Phonetic Matching: A Better Soundex

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Introduction

Researchers are often confronted with the problem of searching for a name in a large imprecise database. The names in the database might be misspelled, or they might not be spelled the way the researcher expected. In either case, looking for an exact match will often result in not finding the name being sought.

Over the years, designers have struggled to develop search applications to cope with this problem. They typically provide an option for finding approximate rather than exact matches. So some criteria needs to be established whereby two names can be said to be approximate matches.

One solution is to say that two names are approximate matches if they sound the same. And a method known as soundex was developed to determine if two names sound alike. A brief history of soundex is given in the next section.

A problem with most soundex-based systems is that they find too many approximate matches, most of which are so far off from the name being sought that they are obviously not useful hits. What is needed is some way to reduce the number of approximate matches by removing the irrelevant ones, while being careful not to inadvertently remove any relevant ones in the process. That is the goal of phonetic matching, and this paper describes how it works and how well it achieves its goal.

The work on phonetic matching was developed jointly by Alexander Beider and Stephen Morse. To simplify the narrative (especially in the case study), this paper is written in the first-person singular as if there were only one author.

The name of the phonetic matching system presented here is *Beider-Morse Phonetic Matching*, sometimes referred to as BMPM. In this paper it will be referred to as just Phonetic Matching, with the leading letters being in upper case.

Soundex

Soundex is a system whereby values are assigned to names in such a manner that similar-sounding names get the same value. These values are known as soundex encodings. A search application based on soundex will not search for a name directly but rather will search for the soundex encoding. By doing so, it will obtain all names that sound like the name being sought.

Russell Soundex – 1918

The first soundex system was developed and patented by Robert Russell in 1918. Its encodings are generated by assigning digits to individual letters in the name, and using the same digit for closely-related letters (e.g., m and n). Once the sequence of digits reaches a certain length, no additional letters in the name are examined. This restricts the name-matching to only the initial portion of the name.

American Soundex – 1930

In 1930 Russell's algorithm was modified slightly and used by the Census Bureau to facilitate name searches in the census. This modification became known as *American Soundex*.

Daitch-Mokotoff Soundex – 1985

The next major enhancement to soundex didn't occur until half a century later when Randy Daitch and Gary Mokotoff announced their *Daitch-Mokotoff Soundex* system. This is a soundex system optimized for Eastern European names. Unlike its predecessors, it sometimes considers sequences of letters, rather than just single letters, in order to determine how the name might be pronounced. Another improvement is that it sometimes produces more than one encoding for a name, and it considers a match if any of the encodings associated with the name being sought matches any of the encodings associated with a name in the database.

Metaphone – 1990

In 1990 Lawrence Phillips published an article describing a more advanced soundex system that he called *Metaphone*. Metaphone attempts to produce its encoding based on how a name is pronounced rather than how it is spelled. But it is based on English pronunciation only. Like Daitch-Mokotoff, it too uses sequences of letters rather than just single letters. And unlike all its predecessors, it bases its encodings on the entire name rather than truncating after considering only some initial portion of the name. It didn't follow Daitch-Mokotoff's lead of allowing a name to have more than one encoding, but instead generates a single encoding for each name as was done in the earlier systems.

Double Metaphone – 2000

Rather than resting on his laurels, Phillips published yet another metaphone article, this one he called *Double Metaphone*. The name comes from the fact that it produces two encodings for each name. So it doesn't have the robustness of Daitch-Mokotoff which can have many encodings, but it is certainly more robust than the earlier systems that have only one encoding per name. Another new feature of double metaphone is that it includes foreign pronunciations, but it lumps all the foreign rules together and doesn't

distinguish which rule corresponds to which language. And Phillips dropped one of the improvements of his earlier Metaphone – namely the encoding is again restricted to the initial part of the name.

Beider-Morse Phonetic Matching – 2008

The *Beider-Morse* system, described in this paper, attempts to solve a problem inherent in all inexact matching systems to date. Namely the number of matches found is often extremely large and consists of many names that could not be considered relevant by any stretch of the imagination. The Beider-Morse system reduces the number of irrelevant matches by first determining the language from the spelling of the name, and then applying pronunciation rules based on that specific language. It considers the entire name rather than just some initial portion of it. And it provides for multiple encodings.

Irrelevant matches are sometimes referred to as false positives. The next section defines these terms and gives an example.

True and False Positives and Negatives

Consider a database that consists of the following names:

Stefan
Steph
Stephen
Steve
Steven
Stove
Stuffin

Suppose that we want to search for the name Stephen using some method that will yield precise as well as imprecise matches. Just how imprecise a match we get will depend on the particular method used.

The matches that the search finds are called the *positives*, and those names that it rejects are called the *negatives*. Those positives that are relevant are called *true positives*, and the others are *false positives*. Whether a match is relevant or not is of course up for debate – it is a judgment call and very subjective. And it has to be subjective – if it were otherwise we could have formal rules for determining relevant matches and the search program could return only those matches that are relevant.

