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A Methodology for Reconstructing Complex Puzzles in Multiple Dimensions without a Prior Vision of the Whole Image: A Case Study: The Genealogical History of the Entire Jewish Population of the Polish Town of Pinczow in the 18th and 19th Centuries

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Abstract

We have developed a new technique for the systematic analysis of civil registration records in a typical Polish town during the period 1810 to 1912. We have applied the technique to the Jewish population of Pinczow, 5,000-strong by 1912. We extracted more than 27,000 birth, marriage, and death records and reconstituted 1900 family histories with the aid of a set of systematic rules, partially computerized, which allows one to make a 1:1 mapping of the subset of pre-1826 records (that did not employ surnames) to the partially overlapping subset of the remaining records, which did use surnames. Mapping requires agreement on the basis of several criteria. Total consistency and lack of ambiguity are hallmarks of the resulting success. The algorithm not only allows one to establish family trees leading as far back as 1700 but also permits one to simultaneously conjecture surnames, where needed, on the basis of those that descendants eventually adopted. This symbiotic process succeeds only because of the application of the algorithm on a massive scale. One can apply the method to any town of similar size, and one can use the results to study sociological behaviour and town history. In the case of Jewish Pinczow, this study also demonstrates an advance in Rabbinic genealogy.

Keywords: patronyms, genealogy, 1:1 mapping, history, sociology, puzzles, methodology, Pinczow

Introduction

The Art and Science of Puzzle Solving

The reconstruction of an object consisting of many pieces is a task, often encountered in the field of archaeology. For example, researchers from Israel and Germany recently unearthed a 12-cm tall unusual 7,200-year-old clay vessel at Tel Tsaf in the Jordan Valley and reconstructed it from 25 or so shards (Rosenberg, Garfinkel, & Klimscha, 2017). Its reconstruction led the researchers to conclude that the vessel may be the oldest evidence yet of political and social class structure among the upper class in relation to food storage rituals in the ancient Near East. That a small 3-D puzzle can lead to such far-reaching conclusions is amazing. Reconstructing a 25-piece puzzle like this can be routine because of the experience of the puzzle-solver who knows the context intimately, even if the object is 3 dimensional and even without knowing in advance what it is supposed to look like. In the Tel Tsaf case, the structure was rather complex, and the archaeologists could solve it arduously, but nevertheless relatively routinely compared to the following cases.

Figure 1
Clay Vessel Unearthed at Tel Tsaf. Photo courtesy of Danny Rosenberg.

At the other extreme, researchers required a less routine approach for a 2-dimensional puzzle involving only a handful of pieces which are repetitive in nature, but for which the magnitude of the puzzle was initially unknown; and, therefore, they required much more tedious effort, particularly since a variety of possible geometric patterns were involved. The investigations of Barkai, Dvira, and Snyder (2016) resulted in the reconstruction of several multi-coloured tiles used to pave the floors of the Second Temple in Jerusalem. The ancient historian Josephus (1982) described these floors in eloquent and admiring terms. It is important to note that, in order to succeed in solving such a puzzle, one has to know not only exactly how many pieces there are in the puzzle, but also to know which pieces belong to a particular tile, and certainly the overall size of the unit cell[57] – without prior knowledge of the outcome. With the restriction that the puzzle pieces must fit precisely, and must match up to their neighbouring pieces in length and orientation, and must form a square, one would think that one could solve

[57] A chemical term used to describe the repeating entity in a crystal structure.

such a puzzle by a computer algorithm. However, because of the non-uniqueness of possible patterns, it turns out not to be so feasible or desirable. Instead, the researchers resorted to simple trial-and-error, taking advantage of many years of experience of what *opus sectile* floors looked like throughout the Roman Empire 2,000 years ago (Snyder, Avraham, 2013, p. 178). The only way to know that one has solved the problem correctly is if the result turns out to be beautiful. This was a necessary requirement of the ancient architects. Aesthetics is not something that a computer can easily learn.

Figure 2
Opus Sectile Pattern Reconstructed from 17 Pieces. Courtesy of "The Temple Mount Sifting Project"

One may ask, then, are there *any* topological problems that we can solve by computer, or at least objectively. The archetypical topological brainteaser is the ubiquitous jigsaw puzzle. And for this case the answer is – yes, in principle; but no in practice. With the goal broken down into four distinct tasks – (a) classification of the puzzle pieces; (b) construction of the edge topology; (c) construction of the internal topology; and (d) local contour matching, De Bock et al. (2004) succeeded in programming a computer to solve a jigsaw puzzle as large as 300-pieces using known algorithms developed by the same group (DeSmet et al., 2003). Such solutions can easily be held hostage by dust particles (noise) or poor cuttings of jigsaw puzzle pieces (poor intrinsic matches). That fact alone is what makes computer approaches ultimately not useful for our own particular study (see below). In other words, pattern recognition or computer vision is one thing; but flexible computer thinking and appreciation of self-consistency, of context, of beauty or of truth-when-you-see-it is quite another. The authors admit that their study was a subset of a very complex generic digital reconstruction problem. Considering the difficulties that such 2-dimensional problems present, one can imagine what would happen for 3 or more dimensions. Such is the case in genealogy.

Consider extracts of individual birth, marriage and death records of a single town as puzzle pieces. Each of these events could potentially reveal the names of parents, birth years, professions, relationships to witnesses, and town origins etc. We can link these pieces together to create a nuclear family tree. Then using the information gleaned from this tree, one knows whose birth, marriage and death record one must subsequently locate for earlier or for later generations. Each link is a boundary between puzzle pieces. Slowly one builds up a more extensive tree of several generations using a single surname. There are built-in uncertainties if registry clerks were inconsistent in recording ages or if a single person's profession or surname changed over time or if a parent's spouse was from a second marriage etc. These would constitute fuzzy edges of the

pieces and at the very least are irritating from the point of view of feeling comfortable with the reconstruction. Notwithstanding this irritant, if one tolerates minor fuzziness, the result is a family tree for a single surname which one can chart in two dimensions. Now, consider any single marriage in this family tree. All of a sudden, we have a new, but imported family whose tree also could be extensive, but which no longer fits on the two-dimensional board. Its family will jut out from the first two dimensions forming a new dimension. This branching is repeated for each marriage. We now have a multidimensional puzzle. Given the fact that, in a given town's population, there are limited numbers of families, eventually the links fold back on each other every time there is a distant cousin marriage. Suddenly, dimensions – even fractal dimensions (Mandelbrot, 1983) – no longer describe the problem at all. It is more properly described as a dense web puzzle. Clearly, the web-like nature of the tree implies that charting the history of a single family, in fact, requires one to make a global family tree for the entire town as a living organism: One family is not strictly isolated from all the others in a single town. Furthermore, a traditional commercial two-dimensional jigsaw puzzle provides the puzzle-solver with an image of the finished product on the box top. Not so for the genealogy of a town. One has no idea of the scope or size of the puzzle until one has actually completed the town's multi-family history. There are not even any regular edges to such a puzzle, as each group extends back to a different point in time[58]. In addition, if one person were to marry a spouse from a different town, the marriage record would not be available to the puzzle-solver who is concentrating on the original town history. The same applies to births and deaths. This feature is analogous to missing jigsaw puzzle pieces. Conversely, one could conceive of the opposite scenario with a newly married couple suddenly immigrating from a distant town, without the puzzle solver necessarily being aware of this. Then one would have an excess of puzzle pieces, and they would not necessarily link up to or add to the original pieces. They belong to a separate puzzle. To complicate matters, in principle it is possible for two different couples having identical names and professions and birth years to give birth to two children having the same names. The uncertain linkages result in ambiguity. In our case, below, spanning a 100-year period, there were about 27,000 events (or puzzle pieces). Clearly, such a jigsaw puzzle can become intractable to solve (certainly by an "unintelligent" computer) because of the sheer magnitude of the possible combination of linkages, were it not for the puzzle-solver's objective and intuitive understanding of the context, and of naming patterns in specific societies etc. Consequently, when studying the genealogical history of a given town or county, one must do it manually, much like the reconstruction of an archaeological artefact. In principle, we can use the same codes that a computer algorithm would use, searching systematically piece by piece for each linkage, using specialized reconstruction rules, elucidated below. These rules have the effect of reducing the complexity of the big-number problem[59]. Thus, our monster problem can indeed be tackled systematically. However, human supervision is a necessary element of the process.

[58] The solution of a jigsaw puzzle is made more efficient if one starts at the edges. Thus, instead of 4 unknown edge matches there would be only one – the remaining one facing the interior of the puzzle. In the absence of a global edge, one is forced to start the puzzle at random points in the interior.

[59] For example, a 30,000-piece puzzle would require 30,000 x 29,999 x 29,998 x …. attempted matches. The product is larger than the number 1 followed by 121,000 zeroes – a number which is enough to fill a 100-page book double spaced font size 12; and this does not take into account the infinite number of variable orientations and rotations for each potential match. Happily, we can eliminate most of these options by using context-based logic, which only the human brain can provide.

