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Proportional Weighting Algorithm for Single-Race Population Estimation Using Multiracial Census Data

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Abstract

A new proportional weighting algorithm is proposed to bridge multiple-race counts to single-race estimates based on 2010 Decennial Census data. The proposed weighting method is based on Census data alone with traceable procedure and reproducible results. It enables researchers to estimate population size of any race category of interest at any level of granularity stratified by other demographic information available in the Census data. If researchers have specific criteria or priorities for classifying certain races, the proposed algorithm can be easily modified to meet their specific needs. The new algorithm provides an intuitive and straightforward alternative for determining single-race population estimates. As an illustration of this approach, we provide the population estimates of the five most populous ethnic groups in Hawaii using the 2010 Census data.

Keywords

Bridging, census, multiple-race, population estimate, single-race

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Introduction

To reflect the increasing diversity of mixed races in American society, the Office of Management and Budget (OMB) changed race and ethnic standards in 1997 for federal data collection of multiracial information (Office of Management and Budget 1997). Census 2000 implemented this new standard by allowing multiracial responses for race/ethnicity classifications. However, this change has created some confusion and difficulty for researchers and policymakers using the multiracial data. For instance, many researchers need to utilize a single-race population size and other data for a single-race. The multiple-race data poses a question on how to estimate mutually exclusive single-race population counts as denominators for such calculations (Durch and Madans 2001; Ventura et al. 2003). In order to bridge the gap between single-race and multiple-race data, the OMB proposed six "bridging" methods to assign multiple-race responders to single-race categories in its provisional guidance (Office of Management and Budget 2000). These "bridging" methods fall into two broad categories: 1) whole allocation methods, which assign multiple-race responses into one of the single-race groups; and 2) fractional allocation methods, which assign multiple-race responses partially into those single-race groups.

The whole allocation methods include three approaches of which the "smallest group" approach assigns individuals with multiple-race responses to the race category with the smallest single-race count, other than the White race category. The "largest group other than White" approach assigns individuals with multiple-race responses to the race category with the largest single-race count, other than White race category. The "largest group" approach assigns individuals with multiple-race responses to the race category with the largest single-race count. The simplest fractional allocation method is the "equal fractions" approach, which assigns individuals with multiple-race responses in equal fractions to each single-race category identified. Two other fractional bridging approaches ("plurality" and "NHIS fractions") use information from the National Health Interview Survey (NHIS) data, an annual household survey conducted by the National Center for Health Statistics (NCHS). NHIS respondents were asked to provide multiple-race information and, as a follow-up question, to identify a single-race group that best represents themselves. Based on the NHIS race information, the "plurality" bridging approach assigns all multiple-race responses to the race group with the highest proportion of responses for the follow-up race question; whereas the "NHIS fractions" approach assigns each multiple-race response fractionally into the single-races identified according to the proportions of races reported in the follow-up race question.

Others have developed more complicated estimation methods (e.g., regression models) (Schenker and Parker 2003; Liebler and Halpern-Manners 2008). Utilizing NHIS data, Schenker and Parker (2003) used logistic regression models to improve the single-race estimation by considering other demographic information, such as age, gender and Hispanic origin. Based on this NHIS regression method, NCHS provides bridging estimates for four major ethnic groups (Asian or Pacific Islander, Black or African American, American Indian or Alaska Native, and White) for all the single-year and five-year age group and gender combinations at each geographic location (National, State, and County) (Ingram et al. 2003). Liebler and Halpern-Manners modified this NHIS regression approach and applied it to public-use microdata using limited geographic information (Liebler and Halpern-Manners 2008). However, the single-race estimates varied depending on which bridging methods were used. Based on different estimates, health disparities research could result in a variety of conclusions (Grieco 2002; Heck et al. 2003; Parker and Makuc 2002). According to Grieco (2002), the proportion of the population reporting multiple-race is the most important determinant of the variability in the bridging estimates of a single-race. This suggests that the single-race bridging estimation for states/regions with a large multiple-race population, such as Hawaii, could be challenging. Even though the NHIS regression method utilized a large nationwide NCHS survey of approximately 35,000 households containing about 87,500 persons per year, the NHIS sample is still too small to provide accurate state level data, especially for states like Hawaii, which have large and diverse multi-racial groups. Furthermore, NCHS provides bridging estimates for only four races (Centers for Disease Control and Prevention 2015), which limits its utility given that researchers may require race estimates for other ethnic groups.

