LINKING HISTORICAL CENSUSES: A NEW APPROACH

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This article describes a new initiative at the Minnesota Population Center (MPC) to create linked representative samples of individuals and family groups from the censuses of 1860, 1870, 1900 and 1910 to the 1880 census. This set of linked samples will provide new opportunities for researchers to carry out individual-level analyses of social and geographic mobility and family transitions.

This study differs from past efforts to link persons across census years in one key respect. The central goal of previous studies has been to maximize the proportion of the population linked. Our primary goals, however, are to minimize selection bias and maximize representativeness of the linked cases. To achieve these goals, we are prepared to sacrifice a significant number of demonstrably valid links.

The project takes advantage of an extraordinary new data source, a complete transcription of the 1880 census of the United States. We will also capitalize on recent advances in record linkage technology.

BACKGROUND: THE 1880 LDS DATABASE AND THE IPUMS SAMPLES

The Church of Jesus Christ of Latter-Day Saints (LDS) and the Minnesota Population Center (MPC) have produced a remarkable machine-readable database encompassing the entire population of the United States enumerated in the 1880 Census of Population. Over a thousand LDS volunteers spent 11.5 million hours over an eighteen-year period transcribing the census data from the original enumerators' manuscripts. Their goal was to create an electronic lookup system for genealogical research.

In 1999, the MPC reached an agreement with the LDS to verify and correct the census transcription in exchange for the right to disseminate the resulting database for scholarly and educational purposes. In addition to making the

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changes required by the LDS, the project involved converting the files from a raw transcription of the census text into a numerically-coded and documented database suitable for statistical analysis.

We have published a description of the editing and coding procedures used for the 1880 project elsewhere.[1] To summarize very briefly, we corrected a range of technical errors introduced by the LDS in the course of data processing; corrected missing and incorrect geographic identifiers; identified missing cases and entered them; eliminated duplicate records; corrected flags distinguishing the breaks between households; identified and edited internal inconsistencies in family relationship, sex, marital status and age; and developed data dictionaries to classify cases according to standardized coding systems for geographic variables, group quarters type, place of birth and occupation.

Because of the large scale of the database, these tasks proved challenging. The 1880 database has fifty million cases, so even routine jobs require substantial investment of resources. For example, we entered several hundred thousand missing cases and coded over 500,000 alphabetic occupational strings into four separate classification systems. Through careful planning and extensive use of automated and semi-automated data editing tools, we have achieved unprecedented cost efficiencies in editing and coding the data. We are now on schedule to complete the project on time and within budget.[2]

The quality of the 1880 population database is good. Because the data were intended for genealogical purposes, the LDS placed a premium on transcription accuracy. LDS volunteers entered each of the fifty million cases twice so they could carry out blind verification. The technical corrections carried out by MPC have resulted in, for practical purposes, a complete transcription: in most instances, the county population totals in the database match the published statistics precisely and the population count for the country as a whole exceeds the published totals by less than 3,000 cases, or 0.006 per cent.[3]

In addition to the LDS data, the linking study will make use of census samples from the Integrated Public Use Microdata Series (IPUMS). The IPUMS is a harmonized series of U.S. census microdata samples spanning the period from 1850 to 2000. The samples range in density from one to five per cent of the population and for the period prior to 1940 they include names and addresses as well as the characteristics of each individual. Since its release in 1995, the IPUMS has attracted many users and has been used approximately 2,000 research papers and dissertations. We have coded the 1880 LDS data to be highly compatible with the IPUMS.

LINKED CENSUS SAMPLES

Perhaps the greatest limitation of the existing series of IPUMS samples is that they are cross-sectional snapshots and do not allow one to trace individuals

across time. Each sample is independent and cannot be linked to other samples to provide two observations for the same individual. It is possible, however, to link each of these samples to the new 1880 database. Using new record-linkage technology, we will construct linked samples covering pairs of census years: 1860–1880, 1870–1880, 1880–1900 and 1880–1910. Each of the linked samples will be independent, but taken together they will provide a rich longitudinal source for the nineteenth and early twentieth centuries.