Genealogy as an Academic Field

Genealogy *per se* is not just a pastime or a matter of vanity. We can address serious issues by tracing ancestral lines. For example, one can predict and, in principle even eradicate genetically inherited medical conditions. Specific genetic mutations affect a person's chances of suffering, from Alzheimers (Jonsson & Stefansson, 2013), from breast cancer (Tulinius et al., 2012), among other conditions and, on the positive side, of acquiring longevity (Gudmundsson et al. 2000). While whole or partial genome analysis might be very useful to determine such genetic properties in single patients after the fact, it follows that by tracing relationships laterally and ancestrally, one can also analyze predispositions to these conditions. Pathological genetic conditions arise sometimes in close-knit communities subject to a lot of inbreeding. But such societies can also serve as test subjects for scientific study. Such is the case of Iceland where approximately 300,000 living members all descend from a small identifiable group which settled the island about 1,100 years ago. What makes this a wonderful test group is that Iceland's population was physically isolated and that, as a result, extensive genealogical records have survived all this time for that unique group, unaffected by wars or massive immigration. Government-supported churches and public institutions have collected these records and ultimately transformed the 11-century old raw data into a computerized genealogical database[60] that was instrumental in the above-mentioned medical advances.

The uninterrupted record-keeping in Iceland made feasible the creation of a single nation-wide family tree, containing potentially as many as 1,000,000 distinct people, and spanning 11 centuries. Ashkenazi Jews, too, formed an insular society with considerable inbreeding. However, the practice of reliable record-keeping for Jews has been around for only 300 years at best in Western Europe, and only 200 years in Poland. Less than 5,000 Jews living in the little town of Pinczow, with nearly complete record-keeping for a mere 200 years, does not compare in magnitude to the 300,000 Icelanders with 1,100 years of documentation. Still, given the fact that Icelandic surnames are essentially patronyms, as was the case in Ashkenazi Jewish society until the early 19th century, the approach ought to be very similar. It is simply a matter of scale.

JRI-Poland has been constructing its large database (Jewish Records Indexing – Poland, 2019)[61] of birth, marriage and death records of Polish Jews during the last 20 years by scouring the Polish archives. Like the Icelandic case it should be possible, in principle, to create a single family tree of Polish Jews. Unlike the Icelandic cases, though, which made use of an existing 1,100 year old database and only at the end applied it to medical issues, Diamond conversely and ironically pursued the ancestral source of a rare blood disorder (Martino et al., 1997; Diamond, S., 2004), thereby spurring the creation of a previously non-existent database. It has now taken on a life of its own. But it is much harder to use this Polish database since the names are not yet grouped by family. The present study shows exactly how to make the most of the database using the town of Pinczow as an example.

[60] Stefansson and Kulason at deCODE Genetics, Rejkjavik spearheaded the effort to computerize the Islendingabok, or *Book of Icelanders* in 1997. They extended the effort by scouring censuses, church records and family archives (Stefansson, 2019). The database includes all living 300,000 Icelanders and all their ancestors stretching as far back as 900 CE, and it encompasses at least 600,000 people, or 95% of Icelanders who have lived during the past 300 years.

[61] The database contains more than five million vital record entries from more than 550 towns. In size, the Jewish database has the potential to surpass that of the Icelandic database.

Genealogy of Polish Jews

Many authors have studied Jewish family history (e.g., Liver et al., 2007; JewishGen, 2015; Amdur, Sack & Mokotoff, 2004). To get a good understanding one requires knowledge of the history of the Jews in Europe. A very large subset of this field deals with Polish Jews (see Wikipedia, 2019) and the 284 basic references therein; Hundert & Bacon (1984); and the bibliographies by Balaban (1930) and by Corrsin (1995)). Pinczow is a good representative town chosen because of the relative completeness of records by Polish standards.

(A) The Jews of Pinczow

Pinczow is a small town in the Kielce province of Poland. According to the Yizkor Book for Pinczow (Shener (1970)) and to Yad Vashem's Pinkas haKehillot series (Wein, 1999), the majority of the town's population was Jewish prior to World War 2. By the mid-19th century there were about 3,000 Jews living in Pinczow, and by the end of the 19th century their numbers grew to over 5,000. As was typical[62] of most towns in central Poland, Jews engaged in a very large variety of occupations; but Pinczow is remarkable for the relatively large number of scholars and Rabbis who lived there since its beginnings. Much of the history of the Rabbinate is described in the Yizkor Book; and for the years prior to 1614 it was the subject of a study by Simon Dubnow (1894). Information on ordinary families of the town is available mostly in anecdotal form, as for example in the Yizkor book. Nevertheless, it is possible to, in principle, reconstruct the family trees from the civil registry records of Pinczow. The Polish State Archives have preserved birth, marriage and death records for the town almost in their entirety from 1810 to the present time, and they are now publicly accessible up to the year 1912 (Polish State Archives). The present study has extracted and analyzed those vital data *en masse*.

(B) The Use of Jewish Surnames

One aim of the present study is to develop a method for determining the genealogical history of the Jews of a typical Polish town, and to demonstrate the technique for Pinczow over an extended period of time back to ca 1700. In the case of Pinczow this means creating family trees of all families in town who eventually used more than 2,000 distinct surnames. The task is made difficult because Jews tended to resist using surnames until well into the 19th century. The Austrian Emperor Joseph II mandated the use of surnames (Joseph II, 1787). (Pinczow was an Austrian possession between 1795 and 1815). Congress Poland, subject to Russian laws, promulgated similar edicts a little later. An excellent description of the processes involved is given by Paull and Briskman (2014, 2016), while we can find the etymology and provenance of

[62] In the 18th century Polish towns had between about 1,000 to 5,000 Jews. The Jews were merchants, small factory owners, innkeepers, agents of farmers and landowners, and scholars. Most of them lived in private towns whose owners were positively pre-disposed to them. See, for example – Hundert (1992) who states that two-thirds of the Jews in 18th century Poland lived in towns, and half of the town dwellers were Jewish. He used Opatow as a case study. Another case in point is the town of Zamosc, founded in 1580 by Jan Zamoyski, Chancellor of the Polish Commonwealth. His descendants inherited the town all the way down to 1821. By this time Jews constituted 53% of the population of Zamosc. Pinczow, too, was a private town. The Myszkowski family owned it since 1586 and then sold it to the Wielopolski family who owned it until its annexation by Austria. All of these towns tended to be insular, at first, with families intermarrying with other local Jewish families.

particular surnames in the work of Beider (1996). Civil registry offices were *beginning* to seriously record surnames around 1821, as we have observed empirically for many towns in Congress Poland. Getting used to surnames often stretched out to about 1835. Consequently, the early records (1810 to 1825), in the so-called "patronymic era" stubbornly exemplify a general lack of surnames. Instead, Jews tended to use the traditional X *ben* Y scheme, or the Polish equivalent, e.g., X followed by "Y"owicz. It is therefore very difficult to make good use of these early data. Yet these extra 16 transitional years are crucial to our understanding of the Jewish history of Pinczow: Those early years contain records of the ancestors of much of the later population of Pinczow. Furthermore, any elderly person who died during this period might have been born as early as 1725. Deduction of his or her parents' names thus would enable us to extend the history of a whole family back to roughly 1700 and make links to other associated families. Accordingly, the secondary aim of this study is to assign surnames (to the people mentioned in these patronymic records) which they themselves never carried but which their descendants eventually adopted. In order to carry out this task for any given family, it turns out, it becomes necessary to conjecture surnames for *all* families, in analogy with the task of solving a large jigsaw puzzle. It is a synergistic procedure. Therefore, the overriding aim of the project is to demonstrate an efficient methodology for conjecturing surnames, *en masse*, which we can apply in the future to other town histories. In addition, it happens that Pinczow was the home of a relatively large number of scholarly families who had ties by blood or by marriage to well-known Rabbinic families all over Congress Poland and beyond. Another aim of the project is, therefore, to analyze these family structures, for the purpose of elaborating the history of historical personalities involved and to resolve various associated historical controversies.

(C) Previous Studies

The extraction of civil registration records of Polish towns is quite popular. Indeed JRI-Poland (2019) devotes itself to making a database of extracts of such Jewish records publicly available. Most family historians are quite capable of charting their own family trees without difficulty using such data. However, in the general absence of surnames, use of the *pre-1826* records becomes intractable, and therefore these records are mostly ignored. Our work differs in that we conjecture surnames for that nebulous era so that those records too can become useful. It happens to be a non-trivial exercise; but we show here how to do it. One recent study published after a mass-extraction project is that of Jankowski (2015) and the International Institute for Jewish Genealogy (2015). This mostly concerned a sociological analysis of marriage and fertility patterns within and without distinct social classes in Piotrkow Trybunalski. However, the author seems to have not conjectured surnames for the very important pre-1826 era. The only other (non-JRI) study which has actually accomplished our mission, as far as we are aware, is the impressive database for Krakow (Hirschberg, 2018), under development for many years, which makes use of conjectured surnames for the period 1798 to 1825. However, nobody has yet published these techniques in academic circles.