To meet the need of bridging single-race population estimation for any specific race, especially in large multiracial populations, we propose a proportional weighting algorithm to derive single-race population estimates based only on multiple-race Census data. Population counts for any Census race categories of interest can be estimated using this approach without any external information (e.g., the NHIS survey), and the approach is easy for any user to implement with traceable steps, and the results are easily reproducible. The proposed method can be applied at any level of granularity stratified by other available demographic information included in the Census (e.g., age, gender). Furthermore, the algorithm can be modified to incorporate any specific criteria for single-race determination as defined by the users. We illustrate the utility of the proportional weighting algorithm by estimating the five major ethnic groups in Hawaii (Chinese, Filipino, Japanese, Native Hawaiian, and White) using Hawaii 2010 Census data.

Methods

The 2010 Census included six major race categories: "White", "Black or African American" (BAA), "American Indian or Alaska Native" (AIAN), "Asian", "Native Hawaiian or Other Pacific Islander" (NHOPI), and "Some Other Race" (SOR) (Jones and Bullock 2012). Each of these categories contained multiple Census detailed races. For example, Chinese, Japanese, and Filipino are all detailed races under the race category "Asian". In this section, we introduce the estimation algorithm based on "Race Category" level information only, and then extend it to the estimation that may also include "Detailed Race" level data.

I. "Race Category" level estimation

We denoted the "Race Category" as $x,$ where $x \in \mathrm{C} =${"White", "BAA", "AIAN", "Asian", "NHOPI", "SOR"}.

I.a. "Alone" and "Alone or in any combination"

For "Race Category" level, Census reported two race counts, "Alone" and "Alone or in any combination" (we denote this as "Any"). The "Alone" count reflects the number of individuals who consider themselves belonging only to one specific race. On the other hand, the "Any" count includes the number of people who identify themselves with a specific race, irrespective of whether they also identify with any other races. For "Race Category" data, we denote the "Alone" category count by T_x^1, and the "Any" category count as T_x^{1+}, where $x \in${"White", "BAA", "AIAN", "Asian", "NHOPI", "SOR"}. We further denote $T_x^{2+} = T_x^{1+} - T_x^1$ as the count of individuals who are mixed for at least two races, including x.

I.b. Census data transformation

Once the desired study races are identified, the Census population counts, both “Alone” and “Any”, of each race of interest can be downloaded via American FactFinder website (American FactFinder 2015). For a specific study, the researcher will need to obtain both “Any” and “Alone” population counts for all the “Race Categories”. The population counts for two or more mixed races can then be calculated by subtracting “Alone” count from that of the “Any” count for all “Race Categories”. For example, the two or more mixed races, including Asian (T_{Asian}^{2+}), would be calculated by subtracting T_{Asian}^{1} from T_{Asian}^{1+}. In addition, for a specific study, one can derive the overall count of unique individuals with two or more mixed races, M, as $M = N - \{\sum_{x \in C} T_x^1\}$, where N is the total Census count (i.e., *N*=1,360,301 for Hawaii for the 2010 Decennial US Census) and C ={“White”, “BAA”, “AIAN”, “Asian”, “NHOPI”, “SOR”}.

I.c. Proportional weighting

For all the multiple-race individuals, we can calculate the sum of two or more mixed population counts for each “Race Category” in *C* as $\sum_{x \in C} T_x^{2+}$, where $x \in C$. Since those individuals that identified with two or more races were included in more than one race group in the Census counts, $\sum_{x \in C} T_x^{2+}$ will be greater than M (i.e., the overall Census count of unique multiple-race individuals).