The new database holds the promise of resolving some of the longest-running debates in American social history. Past studies were often inconclusive because of their exclusion of migrants and their small sample size. Scholars will be able to gauge the extent of social and geographic mobility, the interrelationship of geographic and economic movement and trends and differentials in social mobility more reliably than heretofore.[4] In addition, the linked samples will allow investigation of family formation and dissolution. For example, they will allow us to settle a debate about the formation of multigenerational households in the nineteenth century, an issue with important implications for the study of intergenerational relations and the twentieth-century transformation of the living arrangements of the aged.[5]

Historians have been linking individuals across censuses for decades, but the results have been problematic. In most cases, linked census studies have been based on local populations because no complete census for a larger area has been available. These studies generally lose between 60 and 80 per cent of the population each decade due to linkage failures.[6] The investigators attributed the high rate of linkage failure to the high migration of the mid-nineteenth century, which meant that individuals moved out of the study area.

There have been two national studies that linked individuals across census years. In 1987, NICHD funded an ambitious attempt by Thomas Pullum and Avery Guest to create a national linked 'panel' of two cohorts of men in the 1880 and 1900 censuses. Pullum and Guest linked 4,014 individuals between these two census years out of a sample of 10,252, for a linkage rate of 39.4 per cent.[7] More recently Joseph Ferrie, with funding from NSF, linked a nationally representative subset of the 1850 public use microdata sample to the 1860 manuscript census.[8] Ferrie limited his study to persons with uncommon surnames, but still achieved only a 19.3 per cent linkage rate for a total of 4,938 linked cases.

The availability of a high-quality census file including the entire 1880 population opens the door to far more sophisticated matching than has previously been possible. The Pullum/Guest and Ferrie samples had to rely on the state Soundex name indexes to locate individuals in the census. Interstate migrants were for the most part lost. The process was labour-intensive, expensive and involved large potential for human error and selection biases.

Using the new 1880 database in combination with recent advances in record-

matching technology, however, the entire country can be searched using such characteristics as age, sex, birthplace, birthplace of mother and birthplace of father, as well as name. The new database will be able to provide samples many times larger than the Pullum/Guest and the Ferrie studies. Just as important, however, we can design the new linked samples to minimize major problems of selection bias that were an inevitable concomitant of previous linking methods.

RECORD LINKAGE PROCEDURES

Overview

We will exploit new record-linkage and data-mining technology to create linked representative samples of individuals and family groups from the censuses of 1860, 1870, 1900 and 1910 to the 1880 census. These representative linked samples will provide unprecedented opportunities for researchers to carry out individual-level analyses of social and geographic mobility and family transitions in the early stages of industrial development.

For over half a century, social scientists have linked records from different sources to create longitudinal historical datasets.[9] During the past fifteen years, however, technological developments have opened new opportunities to create more powerful linked historical datasets than were previously possible.[10] This new technology derives from two main sources. First, central statistical agencies in North America and Europe have invested in the development of techniques for matching information from censuses, vital statistics and administrative records. Second, work on data-mining techniques – carried out by both academics and commercial software developers – has contributed to methods of data cleaning and probabilistic linkage

Our procedures will build on these innovations. Our goals, however, differ significantly from those of most recent researchers. The primary goal of virtually all the work on record linkage has been to maximize the number of valid links. A typical data-mining application, for example, would involve linking membership records to address lists to identify potential sales prospects. The goal of such an application is not to create a statistically valid representative sample, but simply to generate the largest possible number of customers. The most important linking application for statistical agencies is the estimation of undercount through the capture-recapture method, so they also aim for the largest possible number of reliable links.

We will not focus on maximizing the number of accurate links. Instead, our procedures will be designed to maximize the *representativeness* of the linked cases. This means that we must pay close attention to sources of selection bias and ignore much of the information routinely used by other record linkage procedures.

The principal applications of the samples will be the study of social mobility, migration, family change and life-course transitions. We therefore must avoid using any information that could bias the sample with respect to those changes in characteristics. For example, record linkage algorithms ordinarily make use of place of residence as a linking variable. This greatly increases the potential for reliable links: if we identify an individual in the 1870 sample who partially matches the name and other characteristics of a person in the 1880 database, our confidence that the two records refer to the same person would be improved if we knew that they both reside in Poughkeepsie. If we use place of current residence in the linking algorithm, however, we will inevitably bias the sample in favour of non-migrants. Likewise, if we use spouse's name in the algorithm we will bias the sample in favour of those who remain married and if we use occupation we will favour cases with low social mobility.