As an example, let us assume that the matches found when searching for Stephen in the above database are:

Stefan
Stephen

Steven
Stuffin

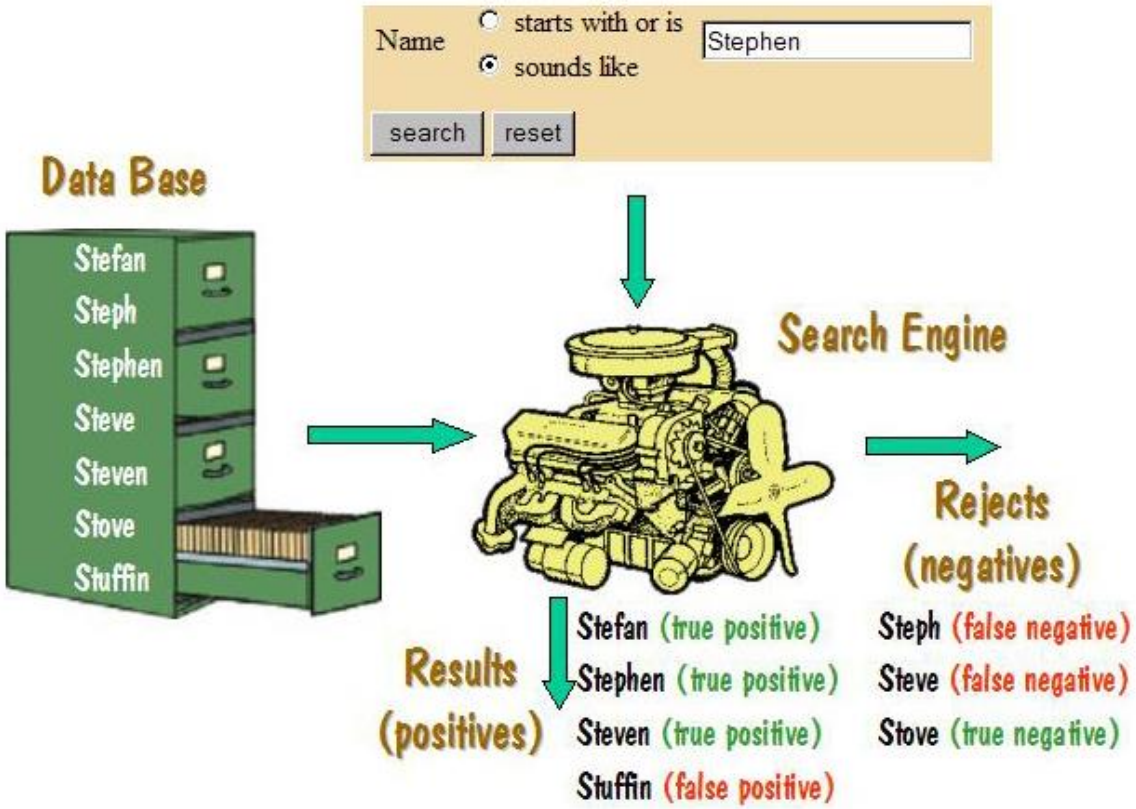
The first three are probably relevant, and are names that we would have wanted to see. So these are the true positives. Stuffin, however, is probably not relevant – it is a false positive.

The names that were rejected are:

Steph
Steve
Stove

Of those, Stove is probably not one that we would have wanted. So it is a *true negative*. But Steph and Steve are ones that we would probably be interested in. They are *false negatives*.

This is illustrated in the following diagram.



Example 1: Washington in the Ellis Island Database

As an example, let's search for Washington in the Ellis Island database (list of 25 million people who came through Ellis Island from 1892 to 1924). Of course George Washington didn't come in through Ellis Island, But many other Washingtons did, so it is a good example to study.

If we search for Washington using American soundex, we get over 3,900 unique names. These include names like Wacknocty, Wegonge, and Wozniak. Clearly those are false positives. And, in fact, all but two of the 3,900 names are false positives – the two true positives being Washington and Washincton.

A search using Daitch-Mokotoff soundex gives nine names, six of them being false positives. The true positives include the two found by American soundex, and also includes the name Vasington, Vasington was a false negative under American soundex.

