v i e n n a

visualization of GPS tracking

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INTRODUCTION

About

This booklet was made as a part of my master studies of International Master of Science in Cartography and it was created to accomplish the course called Project map Creation at Vienna University of Technology in summer semester 2013. I chose working with GPS data because I had never worked with them before and I found very appealing how they can be used and visualized. My biggest motivation was to produce nice looking booklet with illustrations of GPS tracks that would be differently classified and visualized.

Data acquisition

Because I did not wish to have any troubles with licences and I wanted to know the data quality I had decided to acquire my own GPS data. Fortunately, I had opportunity to borrow GPS tracker devices from the Research Group of Cartography at Vienna University of Technology. I would like to thank Felix Ortag who is a member of the Research Group for giving me this amazing chance and for his smooth communication, and assistance.
Firstly, I asked few colleagues to help me and luckily I was able to create a group of 11 volunteers who were willing to participate in my project and who agreed with anonymous usage of their recorded data. Secondly, I tested the GPS trackers by myself for few days and then following three weeks (8 - 22 April 2013) the volunteers were recording their movement. However I had only 8 working devices so I had to create a week schedule dividing the devices between the volunteers. Important thing to mention is that I was using three different brands of devices: QSTARZ Travel Recorder BT-Q1000P (4 devices), Blumax Bluetooth GPS-4044 (3 devices), and one iGotU device. This is the reason why the acquired data could be sometimes inconsistent, but in many cases the inconsistency was even among the devices from the same brand. This could be visible for instance on elevation values because they should correspond to each other at one location, nevertheless some values recorded by same brand devices had big discrepancies.

Data processing

As mentioned above I arranged a group of volunteers collecting the data to avoid unwanted complication with data privacy and licences. Firstly, recorded tracks were exported and then removed from GPS devices once a week to prevent lack of memory in the devices. I used original softwares for each brand of the trackers to export the data to my laptop where I saved it in all possible formats (GPX, KML, CSV, and NMEA). However I was using only two of them: GPX format to create point features in ArcMap 10.1., and CSV format to assign needed attributes to the points. Main reason, why I had chosen this complicated procedure, was that I wanted to use ArcMap to clean and classify the data but unfortunately when I converted GPX to point features the values of speed, elevation were missing, more over the time and date attributes had strange coding so it was too much complicated to extract only needed information. Therefore I needed to load CSV files to Microsoft Office Excel 2007 where I could clean and edit all recorded attributes and as a result I got Excel sheet containing rounded values of speed, elevation, hour and date. Then I simply joined these Excel files to corresponding line feature classes that had been created from the original point feature classes with point to line tool in ArcMap and the lines had been subsequently split at vertices in order to have right amount of particles on which the join was done.

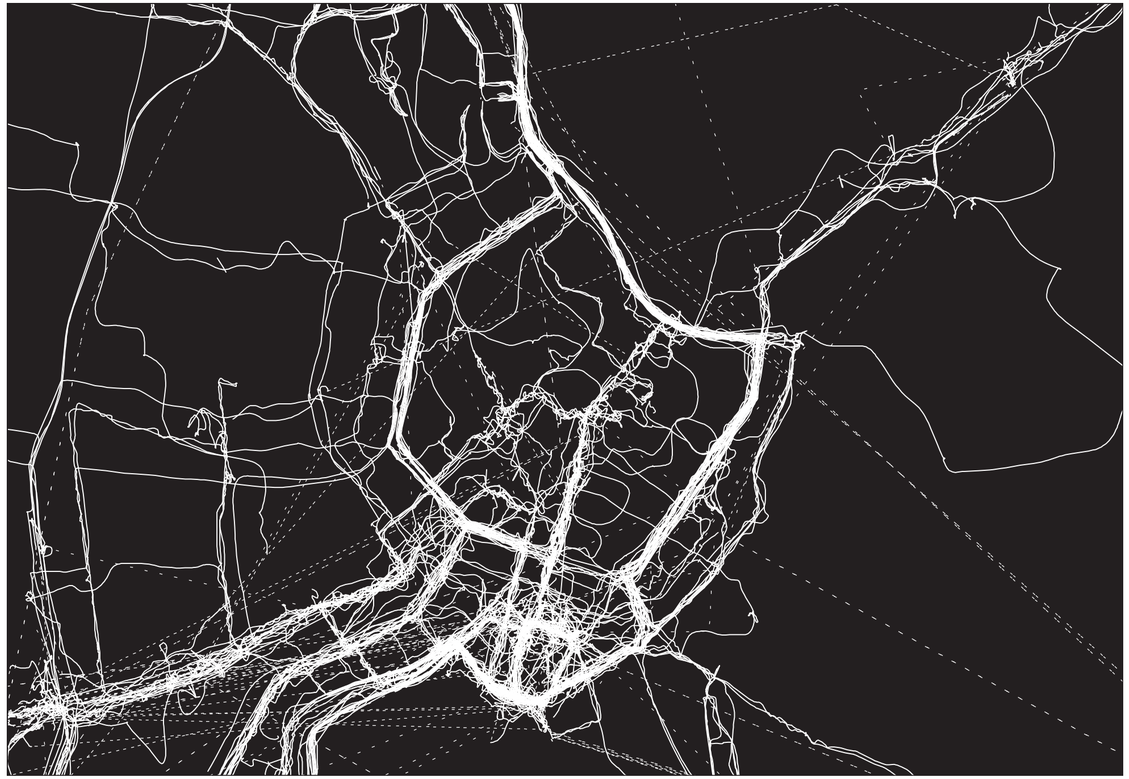
After these steps I got to the second phase that included cleaning the data. All volunteers were told to switch off their trackers while entering some building and again to switch them on while going out again. However the reality was not that idealistic because it is obvious that everybody forgets, furthermore sometimes the recorded data showed strange lines especially when the devices were locating their position after being turned off or having no signal. Cleaning the data simply means deleting some parts of the lines and it was done manually.
Third phase of the procedure was data classifying that was probably the most time consuming part of this project. Some classifications were very simple, like personal map that only distinguishes different volunteers or week day map showing different days of the week. However in some cases I had to determine the classes very carefully so that the final output would be meaningful. I originally decided to have 7 classes in each classification because I wanted to have smooth visualizations but I had to disobey this rule in cases regarding personal map (since I had group of 11 volunteers) and day time map because the most logical way that I found was to divide day into 8 classes per three hours. Fortunately I was able to keep the 7 classes rule in the remaining visualizations. More information of single classification is written on following pages next to the related maps.
This may look as the last step but since I spent many hours with processing the data I wanted to have nice looking and good quality results, therefore I decided to come up with fourth phase that contained smoothing of the lines. This was the most challenging step for me because each line consisted of many particles so it was impossible to use smoothing tool in the first time. To solve this problem I created new attribute field for each line and into this field I assigned same value for all features belonging to one class. After this step I was able to dissolve the lines to get limited number of line features that could be smoothed. However this solution might not have been completely accurate since each classification shows slight differences in smoothed results.