Planned samples

We plan three categories of linked samples, each with a different universe: all males, females who do not marry in the census interval and married couples. All three samples will be further restricted to the population old enough to have been alive in both census years. Although none of these groups is representative of the entire population, our goal is to make each category representative of its defined universe. The male individual sample will be general purpose, useful for studying economic and geographic mobility, transitions to adulthood, changes in family composition and retirement. The female sample will be useful for studying many of the same topics, but will apply to the subset of women who do not change their surname between censuses and therefore will be inappropriate for some topics. The married-couple samples will offer the greatest reliability, since it will allow us to link on characteristics of both husband and wife and will be especially useful for topics relating to fertility, child mortality and age of leaving home. Because it is restricted to the continuously married population, however, it will be less useful for population-wide generalizations about social and geographic mobility. Although we are linking individuals or couples, we will also capture all characteristics of all co-resident household members.

For each sample, we will start by identifying a subset of individuals in the IPUMS one-per cent samples (1860, 1870, 1900, or 1910). We will then search for these individuals in the complete 1880 census database. We will create three linked samples for each pair of census years, for a total of twelve samples. Half of the samples use forward links (1860 and 1870 to 1880) and half rely on backward links (1900 and 1910 to 1880). Forward-linked samples are more challenging than the backward-linked ones because mortality and emigration substantially reduce the potential for links. Moreover, the 1860 and 1870 censuses are missing two key linking variables, birthplace of mother and

birthplace of father. Nevertheless, we believe that the substantive importance of linked samples in the earlier period justifies linking in both directions. The 1870 census offers the earliest potential to trace the bulk of the black population and the geographic and occupational mobility of blacks after the Civil War is a subject of enormous historical interest and importance. Linking to the 1860 census, though restricted to the free population, will help us to gauge the demographic consequences of the war itself.

Backward linkage is simplified by the availability of retrospective information in the 1900 and 1910 censuses about year of immigration for the foreign-born population. Together with age, this question will allow us to define a universe that includes only persons who were alive and resident in the United States in 1880. Although this universe will be imperfect because of errors in enumeration and transcription, it will allow more aggressive linking strategies by reducing uncertainty. The 1900 and 1910 samples also include a richer set of census questions than any censuses before the mid-twentieth century, including retrospective inquiries about marriage, children born and surviving, immigration and naturalization, which will augment the longitudinal dimension of the linked samples.

Linking characteristics

Our algorithm will rely exclusively on characteristics that would not change over time if there were no enumerator errors, transcription errors, or name changes. The linking characteristics we plan to use for each census year are given in Table 1. For the married-couple samples, these characteristics are available for both husband and wife.

Genealogists and data miners make use of a considerably broader range of characteristics to confirm links and resolve ambiguities. We believe, however, that knowledge of any additional characteristics would introduce biases that would severely damage the samples. The chief problem posed by our approach is that this limited set of variables is insufficient to identify individuals uniquely.

Table 1. Variables available for record linkage, 1860–1910.

1860 to 1880	*1870 to 1880*	*1900–1910 to 1880*
First name	First name	First name
Last name	Last name	Last name
Birth year	Birth year	Birth year
Sex	Sex	Sex
Race	Race	Race
State or country of birth	State or country of birth	State or country of birth
	Father foreign-born	Father's state or country of birth
	Mother foreign-born	Mother's state or country of birth

For example, the 1880 census includes seventeen white men aged thirty-three who were named John Smith and born in New York State. This is, of course, a worst-case scenario, since John Smith was the most common male name and New York was the largest state. Nationally, we estimate that over three-fourths of the population can be uniquely identified by the limited variable set available in 1860. For the married-couple universe, virtually every case would be uniquely identified.

In practice, however, those numbers are optimistic. Because of errors in enumeration and transcription, a high proportion of matches are imperfect: linking must be carried out on a probabilistic basis, allowing for imperfect correspondence of names and ages. Allowing for such near matches, the proportion of uniquely identified individuals would decline significantly.

To reduce the potential for ambiguity, we will follow the precedent of Ferrie and eliminate names that identify multiple persons of the same age and birthplace.[11] Ferrie found that this procedure creates little bias with respect to ethnicity or other characteristics, but we will weight the remaining cases to eliminate any significant biases with respect to birthplace and parental birthplace, state of residence, or occupation.