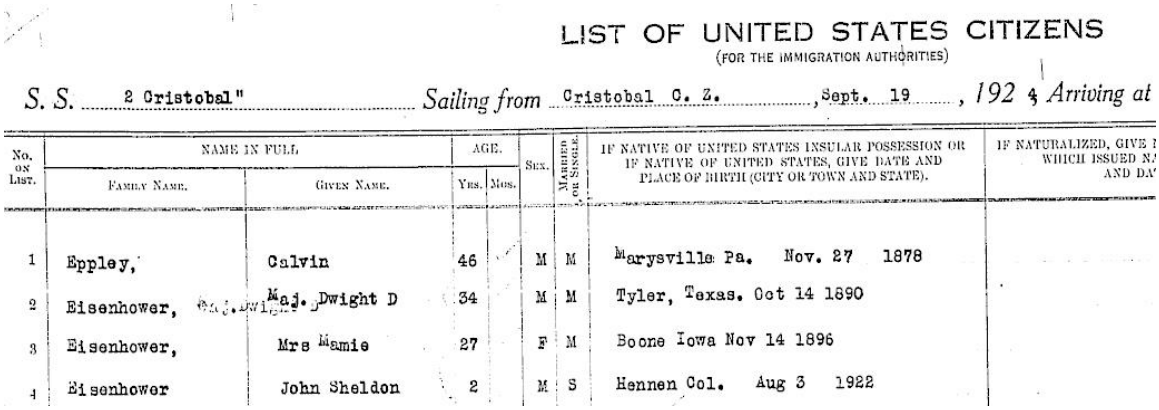
A search using Phonetic Matching gives only four names, but only one of those is a false positive. The other three are the same three true positives found by Daitch-Mokotoff soundex.

The true and false positives for Washington are shown below.

The bottom line is that more than 99% of the positives for Washington under American Soundex are false, 67% under Daitch Mokotoff are false, and only 25% under Phonetic Matching are false.

Example 2: Eisenhower in the Ellis Island Database

Would it surprise you to learn that Dwight and Mamie Eisenhower are in the Ellis Island database? The image of their manifest is shown below.



LIST OF UNITED STATES CITIZENS
(FOR THE IMMIGRATION AUTHORITIES)

S. S. 2 Cristobal" Sailing from Cristobal C. Z. , Sept. 19 , 192 4 Arriving at

No. on List.	NAME IN FULL		AGE.		SEX.	MARRIED OR SINGLE.	IF NATIVE OF UNITED STATES INSULAR POSSESSION OR IF NATIVE OF UNITED STATES, GIVE DATE AND PLACE OF BIRTH (CITY OR TOWN AND STATE).	IF NATURALIZED, GIVE ... WHICH ISSUED N... AND DA...
	FAMILY NAME.	GIVEN NAME.	YRS.	MOS.				
1	Eppley,	Calvin	46		M	M	Marysville Pa. Nov. 27 1878	
2	Eisenhower,	Maj. Dwight D	34		M	M	Tyler, Texas. Oct 14 1890	
3	Eisenhower,	Mrs Mamie	27		F	M	Boone Iowa Nov 14 1896	
4	Eisenhower	John Sheldon	2		M	S	Hennen Col. Aug 3 1922	

Of course Eisenhower wasn't an immigrant. Rather he returned to the US in 1924 after serving as an officer in the Panama Canal Zone, and before beginning his next assignment as an officer in Baltimore. This 1924 arrival is in the Ellis Island database.

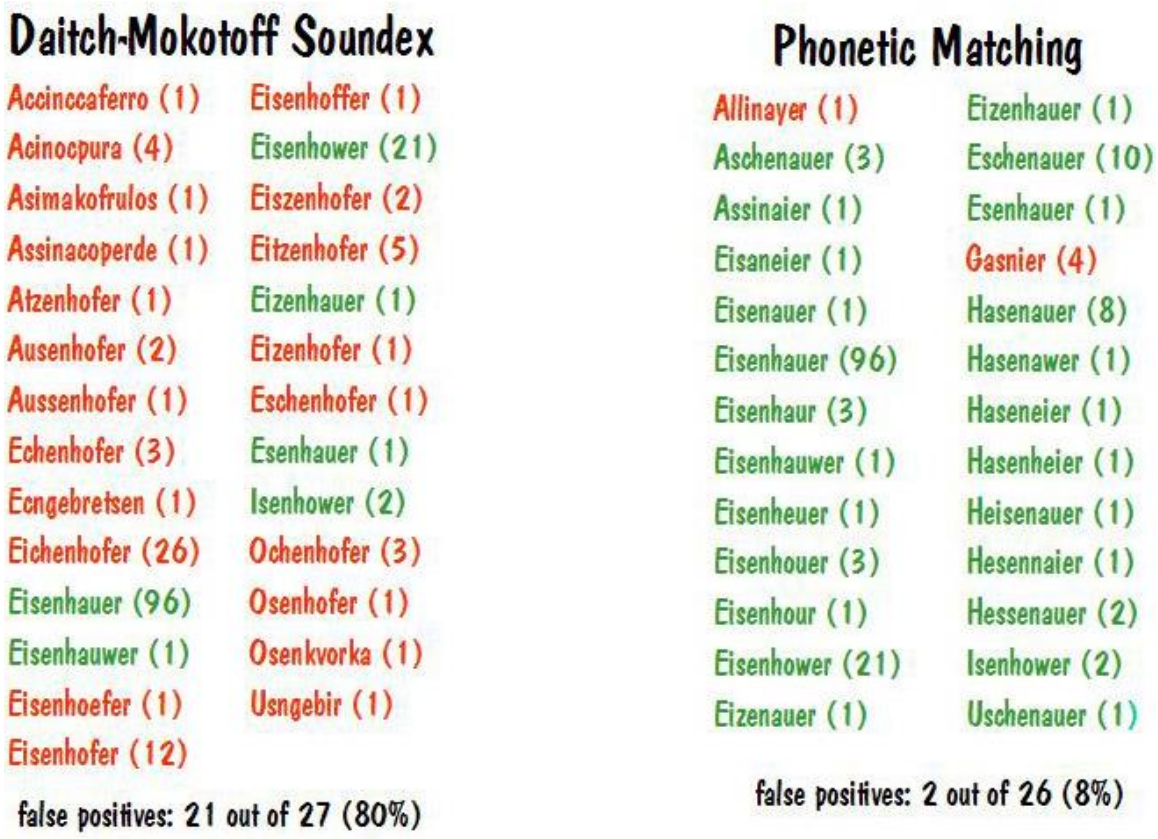
If we search for Eisenhower in the Ellis Island database using American soundex, we get 388 unique names, 375 of them being false positives. That means 97% of the positives obtained are false.

