On Building and Processing of Large Digitalized Map Archive

Milan Simunek
milan.simunek@praha4D.net

DOI: 10.20470/jsi.v2i3.98

Abstract: A tall list of problems needs to be solved during a long-time work on a virtual model of Prague aim of which is to show historical development of the city in virtual reality. This paper presents an integrated solution to digitalizing, cataloguing and processing of a large number of maps from different periods and from variety of sources. A specialized (GIS) software application was developed to allow for a fast georeferencing (using an evolutionary algorithm), for cataloguing in an internal database, and subsequently for an easy lookup of relevant maps. So the maps could be processed further to serve as a main input for a proper modeling of a changing face of the city through times.

Key words: PRAHA4D, raster map, cataloguing, georeferencing, vectorization, RamaGeo, GIS

Focus and Scope: interdisciplinary integration, software engineering and databases, computational intelligence

1. Introduction

The PRAHA4D virtual model of Prague goal of which is to show the city and its history using virtual reality [13] is truly an interdisciplinary project. Right from the beginning it requires a systematic integration of non-trivial knowledge from such distant domains as computer graphics, history, cartography, architecture, mathematics, mechanics, photography, acoustic, software engineering and others (see e.g. [14], [15]). Knowledge must be combined with a time consuming effort to crawl many kinds of sources to gather necessary data – the most important of them are large-scale maps, including city plans. A big-enough archive of such maps is a prerequisite to deliver the main goal of the project – to create a three-dimensional virtual model of Prague with the fourth (temporal) dimension incorporated. So not only contemporary Prague will be modeled, but also its urban development since end of the 18th century at least, when the first geodetically properly measured city plans were created (see e.g. [4] and [12]).

There were already thousands of maps and plans processed up to now. An ability to easily and quickly search through such a large archive is very important. It is necessary especially to lookup all the maps from a chosen location and time period. Therefore maps have to be catalogued in an appropriate way. Positioning maps onto a referential plan of the city (i.e. georeferencing them) together with accompanying categorical attributes (e.g. map type, year of creation etc.) for easy filtering is used. Accuracy of each map is evaluated and the best maps are used then to create vectorized maps of the whole city for the every year between years 1800 and 2000. A supporting software application integrating GIS features with historical maps domain knowledge is prerequisite to deliver such goals.

The text is organized as follows. There are types of processed maps mentioned in the next section, followed by a description of obstacles faced during digitalization. The third section aims at georeferencing of maps and the used evolutionary algorithm. Vectorization of georeferenced maps is discussed in the fourth section. All the functions necessary for georeferencing, vectorization, cataloguing and subsequently for a lookup of maps were implemented into the RamaGeo, a tailor-made GIS application, which is introduced in the fifth section. Finally, a conclusion follows.

2. Map Types and Sources

There are many different types of maps considered for cataloguing – topographic plans, zoning plans, architectural drawings of buildings, situation plans of bridges or tunnels, proposed river-banks and terrain regulations, technical layouts of rail tracks (for railways, tramways and for horse-trams). Even an orientation map could sometimes uncover some interesting and otherwise unknown topographical facts, albeit in a lower detail and accuracy. Suitable maps for modeling of a city-sized area are generally of scale from 1:300 to 1:4000. Higher scales are too detailed, while lower lack necessary detail. An example of a catalogued plan is in Fig. 3 later in this text.
A contemporary shape of the city is precisely mapped (accuracy class III, $m_{xy}$ – mean coordinates error of 14 cm) in vector format on the Unified Digital Map of Prague [7]. This map is used as a referential map for georeferencing of raster maps and as a starting point for building vectorized maps for every year from now backwards to the year 1800. Historical grayscale ortophotomaps (orthogonal aerial photographs) of Prague from the years 1938, 1953, 1975 and 1988 respectively (captured by army authorities) are a special case somewhere between maps and photos [6]. Contemporary ortophotomaps, periodically captured in color in recent years (by civil authorities), are available in very good resolutions, generally in units of centimeters per one pixel [3].