To estimate the population count of a single-race of study interest, M would need to be allocated into each race using the following proportional weighting algorithm:

For “Race Category” x,

$$T_x = T_x^1 + M(T_x^{2+}/(\textstyle\sum_{x \in C} T_x^{2+})) \qquad (1)$$

II. “Race Category” and “Detailed Race” level estimation

We denoted the “Detailed Races” that were contained in “Race Category” x by adding an index i , i.e., x_i, $i = 1, \cdots, K_x$, where K_x is the number of “Detailed Races”. For example, for the “Detailed Races” Chinese, Japanese, and Filipino under “Race Category” Asian, we denoted them as Asian_Chinese, Asian_Japanese, and Asian_Filipino. For a study that involves races belonging to both Census “Race Category” and “Detailed Race”, we denote *D* as the subset of “Race Categories” that contains any “Detailed Races” of study interest. We denote *C* as the subset of all the rest of “Race Categories” which are not included in *D*. By way of example, a health disparities researcher might be interested in studying the differences of hospitalization rates among the five major ethnic groups in Hawaii, i.e., Chinese, Filipino, Japanese, Native Hawaiian, and White. White is a “Race Category”, while Chinese, Japanese, and Filipino are all “Detailed Races” under Race Category “Asian”, and Native Hawaiian is a “Detailed Race” under Race Category “NHOPI”.

As a result, we have *D*={“Asian”, “NHOPI”} and *C*={“White”, “BAA”, “AIAN”, “SOR”}.

II.a. “Alone” and “Alone or in any combination”

As we defined the “Any” and “Alone” at the “Race Category” level, similarly we can define the “Any” and “Alone” at the “Detailed Race” level data, x_i, as $T_{x\_i}^{1+}$ and $T_{x\_i}^{1}$, and the count of individuals who are mixed at the “Detailed Race” level as $T_{x\_i}^{2+} = T_{x\_i}^{1+} - T_{x\_i}^{1}$.

For example, the Census "Alone" count for Chinese, a "Detailed Race" under "Asian", will be denoted as $T^{1}_{Asian\_Chinese}$, reflecting the count of individuals who have identified themselves as Chinese only. Whereas for someone who is both Chinese and Native Hawaiian, they would be included in both the Chinese "Any" count (denoted as $T^{1+}_{Asian\_Chinese}$) and the Natives Hawaiian "Any" count ($T^{1+}_{NHOPI\_NH}$). In fact, for someone who is classified as Race Category "Asian Alone", they could still, in effect, be multiracial. For example, an individual who is Chinese and Japanese will be listed as "Asian Alone" in the Census report with both Chinese and Japanese being "Detailed Races" within the Race Category "Asian". Besides being included in the count of Asian "Alone", they will also be included in the Chinese "Any" and Japanese "Any" counts, i.e., $T^{1+}_{Asian\_Chinese}$ and $T^{1+}_{Asian\_Japanese}$, respectively.

II.b. Census data transformation

For a specific study, the researcher will need to obtain both "Any" and "Alone" population counts for all the "Detailed Race" in *D* and for all the "Race Categories" in *C*. The population counts for two or more mixed races can then be calculated by subtracting the "Alone" count from that of the "Any" count for all "Race Categories" in *C* and for all "Detailed Race" in *D*. For example, the two or more mixed races including Chinese ($T^{2+}_{Asian\_Chinese}$) would be calculated by subtracting $T^{1}_{Asian\_Chinese}$ from $T^{1+}_{Asian\_Chinese}$. In addition, for a specific study, one can derive the overall count of unique individuals with two or more mixed races, M, as $M = N - \left\{\sum_{x\in C} T^{1}_{x} + \sum_{x\in D}\sum_{i=1}^{K_x} T^{1}_{x\_i}\right\}$, where N is the total Census count (i.e., *N*=1,360,301 for Hawaii for the 2010 Decennial US Census).