(D) On the Nature of Civil Registry Records of Jews in Congress Poland and the Reliability of such Raw Data for Research

The records of Jews living in 19th century Poland are of three types:

(1) Prior to 1826 parish offices of many towns in Congress Poland kept records in books wherein there was usually no separation between Jews and non-Jews. Without separate lists and in the absence of the systematic usage of surnames, care is required to identify Jews. Some Polish given names are Biblical in origin and one might erroneously identify them as Jewish. Jewish records, though, can usually (but not always) be recognized by the Hebrew signatures of witnesses at the end of the document, and by the phrase "follower of the Old Testament" after the declarant's name. Pinczow's Jewish records are exceptional since, although in the same books as Catholic records, officials listed them in separate sections.
(2) After 1826 civil registrars kept records of Jews in books which were separate from those of the general Catholic population. The clerks often (but not always) indexed them at the end of each volume or year. One stylistic change after 1826 is the absence of recorded house numbers.
(3) Starting in mid-1868, after a failed Polish rebellion against Russian rule, clerks wrote the records in the Russian language and in Cyrillic script.

At least in Congress Poland, before 1826 the use of surnames, although apparently required after 1821, was not common. After 1821, Jews began to adopt surnames in keeping with the law, but in some towns the transition period dragged on sometimes for as long as ten years or longer. We note that

(1) When the transition period lasted a long time, patronyms and surnames were often interchangeable for many years before a surname finally "stuck". In some cases, families adopted patronyms as official surnames.
(2) It also often happened that a young male might choose a surname which was entirely different from what his father or his brother(s) chose. Except for references to towns of origin or to professions, or to an honorific acronym, or to intermarriage with a famous Rabbinic family which already carried an ancient surname, there was no obvious reason for the choices of invented surnames. Sometimes sons even chose their mother's maiden names as their own surnames. On rare occasions, families invented a brand-new surname a few years later to replace the first choice.
(3) Clerical errors often abounded (spelling, confusion between father and declarant, house number slightly off, etc.)
(4) People sometimes had double given names. In the records they might appear with one or the other or both, and one has to be prepared for inconsistent usage. For example, sometimes a man might appear with the name Moszek, another time with the name Jakob, and other times with the full name Moszek Jakob. Of course, one has to be sure that the second name is not simply a form of patronymic following the German-language tradition. Hebrew signatures, if available, help to untangle this issue.

(5) People sometimes used nicknames, and one has to be prepared to recognize them as belonging to the same person. For example, Leyb, Leybusz, Lewek are interchangeable. The Hebrew version adds yet another option. For the same example, Yehuda (or Juda) Leib is also interchangeable with the above. "*Kinnuim*" can also add to the mix. For example, Aryeh is the Hebrew *kinnui* for the Yiddish form, Leib, but some used it as a unique given name.
(6) Patronyms sometimes reflected the names of the fathers, and sometimes the names of the grandfathers of the subject of the record, depending on how the declarants perceived questioning by the clerk – e.g., was it the patronym of the child or that of the father?
(7) Although women's patronyms follow the simple grammatical rule of "owa" = wife of; and "owna" = daughter of, it often happened that a clerk would refer to a particular woman as daughter of "x" at the birth of one child, the daughter of "y" at the birth of her next child, and the daughter of "z" at the birth of yet another child. x, y, and z were sometimes her real father, grandfather or even husband's father depending on the whim or memory of the person making the declaration to the clerk.
(8) Widowed heads of households often married more than once. Thus, some children in the family might have one mother, while others would have a different mother. And in some cases, a young orphaned child might never have known his or her real mother, and would get used to identifying the stepmother as the mother.
(9) Declared ages were rarely accurate, and often drifted further and further from the truth, the older the people became. Inconsistencies as large as 10 years were not uncommon.
(10) Poor clerical handwriting can lead to errors of interpretation by the modern researcher.

Stroweis (2011) has reviewed many of these sources of error or uncertainty.

Methodology for Conjecturing Surnames

The following is a glossary of the words used in this study:

B,M,D	birth, marriage, and death
Akta	file number
Micro-tree	a family tree for a small group containing father, mother and children, and possibly with siblings and their children, etc, and possibly grandparents – *all living in the same house*.
Mini-tree	a family tree for an extended group containing several related households not necessarily living in the same house.
Patronym	An apparent surname based on the given name of the subject's father or, if it is more than one generation old, then based on the given name of the grandfather.

Although we entered all the data into a computerized and searchable database, and although we attempted to standardize variant spellings of names, it was not possible to automate the entire procedure. Human intervention is required because of the need for visual inspection of

charts of micro-trees in order to match with other charts and with those generated for the post-1826 era. In addition, one of our procedural tools is to inspect the names of *couples* (as opposed to those of single people) for additional matching, especially if the families spread to adjacent houses. Prior to this work nobody ever attempted to take advantage of the unique information available in pairs of given names, as far as we are aware. By its nature, however, it prevents a fully automated computerized mapping, especially since the mapping must be done in the context of an extended family group. The following procedure for conjecturing surnames is as objective as one can expect to make it.

Given the multiple sources of confusion described above, we have to be a little (but not too) flexible when conjecturing surnames from large bodies of data containing some variability. We have to develop objective rules. The general principle used in this work is that a family should be assigned a surname only if there is a match between it and a surnamed family on at least three major counts – same house number (if pre-1826 data are compared), same parents, agreement between patronyms and the given names of parents, identical occupations, and very similar years of birth. A surname is assigned, recorded in a prominent colour, say red, and placed in square brackets if there are three or more positive counts. With only two counts and some other partially supporting evidence (e.g. extra information from Hebrew signatures or from witness identity), the square bracket is accompanied by a question mark. For less than two additional counts, it is too risky to assign a surname, unless agreement is supported by evidence from a third generation (later or earlier) or by a Hebrew signature, etc.

In order to successfully link patronymic era records to those of surnamed families it is important to use all of the *post*-1826 B, M, D records in order to chart the family trees of *all* families in town and to search for matches to earlier records. This might seem like overkill if one is only interested in one or two families. However, since we are interested in identifying *all* people in the patronymic era, we are left with no choice. At the very least, this allows us to distinguish between different families with virtually identical name and age characteristics, and thus to reduce the level of ambiguity.

In the following section we describe the steps used in the process, and we illustrate them with the data for particular family groups. We have also arbitrarily chosen the HOROWICZ family to show the net result of all steps.

(a) The first step in the procedure is to create a spreadsheet (in order of Akta #s i.e., in chronological order) giving, in separate columns, the following items: family surnames, followed by given names, parents' names, professions, and house numbers. (Usually the marriage records will not have house numbers, but they will have the names of the towns of origin.) We include all additional data, including the names of witnesses and their relationship to the family, if any, as well as any peculiar information. For the patronymic era we use the clerk's spelling of the surname as recorded in the registry index. In those cases where there is no index we use the "surname" as recorded in the body of the text. As a modification we add columns with standardized surnames and given names in order to facilitate comparisons (either visual or computer-searched). Some of these entries will have true surnames, as opposed to patronyms. These surnamed records form the raw database from which to conjecture surnames in pre-1826 records.

(b) Next, we use post- and pre-1826 records in order to make charts of families *having surnames*, including house #s where possible. (It is very rare to find house numbers in post-1826 records). These are surname charts and could include many groups using that surname whether or not related to each other.

(c) We then re-order the B, D lists from the patronymic era, each in order of house #s. Our example from house # 13 is shown in Figure 3. Clearly, we have been able to conjecture seven surnames based on the principles listed above. Furthermore, even though there were five family groups associated with house # 13 (HOROWICZ, SAFRAN, MIERNIK, WAJS, and EJBUSZYC) we have shown that at least two of them were related by marriage. This was not uncommon in Pinczow, since the brides' parents often supported young married couples in the existing homes for a fixed number of years during which time the grooms, especially from Rabbinical families, advanced their scholarly activities.

(d) Next, for each house # we make micro-trees of each family group using the combined B, D lists, on a single page if possible, in order to facilitate visual inspection, all the while conjecturing surnames for those parents who are sometimes identified by patronyms, and sometimes by surnames, adding those conjectures to the B, D lists (in square brackets). We also take advantage of additional information like Hebrew signatures or declared relationships of witnesses.

(e) We then re-order the B, D lists according to surnames in order to discover if members of any given family (who used surnames) might have moved around from house to house, perhaps to neighboring ones.[63] This re-ordering ties multiple micro-trees together and sometimes identifies more surnames by inspection. Thus, we see that some members of the same HOROWICZ family described above also appeared in house numbers 11, 12, and 14. By inspection and by comparison with the families from house # 13 we can deduce four additional HOROWICZ names and relationships, and we have added them to Figure 3.

(f) In the next stage we use the micro-trees in order to identify *couples* born ca 1780-1810 who might have married in the time period, 1810-1825. We search for them in the M list and, when we find them, we conjecture surnames. Conversely, using surnames found in the M list we can augment the B, D lists. Thus, we find marriage records for our example, shown in Figure 4 below:

[63] House numbers were not street addresses like those in modern cities, and they were not physically affixed to the buildings. A house number was merely an administrative device and could easily drift in people's minds even if there were no real move. Consecutively numbered houses were not necessarily neighboring houses. The town could have assigned the numbers in chronological order of construction. Consequently, they might even be at two ends of the city. However, if a large family outgrew its quarters, then it might be tempted to purchase or to rent the neighboring house, especially since parents would often support newlyweds while housing the displaced family members nearby. So it makes more sense that similar numbers really meant either the same living complex but numerically confused, or else they were truly neighboring houses. Therefore, it is worthwhile paying particular attention to houses having nearly identical numbers.