A small part of historical maps could be obtained electronically, especially from publicly available results of digitalization projects of libraries and archives (e.g. project Kramerius, see [9]). But the majority of old maps had to be digitalized from publications or better from theirs paper originals buried in state, municipal and in private archives. The maps processed so far have been digitalized mainly from funds of the National Archive of the Czech Republic and the Central Archives of Surveying and Land Register of the Czech Republic.

3. Digitalization of Raster Maps

When only a paper version of a map is available, it needs to be digitalized first. Quality of the used digitalization device is important – it must not introduce any unwelcome deformations during scanning. And, even more crucially, it should not deform each scanned image in a different way, especially if a single map has to be scanned incrementally, part by part.

A caution is recommended too when scanning maps from books or downloading ones digitalized already from the Internet. In those cases the primary method of digitalization is unknown and non-welcome deformations could have been introduced anywhere through the process of publication which are very hard to spot and to correct.

3.1 Scanning Device

The best option an institution could choose for digitalizing its archived maps it is to use a certified flatbed scanner specialized for scanning of cadastral maps. Deformations of scanned images are minimized and it is moreover friendly to scanned originals. Unfortunately, there are still some very large or irregular-shape maps which even the biggest flatbed scanners could not handle (see section 3.2 later). And very high costs of such a device limits its availability and even well funded subjects opt often for simple photographing of materials which is much easier and faster but which introduces significant distortions due to physical properties of camera lenses and above all shortsens lengths on wider angles. This significantly devalues the whole effort of an (map) archive digitalization.

Physical state of (aged) materials rules out often using a large-format running scanner, which often introduces very problematic “skips” when the scanned paper suddenly “jumps” while running through. Irregular-shape maps are not suitable for this type of scanners too. A preservation policy of archives forbids taking materials away. So the only option left for an independent researcher is to use a portable scanner, moreover one, which makes no damage to scanned materials.

There is no such a device currently available that could meet given criterions and simultaneously that would be able to scan maps in a sufficient quality. Only the HP ScanJet 4600 see-through flatbed scanner had met some of them, albeit with several caveats. This was the only portable scanner ever on the market with a very helpful feature of seeing exactly what part of image is scanned. So it could be easily shifted across a large map to scan each part while doing no damage to it. Unfortunately, this model has been already discontinued with no successor available across the whole market. And due to its low-cost nature it has not so good mechanical properties and durability. Very inconvenient is also its small working area limited to the A4 format, which is understandably price for its portability.

3.2 Very Large and Irregular-Shape Maps

If a map is larger than the working area of the used scanner, it has to be scanned incrementally, per partes, and all parts have to be subsequently either (a) stitched together by some image-stitching application (if sufficient overlays exist among scanned parts), (b) stitched together manually in a general image processing application (very time consuming and with not very good results) or (c) to be georeferenced individually (if enough reference points are available on the each individual part). If an image-stitching application is used then it should be tailored for map-stitching instead of panorama-photography because the later produces some non-linear deformations, especially in the corners of the panorama that are undesirable while joining together pieces of a map.
A map in top-left corner of Fig. 7 (later in this text) shows layout of the tram route Nr. 3 in the year 1906. Tramway’s situation maps include only the nearest surroundings of the concerned tram route. They consist of many A4-approximately-sized pages joined together following precisely each change in the route direction – so the unfolded map has an irregular shape. In the case of tram route Nr. 3, the real world length of the covered area is 4 km and the vertical physical dimension of the original map is 5.5 meters. Continuous map of this shape and size could not be scanned _en bloc_, so each segment was scanned and georeferenced separately.

### 3.3 Scanner-Introduced Deformations and theirs Corrections

Any scanning device introduces some deformations to scanned images. It is worth up to the expected accuracy of the original map to identify deformations and possibly to repair them through some post-processing.

