Grid analyses in Prague urban planning

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1 ABSTRACT

Understanding of spatial aspects in a city can be significantly supported by grid analyses. The paper is focused to implementation of grid analyses into the town planning procedures in Prague. Analyses and visualisation of town landscape morphology is the core part of grid creation and derivation from the primary terrain and 3D vector data to the grid surface dataset covering the built structures and/or green. Town surface grid data are ideal input for surface visualisation – hillshade built-up area for visualisation the spatial structure and density or the near-real visibility analyses with taking the on-the-surface objects into account. Grid analyses are applied also to the transportation modelling, mostly for walking relation studies as the refinement of gravity or other types of accessibility models. In the near future, using the grid models for modelling the town processes – i.e. development scenarios or value or quality changes in time - is seen as very promising.

2 INTRODUCTION

Spatial analyses have traditionally been the essential part of urban planning in Prague. Due to the planning subjects are physical or virtual objects best represented by vector data model, analyses methods normally do not need take rasters much into consideration. Majority of spatial analyses for planning are based on simple overlay, intersect or buffer functions in connection with more-less advanced database and cartographical postprocessing. Traditional orientation to vector data model also may acted as a kind of curtain blocking thinking of planners from use of other techniques. In connection with new requirement on refinement and completion of standard analyses with detailed surface analyses or distance analyses, use of grid data model has been inevitable.

First applications of grid model were connected with transport planning, for optimisation of walking distances to the public transport stops. As the planners tasks during the time shifted toward studying the land in a rather detailed scale, the problem of discrepancy between traditional rough “circle buffer” method for distance estimation and the real pedestrian network distances was not further possible to ignore. As the topological quality of input pedestrian network data did not allowed use the vector network analyses without demanding data topological cleaning, grid analyses have been successfully used instead. Further applications have been connected with viewshed analyses in urban built-up areas. Grids, in this case, helped effectively overcome problem with TIN building in the vast city areas. Both transport and surface modelling has fast become used commonly and its outputs have been often required. Latter tests are dedicated to the first steps to the dynamic modelling of town development, starting with grid analyses of specific spatial qualities as the “index of centrality” etc.

2.1 Walking distance analyses

Information on real or near-real accessibility of local destinations is essential especially when locating public services. As move in the city is possible on the road or pedestrian network, the distances between origins and destinations depends on geometry and the flow properties of the network. Traditionally, distances are approximately represented as the rings with the centre in public service destination. Taking the area population as the criterion, according to our tests, average difference between ring – buffered population and network analysed population living in the “same” distance from public transport stops in Prague is about 25%. Ring estimation is always too optimistic.

Practical methodology of walking distance analysis in Prague planning is based on estimation of addresses or population living at these addresses, which fall into the defined walking distance from the destination. The most often, destinations are public transport stops, however, accessibility of schools, kindergartens or similar services is also calculated.

Input data for the analysis is the pedestrian network (polylines), stops (points) and addresses (points). Pedestrian network data does not need to be topologically clear which is helpful for the preparation. The topological errors in the data may be within the tolerance of expected grid resolution. To enable distance calculation, network must be constructed in a way, which ensures that all origins and destination points lies on the network. Usually, the custom script by Michele Lundeen from http://arcscripts.esri.com/details.asp?dbid=13012 is used for this data tuning. The completed network is then converted into a grid. Normally, resolution of 1m is used. If the input data topological quality is poor, better grid result is given if some small buffer (1m) is generated around the network polylines before making grid.

Once having the input grid, the distance analyses may be calculated. Optimal method for such calculation is Cost Distance function, designed for spreading modelling on the surface of heterogeneous resistance. For walking distance only two values of resistance are used – 1 for network, "no data" for other surfaces. The value representing network has in fact meaning speed of move in m/s. In fact value 1 is interpreted as 3,6 km/h, which is also good approximation for walking speed. Cost distance method calculates the value of time necessary to get from the destination (stop) to the particular cell within a grid along the network. If destination layer contains more origins, the time to the nearest origin is calculated. For more complex analyses, which calculates also with e.g. time losses by transfer or waiting, the distance must be calculated for each destination separately. Recalculation and combination of these grids should be then provided by map raster algebra operations. If the value representing the network in input data is set to 1 and input speed was interpreted as 1 m/s, the analysis result also means the distance in meters.