Name cleaning and metaphones

Record linkage begins with software for parsing and standardizing names. Names are by far the most important piece of information available for record linkage, but they are the most problematic. Errors in naming can arise from respondent error (as when, for example, a farm wife responding to an enumerator misstates the name of a farm hand), enumerator error, or transcription error. Moreover, names often change over time, sometimes did not have standard spellings and in some cases people will be enumerated under a nickname or middle name in one census and under their formal first name in the other.

To minimize error from these sources, we plan a comprehensive program of name cleaning, accounting for common typographical transpositions, handwriting recognition errors and common nicknames. This work will draw on the rich body of research on name cleaning carried out during the past decade.[12]

We will also employ phonetic name coding, a standard tool for record linkage since the 1930s. The most commonly used systems are Soundex, NYSIIS and Phonex. All of these systems lose much of the phonetic detail, however. Although we have not yet finalized our phonetic coding plans, we prefer the more subtle Double-Metaphone system, which returns two encoded strings corresponding to variant pronunciations.[13]

Linking algorithm

Because there are multiple opportunities for errors to be introduced, it is essential that the linking algorithm accommodate approximate matches on a probabilistic basis. Planning and design of the linking algorithm is therefore a significant component of the project. The design must consider not only optimization of links, but also computational efficiency: some techniques are extraordinarily computationally intensive and would be unfeasible for a project of this scale.[14]

The theoretical framework of record linkage originates from Fellegi and Sunter, who demonstrated that it is possible to define an optimal linkage rule that minimizes the number of false links.[15] In addition, Fellegi and Sunter derived a test statistic for evaluating error rates and specified the assumptions necessary for estimating the matching probabilities used to calculate the test statistic. Extensions and refinements of record linkage theory were contributed by Jaro, Winkler, Belin and Rubin and Larson and Rubin.[16]

All these models assume that every pair of records drawn from two files are either matches referring to a single individual or non-matches describing two different persons; optimal matching requires that every individual be compared with every possible match. It is not computationally feasible to implement every potential match; for example, implementation of such a linking algorithm for the full 1880 database and the 1900 sample would involve over fifteen trillion comparisons. To reduce the computational requirements, we will introduce 'blocking factors' – such as state of birth, race and sex—and limit comparisons to persons who share the same blocking factors. If necessary, we will make an additional blocking pass based on metaphone. The computational problem will nevertheless be large and we will carefully explore various methods that have been proposed to improve efficiency.[17]

Our linking algorithm will depart from current practice in several respects. As noted, we will ignore information that can change over time for reasons other than misreporting, data-entry error, or deliberate name changes. The elimination of common names will reduce the number of multiple matches, but it will not eliminate them. Wherever there is no a clear favourite, we will drop the case. Some linking strategies make use of the relative frequencies of different linking variables.[18] Thus, for example, individuals with uncommon characteristics, such as persons aged ninety-five born in Delaware, receive a higher linking score than persons with common characteristics, such as five-year-olds born in New York, simply because of the differential probability of those characteristics occurring by chance. We will avoid this approach since it will introduce selection bias favouring persons with uncommon characteristics.

Because our linking strategy must rely heavily on names, identification of the optimal approximate string comparison algorithm is of paramount importance. Many algorithms have been proposed. For example, the Jaro string comparator

as modified by Winkler computes a similarity measure between 0.0 and 1.0 based on the number of common characters in two strings, the lengths of both strings and the number of transpositions, accounting for the increased probability of typographical errors towards the end of words.[19] Since developments in this field are proceeding rapidly, however, a superior algorithm may appear during the course of the project.

The other linking variables – birthplace, parental birthplaces, age, sex and race – pose few string comparison problems because those variables are already classified and numerically coded according to the IPUMS coding system. Thus, for example, we will not have to cope with the innumerable spelling variations of Massachusetts. We will, however, need to develop an algorithm for age misreporting that can account for digit preferences: inconsistencies in age between two census years should be partly discounted if age is rounded to a five or zero in one or both census years.

Whenever possible, we plan to build on open-source software for both data cleaning and record linkage. In particular, we are making extensive use of the 'Freely extensible biomedical record linkage' (Febrl) software created by Peter Christen and Tim Churches at the Australian National University.[20]

Training data

To estimate the matching parameters and error rate of the linking algorithm and to refine the linking strategy, we need a set of training data. Training data consist of cases where the true links are known. Ordinarily, training data are compiled by hand-coding a subset of cases and we will follow that procedure. In addition, however, we will capitalize on a very large set of training data we already have in hand: the one-per cent sample of the 1880 census created by the MPC.