---

---

---
the bottom of image). Color in background represents direction of deviation (vertical in red, horizontal in green) and brightness the size of deviation (the brighter the greater).

It could be seen from image on the left of Fig. 2 that the scanning head of the used scanner is not exactly perpendicular to the direction of its movement during scanning. The referenced points on the left side of the scanned image are rather below theirs ideal positions and the points on the right side rather above. Thus, an exact rectangle is deformed (skewed) into rhomboid. It implies that we must include one more operation – skew – into the 2D transformation used for georeferencing.

Average size of deviations is really significantly reduced after a skew is included (independently for $x$ and $y$ axis) – see Fig. 2, the image on right. A small deviation is still visible approximately in the middle-column of the scanned image – the points are rather bellow theirs ideal positions, so the scanning head has shape of an very thin arc.

Fig. 2 – Left: Deviation-map for scan grid of lines when only an affine transformation used, Right: Ditto while a skew operation is incorporated (source: RamaGeo application), a larger copy of the image is on [source: Fig. 2, image on right].

Generally, the results obtained after the skew-operation is included are completely satisfactory because deviations are under 0.2 mm and thus under the expected best possible accuracy of scanned (mainly hand-drawn) maps.

4. Georeferencing of Raster Maps

By georeferencing a raster map we mean to translate, rotate and to scale a digitalized copy of the original map so its (significant) points do align with theirs corresponding points on a referential (vector) map. One of the goals of georeferencing is to know the exact coordinates of the area covered by the map so we are able to quickly lookup all maps concerning given location. As an example, a georeferenced map of the Prague’s Exhibition Area in 1891 taken from [8] is in Fig. 3.

4.1 Optimization Task

To properly georeference a raster map it means to solve an optimization task of finding such parameters of a 2D transformation for which aggregated alignment error of defined pairs of control points is minimized. Each pair of control points consists of one point on the raster map and one on the referential map. This two points link together the same location on both maps, carefully chosen so we
could be confident the location is truly identical. The bigger difference in time of publication of the referential and the raster map the more difficult it is to identify pairs of control points. There should be several of such pairs identified and they should be scattered evenly around the whole area of the georeferenced map. If an affine transformation is used then at least three pairs of controls points should be defined. If a skewing is enabled, then at least four pairs are necessary. It is better to define more pairs of points and to give gradually more weight to ones that look more reliable.

Fig. 3 – Georeferenced raster map from publication [8] – drawings aligned with lines of today’s cadastral map (in blue). (source: RamaGeo)

The goal of optimization is to minimize the sum of distances between points in the every pair after the transformation is applied to the point on the raster map. There is cadastral map of the Bubeneč district as the referential map in Fig. 4 (left) and the georeferenced raster map (right). We can see (in red) linked pairs of control points – one from the referential map on the left and one from the raster map on the right.

Fig. 4 – Linked pairs of control points (in red). (source: RamaGeo)
4.2 Implementation

An evolutionary algorithm was implemented for solving the optimization task due to its indifference to the number of control pairs defined and for its indifference even to the number of optimized parameters, which makes it very general and suitable for other optimization tasks (not mentioned in this paper) as well. A sub-optimal nature of evolutionary algorithms is insignificant in this particular case due to a reasonable small number of optimized parameters and to the shape of its fitness function.

The algorithm implementation is based on the SOMA (Self-Organizing Migrating Algorithm) [19] evolutionary algorithm, which was newly programmed in the C++ using the object-oriented approach. The size of population is 100 individuals and the maximal number of rounds is 2000, but a good solution is reached within 150 rounds on average. Remaining SOMA parameters were set as follows: Step= 0.01, MassBehind= 5.0 and PRTLevel= 0.7. There are also some extensions introduced compared to the original version:

- an individual representing the initial set of optimized parameters is explicitly created and inserted into the otherwise randomly generated population before an optimization begins;
- maximal limits for deviation of the optimized parameters from their initial values are introduced (i.e. not only absolute limits, but relative limits too, relative to the initial value of the concerned parameter). Relative limits were set as follows:
  - translation $\pm$ 50 % of the actual width and height respectively of the processed raster map (in $x$ and $y$ directions respectively);
  - rotation $\pm$ 30 degrees from the current state;
- the current leader is allowed to make optional steps in random directions to find possibly even some better position (helpful when there is no change of the leader in the current round).