II.c. Proportional weighting

For all the multiple-race individuals, we can calculate the sum of two or more mixed population counts for each "Race Category" in *C* as $\sum_{x\in C} T^{2+}_{x}$, where $x \in C$, and the sum of two or more mixed population counts for all the "Detailed Races" in *D* as $\sum_{x\in D}\sum_{i=1}^{K_x} T^{2+}_{x\_i}$, where $x \in D$ and $i = 1,\cdots,K_x$. Since those individuals identified with two or more races were included in more than one race group in the Census counts, $\sum_{x\in C} T^{2+}_{x} + \sum_{x\in D}\sum_{i=1}^{K_x} T^{2+}_{x\_i}$ will be greater than M, the overall Census count of unique multiple-race individuals.

To estimate the population count of a single-race of study interest, M would need to be allocated into each race using the following proportional weighting algorithm:

For "Race Category" x,

$$T_x = T^{1}_{x} + M(T^{2+}_{x}/(\textstyle\sum_{x\in C} T^{2+}_{x} + \sum_{x\in D}\sum_{i=1}^{K_x} T^{2+}_{x\_i})) \qquad (2)$$

and for "Detailed Race" x_i,

$$T_{x\_i} = T^{1}_{x\_i} + M(T^{2+}_{x\_i}/(\textstyle\sum_{x\in C} T^{2+}_{x} + \sum_{x\in D}\sum_{i=1}^{K_x} T^{2+}_{x\_i})) \qquad (3)$$

The above weighting procedure allocates the overall count of all multiple-race individuals of interest, M, uniquely into the separate races based on their proportions in the aggregated mixed count, i.e., $\sum_{x\in C} T^{2+}_{x} + \sum_{x\in D}\sum_{i=1}^{K_x} T^{2+}_{x\_i}$. Figure 1 (see Annex 1 to the present document) illustrates the process for proportional weighting algorithm to estimate single-race count from mixed race Census data. This method can be applied at any desired level of granularity stratified by other demographic information included in the Census (e.g., age, gender).

III. Modified weighting

A researcher can modify the proportional weighting algorithm if the population estimate of a specific race is constrained by other conditions and/or requirements. For example, the State of Hawaii utilizes the Vital Statistics Race-Ethnicity Methodology for the Native Hawaiian population, which classifies individuals as "Native Hawaiian" if Native Hawaiian is one of multiple ethnicities identified by the individual (Hawaii Health Data Warehouse 2011). Therefore, to fulfill this methodological requirement in Hawaii, one should use the Native Hawaiian "Any" count ($T^{1+}_{NHOPI\_NH}$) as the population estimate for Native Hawaiians. For other similar requirements, the proposed proportional weighting algorithm can be easily adapted to obtain the estimates for other races by first excluding any pre-assigned race(s) (e.g., Native Hawaiian in the above example) from C or D, and the related counts from the above calculations, such as T^1, T^{1+}, T^{2+}, N and M.

Results

The Decennial Census includes detailed race information. As an illustration of the proposed proportional weighting algorithm, we focused on single race population estimation for the diverse multiracial State of Hawaii. In Hawaii, the five most populous races are Chinese, Filipino, Japanese, Native Hawaiian and White. Population estimates for Chinese, Filipino, Japanese, Native Hawaiian and White in 2010 US Census were derived using the equal fractional algorithm, our proposed proportional weighting algorithm and a modified weighting approach, incorporating the unique classification of Native Hawaiian in the State of Hawaii (see Table 1 in Annex 1 to the present document). The equal fractional algorithm assigned a population of 64,416 for each race. White race category had the largest population estimate in Hawaii (n=401,015), followed by Filipino (n=261,913), Japanese (n=249,918), Native Hawaiian (n=144,753), and Chinese (n=119,937). For proportional weighting algorithm, White race category still had the largest population estimate in Hawaii (n=422,381), followed by Filipino (n=251,265), Japanese (n=232,834), Native Hawaiian (n=159,705), and Chinese (n=109,785). Since Native Hawaiian was the second highest population estimate among the two or more mixed race counts, the allocated number of individuals from the proportional weighting algorithm was also the second highest (n=79,368). With the modified weighting approach, Native Hawaiian showed the second highest population estimate (n=289,970) since any individual who identified themselves as part Native Hawaiian was assigned to the Native Hawaiian group as described in the Vital Statistics Race-Ethnicity Methodology for Hawaii. The proportional weighting algorithm was then applied to Chinese, Filipino, Japanese, and White races, with White still having the highest population estimate (n=384,222).