Figure 3

Records of Births and Deaths for Occupants of House # 13 in Pinczow in the Patronymic Era (1810-1825)

Year	Type	House #	Akta #	Surname	Patronym	Given Name	Age	Father	Occupation	Mother	Notes
1812	B	**13**	26	[HOROWICZ]		Herszel		Josek Mortl	plotniarz	Hai Abraamow (22)	
1812	B	**13**	80	MIERNIK		Hajm Jonas		Haim (50)	przekupniarz	Bayla Szmulow (28)	
1813	B	**13**	60	WAYS		Josek Berek		Szulim (Maier) (40)	targownik	Anna Leybusiow (26)	
1815	B	**13**	34	HOROWICZ		Izrael		Josef Dawid (34)	plotniarz	Haia Lewkow (30)	signed: Abraham HOROWICZ (54) duchowny
1816	B	**13**	1	HOROWICZ		Gittl		Berek (29)	kramarz	Bayla Abramow (24)	
1818	B	**13**	103	HOROWICZ		Michel Meyer		Josek (32)	bakalarz	Haia Sara Lewkow (28)	
1819	B	**13**	33	HOROWICZ		Taubele		Abram Mordka (57)	duchowny	Fayga Mortkow (30)	
1819	B	**13**	73	[HOROWICZ]	Jakubowicz	Sara Frumet		Berek (32)	handlarz	Baila Abramow (28)	witnesses: Abram Mordka HOROWICZ and his son Josek
1821	B	**13**	2	[HOROWICZ]	Jakubowicz	Wolf Majer		(H) Berl Yakov (28)	handlarz	Baila CHOROWICZ (23)	witness: Abraham HOROWICZ (50) duchowny & Josek Dawid HOROWICZ (35) handlarz
1821	B	**13**	60	HOROWICZ		Hawa Ester		Abraham (55)	duchowny	Faygele Mortkow (24)	
1823	B	**13**	38	HOROWICZ		Izrael Maier		Abraham (62)	duchowny	Fayga Herckow (36)	witnesses: Josek HOROWICZ (38), Boruch HOROWICZ (30)
1824	B	**13**	37	[SAFRAN]	Heyzykowna	Hinda Sara		(H) Eyzyk b Sender (22)		Gittl Abramow (20) HOROWICZ	
1824	B	**13**	73	[HOROWICZ]	Abrahamowicz	Haim		Abraham HOROWICZ (57)	duchowny	Fayga Mortkow (36)	witnesses: Abraham Mordechai HOROWICZ (63), Josek HOROWICZ (38); Abraham was the Chassidic Rebbe of Pinczow; Eyzyk later became the Chassidic Rebbe of Komarno.
1824	B	**13**	136	[LELOWSKI - EJBUSZYC]	Heyzykowicz	Abraham Mendel		Eyzyk Eliaszowicz TARNOWSKI (22)	handlarz	Hana Zysl Izraelow (30)	witnesses: (H) Yonatan b Moshe (40) handlarz; Natan b Moshe (45)
1825	B	**13**	143	[SAFRAN]	Heyzykowicz	Abraham Mortka		(H) Eyzyk b Sender (23)	wyrobnik	Gittl Abramow (20) HOROWICZ	witnesses: Dawid HOROWICZ (38), Boruch HOROWICZ (32)
1813	D	**13**	73	HOROWICZ		Malka	3 1/2	Josek	handlarz	Hai	
1814	D	**13**	34		Dawidowa	Frumet (widow)	68	Berek			
1817	D	**13**	21	HOROWICZ		Ryfka Rochl	28	Zelman			husband = Abraham (duchowny)
1819	D	**13**	78	HOROWICZ		Taubele	7 mos	Abraham Mordka	duchowny	Fayga z Morkow	
1823	D	**13**	73	HOROWICZ		Izrael Majer	2 wks	Abraham (62)	duchowny	Fayge z Mortkow	
1825	B	**11**	95	HOROWICZ		Abraham Mortka		Ber (35)	drobny handlarz	Bayla Abramow (27)	
1821	B	**12**	19	HOROWICZ		Judes Fremet		(H) Yosef David (35)	plotniarz	Haia Sara Lewkow (26)	
1814	B	**14**	27	[HOROWICZ] ?	Wolfowna	Ryfka Ester		Abraham (41) b (H) Zev [Wolf]	wyrobnik	Gitla Herszelow (36)	
1816	B	**14**	64	[HOROWICZ]	Abrahamowicz	Jankel Jcyk		Josek (60) b (H) Abraham	duchowny	Haja Sara Leybuszow (30)	
1823	B	**14**	65	CHOROWICZ		Dawid Izaak & Perl Marya		(H) Berek (38)	handlarz	Bayla Abrahamow (26) [HOROWICZ]	
1823	B	**14**	96	CHOROWICZ		Perla		(H) Yosef (39)	handlarz	Haia Sara Lewkow (32)	
1825	D	**11**	2	[HOROWICZ]	Berkowna	Perl Marya	1 1/4	Berek HOROWICZ (30)	drobny handlarz	Bayla z Abrahamow	
1822	D	**14**	24	[HOROWICZ]	Wolfowiczowna	Ryfka Ester	7 1/2	Abraham Wolfowicz (handlarz)		Gitl z Herszlow	

Figure 4
Marriage Records with Conjectured Surnames for the HOROWICZ Family

Year	Akta	Surname	Patronym	Given Name	Father, occupation	Mother	Town, notes
1822	7	[SAFRAN]	Senderowicz	Eyzyk (20)	(H) Sender Eyzyk, handlarz	Rochl Kopelow	Chmielnik
	7	[HOROWICZ]	Abrahamo-wiczowna	Gitla (19)	Abraham Mortka HOROWICZ, duchowny	Hindy Dawidow	Pinczow
1818	1	HOROWICZ		Abram Mordka (60) duchowny widower	Wolf, handlarz	Sara Icykow	son = Josek HOROWICZ (37) duchowny; witness Moszek LEDERMAN (38) kupiec
	1	[LEDERMAN]	Berkowa	Frayndl (30) widow	Mordka LEDERMAN, dead handlarz	Klerl Wolfow	widow of Icyk [Ber] WOLBROMSKI from Wolbrom

Abram Mordka HOROWICZ is identified as a clergyman, and he is, in fact, none other than Avraham Mordechai HOROWICZ, the Admor[64] of Pinczow. It is known that he had a son-in-law named Eyzyk SAFRAN, the son of Alexander Sender, the Admor of Chmielnik. Eyzyk himself would later become the Admor of Komarno. Although this marriage (#7) is known from Rabbinic sources without the aid of our technique, marriage # 1 was not previously known. This turns out to be an extremely fruitful exercise in general, as we can see from the relatively large number of conjectured names in the final marriage (M) file. Unrelated to our HOROWICZ example, we illustrate here again, in Figure 5 below, the power of the technique by showing a sample of several consecutive extracted marriage records:

Figure 5
Sample of Extracted Marriage Records with Conjectured Surnames

Year	Akta	Surname	Patronym	Given name (age)	Father	Mother	Notes or witnesses
1811	1		Joskewicz	Hajm (24)	Josek	Malka Izraelow	witness: (Hebrew) Yeshayele b Yosef
		[KANTOREK]	Jakubowiczowna	Haja (20)	Jakob (dead)	Baila Haimow	brother = Symcha KANTOREK
1811	2	[SZWICER]	Mozeszow	Izrael Fiszel (22)	Zelig Pinkes	Szewy Moskow	witness: (Hebrew) Zelig b Pinchas
		[KANTOR]	Joskowna	Etl (20)	Joska KANTOR	Jachet Moskow	
1811	3		Josek	Herszel (24)	Josek	Ester Nechow	
		[LANDAU] ?	Josefow	Sara (20)		Hana Joskow	
1811	4	[WOLBROMSKI]	Lewkowicz	Moszek (34)	Lewek WOLBROMSKI	Gittl Moszkow	
		[KATZ-RAPPOPORT] ?	Dawidowicz	Perl (26) widow	[Dawid Ber Abele]		Perl = widow of Moszek; parents dead

[64] Admor is a Hebrew-language acronym for **A**doneinu **M**oreinu **V**e **R**abeinu, i.e., "our master, teacher and Rabbi." This is an honorific title given to the leader of a Chassidic court typically with many followers.

(g) We use the augmented B, D lists to create a master index in an spreadsheet with 4 columns: A) House #; B) Surnames including conjectured ones in square brackets (leaving a blank if there is no real surname); C) First names of couples born between 1780 and 1800 who would be having children during 1810-1825; and D) First names of couples who were parents (born before 1780) of couples who were having children during 1810-1825. We include couples from the M list (who apparently were not having children in Pinczow), at the end of the index, and give lettered symbols to houses in which they were living. (But we double-check to see if these couples appear somewhere on the B, D lists and were somehow missed.) Sometimes this process alone identifies some additional surnames.

(h) We then re-order the main index according to column C (followed by house #) and identify similarly named couples where there is agreement on two more counts (living in the same house, having the same ages and profession, etc.), thereby linking more micro-trees together, and in this way conjecture additional surnames. We add these surnames to all micro-trees involved as well as to the master index and to the house-#-ordered B, D lists and to the M list.