The 13 true positives are

Eisaneier (1)
Eisenauer (1)
Eisenhauer (96)
Eisenhaur (3)
Eisenhauwer (1)
Eisenheuer (1)
Eisenhouer (3)
Eisenhour (1)
Eisenhower (21)
Eizenhauer (2)
Eizenhauer (1)
Eschenauer (10)
Esenhauer (1)

The number in parenthesis is the number of times each name appears in the database.

If we do the search using Daitch-Mokotoff soundex, we obtain 27 unique names, 21 of which are false positives (80%). And Phonetic Matching gives 26 unique names with only 2 false positives (8%). See the chart below.



Counting matches instead of unique names gives 2421 false positives out of a total of 2553 hits for American soundex (95%), 70 false positives out of a total of 192 hits for Daitch-Mokotoff soundex (37%), and 5 false positives out of a total of 168 hits for Phonetic Matching (3%).

Throwing out the Baby with the Bath Water

Reducing the number of false positives is a good thing, provided we don't wind up creating some false negatives in the process. In other words, we need to be careful not to throw away the baby with the bathwater. So let's see if that happened in the case of Eisenhower in the Ellis Island database.

Of all the unique names rejected under American soundex, 11 of them could be considered to be ones we are interested in. Thus they are false negatives. Under Daitch-Mokotoff soundex, 19 of the unique names rejected could be considered false negatives. And under Phonetic Matching, none of the names rejected are ones that we would have wanted. This is shown below.

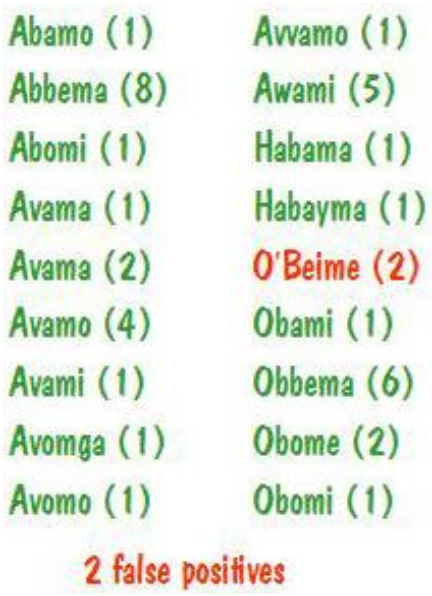
We shouldn't get too excited over the fact that Phonetic Matching produces no false negatives. This example paints too rosy a picture, and occasionally there will be some false negatives. But hopefully the few false negatives introduced will be more than compensated for by the reduction in false positives.

Example 3: Obama in the Ellis Island Database

Surely Barack Obama won't be found in the Ellis Island database – he was born 6 years after Ellis Island closed for good, and 37 years after the last entry in the list of 25 million passengers. But that shouldn't stop us from searching for names that sound like Obama in the database.

Searching for Obama using American soundex gives 781 hits, many of which are false positives. And of the names rejected, many are false negatives. A search using Daitch-Mokotoff soundex gives 11,584 hits, most of which are false positives. And a search

using Phonetic Matching gives just 40 hits, only 2 of which are false positives. The 40 Phonetic Matching hits are shown below.



Overview of Phonetic Matching

OK, that's enough of a marketing pitch. Hopefully it has convinced you that Phonetic Matching is good. Now let's see how it works.

Phonetic Matching is based on the principal that pronunciation depends on the language. So the first step is to determine the language from the spelling of the name. Then the name is converted into a sequence of phonetic tokens using pronunciation rules specific to that particular language. And, finally, names are compared based on their phonetic-token sequence.

We have selected a set of languages, and have developed tables for each one. These tables consist of detailed pronunciation rules, as well as rules for determining if a spelling of a name corresponds to the language.

The languages we currently support are Catalan, Czech, Dutch, English, French, German, Greek (in Greek characters as well as translitered into Latin characters), Hebrew, Hungarian, Italian, Polish, Portuguese, Romanian, Russian (in Cyrillic characters as well as various transliterations), Spanish (including its Latin American dialects), and Turkish. New language tables will probably be added in the future.