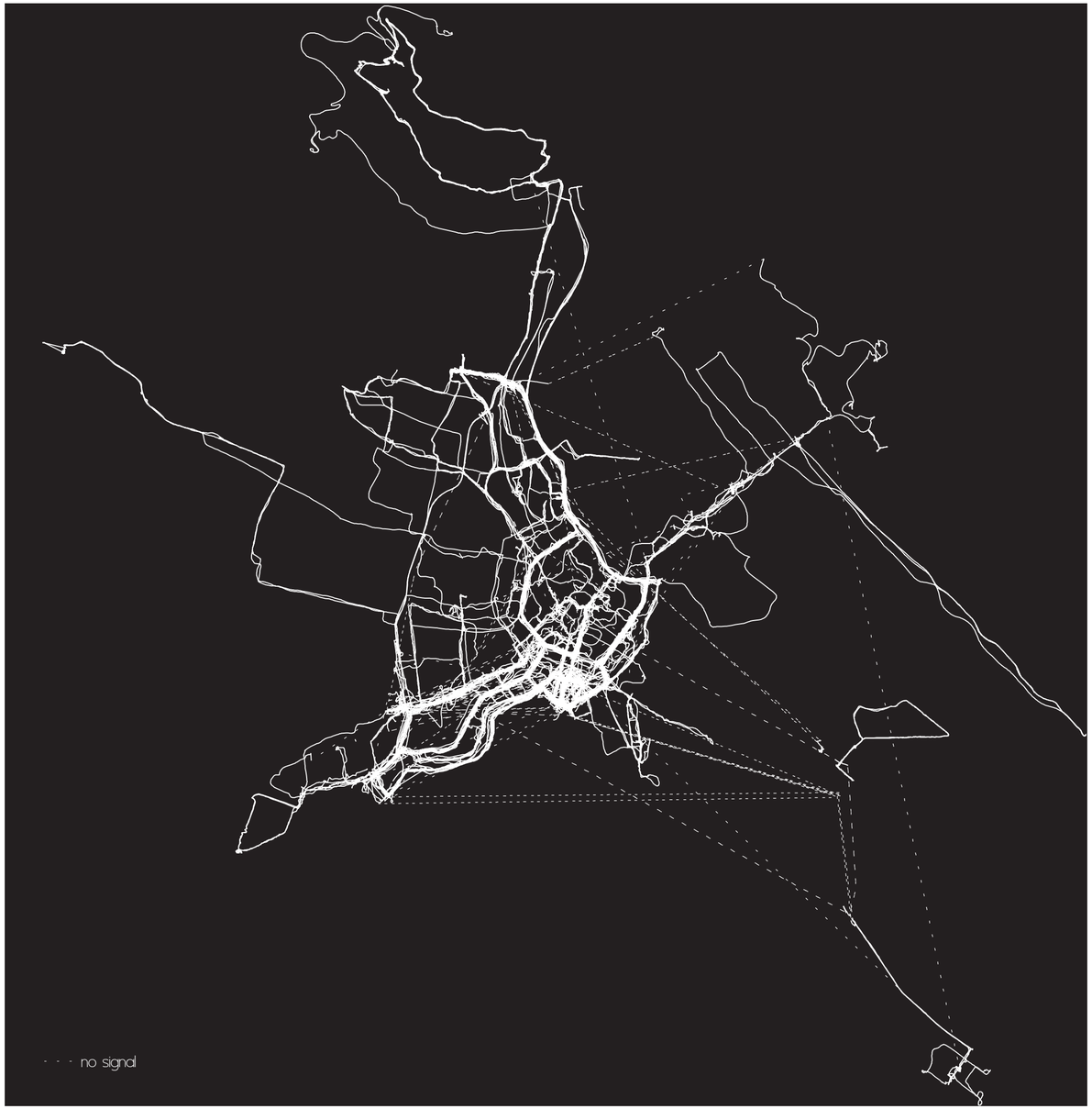
Data visualization

Last steps of my project were data visualization and designing of this booklet. I designed several colour ramps to show different maps furthermore I designed five different colour ramps using white or black background. The reason why I chose more colour ramps and backgrounds was that I wished to clearly distinguish different topics. Besides the speed, elevation, day time and week day map I added three more maps: black and white, white and black, and map with Open Street Map base map (see more information on page 20). Even though the first two maps do not bring us any additional information I just like how the map could easily change to piece of art and that's why they can make this booklet more attractive for some part of its audience.
Because the data have large extent I decided to show two maps for each topic; the larger map shows almost whole extent of the data in scale 1:80 00. The smaller map is cut out from the larger map and it presents the area of the city centre in scale 1:30 000.
Last thing that I would like to mention are places where GPS devices had no signal. If you have worked with GPS data before you know that when the GPS tracker has no signal the output lines are straight because they are created between the last and first point with fixed signal. Unfortunately I had to deal with many examples of these lines because the volunteers were using subways a lot. My first consideration was to completely delete these lines but then some areas could appear as cut off thus I visualized these lines as dashed lines so it can be assumed where the volunteers were out of signal which mostly corresponds to use of subway.

b l a c k & W h i t e

Black & White map presents only the simple visualization of GPS tracks with no further classification. This type of visualization could serve for general overview of location and frequency of the tracks. More over it could be used as a piece of art since it attracts user's attention because some well known features like main streets or districts could be recognized while watching this map. All collected data were used to create this map since there was no need of further classification.
If you look at this visualization in detail you can see the Inner city and the main rings around it at the first sight. Furthermore you can determine where the places with the biggest density of lines are - of course it is Karlsplatz and area around main buildings of Vienna University of Technology because that is the place which the volunteers have to visit as local students.