For example, an 1825 marriage record lists the bride, Ryfka (born 1802), as the daughter of Abram Moszkowicz and Haja Lewkowicz. Because it is a marriage record the clerk did not record the house number. Thus, it seems like one would never be able to identify the bride's parents. (The groom was not from Pinczow). However, by visual scanning of the list, re-ordered according to *couples* (in this case the bride's parents), we see only a single other patronymic era couple by the name Abram and Haja (also without surnames) of the appropriate ages. They lived in houses # 257 and 258. We had already independently conjectured their surnames. Abram was a TENENBAUM, while Haja was a CHYMBERSKI. The births of many of the children of Abram and Haja occurred in house # 257. Ryfka was not among them; but that is to be expected, since she was born too early (1802) for any clerk to have recorded her birth. Unfortunately, in house 257 Abram was the Lewkowicz, while Haja was the Moszkowicz. So it appears that the clerk switched the bride's and groom's patronyms while writing the 1825 record. As mentioned in the introduction, these kinds of clerical errors occurred occasionally; so we are not totally surprised. Nevertheless, we can address the lingering doubt by tracking and confirming the identity of the couple in the post-1826 records.

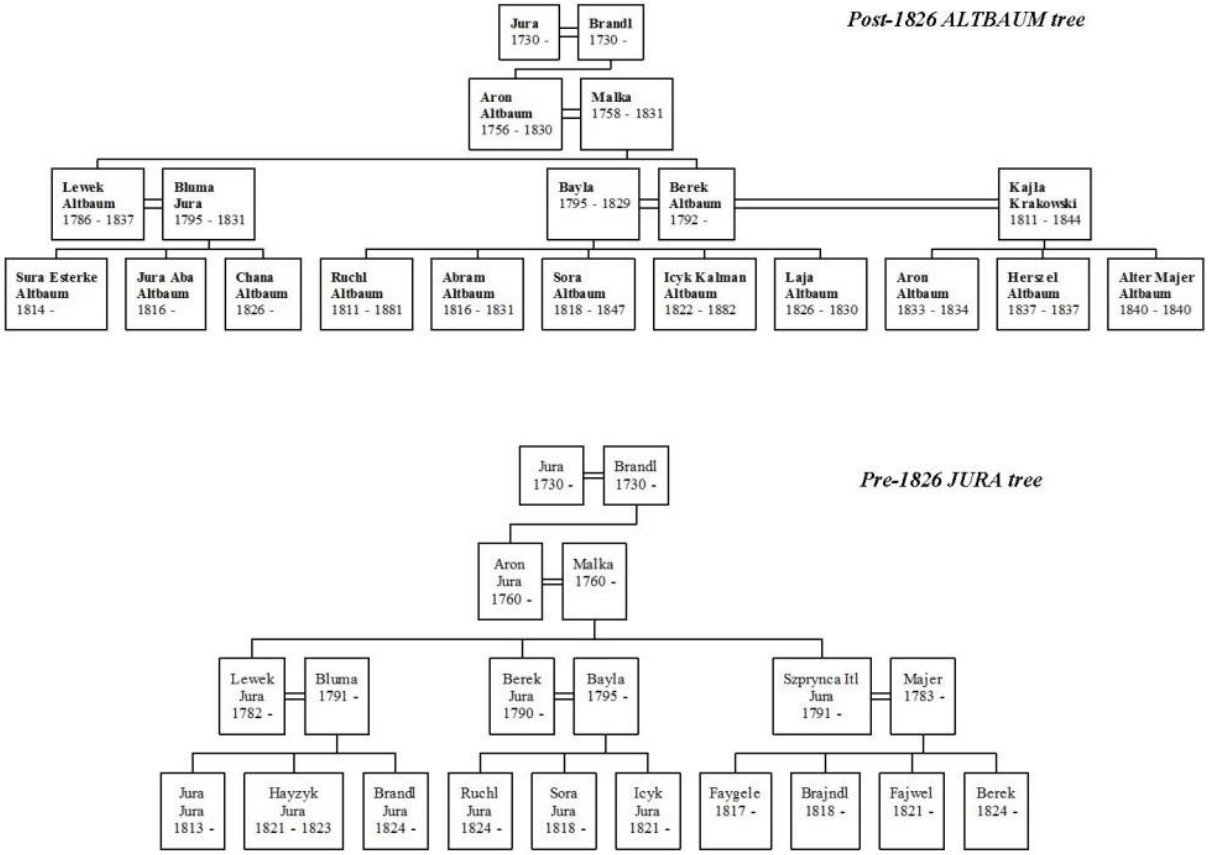
(i) We then re-order the index according to column D (followed by house #) and identify similarly named *elderly couples* agreeing on two more counts (e.g. living in the same house, having the same ages and professions, etc.), thereby linking yet more micro-trees together, and in this way conjecture even more surnames. We add these surnames to the micro-trees and to the master index, and to the house-#-ordered B, D lists, and to the M list.

For example, the 1814 marriage record of Laja Cypa (born 1792) reveals her parents to be Juda Lewek and Hana Szmulowna. We search through our list of aged couples and find exactly the same aged couple listed as parents of Brajndl (born 1802) who married in 1823. Thus, we are able to link their respective micro-trees. Now, it turns out that Laja Cypa was living in the same house as Haskel KAM who was a witness to the 1822 death of his paternal uncle, Juda Lewek. Thus, we are able to not only link two micro-trees, but at the same time conjecture a surname for Juda Lewek (KAM), born in 1755.

(j) We then re-order the improved master index according to surnames (this time including conjectures), and we use this to draw extended mini-trees. We also draw separate mini-trees of those groups for which we have not yet assigned surnames.

(k) 1. We now directly map by overlapping the extended mini-trees into the post-1826 trees (which we had charted as a preliminary step) if both sets have surnames. Cross referencing the pre-1826 mini-trees with the post-1826 family trees identifies more individuals, and reveals yet more surnames in the main trees as well as in the mini-trees. As an interesting example we show, in Figure 6, the same family group as revealed by each set of data. Prior to 1826 the entire family was using the surname JURA exclusively. Although it appears that the surname owes its origin to a certain Jura who was born ca 1730, his descendants used Jura as a real surname for many generations thereafter. However, immediately after 1826 two out of a dozen branches of the family suddenly switched the surname to ALTBAUM for no apparent reason. Without our investigation it would probably have never dawned on researchers that ALTBAUM was really a branch of the JURA family.

Figure 6
One Portion of the JURA – ALTBAUM Family of Pinczow from 1730 to 1840



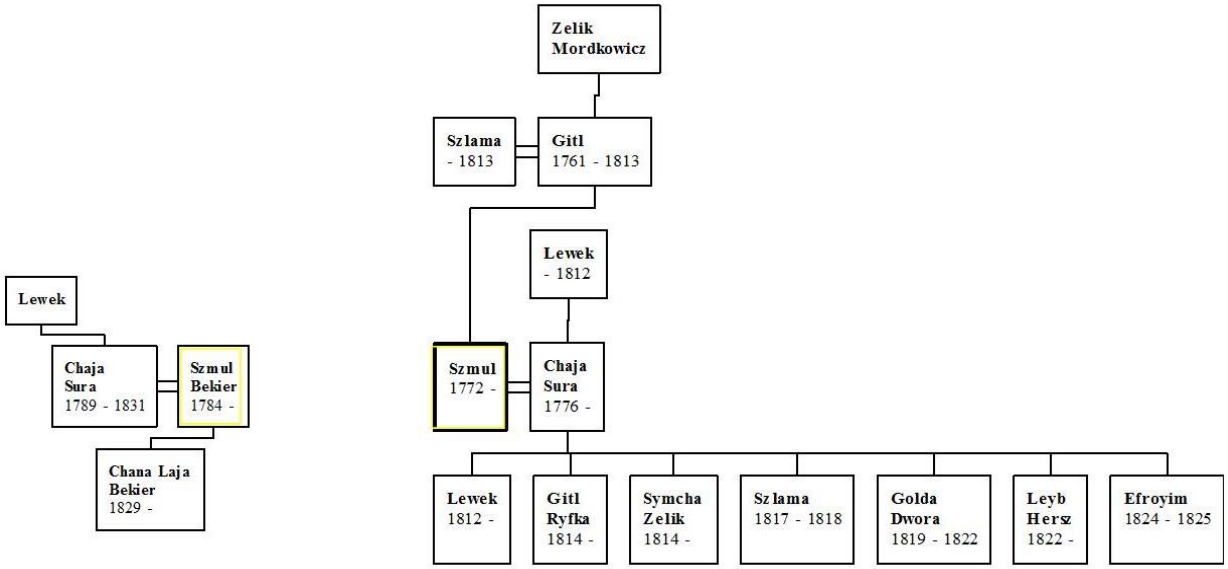
(k) 2. We then compare mini-trees still *without* conjectured surnames to appropriate people on the post-1826 charts, using older couples' names as a guide for cross-referencing, thus adding more conjectures. Similarly, we find elderly couples on the post-1826 family trees who are unidentified by surname and compare them with elderly couples on the mini-trees who do have surnames, thus adding even more conjectures. As an example, we display the results for one particular BEKIER family in Figure 7. Szmul BEKIER was an "agent' by profession, but he appears to have adopted the surname because his father was a baker by profession. *Bekker* in

Yiddish or German means *baker*.