Discussion

OMB changed race and ethnic standards to collect multiracial data in 1997. However, this change resulted in an issue where the new Census multiple-race data is not directly comparable with race data from the previous single-race Census data. To resolve the issue, OMB proposed several "bridging" methods to assign multiracial individuals to single-race categories in 2000, but the single-race estimates varied among the different bridging methods, which potentially result in different conclusions for research studies based on the single-race population estimates. Furthermore, the "bridging" methods may not be easily traceable and can only be applied to specific race categories, which limits their usability.

For states with a very small proportion of mixed race individuals, the population estimates may not be significantly affected. However, the population estimates pose an issue for states with large proportions of individuals of mixed races, such as Hawaii and California. For example, the State of Hawaii is the most multiracial state in the US, where 23.6% of the Hawaii population reported two or more races in the 2010 decennial Census (Jones and Bullock 2012), while less than 3% of the US population self-identifies as two or more races. Similar issues can exist for some smaller geographic regions with a relatively high proportion of mixed race individuals. For example, in the city of Honolulu, HI, 16.3% of its population identified with two or more races, followed by Fairfield, CA (8.8%), Anchorage, AK (8.1%) and Tacoma, WA (8.1%). A researcher comparing different racial populations needs to understand that the race definitions could be different locally, especially in a multiracial setting.

We propose a non-equal fractional allocation approach – the proportional weighting algorithm – to estimate single-race population size based on multiple-race US Census data. The proportional weighting is based on the count of mixed races, including the specific race of interest and the total count of all mixed-race individuals. This approach is easily traceable, and the results are reproducible. Furthermore, this proposed method can be customized to fit a specific state/region or minority population and can be applied at any desired level of granularity stratified by other available demographic information (e.g., age, gender, county) included in the Census. This algorithm also enables researchers to estimate the population of any Decennial Census race of interest. If researchers and/or policymakers have any specific racial definition criteria or requirements for a race group, these can easily be incorporated by modifying the algorithm.

Many governmental agencies set up funding priorities by allocating resources based on single race composition of the population, e.g., NIH minority health research funding, Minority Business Development Agency grants and loans program. Different single race estimation approaches could have a direct and significant impact on the establishment of such policies. Unfortunately, the assessment and comparison of the bridging methods is not straightforward as there is no gold standard available. While the equal fractional algorithm assigned equal population numbers for each race of interest, our proposed algorithm has proportional allocation based on the proportion of two or more mixed populations among the races of interest. If a local area has unequal race proportions with a large mixed-race population, the equal fractional allocation approach could significantly underestimate a single race, compared with the proportional weighting approach. Intuitively, if we were to assign a mixed-race population into populations of single races, the single race that had the highest proportion in the total population should acquire more individuals than any other single races. In Hawaii, as White had the most multiracial proportion, a total of 21,366 more individuals would be assigned to White than the equal fractional result, and 14,952 additional individuals would be assigned to Native Hawaiian. These differences are not ignorable and become an issue for bridging to single race as America becomes more racially diverse and interracial marriages continue to increase.