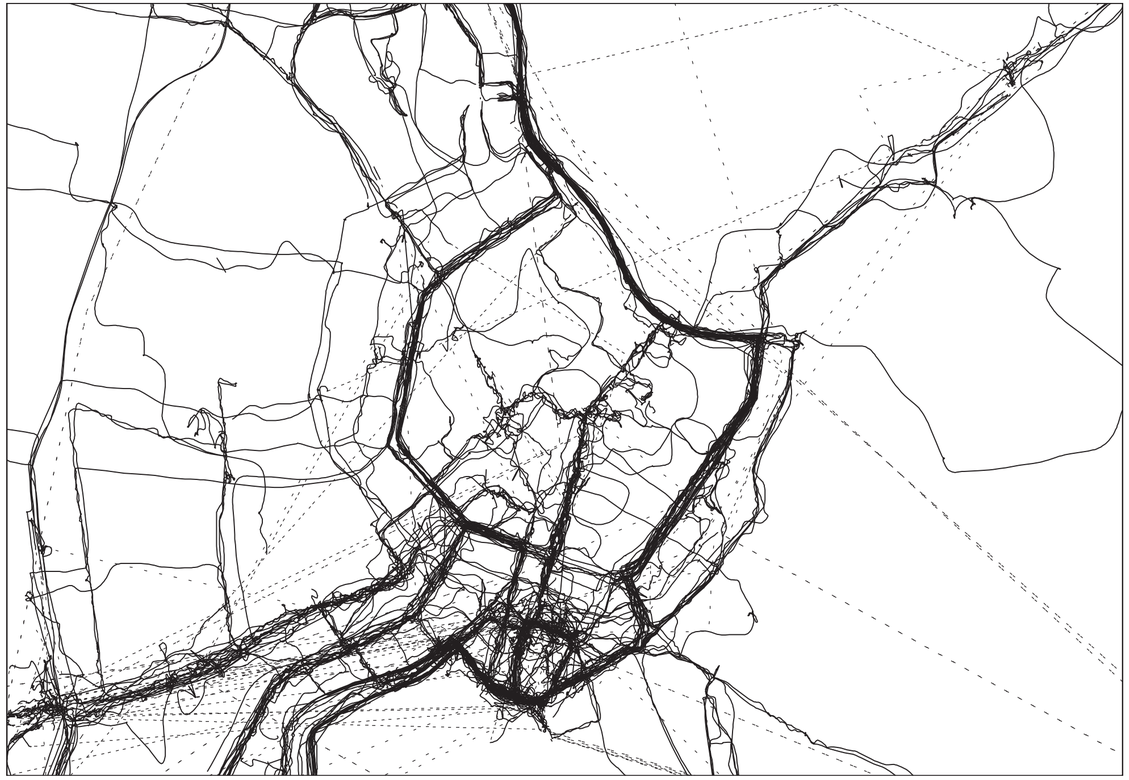




White & black

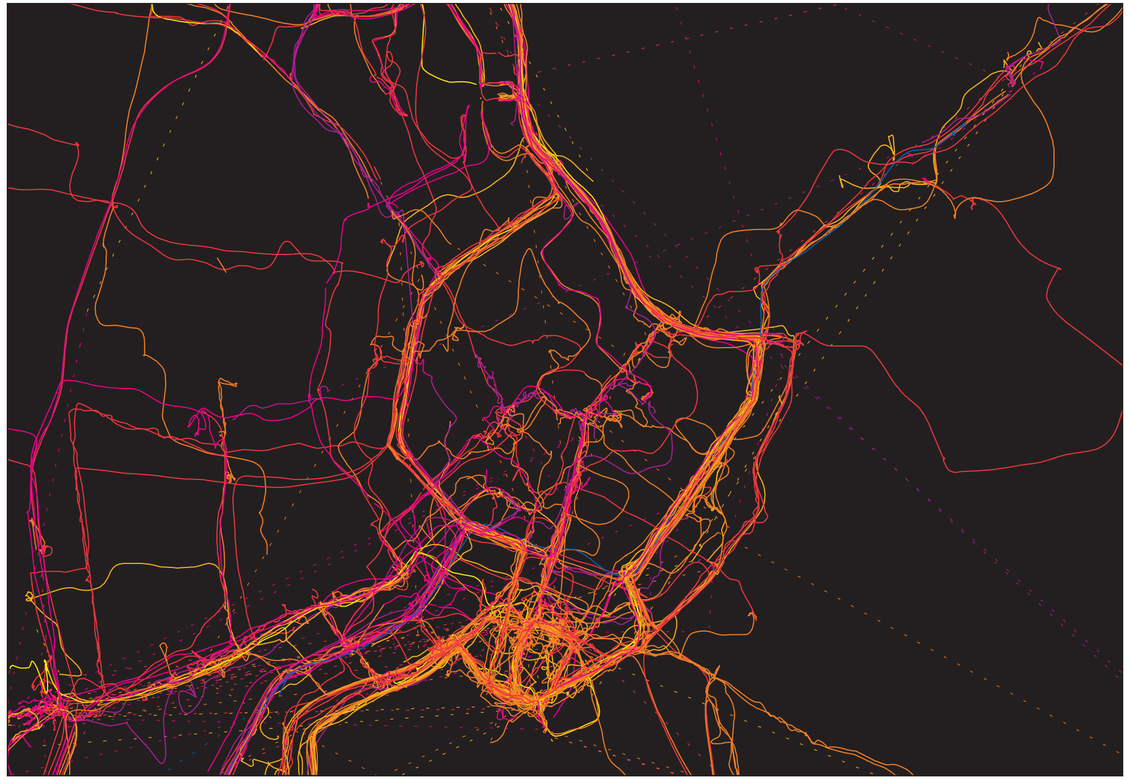
White & Black map shows almost exactly the same as the previous Black & White map, but only the colours are inverted. It could be again used to get the general overview of localization and frequency of the tracks. More over it could be used as a piece of art since it attracts user's attention because more and more well known features like main streets or districts could be recognized while watching this map. All collected data were used to create this map since there was obviously no need of further classification.

If you look at this visualization in detail the Inner city could be seen at the first sight. Additionally, it is possible to detect the main rings and streets of the Viennese city centre. Furthermore you can determine the approximate location of the Danube channel and what the extent of the whole dataset.



DAY TIME

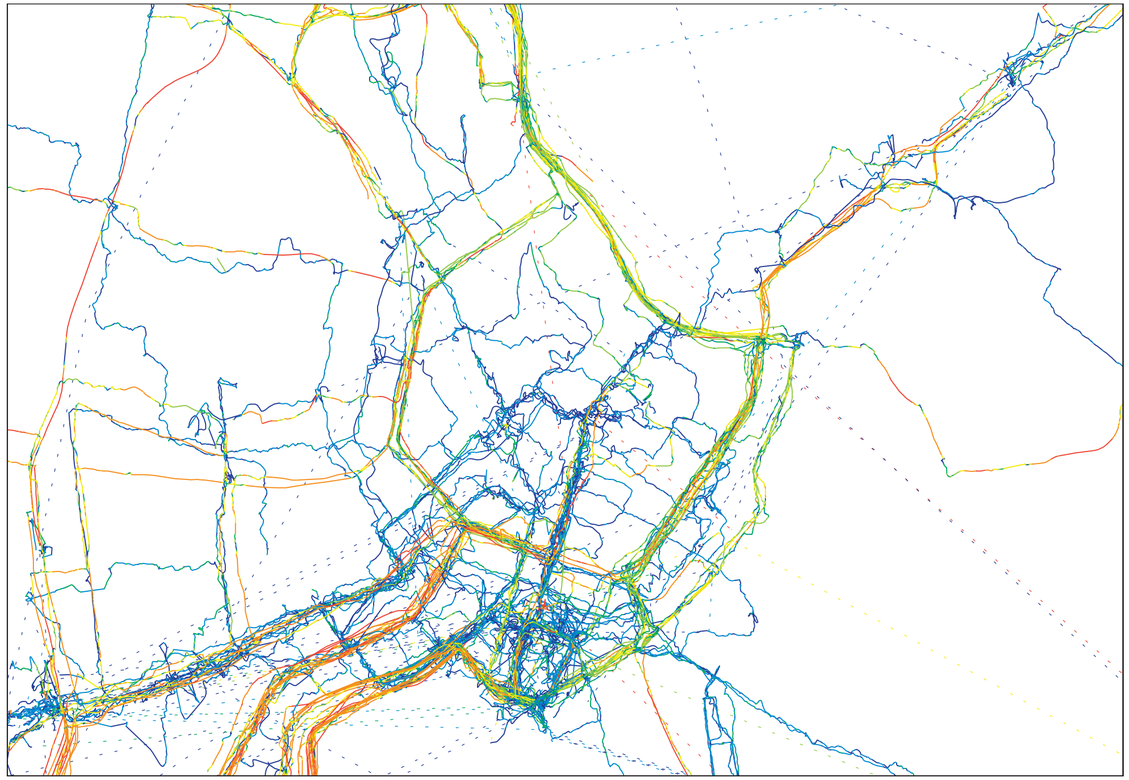
Day time map is the first visualization showing classified data according to the day time. Fortunately all GPS trackers were recording time correctly so it was possible to use whole dataset to generate this result. As you can see all tracks are divided into eight classes lasting for three hours each so it allows reader to determine many patterns of movement related to the time.
For instance, one pattern that could be derived is that most of the volunteers had to attend lectures mostly between 9:00 and 15:00, but there are some exceptions when the volunteers stayed longer time at university. Unfortunately, all volunteers that took part in this project are responsible students that are not going out after 3:00 in the morning and therefore it is hard to find some tracks that belonging to the last class that covers time between 3:00 and 6:00 in the morning.