Time necessary to solve the optimization task with the above-presented size of population and terminating conditions is up to two seconds on an average PC. A size of the searched vector space is significantly reduced by the absolute range for each parameter and mainly by limits for a parameter change from its initial value. This is supported by the learned best practice for georeferencing a large number of maps – to reuse a position of another already georeferenced map (some in a similar position where we expect to georeference the actually processed map). The copied transformation parameters are used as an initial state (the first individual in the newly created population will represent this state) and to set up permitted ranges for the optimized parameters. This speeds-up significantly the whole optimization tasks in majority of cases. A new optimization process could be launched repeatedly from the newly computed position if the allowed deviation from the initial state is not sufficient to find a good enough solution. Another possibility is to setup the initial transformation manually by providing values for the translation, rotation and scaling. A subsequent optimization run will find a precise solution.

A crucial factor for practical usability of evolutionary algorithms is a good generator of (pseudo-) random numbers. It became clear right from the first tests that the built-in generator of the used compiler (MS VC++ 6.0) could not be used due to its unsuitable characteristics. A well-designed generator algorithm with a uniform distribution of random values (see [5]) was incorporated instead.

Fig. 5 – Left: vectorized map sheet Nr. 298 of the cadastral map 1946 [1], Right: the whole processed area. (source: RamaGeo)
5. Vectorization of Raster Maps

Afterwards, selected georeferenced raster maps (the most accurate ones for a given location and a time-frame) are converted into vector representation for further processing. It means to mark all the line boundaries of plots, parcels and buildings; to mark all the tracks, positions of trees, lamps, traffic-signs etc. and to create theirs vector representations in the form of poly-lines and polygons (a spline-curve could be considered for railway and tram tracks, but an approximate poly-line with enough segments is a better option for further building of the 3D model).

A proper identification of the lines depends on physical state of the original map. Our experience shows that the vectorization is better done manually than to use an automatic vectorization tool (see Fig. 13). This is true especially when the vectorized maps are further automatically processed and for aged or damaged maps. Any artifacts of an automatic vectorization are very time consuming to deal with (both for implementing proper checks for input data and even for manual corrections). Several features were implemented to help with a manual vectorization. Crucially, the whole philosophy of incremental steps backwards in time minimizes number of areas that have to be each time vectorized from scratch – see later.

It is practical to vectorize a raster map that was already transformed into geographical coordinates – i.e. already georeferenced (see the previous section) – so the vectorization could take into account regions where two or more raster maps do overlap and to tie up properly poly-lines and polygons from an already vectorized neighboring maps. It is necessary also to compare topographic quality among raster maps from the same location before vectorization to choose the best one as a master-map.

A general vectorized map of the whole city slowly emerges through vectorizing each single map sheet. Fig. 5 shows vectorization of the cadastral map of Prague from the year 1946 [1].

6. RamaGeo Application

A special software application called RamaGeo was developed for purpose of RAster MAps GEOreferencing (using the above-described evolutionary algorithm), cataloguing and vectorization. This application main feature is a database of raster maps and a comprehensive map lookup based on theirs positions and several categorical attributes. RamaGeo application offers also tools for vectorization of raster maps with user-defined vector layers and their types (e.g. buildings, railway tracks, trees…).

Fig. 6 – RamaGeo application main window (list of maps on the top-left, the selected map preview on the bottom-left and positions of georeferenced maps on the right).
Immediately after a map is digitalized it is placed into pre-defined location-based directory structure and automatically indexed. A To-Do list is automatically maintained by the RamaGeo application, sorting yet-to-be georeferenced maps by priority (based on categorical attributes – year, type of map, preliminary location etc.). So no map is left ungeoreferenced and the more important maps are georeferenced first.