The proposed proportional weighting algorithm has several limitations. First, the approach is based on assumption of proportionality in assigning individuals of mixed races into single races. As a result, the higher proportion of mixed-race individuals sharing a particular race will result in more mixed-race individuals allocated to that race and will clearly increase the final single-race estimation of that specific race. Even though this proportionality is plausible in theory, the reality might be more complicated, and a mixed-race individual may or may not identify with a particular race. Therefore, the final single-race estimates based on the proportional assumption may not reflect the estimates based on a self-reported single-race determination approach. For example, if we report Native Hawaiians as any individual with any Native Hawaiian blood in their family, then the Native Hawaiian estimates by proportional weighting could result in underestimating the Native Hawaiian population, as compared with the population estimates based on the Vital Statistics Race-Ethnicity Methodology used in Hawaii. Since NHIS survey includes a questionnaire about the single-race identification, the bridging approaches utilizing the NHIS sample could be more realistic, but it is questionable whether the NHIS sample is large enough to provide state level data with acceptable precision, especially for states with a large proportion of multiple-race individuals. For example, to estimate a race population size that is about 5% of the total population size, 7,498 individuals of that race group in the NHIS survey are required to achieve a precision level of 1% margin-of-error of the estimates, at a 95% level of confidence. Second, the proposed approach will not be able to provide race count estimates of all the detailed race combinations. Even though data on 57 race combinations based on the six major Census Race Categories were reported in the 2010 Census redistricting data (Public law 94-171), more refined race information involving any detailed races could still be difficult to obtain. For most racial groups in most states of the US, this limitation may not be as critical. Third, the algorithm has limited utility in providing annual estimates of mixed race populations, especially involving Census detailed races. US Census collects data decennially and estimates the population annually, incorporating births, deaths, and migration. However, the changes in the counts of "Alone" and "Any" for detailed races are not tracked annually. As a result, the proposed proportional weighting approach cannot be used to update the annual estimates of the bridged race populations.

Different bridging methods could result in different population estimates for races. Since population estimates depend on the true definition of each race of interest, identifying the best bridging method would be difficult. To better quantify single-race information out of multiple-race data, future Censuses could consider implementing additional questions to allow mixed-race individuals to identify with a single race. The resulting race counts could provide a gold standard in US population studies without the need of using bridging methods or relying on other data, such as the NHIS survey. However, under the current circumstances, selecting a bridging method is still very important for population studies, especially for states with a large proportion of mixed races. The proposed proportional weighting algorithm provides an easy and straightforward alternative for determining single-race population estimates. For future study, NHIS survey can be utilized as a supplementary tool that can incorporate with the proportional weighting method if details on mixed races and bridging to single races are revealed. To overcome the sample size issue from NHIS survey data, the aggregates of information from multiple years should be explored.

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Annex 1

Table 1. Population estimates based on equal fractional and proportional weighting algorithms using Hawaii 2010 Census data

Race of interest	Census Race Category or Detailed Race			Equal Fractional Estimates		Proportional Weighting Estimates		Modified Weighting Estimates*	
	"Any" (T^{1+})	"Alone" (T^{1})	Two or more mixed (T^{2+})	"Allocated"	"Alone" + "Allocated" (T)	"Allocated"	"Alone" + "Allocated" (T)	"Allocated"	"Alone" + "Allocated" (T)
Chinese	199,751	54,955	144,796	64,416	119,371	54,830	109,785	30,472	85,427
Filipino	342,095	197,497	144,598	64,416	261,913	54,768	251,265	29,733	227,230
Japanese	312,292	185,502	126,790	64,416	249,918	47,332	232,834	26,221	211,723
Native Hawaiian	289,970	80,337	209,633	64,416	144,753	79,368	159,705	**209,633**	**289,970**
White	564,323	336,599	227,724	64,416	401,015	85,782	422,381	47,623	384,222