And for Jewish names we have gone one step further. We have a special variant of Phonetic Matching that is customized for Ashkenazic Jewish names (languages are English, French, German, Hebrew, Hungarian, Polish, Romanian, Russian, and Spanish),

and one that is customized for Sephardic Jewish names (languages are Catalan, French, Hebrew, Italian, Portuguese, and Spanish).

Determining the Language

The Phonetic Matching system has about 200 rules that allow it to determine the language that a name is written in, based on the spelling of the name. For example, consider the following two spellings of the same name:

1. Schwarz

    The following rules are appropriate in this case:

        "sch" at beginning: language is German or transliterated Russian
        "rz" at end: language is German or Polish

    From these two rules we can conclude that the language is German.

2. Szwarc.

    Here we will apply the following rules

        "sz": language is Polish or Hungarian
        "c" at end: language is Polish or Romanian

    From this we determine that the language is Polish

A Schwarts by any other Name

Here are still more spellings of the same name, and the language corresponding to each:

Schwarz: German
Szwarc: Polish
Schwartz: alternate German
Szwartz: blended Polish German
Şvarţ: Romanian
Svarc: Hungarian
Chvartz: French
Шварц: Russian
שורץ: Hebrew

More Rules for Determining Languages

Some of the language rules enable us to determine the language uniquely. For example:

"tsch", final "mann", final "witz": German
Initial or final "cs" or "zs": Hungarian
"cz", "cy", initial "rz", initial "wl", final "cki": Polish

Other rules narrow it down to a small number of languages

final "ck": German or English
"sz": Polish or Hungarian

And yet other rules eliminate certain languages

"y", "k": not Romanian
"v": not Polish
"kie": not French or Spanish

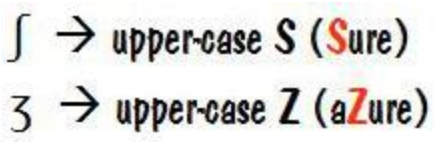
Phonetic Tokens

Once the language is known, we can use language-specific pronunciation rules to convert the name into a sequence of phonetic tokens. One possibility for such tokens is the International Phonetic Alphabet (IPA), where each character in the alphabet corresponds to a unique sound. The characters are shown below:

iː READ	ɪ SIT	ʊ BOOK	uː TOO	ɪə HERE	eɪ DAY	John & Sarah Free Materials 1996
e MEN	ə AMERICA	ɜː WORD	ɔː SORT	ʊə TOUR	ɔɪ BOY	əʊ GO
æ CAT	ʌ BUT	ɑː PART	ɒ NOT	eə WEAR	ɑɪ MY	ɑʊ HOW
p PIG	b BED	t TIME	d DO	ʧ CHURCH	ʤ JUDGE	k KILO	g GO
f FIVE	v VERY	θ THINK	ð THE	s SIX	z ZOO	ʃ SHORT	ʒ CASUAL
m MILK	n NO	ŋ SING	h HELLO	l LIVE	r READ	w WINDOW	j YES

One problem with the IPA set of characters is that it makes too fine a distinction between similar sounds. Another is that most of the characters are not found on standard computer keyboards.

For our phonetic tokens we used the characters in the IPA but simplified it by dropping characters that have similar sounds to other characters. Where possible, we tried to use the same character for a sound as is used in the IPA. And we limited our selection of characters to those found on standard keyboards, sometimes replacing an IPA character with a standard one that looked similar. For example, we used **S** instead of **ʃ** for the "s" sound in "sure", and similarly we used **Z** instead of **ʒ** for the sound of "z" in "azure".



Below is a list of the simplified phonetic tokens that we selected, along with the sound (in an English word) that each represents

a (part)	**b** (boy)	**d** (dog)	**e** (set)	**f** (flag)
g (girl)	**h** (hand)	**i** (ski)	**j** (yes)	**k** (king)
l (lamp)	**m** (man)	**n** (neck)	**o** (port)	**p** (pot)
r (ring)	**s** (star)	**t** (tent)	**u** (flu)	**v** (vase)
w (wax)	**x** (loch)	**z** (zoo)	**S** (Sure)	**Z** (aZure)

Converting Names to Phonetic Tokens

For each of the languages we support, we have developed a set of rules to convert a name in that language into a sequence of phonetic tokens. Let's look at two examples.

1. Schwarz

> We have already determined that this is German. Our set of German pronunciation rules includes the following:
>
> "sch" → **S**
> "w" → **v**
> "z" → **ts**
>
> Applying these rules, we have the following result for Schwarz
>
> "Schwarz" → **Svarts**

2. Szwarc

We already found that this is Polish. Our Polish rules include

"sz" → **S**
"w" → **v**
"c" → **ts**

So in this case we get

"Szwarc" → **Svarts**

Not surprisingly, we get the same set of tokens in both cases.