Although there are already (GIS) applications able to georeference a single map or few, the application described here is capable of cataloguing of thousands of georeferenced raster map and filtering of maps based on several criterions. A total control over development of the application allows also for tailor-made exports (see section 6.3 later).

6.1 Catalogue of Maps

The main window of the application is in Fig. 6. There is a list of already georeferenced maps on the left and their geographical positions are shown as gray bounding rectangles on the (simplified) map of Prague (see map on the right). A red rectangle highlights the position of the currently selected map in the list, which could be also previewed as a raster image in the bottom left corner of the main window.

Fig. 7 – Examples of filtered maps (source: RamaGeo)

Basic categorical attributes of every raster map are: year of creation (with an imprecise dating possible), type of map (cadastral, transportation, zoning…), source of the original map, type and quality of digitalization and possibly some textual description. The most important property is but the geographical position of each map as a result of georeferencing. Some of the categorical attributes
are automatically derived from the digitalized map file name, which speeds up cataloguing and allows for better results of filtering and lookup of maps.

An implied map-scale is also computed for each map from the known quality of scanning (in DPI) and the real-world size of the covered area (a known result of the georeferencing). Accuracy is based on the quality of georeferencing. Values of the map-scale, size of covered area, pixels-per-meter ratio and accuracy could be also used as other criterions for looking up of maps.

6.2 Lookup of Maps

A single click with mouse somewhere into the simplified map of Prague filters only maps its bounding rectangle contains this point – e.g. only the maps concerning the pinpointed location. Maps in the list could be further filtered by categorical attributed described above and by several Boolean flags (i.e. whether successfully georeferenced, whether not enough referential points could be found, whether a better copy of map is needed etc.). There are examples of other filtering possibilities in Fig. 7.

In Fig. 7, there are shown particular sheets of the tram-route Nr. 3 (top-left), cadastral maps between 1900 and 1910 (top-right, color representing the map accuracy), all the maps covering Hybern Square (bottom-left, color represents the map-scale) and maps from the source [11] (bottom-right, color represents the map-scale).

6.3 Export Possibilities

A completely in-house development of the whole application allows for various kinds of possible outputs both for a better insight during modeling of a particular location and for presentation. So it is possible for example to create special purpose synthetic maps where color shade represents the year of creation of the particular georeferenced map. Or where color shade represents the map scale, quality of map etc. Two such examples are shown in Fig. 8.

6.4 Same-size Clips of Maps

An automatic preparation of same-size clips of original raster maps concerning given location is another export feature. The same real-world location is positioned differently on different maps due to
theirs orientation, scale and of course an area maps do cover. But it is possible to prepare clips of original raster maps that share the same size and the same orientation, provided that raster maps have been georeferenced. Clips are generated after the concerned area is defined by its center point and by distance of its surrounding, see Fig. 9.

For a location defined in the simplified map (Fig. 9, bottom left) – the crossroad by Powder Tower in this case – maps are filtered (top left) and clips are generated (on the right side). It is possible than to make even a movie-like sequence animating changes of the location through times as presented on each particular map – see [http://www.Praha4D.net/ruzne/jsi2011](http://www.Praha4D.net/ruzne/jsi2011).

Fig. 9 – Generated the same-size, same-orientation clips from all maps concerning given location (source: RamaGeo)

![Fig. 9](https://example.com/fig9.png)

For a location defined in the simplified map (Fig. 9, bottom left) – the crossroad by Powder Tower in this case – maps are filtered (top left) and clips are generated (on the right side). It is possible than to make even a movie-like sequence animating changes of the location through times as presented on each particular map – see [http://www.Praha4D.net/ruzne/jsi2011](http://www.Praha4D.net/ruzne/jsi2011).