Considering that ages were often approximate, the existence of a single Szmul / Chaja Sura pair in Pinczow in the relevant time period makes the one-to-one mapping fairly certain, and adds a conjectured surname to the ten pre-1826 events.

Figure 7

Comparison of the Szmul / Chaja Sura Family Group with the BEKIER Family in pre-1826 Pinczow



Post-1826 tree of BEKIER family

Pre-1826 tree of Szmul / Chaja family using patronyms

Mapping of early family trees, such as in the above two cases, onto the family trees of post-1826 records on a large and comprehensive scale, when there is a partial lack of surnames, relies on two principles: a) the matching of given names of ***couples*** in both sets along with other identifying features; and b) the finding of the births, marriages and deaths in the pre-1826 records of people mentioned in the post-1826 records. Nobody has ever systematically used couples' given names before this study, as far as we are aware. One might think that there is a danger of misidentification if there were to be more than one elderly couple having the exact same set of given names. While this does happen occasionally, it turns out to be rare and, since not every aspect of their family structures can be absolutely identical, it turns out that we never had a conflict, although we could not know this for certain without trying. We matched all relevant post-1826 surnames successfully, and there was no case of more than one patronymic era family "claiming" the same surname. Nor were there any residual pre-1826 families who could not post-facto "adopt" a surname, except for those who moved away from Pinczow, or whose family died out, or who had only daughters using their husbands' surnames, or who decided to turn their patronyms into surnames. Ours is a technique that one simply had to attempt, and fortunately it succeeded. In retrospect, one might think that this success has much to

do with the size of the town, since the limited numbers of given names in the Jewish population would be conducive to repeated use of couples' names, leading to ambiguity.

On the other hand, the larger the city, the greater the number of identifiable and unique house numbers, and this more than compensates for the commonality of given names. Therefore, it turns out, that conjecturing of surnames in the large city of Krakow is remarkably successful also (Hirschberg, 2018).

We illustrate the last stage of the technique, as described in paragraph (k) above, with one last example out of many, many cases in point, chosen to demonstrate that, without our technique, we would not have otherwise noticed the existence of a particular Rabbinic family: At the death of a certain Tewel GOLDFARB (1758-1830) the clerk recorded Tewel as the son of Icyk and Malka. The clerk listed Tewel's surviving wife as Perl. A search of our mini-trees for couples with the *unique* combination of Tewel and Perl reveals the existence of such a couple in the patronymic era, whose surname can now be conjectured. At Perl's death, also in 1830, the clerk listed her as the daughter of Gabryel and Bayla RABINOSTWA, suggesting a Rabbinic origin. Thus, it is not surprising that Tewel and Perl had a daughter, Malka, probably named after her paternal grandmother, who was married to Abram Mendel EJBUSZYC (1798-1823) who was the son of the Rabbi of Pacanow. The latter used the toponym, LELOWSKI-WADISLAWSKI, suggesting a multi-town career. Tewel and Perl also had a son, Saul, living in Chmielnik, but who died in Pinczow in 1823. (He had no surname; but we can now assign it, obviously). Saul married in Chmielnik in 1814 to the daughter of the Rabbi of Chmielnik, Dov Ber (no surname)[65]; but we believe we can determine his identity[66], as there are only two possible known candidates: Clearly, there is a lot of interesting history that we need to flesh out here.

(l) Ultimately, we re-ordered the improved B, D lists according to chronological order for presentation. In the end, we were able to extend any given family history typically by up to 2 generations by using our mapping and surname-conjecturing techniques.

Results

We illustrate the result of all twelve stages of our method in the chart for our HOROWICZ family, shown in Figure 8, below. This is a fusion of the post-1826 data (generally characterized by actual surnames) and the pre-1826 data augmented by conjectured surnames. We have shown in red those persons and events, whose existence or links we would not have otherwise easily deduced in the absence of our conjecturing process. An additional two generations thus have become accessible stretching back to about 1710 in this case.

There are several interesting facts which our sample analysis reveals:

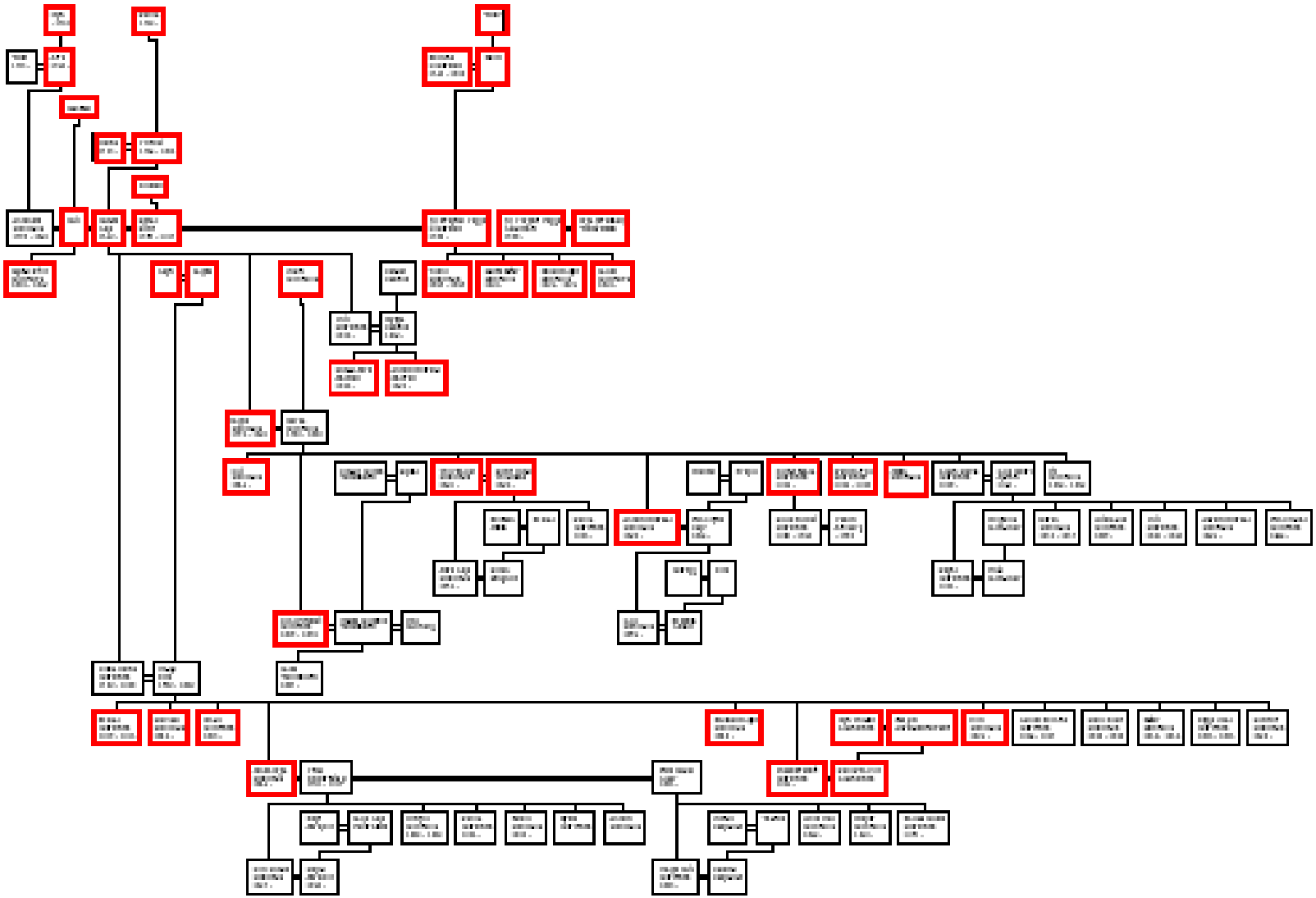
(a) The Admor, Avraham Mordechai HOROWICZ (non-Levite), seems to have married at least four times. His brides were Hinda Laja bat Dawid (died between 1803 and about 1809); Gitl bat Herszel (died between 1814 and 1817); Ryfka Rochl bat Zelman (died 1817); and Fraydl Fayga bat Mordechai LEDERMAN (died after 1824). This is probably the first time that anyone has ever revealed matrimonial details for this well-known Rabbi.

[65] The 1814 marriage record (Akta # 20) is not available at the Polish State Archives. It is in private hands but made available to the author for scholarly purposes.

[66] Manuscript in the process of preparation.