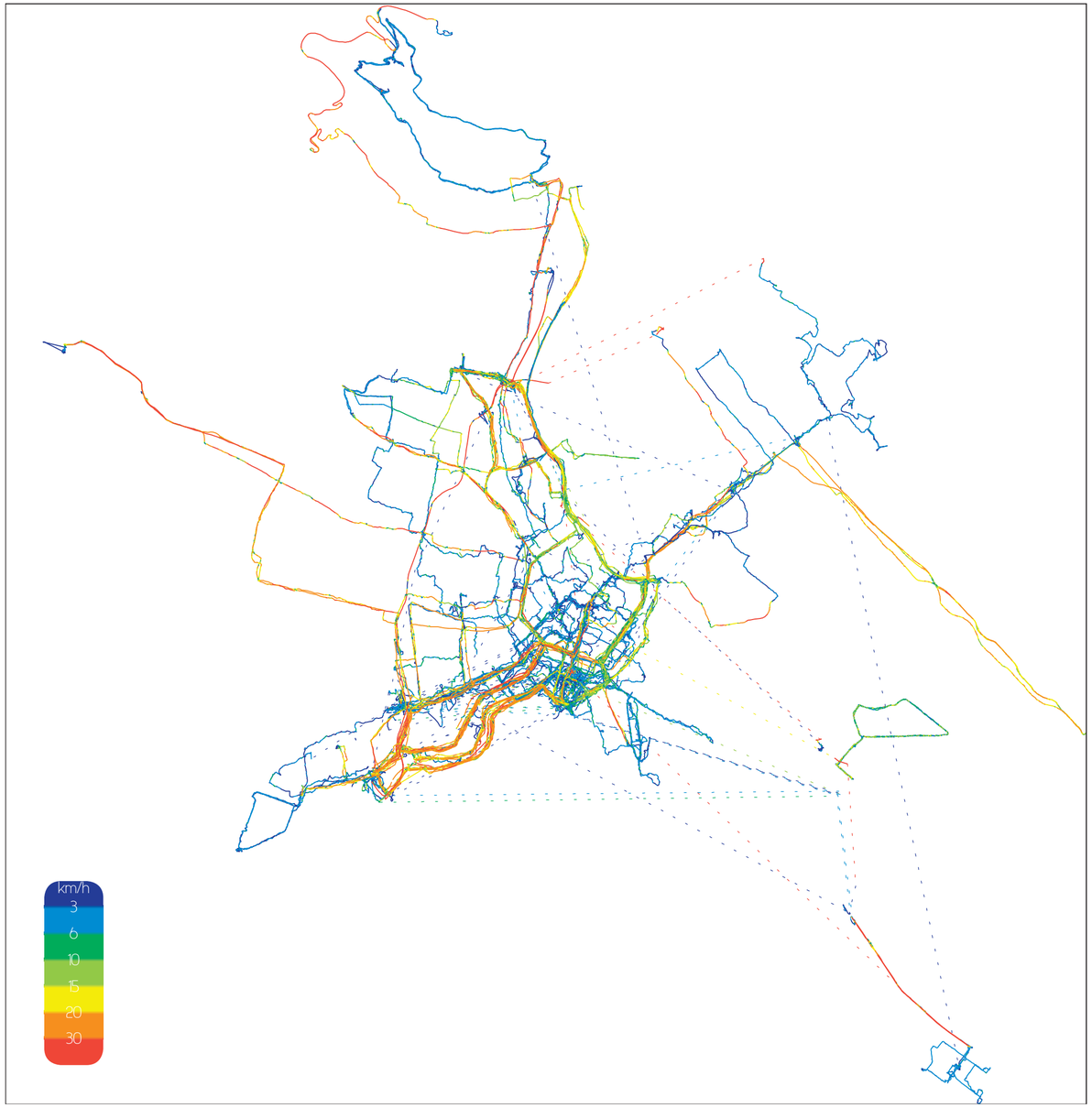


S P E E D

The visualization of speed is amazing because we can determine detailed characteristics about the means of volunteer's transport and their habits. Fortunately all GPS trackers were recording speed correctly so whole dataset could have been used to generate this output.

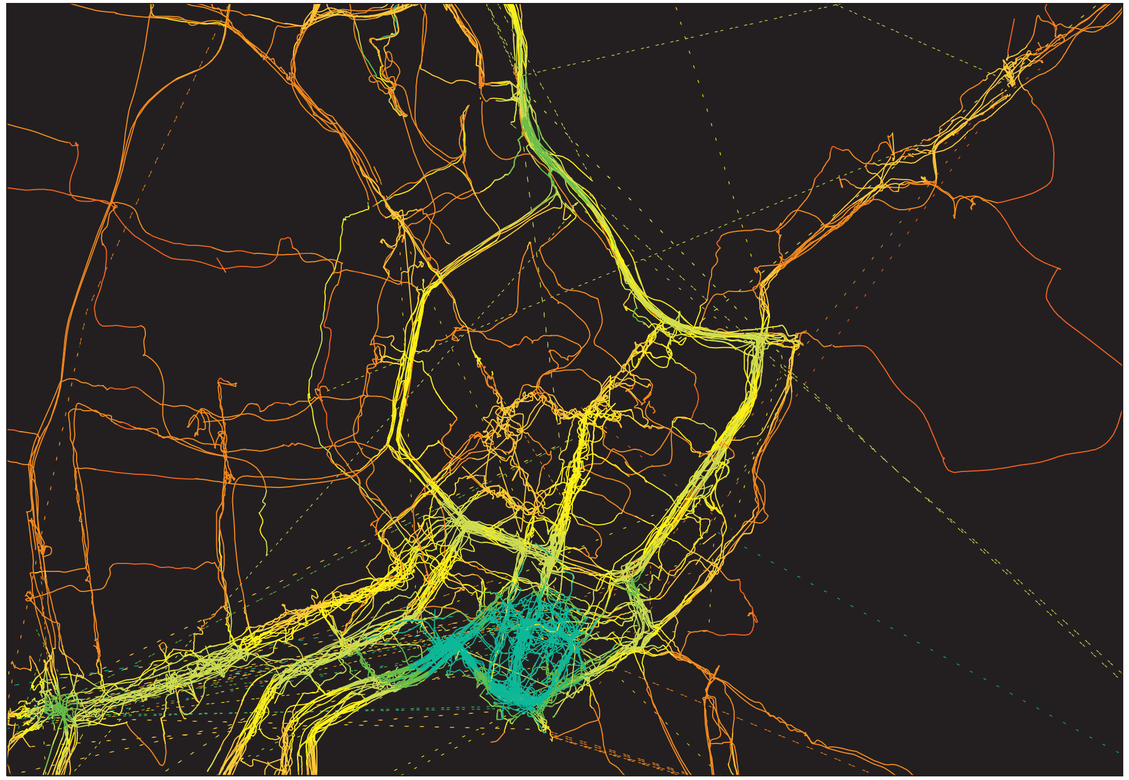
The definition of the first two classes is adapted to pedestrian volunteers and it distinguishes slow (up to 3 km/h) and fast walking (3 – 6 km/h). Next class defines very slow cycling or running (6 – 10 km/h). While examining following classes we can find many differences among the speed of cyclists: there are cyclists that are riding quite slow (10 - 15 km/h) or faster (15 – 20 km/h). However there were apparently volunteers riding even faster (20 – 30 km/h). Last category mostly includes volunteers using buses or cars (more than 30 km/h).