Fig. 10 – Left: map sheet index for S-JTSK 1:4000 and 1:1000, Right: comparison of the S-JTSK and the S-SK (Gusterberg) map grids. (source: RamaGeo)

![Fig. 10](https://example.com/fig10.png)
6.5 Georeferencing Features

Pairs-of-points identification is often not easy and requires a good level of reading of both the (old) map being georeferenced and the referential one. However, once a good point is already found it could be used for georeferencing other raster maps from the same area. Therefore a feature of highlighting such already used referential-points was implemented and is of a great help when georeferencing several maps from the same area. It useful especially for georeferencing of subsequent overlapping segments of tram-route maps. An approximate position is quickly discovered using referential points from the previous segment and then a precise position is obtained by finding additional points on the other side of the segment (which in turn will be used as a basis for the next one).

Once the pairs of points are defined, the optimization task is executed and the raster map is repositioned. The implemented solution for georeferencing of raster maps is entirely sufficient for practical use due to its quality of found transformation parameters and very short solution-times. Finding of good pairs of points is much easier when a raster map is positioned roughly in its right position. So it is possible to copy position from a previously georeferenced map (in the same location). An actual position and rotation could be changed manually then by a mouse click.

There is a so called georeference-frame included for some raster maps, especially the cadastral ones. Frames refer to a map sheet grid and could be used for an accurate georeferencing instead of subjective selected referential points somewhere inside the map. An example of the S-JTSK 1:1000 cadastral map sheet grid is in Fig. 5. Each map sheet has unique identification number and precise coordinates of its four corners. A “magnifier-glass” tool was implemented to precisely identify the pixels of raster maps that represent corners of the georeference frame. These points are used then for a standard optimization described above to find the best transformation parameters for georeferencing.

Several geographical coordinate systems were used through the last two centuries for maps from geographical area of the city of Prague – e.g. S-SK (Gusterberg), S-JTSK, S-42, WGS-84, UTM (for some details see e.g. [10], [2]). Moreover, several map sheet indexes were developed for some coordinate systems (for different map scales). There are examples of map sheet indexes for cadastral coordinate systems S-JTSK and S-SK in Fig. 10. A database of corner-points coordinates is implemented in the RamaGeo application and could be used for fast a georeferencing of raster maps with frames.

Another feature of an approximate position setting was implement for georeferencing of map tiles of a single raster map, scanned part by part. Starting from the position of a neighboring map tile (already georeferenced) we can move the actually processed map tile by an offset in either direction (in units of a tile size). Subsequently a precise position is found using referential points and this map tile could serve as base for yet another tile.

Fig. 11 – T-joins (A), Perpendicular “dents” (pillars) on a ground plan of a church (B), Straight direction from a segment point or a intersection (C), An eight-angle shape with angles of 45 degrees (D). (source: RamaGeo)
6.6 Vectorization Features

Manual vectorization is a very tedious task so a great effort was given to implement supporting functions and features. Some features even add a new quality to the vectorized map so it is in some sense even better than the original version – see later.

During vectorization a single new line could be created and subsequently its segment points could be added to copy the shape on the underlying raster map. But a whole group of lines could be copied also from another already vectorized map.

Any map area could be zoomed in and out when a complicated intersection of lines needs to be carefully examined. There are limits for zooming in (based on quality of scanning – used dots-per-inch factor). But a modest magnification could significantly improve precision of vectorized lines. Functions for both zooming and moving of visible area of the map are associated with convenient shortcuts for the left/right hand so the mouse could be held in one hand and shortcuts could be triggered by the other.

![Fig. 12 – More complex building with perpendicular and parallel walls and with T-joins (A), Rectangular shape building (B), Circle-shaped sand-playground (C). (source: RamaGeo)]

One of the important features implemented is a possibility to add a new segment point exactly on an existing line (see Fig. 11 A). These T-joins are very common on maps of cities where three buildings or plots are neighbors of each other. A proper calculation of coordinates of the intersection point is very difficult during automatic vectorization and could introduce unwelcome deviation from the straight direction.