Figure 8

Ancestors and Descendants of Avraham Mordechai Horowitz, Ad · Pinczow (1758-1824)



(b) Avraham Mordechai HOROWICZ's paternal ancestry is known from Rabbinic sources (Horowitz, 1931).[67] His father was Zev Wolf MARGOLIS, Av Beit Din of Zarnowiec and Wolbrom (Horowitz, 1931; HebrewBooks, 2019). This MARGOLIS family is not Levitical. It stretches back to Menachem Mendel MARGOLIS (ca 1575-1652) of Przemysl and Pinczow and beyond. Avraham's brother and uncles kept the surname MARGOLIS. This raises the question of why Avraham Mordechai adopted the surname HOROWICZ? No one has ever solved this mystery, and perhaps not even posed the query in the first place. Furthermore, it is probably not by chance that one of Avraham Mordechai HOROWICZ's daughters married Berek HOROWICZ (a true Levite, and possibly her cousin. We know that Berek was a Levite because one of his sons, [Jakob] Herszel, signed a record in Hebrew stating as much.) It appears to the present author that Avraham Mordechai may have adopted his mother's maiden name sometime after 1814, prior to which he was content to use the patronym Wolfow (son of Wolf). There is no other logical explanation. The record of his last marriage in 1818 reveals that his mother was Sara, the daughter of Icyk. If Icyk (born ca 1710) was the true Levitical HOROWICZ, then one good candidate for his identity is the famous Rabbi of Hamburg, Yitzchak (HaLevi) HOROWICZ, who was born in 1715. He did indeed have a daughter Sara (though not married to a Wolf MARGOLIS (Rosenstein, 1976)[68]); so, our speculation might be wrong; but it is a good working hypothesis, and it is worth investigating if Sara was married more than once. It is also worth checking if there was more than one contemporary Rabbinic Yitzchak HaLevi HOROWICZ. In any case, the identities of Sara and of Berek ben Yakov HOROWICZ, are worthy of further study.

(c) Avraham Mordechai's first wife, Hinda Laja, was the daughter of Dawid and Frumet. Indeed, Avraham Mordechai's mother-in-law, Frumet, seems to have died in his house # 13. The chances are very high that Dawid and Frumet were from Rabbinical families; and this too is worthy of further investigation. The chances are also high that Avraham Mordechai settled in his wife's hometown in the first place, and that Dawid himself might have resided in Pinczow, perhaps as an early Rabbi, on whose identity we can now easily speculate using the Pinczow data at hand.

(d) Statistics. All in all, the history of this single, fascinating and prominent family is significantly augmented – all because of our analysis of patronymic records. We have dwelled on this particular family for the purpose of illustration; however, we have actually analyzed all 2,901 events recorded during the patronymic era, 1810-1825. Most of them had no surnames originally. However, in the end, we were able to conjecture surnames for 2,432 of them, that is, our overall success rate was 86.6%. Most of our "failures" were for deaths of the elderly who died without spouses or relatives; and, therefore, we were unable to put them into context. The success rates for births and marriages were 90.7% and 90.0% respectively. The remaining events are for families who must have retained patronyms as their permanent surnames.

[67] Meir Horowicz of Kielce was born in 1868. He was the great-grandson of Avraham Mordechai (see Fig. 8). His work, *Pa'aneach Raza*, states that Avraham Mordechai was supposedly named posthumously after his father, an earlier Avraham Mordechai; and it also states that the daughter who married Eyzyk SAFRIN was named Liba. Neither of those two assertions are borne out by the civil registry records analyzed in our study. On the other hand, considering the possible sources of error listed above, Abram Mordka's patronym, i.e. Wolfow, may very well refer to the young orphan's grandfather, who would clearly be the only father-figure he ever knew. Also, we cannot rule out that Avraham Mordechai's daughter's full name could have been Liba Gitl.

[68] Rosenstein, N. (1976) *The unbroken chain* (1st ed.) p. 561. NY: Shengold Publ.

Within the set of 24,323 *post*-1826 records there are 1,901 unique family surnames cumulatively by 1912. In addition, within the set of 2,901 *pre*-1826 records we determined 293 patronymic era family surnames. However, 107 of those family names were there to start with and do not appear in the post-1826 database. Those extra families appear to have died out by 1826, or had only daughters who adopted their husbands' surnames, or else moved away prior to 1826. So altogether there were 1,901 + 107 = 2,008 uniquely surnamed Jewish families who ever lived in Pinczow by 1912. We also determined that by 1830 (the beginning of the "November revolution" against Czar Nicholas I) there had already been 446 uniquely named families; while by 1825 there were only 293[69], as stated above. Although not a measure of population *per se*, this nevertheless indicates an explosive growth of a factor of 7 in surnamed families in a period of less than 100 years.

Discussion and Questions

Accuracy, Sensitivity Analysis, Redundancy, Reliability, and Self-Consistency

The method described in this study reflects the brute force approach using objective criteria for matching edges of the puzzle pieces. Because the number of criteria is somewhat arbitrary, there are two questions which one can pose: how reliable are the results as they now stand; and what is the effect of more restrictive criteria on the quality or quantity of the conjectures? One can try to estimate such issues by applying one or more of the following scientific approaches[70]:

(1) Compare the results of the present analysis with those obtained from other sources, such as family archives, cemetery records, and censuses; or

(2) Repeat the approach and determine the error rate as a function of the percentage of records randomly removed from the database; or

(3) Repeat the approach, as above in (ii), but modify records randomly in order to induce failure, and thus determine if the error rate is proportional to the number of modifications or if this simply reduces the ability to conjecture at all; or

(4) Repeat the approach, as above, but vary the number of matching criteria or the magnitude of, e.g., the precision of birth years.

We have addressed these issues, as follows:

(1) World War II saw the destruction of the Jewish cemetery of Pinczow. The ancient cemetery of Krakow is extant. However, even there, surviving headstones dating to the patronymic era rarely, if ever, mention surnames, anyway. Only in rare cases can

[69] We have associated 293 family surnames with 2,432 events (out of 2,901) recorded in the time span, 1810 to 1825. If we make a 1:1 correlation between the number of family surnames and the number of events, then we can deduce approximately that there was a total of 349 unique families, 56 of whom had surnames.

[70] The author is grateful to a reviewer of this study for suggesting the proposed strategies.

they reduce uncertainty by adding puzzle pieces, such as priestly or Levitical status. Thus, for example we could, in principle, distinguish between HOROWITZes who were Levitical from those who were not. Unfortunately, we cannot take advantage of this approach for Pinczow.

The 1798 census for Pinczow (Kielce Archives) lists names which were almost 100% patronymic, and it lists only the heads of households. House numbers, presumably the same as those found in the patronymic era parish records, are indeed listed; but ages of the owners are missing. Consequently, the census is not at all helpful in determining the reliability of the present approach. In fact, as the Krakow study shows, where the aim was to conjecture surnames in the censuses, the other way around is actually more fruitful. Second, Rabbinic sources could, in principle, verify the accuracy of the present results. However, it is ironically the opposite which is true (Wunder, 1995). For example, Figure 8, above, shows that the present analysis **extends** what is already known about the HOROWITZ family. Although not applicable to the HOROWITZ case, **rare** family archives can indeed be extremely helpful.[71]

(2) Removing records from the database, tantamount to removing pieces from a jigsaw puzzle, has one of two possible effects. If the record is from the surname era, then the result depends on the nature of the record. A missing birth record will not affect the conjecturing process for events that occurred one or two generations earlier. A marriage or death record which contains the names of people who lived during the patronymic era, is crucial data. Its absence could simply leave a person or a couple isolated, not allowing us to link them to any of several possible ancestors. We would have an un-placeable puzzle piece. A record missing from the patronymic era is more disastrous:[72] This has the potential effect of isolating an assembled group of many puzzle pieces. However, in no way does the intentional removal of a puzzle piece

[71] Two case studies illustrate this: 1. The family tradition as well as the headstone in Warsaw of a certain Jochanan FOGEL (a Cohen), son of Yeshaya and Faygl, proclaim that the family came from Pinczow. And yet, there are absolutely no records for FOGEL in Pinczow at any time period, nor are there any relevant KOHEN or KAC records nor even patronymic Szajewicz records to match. However, upon searching for *any* couple – Szaja married to Fajgl – we came across one and only one case in the time period in question using an unexpected surname GOLDSZLAK. The progenitor of the family was a goldsmith, Szaja GOLDSZLAK, married to Fajgl (daughter of Jakob). Their surname started being used during the time of compulsory surname adoption in Pinczow. The son, Jochenen, moved to Warsaw in 1824 for the sake of marriage, whereupon he adopted the new surname FOGEL presumably to commemorate his mother, Faygel. This allowed us retrospectively to increase the size of the puzzle and to conjecture an alias surname of GOLDSZLAK. 2. In the second case, a family of hatmakers, surnamed HALEVY, which immigrated to London in 1846, had the tradition of a Pinczow origin. There were no matching records, though. Nevertheless, the family archives provided enough information, in the form of given names for two critical generations, to allow us, with the aid of patronymic era records and conjectured surnames, to identify it as the ROTH - ROJT family of hatmakers and to amplify an edge of that family's puzzle. There were no ambiguities.

[72] In the above-mentioned ROJT family, without a key patronymic era death record of a certain Bluma (1753-1816) married to a Hersz Lewek, which we conjectured to be a ROTH, we would not be able to tie the heretofore earliest ancestor, the hatmaker Dawid Lejb (born in 1799), to Hersz Lewek (born 1753) son of Moszek (born ca 1725), or to Bluma daughter of Lewek and Rejla who was the daughter of Abraham (born ca 1700).