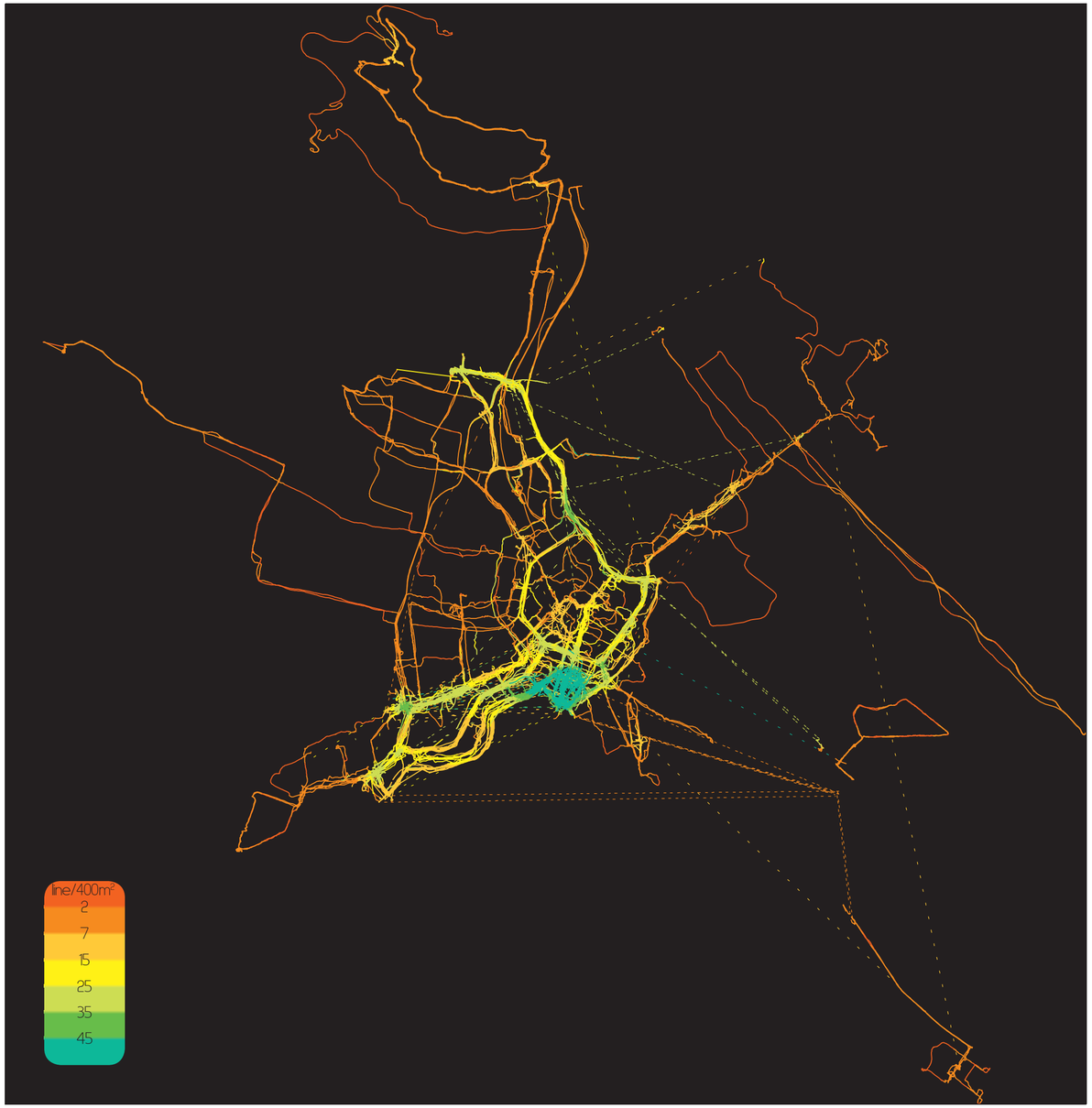




F r e q u e n c y

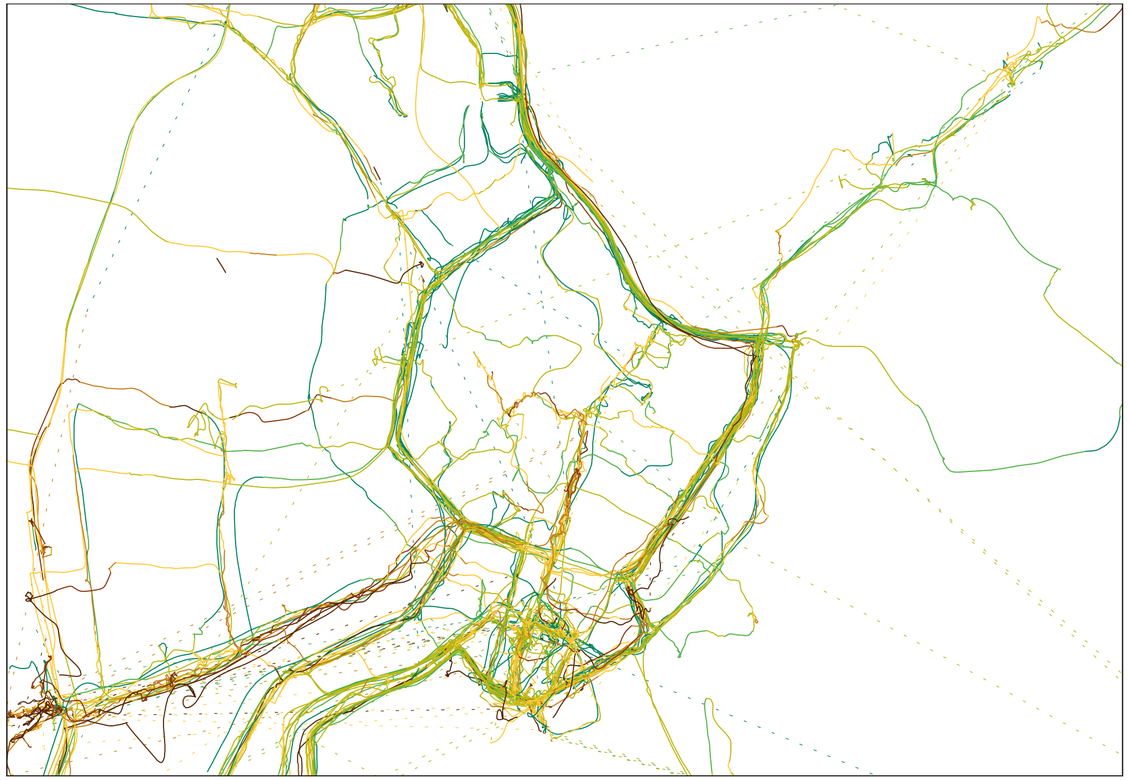
Frequency map or line density map was probably the most challenging visualization because I had to work with whole dataset in once containing thousands of features to create line density raster. Unfortunately only major part of data were used for this visualization because one dataset gained from iGotU GPS tracker was not working correctly during the visualization process.
The classification was made from density raster as you can see in the legend each colour is associated to different number of lines which are located within the area of 400m^2, further more the colour ramp helps to delineate where the most visited places are. This visualization is alluring thanks to its difference to the rest of classified maps because the classes were defined on the base of the whole dataset not on the characteristics of single lines.

