910 census by Helgertz et al. (2022) revealed a significant overrepresentation of the linked individuals who were white, young males aged 7–20, predominantly from larger households living with their parents. Additionally, while overall coverage of women in the MLP dataset is less comprehensive than that of men, white women, those residing with family members, and individuals from larger households were notably overestimated compared to census figures. Regardless, the MLP change of residence migration dataset is probably the best proxy for representing the large-scale migration moves of the entire population between the states. We employed the cosine similarity metric to assess the similarity between state-to-state flow matrices derived from the child-ladder and the MLP change of household residence from 1850 to 1860, finding a high degree of similarity with a value of 0.91. This indicates a substantial commonality in migration patterns across the networks. Although we do not illustrate the MLP household migration flows in this article, the MLP map is very similar to the child-ladder migration (Figure 1), which is affirmed by the high cosine similarity score.

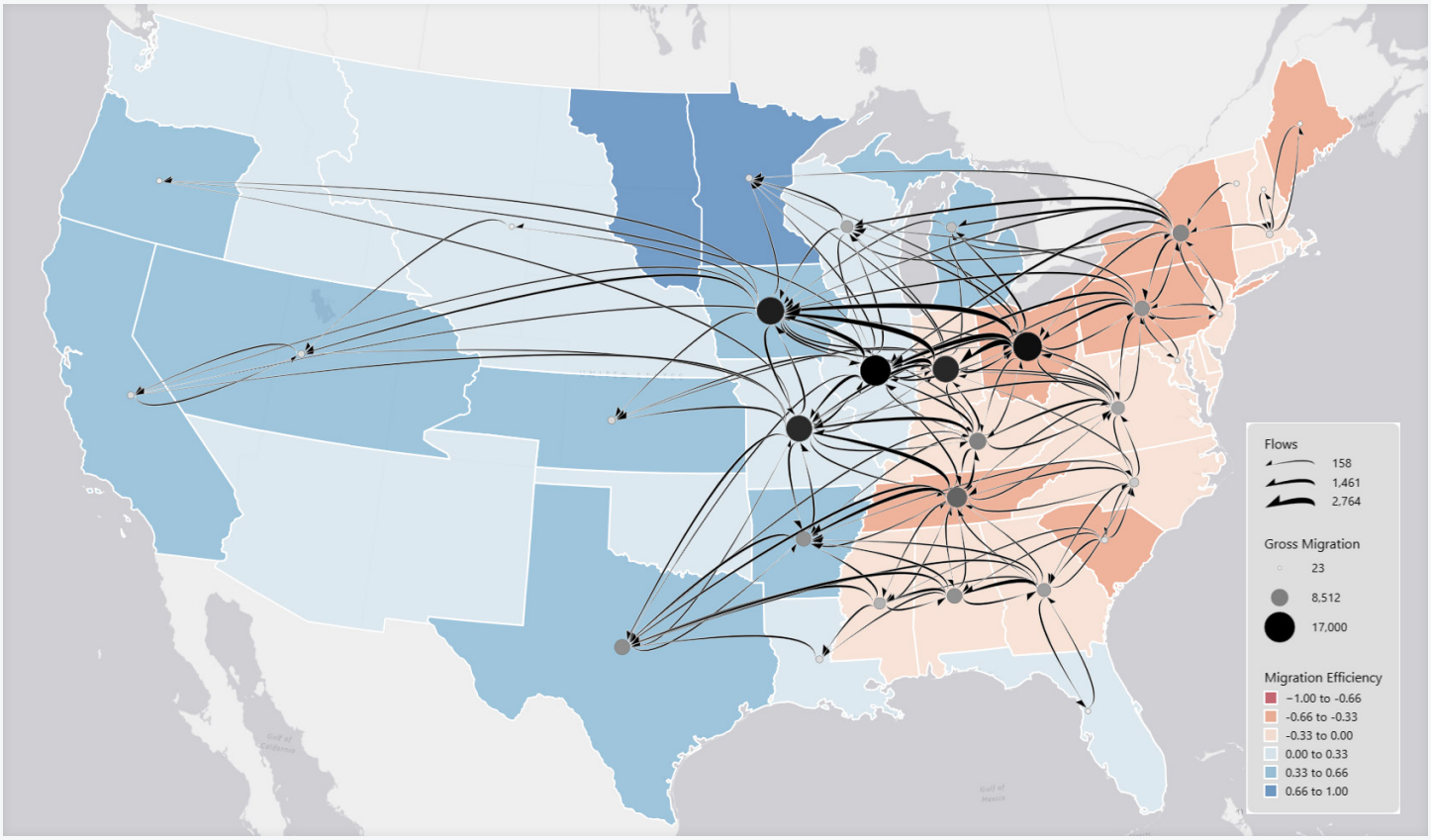

Figure 1. Family migration in 1850–1860 (child-ladder from family trees).