We can divide the potential sources of failure in record linkage across census years into seven categories:

1. Departure from universe through death or emigration. (This applies only to the forward links, 1860 and 1870 to 1880.)
2. Name changes due to marriage, Anglicization, etc.
3. Enumerator error in recording names or other characteristics.
4. Census under-enumeration.
5. Multiple valid links: two or more persons exist with similar or identical linking characteristics.
6. Transcription error, either by MPC staff or by the LDS.
7. Omission of records from the LDS file.

Of these seven sources of linkage failure, the first four are only relevant for links across census years. The last three sources of error, however, also apply to links between the one-per cent 1880 sample produced by MPC in the early 1990s

and the complete 1880 database entered by the LDS. Since both files include locater information (microfilm reel number and census page number) it is straightforward to identify true links. Using only the variables that will be available for cross-census linking, we will be able to tune the algorithm to maximize accuracy for the 500,000 persons in the one-per cent file. We will then apply the algorithm to a much smaller set of hand-coded data from the other census years and make further adjustments needed to account for the other four sources of linkage failure.

Discussion

By deliberately ignoring much of the information available for linking in order to minimize selection bias, it is possible that our linked samples will include a higher percentage of false matches than do previous linked samples. This would bias the results through a different mechanism: true links are likely to have lower geographic and social mobility than would random pairs of individuals who are incorrectly linked. This means that although conventional linking procedures almost certainly understate geographic and social mobility, if our samples have a higher frequency of false matches they could actually *overstate* such mobility. We will take several steps to evaluate the potential for this problem and to minimize its impact.

We will have three main sources of information about false-positive matches. The first is the training data described above, including both hand-linked samples and the 1880 IPUMS sample. The second will be the cases rejected because of multiple competing matches. As described above, where there are multiple competing matches that all have a reasonable probability of being correct, we will not make any match. We will, however, evaluate such cases by examining additional characteristics and determine where possible which match is correct. Even though the corrected data will not be added to the linked samples, it provides an excellent source for the study of false matches. The third source of information about false links will be the married couple samples. We will carry out analyses of the married-couple linked samples to identify cases in which the extra information on spouses yields results that differ from what would be attained with individual links only.

Each of these three sources has technical limitations, but taken together they will provide a rich body of evidence on the success of our linking strategy and will allow us to develop estimates of unobserved error rates in the linked samples. Because these sources will allow direct comparison of transitions for false links and true links, they will help us understand the ways in which false-positive links bias the results. Moreover, information from rejected multiple matches, married-couple samples and training data will help us further tune the algorithm to specify thresholds for matches that minimize false positives.

We do not contend that our approach – using a minimal set of matching variables and a fully-automated algorithm – will result in perfectly unbiased samples; given the available information, that is probably impossible. We do expect, however, that the new samples will be far more representative of the population than are hand-linked samples that make use of all the information on the record.

ENDNOTES

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[2] We completed the work required by the LDS on schedule and they released the database on a set of fifty-five CD-ROMs and through an on-line lookup system (http://www.familysearch.org). We released a preliminary, partially coded version of the database to academic researchers in 2001 and a revised, coded, version in 2003.

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ABSTRACTS

Introduction: Longitudinal and cross-sectional historical data: intersections and opportunities
Lisa Dillon and Evan Roberts

Historians and other social scientists have become increasingly interested in the construction of historical, longitudinal datasets in the past decade. This special issue of *History and Computing* brings together eight articles from a recent workshop on methods, materials and results from historical, longitudinal data. We summarize the contribution of these articles, and connect their themes and results. In particular, we discuss the trade-offs between accuracy, representativeness and sample size in creating longitudinal databases from cross-sectional sources. Procedures for linking individuals across different data sources vary among the different projects in this issue, with implications for the analyses that can be performed. Another set of papers in this issue discuss the construction of longitudinal databases from explicitly longitudinal sources, such as population and event registries. Although these sources are longitudinal in their original design, like the cross-sectional data sources, differences in the social context of data collection affect the type of data that was collected. Despite these intrinsic research challenges, the analysis of historical, longitudinal databases have contributed important new findings in demographic and economic history, and will continue to do so.