(record) reduce the accuracy of the reconstruction. It merely results in placing holes in the puzzle.

(3) Assuming that we are faithful to the application of our criteria for one-to-one matching, then modifying a patronymic era record in order to introduce errors has the effect of ruining a puzzle piece. We would place it in a wrong location without ever knowing that it is a wrong location, or else if it competed with another puzzle piece for fitting into a particular location it would render two pieces ambiguous, thus ruining two puzzle pieces, or else we would be unable to place the piece at all. There is no unique rule. Each case is different.

(4) The number three (minimum criteria) for acceptable one-to-one mapping is actually determined by trial and error. Relaxing the criteria has the effect of possibly linking a particular person to a wrong family. At the same time it could prevent us from linking him to the correct family. Two errors would occur, resulting in excessive ambiguity. On the other hand, being more restrictive by expecting matches to all seven variables – professions, house numbers, given names of parents, given names of spouses, patronyms, partial overlap of children`s names, and exact years of birth – is counterproductive and prevents any linkage at all. Occasionally, we are lucky, and all seven criteria are satisfied exactly, and we might even have extra information from a Hebrew signature or from a witness' professed relationship. But in general, we must allow for some flexibility since we know that families moved from time to time, a name could be part of a double name, a patronym could be that of a father or of a grandfather, people often forgot or estimated their age, clerks did not often mention names of relatives etc, aside from clerical errors. Too much rigour results in too many leftover puzzle pieces. Our choice of three is a compromise which resulted, by trial and error, in the minimum amount of ambiguity and the minimum number of excess puzzle pieces. We can reasonably interpret the final 10% missing conjectures as representing puzzle pieces which belong to another puzzle, that is we must search for their extended family in other towns. On the other hand, we can interpret completed puzzles displaying lakes of missing pieces as representing events for people who moved from Pinczow to a different town.

Summarizing the above issues, in this kind of a puzzle (family reconstruction), where there is only a single correct answer, the goal is to avoid ambiguity, and to maximize consistency. We believe that we have achieved this with our procedure.

Is this a Big Data Problem?

One might wish to solve jigsaw puzzles or genealogical puzzles by means of big data techniques (Márquez, 2017). However, we believe that ours is not a big data problem *per se*. Big data involves the continual generation of data which feedback on themselves and which grow at faster than exponential rates, without limit, such as phone-generated, credit-card-generated, or Internet-generated data. Businesses, in general, must collect and analyze their big data because the exercise leads to accurate projections. Of course, some type of business analysis software is required. However, the analysis of such big data results in an overall fuzzy image, with defined

priorities, perhaps revealing patterns (Arora, 2016; Pyne et al., 2016). Certainly, the only thing which can possibly matter is the current average and the trends, but not the detail. Analyzing DaVinci's painting, Mona Lisa, by aggregate techniques, for example, might reveal a level of beauty, but that painting too is not a big data problem because there is a finite, immutable number of molecules in the painting, and because one is interested not only in the overall effect, but also actually in details: we would probably like to know, for example, if a particular feature in the painting is a dimple or a pimple. So too, is our puzzle not really a big data problem. The working definition of "big" is petabyte-size, i.e. 10^{18} or greater. Although large numbers (30,000) of semi-structured puzzle pieces are involved, along with $10^{121,000}$ possible permutations, we are actually truly interested in the gory details of the "mere" 30,000 data pieces. Big data solution techniques, such as wavelet analysis (Teitelbaum, 2000), even though they may be good for pattern recognition, are therefore of not much use in such a case. Although, in principle, one can solve our problem by computer-aided permutations (Heule & Kullmann, 2017), i.e. by the brute force method, it is not truly feasible here, because a human is required to distinguish between ambiguous permutations, i.e. a human is more capable of filtering out the vast majority of the useless permutations, simply by observation. Realization of a solution sometimes simply involves guessing and verifying. Clearly, the human approach thus is also a brute force method; but by virtue of the filtering, the human's understanding of the context, and his ability to factor the problem into smaller pieces (family groups), the human brain is the better computer in this case.

Impact of the Trend toward DNA Testing

One might ask if DNA testing can aid in reconstructing family histories to the point where we can conjecture additional surnames. The answer is yes, in principle; but, the procedure is limited to the earliest documented record, even though vague relationships can point to earlier times. For precise identification, someone has to know his ancestry far enough back to the pre-patronymic era, while another party (who has hit a dead end in his paper trail research) has to take a DNA test as a fishing expedition. Careful comparison of the two known family histories can identify the common ancestor. At the same time, comparison with the resolved patronyms can identify the as-yet unconjectured surname.[73] For this to become a powerful tool, many people with roots in Pinczow must participate in DNA testing.

[73] As a case in point, two researchers (one ASPIS, the other RAYZ) with roots in Pinczow dating to at least as far back as 1750, each carried out an autosomal DNA test without being aware of the other's existence. Family Tree Finder Inc. determined that they were 3rd to 5th cousins with a substantial continuous block of common DNA segments. The same test applied to 2nd and 3rd cousins of one of the test subjects did not match with the results of a similar test for the second test subject. From this exercise we could eliminate many ancestral lines of the two test subjects as sources of the 3rd cousinhood. The single remaining relevant family lines led back, in each case, to two Icyk Ber Nochymowicz's living in Pinczow, each born ca. 1750. We determined one of them to be a RAYZ (by the methods described in this work.) Without a DNA analysis we would not have been able to unambiguously determine that both ancestors were one and the same person. Clearly, we also could conjecture the surname of the matched test subject. This case represents the limit of applicability. In most other cases, the best that DNA testing can accomplish is to give a statistical estimate of cousinhood without being able to identify the names of the most recent common ancestor.

Applicability to Other Cases

Pinczow is not the first Polish town`s genealogy where researchers used tactics similar to those described here: The family tree of the Jews of Krakow, under construction for more than 20 years by Dan Hirschberg (2018), is about six times the size of Pinczow`s. The present author was one of several original participants in developing the procedures for assigning surnames to Jews of Krakow prior to the general adoption of surnames. The present study describes and expands on that methodology. The success of both projects is proof that the size of the town is not important. One might think that with the limited number of given names and occupations, the risks are much higher for more than one couple to have exactly the same name combinations, ages and occupations, i.e., the risk of ambiguous results would be higher in larger towns. However, it turns out that the larger the town size, the larger the variety of surnames and the larger the number of houses (and thus house numbers) that can act as identifiers, and this latter fact apparently is sufficient to guarantee uniqueness.

Conclusions

We have developed a methodology for the conjecturing of surnames of Jews who were experiencing births, marriages and deaths in Pinczow, but who were not commonly known by their surnames. Although we have used the HOROWICZ family history, and a few others in part, as illustrations of the scope of the project, we have actually applied this technique to *all* of families living in Pinczow from ca 1700 to 1825. The surnames which we deduced are those that their descendants eventually adopted. By combining the patronymic era data (including conjectured surnames) with the post-1826 data, we are now poised to publish the entire genealogical history of the Jews of Pinczow, distributed among 2,008 families, over a 200-year period from ca 1700 to 1912, as a memorial to the decimated Jewish population of Pinczow.

We can apply the methodology shown in this project to other Jewish towns in pre-war Poland. Our success rate of 87% overall is a conservative estimate. The remaining 13% living in Pinczow between 1810 and 1825 consist of either male lines who might have died out (possibly leaving only daughters who adopted their husbands' surnames) or else males who moved to Pinczow in order to marry but settled down elsewhere,[74] or else males who could have simply solidified their then-current patronyms as actual surnames.

It is fairly obvious that the present study has generated a valuable database that now can be used to further our understanding of the culture and sociology of Ashkenazi Jews, at least in Poland. Aside from providing an increased ability to identify family relationships in a "dark" period of archival information, the present study now permits us to examine such issues as the frequency of Rabbinic intermarriages, the frequency of cousin marriages of any degree (whether Rabbinic or not) and uncle-niece marriages (permitted under Jewish law) etc. An examination of such issues requires us to have the entire town history presented in web-like format for easy identification of relationships. We are in the process of constructing this web-tree for Pinczow.

Our methodology also gives hope to researchers in other disciplines that, sometimes, the best method is brute force. It is, in our opinion, doubtful that a computer algorithm, even if properly instructed to follow the straightforward rules presented in this study, and even using soundex and fuzzy techniques, could replicate our success rate. All it could possibly accomplish

[74] Of course, we may bump into these people in the course of future research of other towns; and so their identities may yet be forthcoming.

is to replace a human eye (able to focus on multiple levels of detail simultaneously) with an overly critical digital processor. It would not surprise us, though, if the present work would spawn such a massive effort in data analytics, worthy of an independent study, with the goal of verifying our assessment.

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Discussion Questions

1. Can artificial intelligence be developed to the point where it would be capable of solving a jigsaw puzzle of at least 1,000 pieces without the aid of a picture?

2. Are there any historians currently studying the history of the Jews of Pinczow and who can contribute to the knowledge accumulated in the present study?

3. Have any readers with Pinczow Jewish ancestry undergone a full genome analysis which would be useful in determining to what extent Jews of Pinczow intermarried with each other in that town in the 19th century?

4. Can one develop a computer program which displays the results of our research using a multi-dimensional web application in graphical format?

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