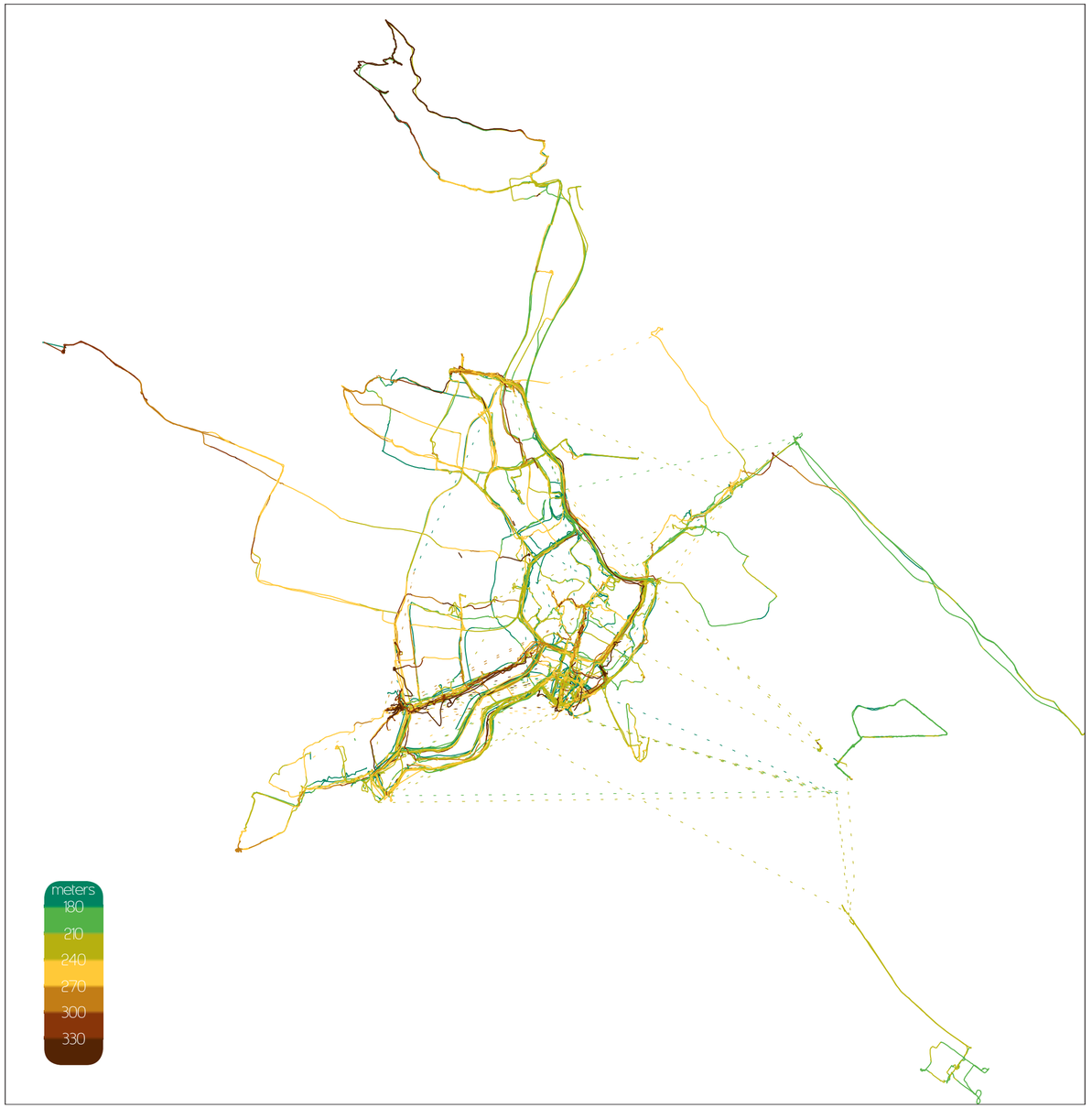




E l e v a t i o n

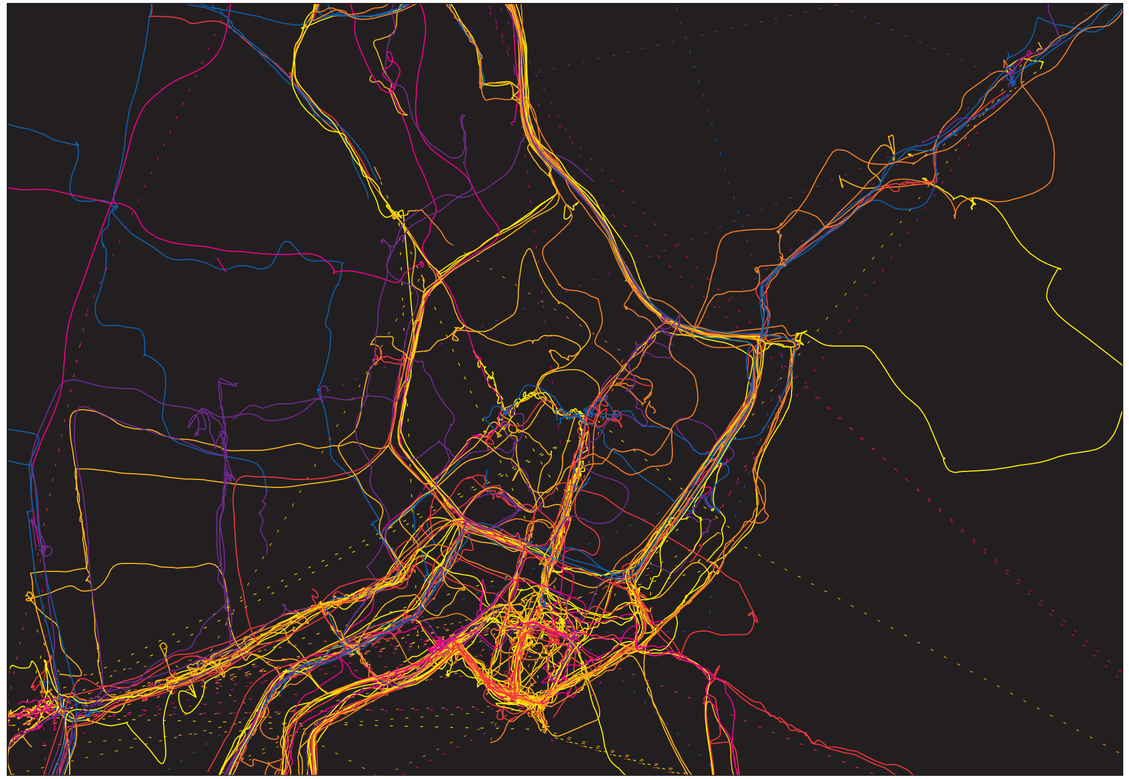
Visualization of elevation is more significant on the larger map since the city of Vienna is predominantly located in a flat area around the river Danube. Unfortunately this output seems to be the most inconsistent one because of using different GPS tracker devices and more over one of the GPS tracker even was not recording the elevation at all. On the other hand the primary concern about using different types (brands) of GPS tracker turned out as irrelevant because while I was testing the accuracy of the trackers I found out that there are big discrepancies even between the single devices from one producer.
Place that stands out on this map is Kahlenberg situated in northern part of the city because it has remarkably distinguishable altitude. On the other hand the lowest parts around the river Danube and the Channel of Danube can be recognized too.