Another important feature is to assure a precise angle between two adjoining segments of the edited line. So the next segment could be for example perpendicular to the previous, which is useful mainly for vectorization of small dents on ground plans of buildings (see Fig. 11 B). The angle of the next segment could be also of zero degrees to assure continuing in the straight direction (e.g. after intersection with another line, see Fig. 11 C) or even 45 degrees eventually (see Fig. 11 D). A precise angle could be further combined with the “intersection feature”. Therefore, it is possible to draw very complicated shapes with a high precision that could even exceed the precision of hand-made drawings on the original map (see Fig. 12 A).

The most common shapes in vectorized maps are rectangles (buildings) and circles (fountains, wells, park lawns or sand-boxes on children playgrounds). Pre-defined functions are implemented to create a precise rectangle from just two (perpendicular) lines given (see Fig. 12 B) or to create a precise circle from just three given points (see Fig. 12 C).

Again, the automatically constructed shapes could be even more precisely drawn than theirs originals on the raster map. Comparison of vectorization in the UDMP [7] (probably done semi-automatically) and in the RamaGeo application is in Fig. 13.

Vectorization of each subsequent map could be speed-up as growing number of maps is already vectorized. It is possible then to use already vectorized lines from the same area and just to add missing lines and/or to delete redundant ones. This approach is more easily understood when there is already a vectorized map from the year 2000 and we gradually vectorize maps from the years 1990, 1980, 1970 and so on. In each step we use already available maps from the nearest already vectorized decade and update only the areas where some changes have occurred. There is therefore a “delete line(s)” function available. All the crossed lines are deleted or the whole encircled area is cleaned.
Another automatic function finds all the neighboring maps already vectorized to allow for a proper joining of overlapping lines. An example of vectorized plots-lines of a single map sheet of the cadastral map is in Fig 5 (left).

Different vector layers could be created for a single raster map. One layer for plots, one for tramway tracks and another for small objects (telephone boots, street lamps etc.) to allow for differentiating in further automated preparation of the 3D model. A special “referential-lines” layer includes important points and lines that could help in georeferencing of further maps. This layer includes also lines representing remnants of an older state, already obsolete in the time of preparation of the map, but still preserved on it (in case of cadastral maps, especially). This layer could contain even clearly wrongly drawn lines if they persist on older maps (until they were corrected later) but could be used for georeferencing.

Fig. 13 – A fountain on a raster map (left), vectorization in UDMP [7] (middle) and result of a vectorization using the circle-shape feature (right). (source: RamaGeo)

The georeferencing parameters are automatically locked after a map is vectorized. Otherwise, if the underlying map changes its position and size, the map has to be re-vectorized either manually or automatically (provided that both the previous and current parameters of georeferencing are known).

7. Conclusion

The goal of the above-mentioned activities is to digitalize, catalogue and vectorize a very large archive of maps and to provide input for further (automatic) processing of geographical data necessary to build a 3D model of continuous urban development. There were already thousands of maps catalogued and hundreds of them vectorized. The proposed approach to georeferencing of raster maps utilizes the SOMA evolutionary algorithm. The obtained results are fully acceptable for supposed use. A new value has been added through an easy lookup of maps concerning given area and through features supporting vectorization.

Proclamation: Work on the independent PRAHA4D project is not supported by any agency or grant.

8. References

[1] Cadastral map of Prague from the year 1946. Central Archives of Surveying and Land Register of the Czech Republic, inventory item B3/3/6068


[12] *Plan of the city of Prague from the year 1816.* Kartografia, Praha, 1972


[18] *Vinohrady district – cadastral map with traces of water pipes around 1895.* National Archive of the Czech Republic, Collection of maps and plans (SMP), inventory item 2414, D XII 12


JEL Classification: C65