Consider the Context

The rules for converting the letters in a name to a sequence of phonetic tokens need to consider the context in which the letters are found. Otherwise we could have nonsense such as the following:

Name: ghoti

"gh" → **f** (as in enough)
"o" → **i** (as in women)
"ti" → **S** (as in motion)

Based on this, we could have the name ghoti matching the name fish. The problem here is we didn't consider the context in which the gh was found. Specifically the first rule should have been

"gh" → **g** (if at beginning)
else "gh" -> **g** or **f** or **w**

Common Rules for Many Languages

There are certain rules that cut across languages. Two examples of such rules are presented here. The goal of this is not to make you a linguistic expert, but rather to have an appreciation that there are such language-independent rules, and to see how the Phonetic Matching system can take advantage of them when producing phonetic tokens.

1. Final Devoicing

Final Devoicing says that at the end of a name (or any word for that matter), voiced consonants are pronounced like their unvoiced counterparts. Some examples are:

Lev is pronounced as if it were Lef
Grand is pronounced as if it were Grant
Tab is pronounced as if it were Tap

That's not to say that you can't pronounce Lev with a voiced-v at the end. But it's just not natural to do so in a number of languages (e.g., German, Dutch, Polish, Russian), and you would be forcing the issue if you tried.

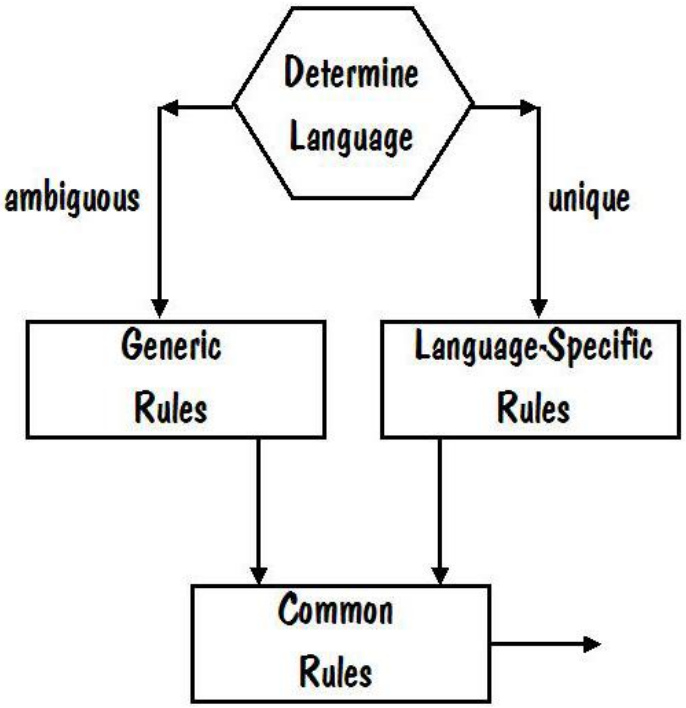
2. Regressive Assimilation

Regressive Assimilation says that consonants acquire the voiced/unvoiced characteristic of the consonant that immediately follows it. Some examples are:

Shabse is pronounced as if it were Shapse
Vitzon is pronounced as if it were Vidzon

Flow Chart

We are now ready to put the pieces together and see how a name is transformed into a sequence of phonetic tokens. Note that there is a special set of pronunciation rules that we apply if we can't determine the language. These are called the generic pronunciation rules.



Approximate Rules

We could stop the development of Phonetic Matching here, and have a perfectly reasonable system. And indeed some implementers of search applications might choose to do so. But in order to avoid throwing out too many babies with the bathwater, we added some approximate rules to the system. The use of the approximate rules to reduce the number of false negatives is totally optional, and at the discretion of the application developer.

Below are two examples of such approximate rules.

1. Unstressed Equivalence

> This rule states that unstressed "a" is pronounced the same as "o" and vice versa. So Nixon is pronounced the same as Nixan, and Reagan as Reagon. However Obama is not the same as Oboma, because the syllable in which the change was made is the stressed (accentuated) syllable. Simarly, Ford is not pronounced like Fard.
>
> For a number of languages, this unstressed-equivalence rule is always true. However, it is not trivial to come up with a set of rules to determine which syllable in a name or word is accentuated. For that reason we will treat "a" and "o" as equivalent in all cases (stressed or not), and that is what makes the rule "approximately" true.

2. Phonetic Proximity of a Pair of Sounds

> Certain sounds occurring in proximity are close to (but not exactly the same as) some other sound. For example, "n" before "b" sounds close to "m". So Grinberg is pronounced approximately the same as Grimberg.

Searching for Matches

There are three steps when searching for matches in a database. First the names in the database must be converted to phonetic tokens (encoded). Then the name being searched for must be converted. And finally a match is sought between the encodings.

The encoding of the names in the database is done when the search application is being developed, long before any searches are done. Since this is not done when the user is trying to do a search, it doesn't matter if it takes a long time to do the encoding, providing we are talking days and not years. The language of the entire database might be known a priori, in which case it is not necessary to test each name to determine the language. For example, the names in a Polish telephone directory could all be assumed to be in Polish. In other cases the language is not known, such as in the Ellis Island database in which the languages are all over the map (literally). In that case, the language of each name would need to be determined on an individual basis.