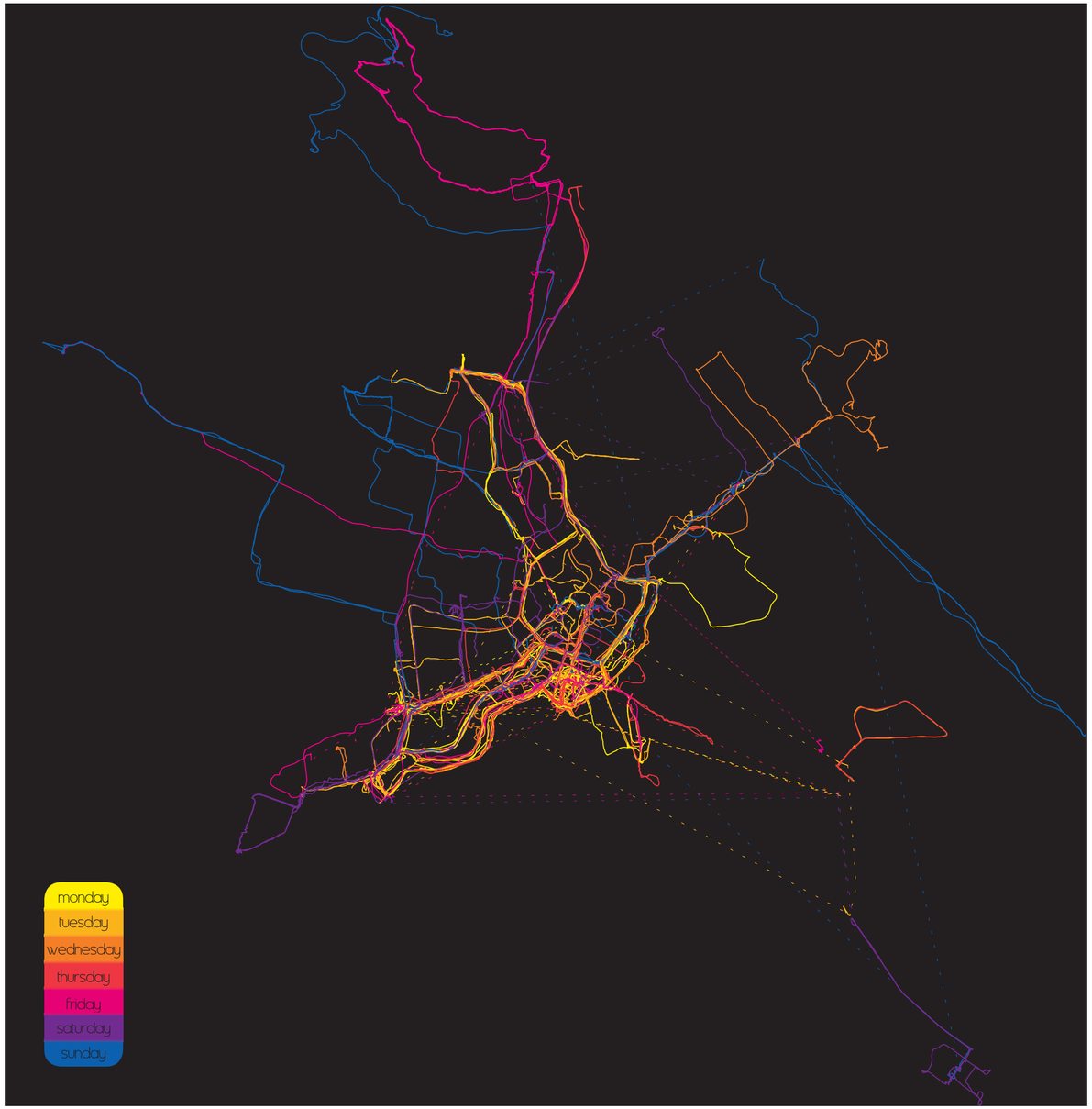




WEEK DAY

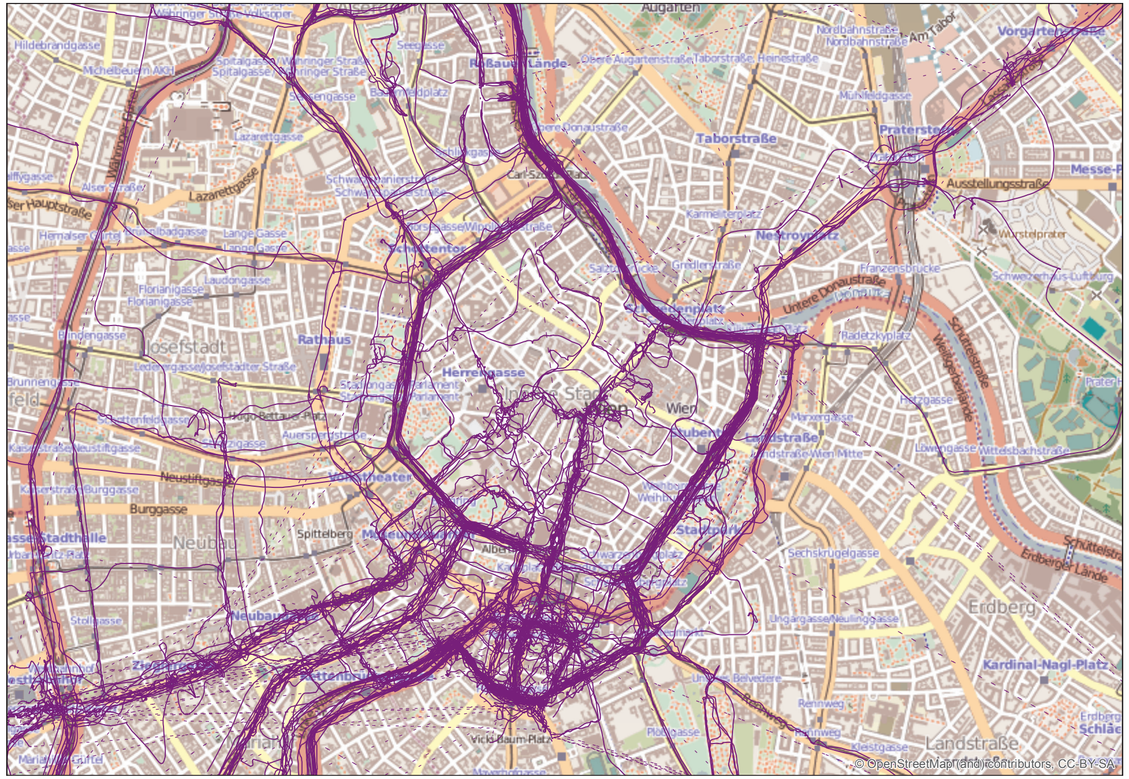
This map is classified according to the week days when the data were recorded. Time and date information was unfortunately not always correct so only major part of the dataset was used to create this visualization. The data were firstly sorted by date of acquisition and then the particular dates were assigned to corresponding week days.
This illustration gives totally different information about the volunteer's movement habits. For instance, it is very interesting that most of the volunteers stayed in the city centre or they were travelling between their residence and university from Monday to Thursday. However since Friday there can be seen the beginning of a big change in volunteer's behaviour because they were going on trips beyond the boundaries of Vienna city centre.