State views and local views of population: linking and comparing genealogies and household registers in Liaoning, 1749–1909
Cameron Campbell and James Lee

To assess the consistency of recording in historical Chinese data, we compare the demography of the same families recorded in two separate sources: household

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registers and lineage genealogies. We find that these sources offer contradictory accounts. Reflecting differences between official and private constructions of kinship, individuals recorded in the household registers are often missing from the genealogies. We apply multivariate techniques to examine how the families that compiled genealogies differed from other families, and how the individuals recorded in genealogies differed from unrecorded members of the same family. We find that the families for which genealogies are available are highly selective in terms of their socioeconomic standing, and that there is additional selectivity in terms of which members were recorded. We also find that fertility estimates from genealogies may be biased upward, rather than downward, because genealogies are more likely to omit adults who have few or no offspring. We conclude by discussing the implications for interpretation of published findings from sources such as lineage genealogies and household registers that have been the mainstay of historical studies of Chinese kinship and demography.

Demography and environment in grassland settlement: using linked longitudinal and cross-sectional data to explore household and agricultural systems

Kenneth M. Sylvester, Susan Hautaniemi Leonard, Myron P. Gutmann and Geoff Cunfer

The Demography and Environment in Grassland Settlement project (DEGS) is a study of the relationship between population and environment in Kansas during its settlement and conversion from grassland to grain cultivation and rangeland. The research team involved in this project had as its goal to bring together data about farms and farm families in order to understand the core transformations in land use and family dynamics that took place during the process of settling and developing an agricultural landscape. Kansas is ideally suited for this study by virtue of its location, history, and the documents that exist about it. We are assembling a linked database of farm and family census records for twenty-five townships scattered across the state. This paper is about the process of choosing that sample, about the data we have accumulated, and about the process we are undertaking to link records about families and farms through time, and to attempt to find their locations in space. The paper also reports on the creation of a semi-automated linkage program in Java. The program allows users to view records in tabular form, one close to the original historical documents, and compare information across the agricultural and population censuses, and make decisions confirming or ignoring the suggested links displayed when employing the matching algorithms in the program. A table preserving linked persons and households, in the same year or over time, is then is stored separately in a relational database with a set of unique time-person identifiers.

Nineteenth-century Scottish demography from linked censuses and civil registers: a 'sets of related individuals' approach
Alice Reid, Ros Davies and Eilidh Garrett

This paper reports on a project to link nineteenth century Scottish civil registration and census records, broadening and extending linking techniques with a new emphasis on using sets of individuals related through families, households, and neighbourhoods to establish links. The project aims to do for Scotland what cannot yet be done for England: to link the comprehensive civil register records of births, deaths and marriages in an area with individuals in the census returns covering the same area to form a reconstitution-like data set. The resulting data set will be richer than reconstitution however, due to the additional information in the Scottish sources (for example, maiden name is routinely given for mothers in civil registers, and birth records also provide parents' place of marriage); censuses yield information relating to household size and structure and also provide decennial observations of those individuals who do not experience any demographic event in the inter-censal period. The paper illustrates the linkage technique in the case of the Island of Skye, and speculates on the prospects for it's successful application to urban communities such as the lowland town of Kilmarnock.

Building life course datasets from population registers by the Historical Sample of the Netherlands (HSN)
Kees Mandemakers

The Historical Sample of the Netherlands (HSN) compiles life course data for the nineteenth and twentieth century population. Most of the data for the construction of life courses are extracted from the population registers that allow us to trace persons from the cradle to the grave. In this article, we will present the way how the HSN reconstructs raw material from the Dutch population registers into output files that can be used by researchers. This process is comprised of several phases, of which the most important is linking all different appearances of the same persons across all entries, dating all individual arrivals and departures, reconstituting households and adding individuals to these households, dating all events related to individuals and households, and finally outputting the data in a new data structure, at the same time removing all redundant information. Discussion of the HSN software is situated in the context of the character and main sources of the HSN database, the population registers, and the variables that can be distilled out of them.