The encoding of the name being searched for is done at the time that the search is done. In this case, no apriori knowledge of the language is assumed and the language is determined by the spelling of the name.

Note that a name in the database might be encoded based on a different language than is used when that name is being searched for. For example, the name Schwartz in a Polish telephone directory might be encoded using the Polish pronunciation rules whereas the name Schwartz being searched for would be encoded with the German pronunciation rules because Schwartz is a German spelling. In that case, the following surprising (but acceptable) things might happen:

1. The search might not be transitive

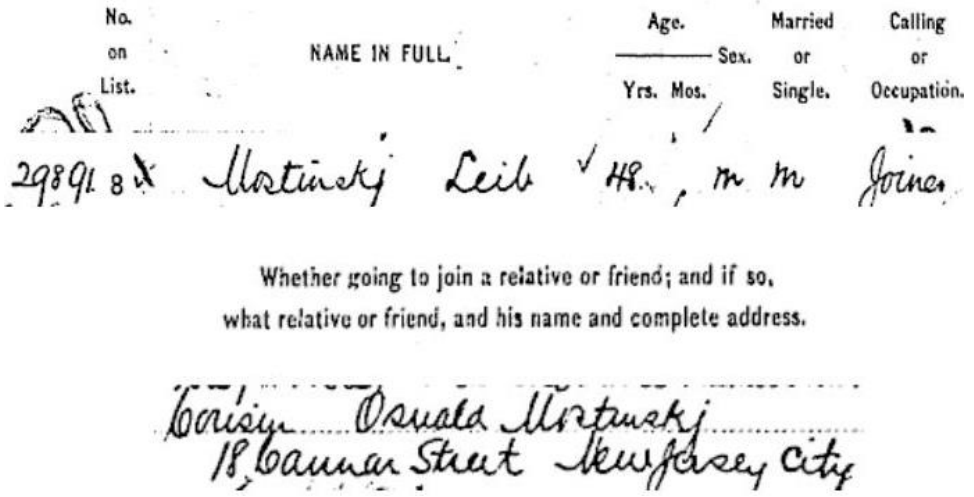
> Transitivity means that if A=B and B=C, then A=C. But that is not the case for our searches. Specifically if a search for A finds B and a search for B finds C, then it does not follow that a search for A will find C.

2. The search might not be commutative

> Commutivity means that if A=B then B=A. But in our case, if a search for A finds B, it does not follow that a search for B will find A.

Case Study

It would be informative to apply Phonetic Matching to an actual case and see how it helped provide new information. My paternal grandfather was Louis Mastinsky (Mastinsky was my father's "maiden name" which he later changed to Morse). I found Grandpa Louis's ship record many years ago the old-fashioned way (using actual microfilm readers), long before the database was ever put on line. Below is a portion of the manifest image that I found.



No. on List.	NAME IN FULL	Age. Yrs.	Age. Mos.	Sex.	Married or Single.	Calling or Occupation.
29891 8	Mastinsky Leib	48		m	m	Joiner

Whether going to join a relative or friend; and if so, what relative or friend, and his name and complete address.

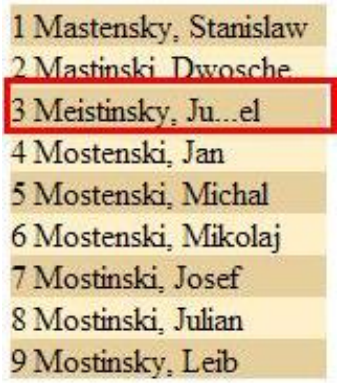
Cousin Oswald Mastinsky
18 Cannar Street Newjersey city

I knew very little about Grandpa Louis. I didn't know if he had any siblings, and certainly knew nothing about his more distant relatives such as cousins. So I was surprised to see that he was going to a cousin, Oswald Mostinsky. But Oswald is listed as living in New Jersey City. There is no such place, so I don't know if it was supposed to be New York City, or Jersey City. Oswald lived on Cannar Street, but I checked and couldn't find a Cannar street in either New York or New Jersey. For many years, Oswald was a dead end.