"Any" (T^{1+}): total population count including a specific race

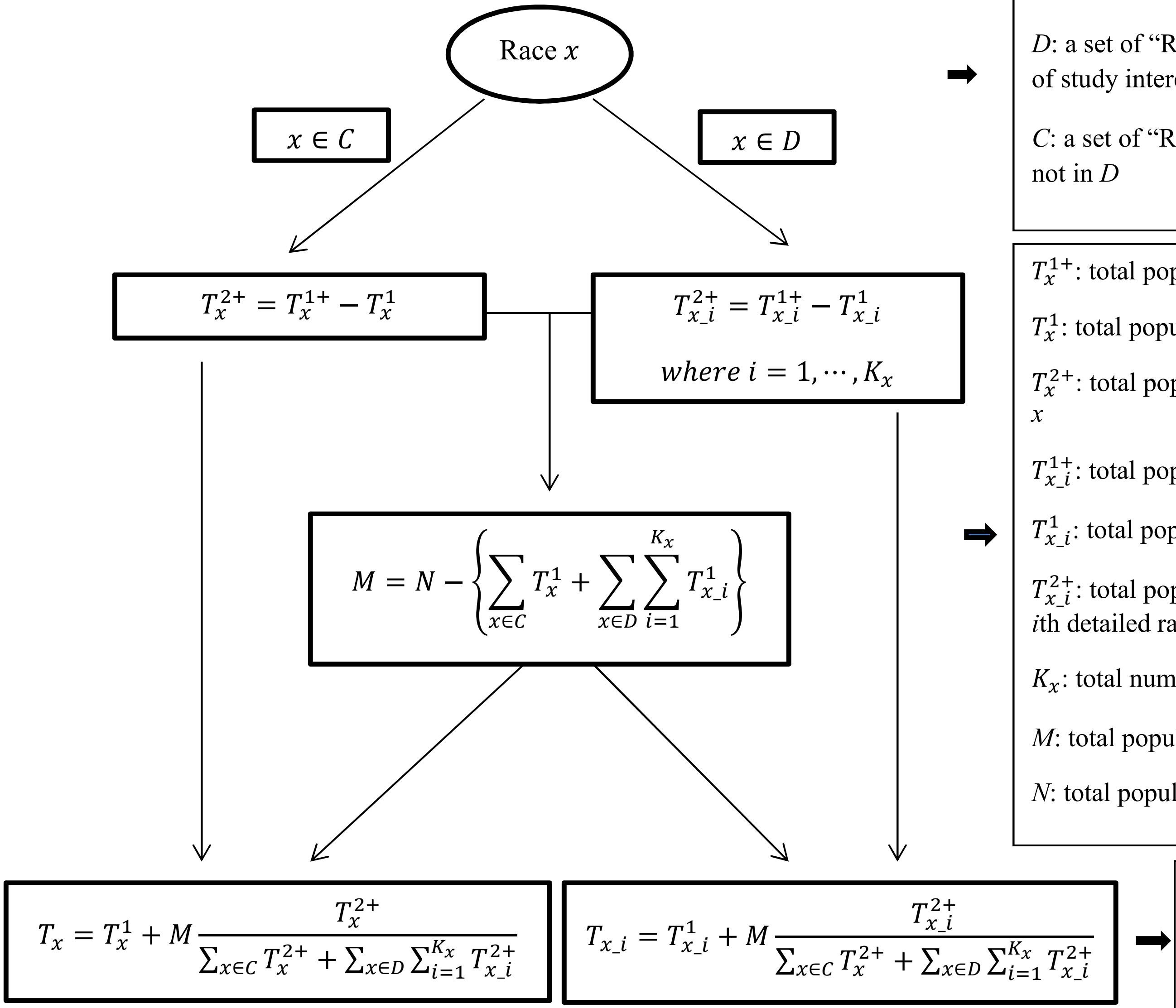
"Alone" (T^{1}): total population count for a race alone

Two or more mixed (T^{2+}): total population count for two or more mixed race for a race

"Allocated": the number of all unique mixed racial individuals of interest, allocated into individual race according to its proportion of the aggregated mixed count

*"Native Hawaiian" includes "Part-Hawaiian" based on Hawaii Vital Statistics Race-Ethnicity Methodology.

Figure 1. Process for proportional weighting algorithm to estimate single-race count from mixed race Census data



x: race *x* of study interest

D: a set of "Race Categories" having any "Detailed Races" of study interest

C: a set of "Race Categories" out of six "Race Categories" not in *D*

T_x^{1+}: total population count including *x*

T_x^{1}: total population count for *x* alone

T_x^{2+}: total population count for two or more mixed race for *x*

$T_{x\_i}^{1+}$: total population count including ith detailed race in *x*

$T_{x\_i}^{1}$: total population count for ith detailed race alone in *x*

$T_{x\_i}^{2+}$: total population count for two or more mixed race for *i*th detailed race in *x*

K_x: total number of detailed races in *x*

M: total population count for two or more mixed races

N: total population count

T_x: population estimates for *x* by proportional weighting

T_{x_i}: population estimates for *i*th detailed race in *x* by proportional weighting