Longitudinal databases – sources for analyzing the life-course: characteristics, difficulties and possibilities
Pär Vikström, Sören Edvinsson and Anders Brändström

The Demographic Database at Umeå University has over the past thirty years constructed large longitudinal databases of the Swedish population from the eighteenth century, based on material in parish registers. The Demographic Database has developed into one of the world's most significant historical, longitudinal data sources. In this paper we discuss some of the advantages and problems of constructing longitudinal databases, and applying them in research. One of the principal problems in longitudinal data based on registers is the inconsistency of information available about individuals, either over time, or between different sources. A solution to this problem that the Demographic Database applies has been the conceptual distinction between source variables, and analysis variables derived from the source according to well-defined rules.

Reconciling cross-sectional and longitudinal measures of fertility, Quebec, 1890–1900
Patricia A. Thornton and Danielle Gauvreau

In the absence of vital registration, studies of the onset and early phases of the fertility transition in North America have been seriously hampered and yet the seemingly early timing of the decline, the multi-ethnic nature of the population and continuous flow of immigrants from Europe suggest that North America has much to offer to this debate. This paper is primarily methodological. By reconciling cross-sectional census measures of fertility using the own-child method (1901) with those derived from a longitudinal ten-year panel (1891–1901) using family reconstitution, for Montreal and surrounding region it exposes some of the weaknesses and the potentials of the two methods most often currently used and the advantages of combining methods. Own-children measures of marital fertility are seriously affected by significant local differences in infant survival between rural and urban areas and between cultural groups as well as by residual effects of duration and timing of marriage, while small-scale longitudinal studies in complex environments cannot always render reliable results for all sub-populations nor can they necessarily be 'scaled up'. They suggest that national and even regional averages of fertility may conceal large diversity, which in turn raises questions about the existence of any single transition with uniform characteristics and timing, or universal cause. Instead we argue different groups in different environments may actually have been fine-tuning their fertility behaviour to compensate for the differential effects of mortality through adjustments to both marriage and fertility within marriage.

Semi-automated record linkage with surname samples: a regional study of 'case law' linkage, Ontario, 1861–1871
Gordon Darroch

With rare exception, North America studies linking nominative historical records beyond single communities have relied on the U.S. census indexes. This paper reports an alternative, semi-automated approach to linkage developed for a large region of South-Central Ontario for censuses of 1861 and 1871. In principle, the procedure applies to any records groups. It combines unique surname samples with linkage procedures based computer sorting and manual matching of a limited number of largely time-invariant variables, but risks selection bias by further enlisting the records of other members of the dwellings of those traced. Labelled "case-law" linkage, final linkage judgements are based on specified rules supplemented by generalized case examples of their many possible permutations in practice. The approach trades off absolute consistency in linkage against saving the considerable costs of developing a fully automated solution for large, complex files. We examine implications of surname samples and selection bias in linkage. Comparisons of linked and baseline (1861) samples suggests quite predictable, but generally modest, differences. The linkage procedure tends to under-represent solitaries and the tiniest households, but multivariate analyses, using dwelling size in 1861 as a proxy for multiple records in the linkage, suggests that this selection bias is modest.

Challenges and opportunities for census record linkage in the French and English Canadian context
Lisa Dillon

This article addresses a new initiative at the Département de Démographie, Université de Montréal, to develop a historical demography research infrastructure which combines cross-sectional and longitudinal population microdata in an effort to better address demographic and family change during the nineteenth century. Here we discuss the record linkage procedures used in a project to link married couples and single persons from the 1 per cent sample of the 1871 Canadian census to the 100 per cent database of the 1881 Canadian census. Following an analysis of differences in the Canadian and U.S. historical populations, differences with implications for record linkage, the article discusses the treatment of Anglophone and Francophone names and describes the linkage criteria used to link persons from 1871 to 1881, beginning with married couples. Linked cases tended to be younger, were more likely to be non-migrants and were more likely to be farmers than the general population of married persons in 1871. To avoid some of the particular biases introduced by the automatic record linkage procedure, it will be necessary to use the automatically-linked cases in conjunction with the manually-linked cases.

Linking historical censuses: a new approach
Steven Ruggles

This paper describes the Minnesota Population Center's ongoing project to create samples of individuals and families linked from samples of the 1860–1870 and 1900–1930 censuses to a complete-count dataset of the 1880 American census. Because of the large populations to be linked, the MPC samples will prioritize creating representative samples rather than maximising the number of linked individuals. This approach differs from several other linking projects, and offers some advantages for researchers.