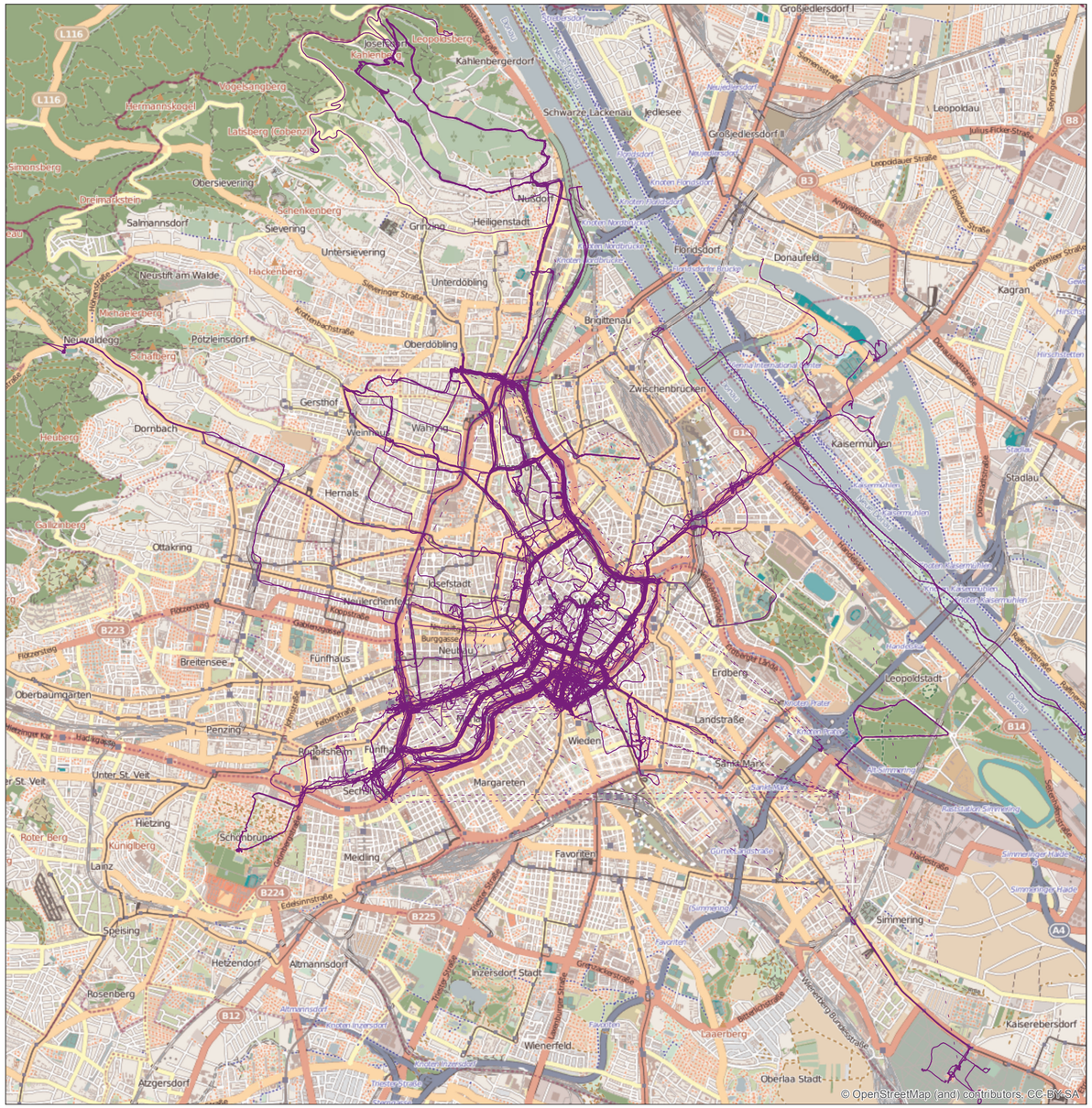




O S M

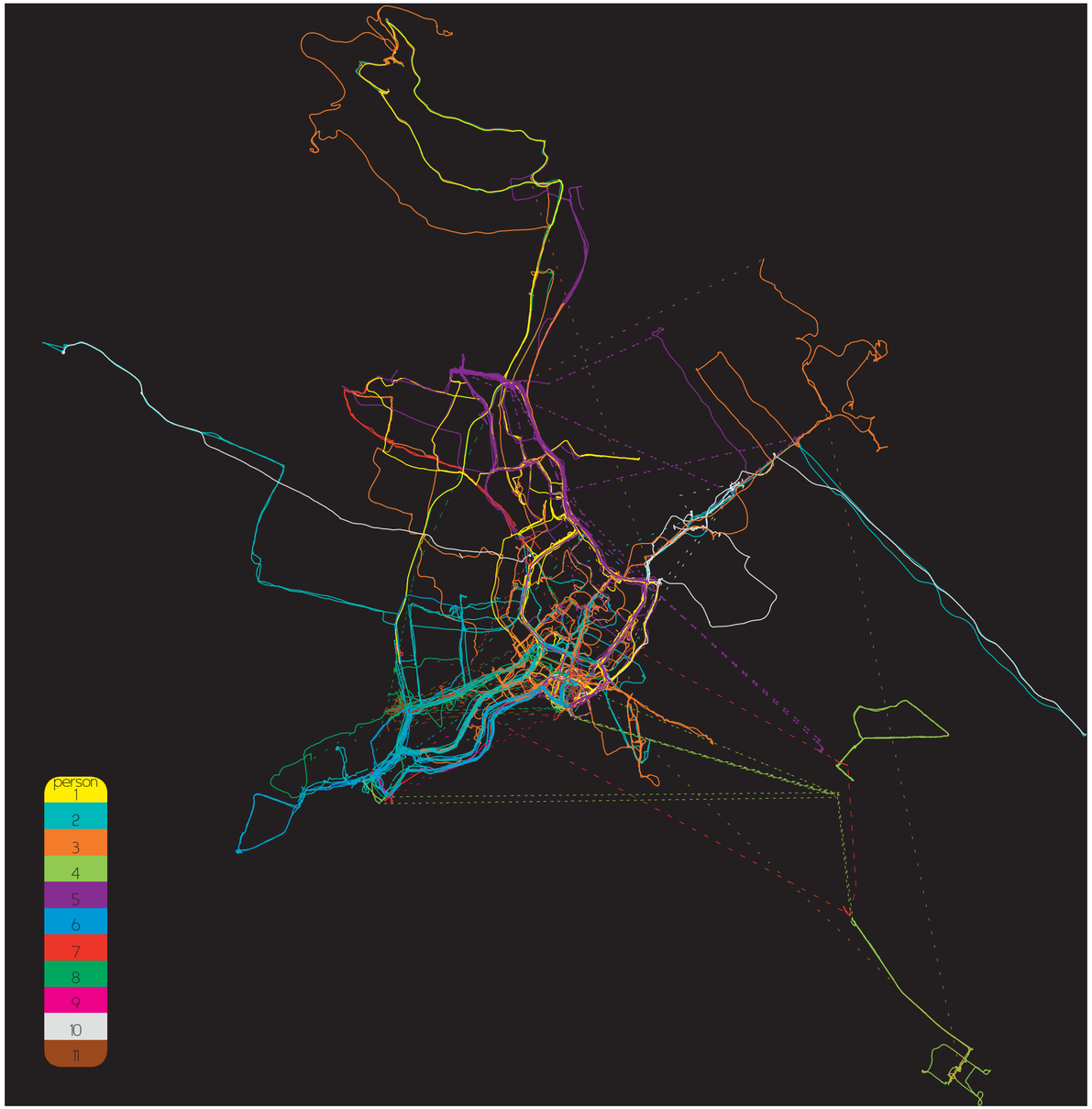
This visualization is unique because it differs from the rest of visualizations and it actually resembles the real map with features like streets and buildings. This map is called OSM because Open Street Map was used as a base map in accordance with their licence CC-BY-SA. According to my opinion it is essential to include map like this in this booklet because only this visualization shows the location of the tracks in comparison with reality.
This map could be used to find out the real location of the tracks and to get deeper insights from all presented maps. Because now reader is able to can compare different characteristics of tracks that are shown in this booklet with their location and thus he does not have to take it only as a piece of part but he can detect new information related to spatial location of the tracks.





P e r s o n a l

Last visualization is classified by different volunteers who participated in this project. However not all of them were recording the data for the whole duration (3 weeks) thus some of the classes might be little bit misleading. Another thing that could be little bit biased is the order of colours symbolising single volunteers and some information could be hidden. However I am still persuaded that despite these defects it is worth it to exhibit this output.
This map could again serve to find the habits of volunteers, for instance it is interesting to focus on subway colours to detect who was and who was not using subway. Moreover it is remarkable to examine the movement radius of single volunteers and finally it is nice that the surrounding of Vienna University of Technology includes all colours as everyone had to attend the lectures.



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