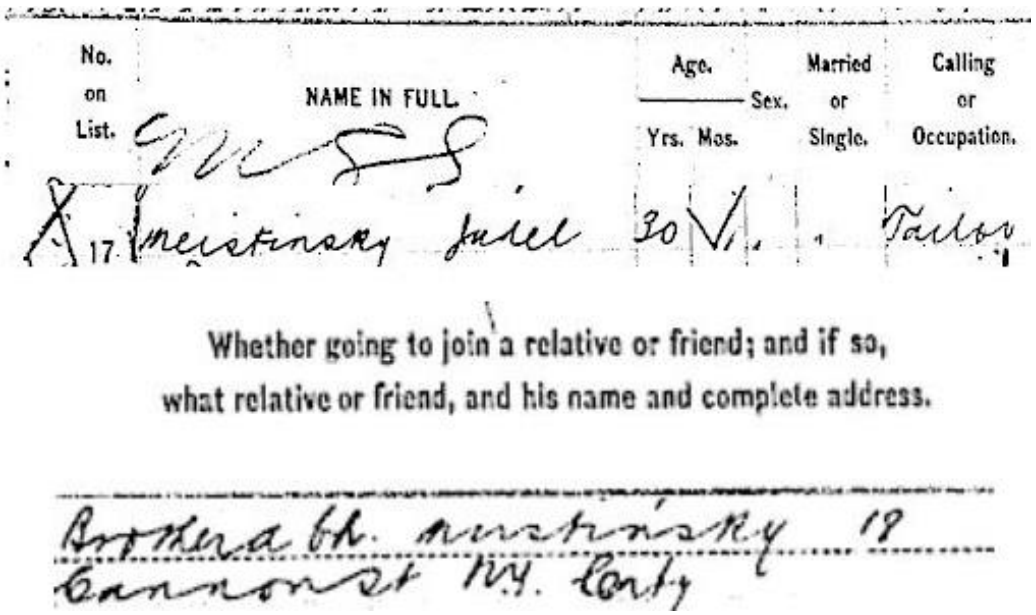
When the Ellis Island database went online, I searched it for all names sounding like Mastinsky using Datch-Mokotoff soundex. I obtained 92 matches. Number 71 was Grandpa Louis. Numbers 55 and 56 were Grandma Bedanah traveling with Uncle Zelig. And number 22 was Aunt Dora. There were a few people named Mostinski in the list, and although interesting, I never found a connection to them. All the other names were out in left field (e.g., Mastinicchio) and obviously false positives that I didn't want to see. And since there were so many false positives, I never really looked carefully enough to see if there might be another true positive lurking among them.

Search EIDB for Mastinsky - DM Soundex

That's where my research stood for many years. When I implemented Phonetic Matching in my Ellis Island search application, I decided to use Mastinsky as a test case. I obtained only nine hits, as shown below. Among them were Grandpa Louis and Aunt Dora. There were also several Mostinkis and a Mastensky, all of whom I had investigated and discarded many years earlier.



But now, without a single false positive on the list, I was able to focus more intently on the names obtained. I noticed a Ju…el Meistinsky, whom I never saw before because he had been hidden by all the false positives. So I decided to bring up Ju…el's record



No. on List.	NAME IN FULL	Age. Yrs.	Age. Mos.	Sex.	Married or Single.	Calling or Occupation.
17	Meistinsky Judel	30		M.		Tailor

Whether going to join a relative or friend; and if so, what relative or friend, and his name and complete address.

Brother Bh. Mostinsky 18 Cannon St NY. City

I could see that what the transcriber read as Ju…el is in reality Judel. Note that Judel is going to his brother at 18 Cannon Street in New York City. I checked a map, and indeed there is a Cannon Street in New York City. Judel (pronounced Yudel) is probably cousin Oswald. And the brother whom Judel is going to must be another cousin of grandpa's. The manifest is not clear on the brother's name – perhaps it is Abh. I immediately checked the 1904-5 Manhattan City Directory for 18 Cannon Street and found an Abraham Mostinsky living there.

I just learned that grandpa's father had a brother (whose name I don't know) and that brother had sons Abraham and Judel. This is information I didn't know before, and I found it because I was using Phonetic Matching.

Implementations

There currently exist several implementations of Phonetic Matching. It is on several databases on my website (http://stevemorse.org) -- namely the Ellis Island database, the Dachau Concentration Camp Records, a database of Jewish surnames, and various naturalization databases. Other websites that have implemented Phonetic Matching are http://sephardicgen.com, http://jewishgen.org, http://jri-poland.org, and http://rtrfoundation.org. In addition, there are several other sites that are currently considering adding Phonetic Matching to their search applications.

The Authors

Alexander Beider

Alexander Beider (or Sasha as his friends call him) was born in Moscow in 1963. He received a PhD in Applied Mathematics from the Moscow Physico-Technical Institute in 1989. In 1990 he emigrated to France where he received a second PhD, this one in Jewish Studies from the Sorbonne in 2000.

He has published several etymological dictionaries of Jewish surnames and given names. He has also written a number of papers on linguistics, specifically dealing with the origins and early history of Yiddish.

Stephen Morse

Stephen Morse is the creator of the One-Step Website for which he has received both the Lifetime Achievement Award and the Outstanding Contribution Award from the International Association of Jewish Genealogical Societies, Award of Merit from the National Genealogical Society, first-ever Excellence Award from the Association of Professional Genealogists Quarterly, and two awards that he cannot pronounce from Polish genealogical societies.

In his other life Morse is a computer professional with a PhD in electrical engineering. He has held various research, development, and teaching positions, authored numerous technical papers, written four textbooks, and holds four patents. He is best known as the architect of the Intel 8086 (the granddaddy of today's Pentium processor), which sparked the PC revolution 30 years ago.