ROOTS & MIGRANTS

To tackle the issue of representativeness and shine a light on the stories of those neither fully captured in historical tree and census records, nor in our quantitative data and analyses, we have started a project called "Roots & Migrants." This project aims to further address the limitations of the data we have with detailed stories and provide a fuller picture of population and migration histories through the use of interactive story mapping. For example, it integrates the visualization of historical events such as the Indian Removal Act between 1830 and 1847 and its the consequences for the dislocation, dispersion, and disappearances of Native Americans (Sturtevant 1967) alongside the movement and expansion of migrants from family trees and historical census. Using story synthesis activities (Chen et al. 2018), the application will be accessible online to the general public and will enable people

with limited background in GIS to understand and communicate the challenges that westward migration posed to First Nations. It will also make the audience aware of how differences in documentation constrain the kinds of stories that can be told, further amplifying the differences between underrepresented populations.

A series of maps will combine what is known about Black, Native American, and Mexican populations with maps of the White population to visualize their different histories and the effect of White expansion on the other groups. Maps of the land that Native Americans occupied by treaty will be inserted onto the base map we use for making the flow maps of the White population. Officially recognized Native Americans were less able to move and mostly remained on their reservations in the nineteenth and early twentieth centuries. While the Mexicans living in the area ceded after the Mexican–American War became citizens and were censused as white, little is known about their migration and whether it can be reconstructed at the individual level. Many in the enslaved Black population were moved west by their masters to populate the New South. We will attempt to reconstruct that migration from census records even if we cannot study individuals. Meanwhile there was a growing population of Native Americans living away from reservations, some of whom were descended from mixed marriages or had never been listed on tribal rolls. There were also populations of free Black persons before the Civil War. These were relatively small in number, but it is important to study the paths people from these groups took to emphasize the diversity within these populations.

We plan to integrate Roots & Migrants into high school social studies curricula through collaborative workshops with high school teachers on the specific topic identified by Iowa Core Curriculum: "Analysis of human population movement and patterns" (Iowa Department of Education 2024). We held a workshop to guide the development of the application, involving seven high school teachers specializing in history, social studies, and geography, as well as three high school students. In this workshop we presented a prototype of the application to the users. The workshop involved focus group discussions and broader group feedback to refine the application's requirements, particularly around curriculum integration, student engagement, and the use of interactive tools. We plan to conduct a second workshop with high school teachers to develop lesson plans to support the Iowa Core Standards, emphasizing both historical content and thinking skills that prepare students to apply these skills in diverse historical contexts—essential for college, career, and democratic citizenship. Roots & Migrants seeks not only to address representational gaps but also to enhance public engagement and foster greater understanding of US historical population dynamics.

CONCLUSION

Our experience in mapping demographic changes and migration using family tree data has highlighted the ethical responsibilities we hold as researchers. Throughout our work, we recognized the imperative to address underrepresentation and bias in historical data actively. This journey compelled us to critically assess our methods and data sources, ensuring that we do not perpetuate inaccuracies or exclude marginalized groups from the historical narrative. By embracing these ethical obligations, we have taken significant steps toward creating a more inclusive and accurate portrayal of the nation's history. Our empirical assessment of representativeness, when compared with historical census records, underscores the persistent difficulties in fully capturing the diversity of the US population. This serves as a clear reminder of the ethical responsibilities that should steer our research and the critical need to constantly improve our methods to accurately reflect the population dynamics and migration patterns of all demographic groups.

In this article, we have confronted the inherent complexities and biases that exist in historical data collection and shed light on the extensive areas of history that remain unknown, unrecorded, or inaccurately portrayed. While we do not provide a comprehensive solution for these data gaps, our goal is to initiate a discussion on these critical issues. Moreover, by examining the underrepresentation of Native American, Black, and Mexican populations, and assessing migration patterns through the lens of family trees and historical censuses, we aim to contribute to the discourse on ethical practices in historical research.

As we move forward, our work continues to evolve, informed by the insights gained from these explorations. By

incorporating detailed narratives and qualitative insights through Roots & Migrants, we aim to bridge the gaps left by incomplete quantitative data, ensuring that the experiences of underrepresented populations are acknowledged and integrated into the broader historical narrative. By integrating stories of underrepresented groups and utilizing advanced analytical techniques, we aim to offer a richer, more inclusive view of American history. Our endeavor to map migration and demographic changes is not just about tracing the past; it's about shaping a more equitable and comprehensive understanding of history that honors the diversity of all its participants.

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