Matching the distances to the addresses is calculated by Neighbourhood statistics function. Distance value of underlaying grid cell is attached to the particular address point. Summary statistics for calculation addresses or population within acceptable walking distance (usually 300 or 500 m) is then provided by standard SQL database queries.

fig. 1: Network classified according to the calculated distances from the origins. Address classification is covered into the calculation.

2.2 Surface modelling

Planning of the new development should always evaluate its anticipated impacts. Usually, environmental or functional impacts are being assessed. In places, where the spatially-landscape values are the subject of protection, it is necessary to model also potential impacts to the local panorama and the relation between development project and the surrounding built up structures.

While visibility analyses in an open landscape depend more less on configuration of terrain, in cities, evaluation of sight impacts requires to cover all physical structures on the surface. Input data preparation is then the key for the success.

In Prague, the TIN terrain model of the area of the whole city and close surrounding has been maintained with the height accuracy from 40 cm in the edges to 4 cm by the river in the town centre. For the major part of built up area also the vector 3D model of buildings and green is available. The height accuracy of the 3D model varies also from 20 to 40 cm. Areas of growth green are modelled as the groups of schematic trees consisted of set of 3D polygons of trunk and treetop. Third part of the model is bridge model of the same technology as the buildings. The 3D model is saved in ESRI 3D shapefile format.

For the further processing, 3D vector data is necessary to convert into 2D data representing the footprints of 3D polygons and exclude all vertical features. To do this task, simple VBA script has been written. The result of transformation is 2D shapefile. Attribute table consists all attributes inherited from the original 3D model layer + new calculated fields: minimal height of feature (MinZ), maximal height of feature (MaxZ), average height of feature (AvgZ), slope of feature in degrees (Slope) and aspect of feature in degrees (Aspect). The transformation was applied to all 3D building, 3D green and 3D bridges source layers.

fig. 2: 3D source data for grid calculation

As construction of 3D model can not be topologically clear in a sense of 2D topology, the result of 2D conversion may contains overlapping features. Therefore, 2D data must be further processed. First, 2D topology must be cleaned in a way that the result will not contain any overlaps or gaps between neighbouring features. In a second loop, all features must be accommodated with attributes of the feature with the highest height (stored in attribute MaxZ) if the area of a feature falls within two original features. The process of topology cleaning has not been automated so far and it is provided by conversion of shapefiles to the ESRI Coverage format and applying the Clean function on the coverage. Matching the attributes of the "highest parent features" has not been automated as well. It is assumed to develop VBA script, which will loop the features calculating its centroid and then selecting source features from the parent layer, which intersects the centroid and finally selecting that one with the highest value in the MaxZ attribute and storing it in the attribute table of topologically clean layer.

fig. 3: Converted 2D data classified by the max height of feature

First attempts of viewshed analyses were based on the idea to add the buildings to TIN. The standard method of TIN editing, based on extrusion of building footprints gave good results for the small-scale analyses, but proved as unfeasible when attempting to model city-scale impacts. The main obstacle was the size of the TIN data, and following PC computation power limits. For this reason, grid model was used instead. TIN model was converted into a 1 m terrain grid. Secondly, transformed 2D data of 3D model of buildings were converted to the same resolution grid and the same operation was provided for the data of green and bridges. As all heights were given in absolute figures, the map algebra operation of replacing the values of surface values with the values of building and green was applied. In the ESRI scripting environment, the conditional (con) function was used:

```
output=con(IsNull[building], [terrain], [building])
```

The operation was done using by ESRI ArcGIS Desktop and Spatial Analyst extension. Because of the data size, the whole model is in fact set of 135 rectangular grid tiles. Manipulation with the grids and application of Math algebra and spatial analyst functions is handled by the set of Python scripts.

After calculation of all grids, merge function was used for merging all tiles into a single grid. The size of such grid is 3 GB. It covers the area of cca 600 km2 with 1 m resolution. The result represents surface grid model of the town surface and it is very useful for many purposes. Alternatively, as shown on the pictures, the surface grid model without green has been elaborated as well.

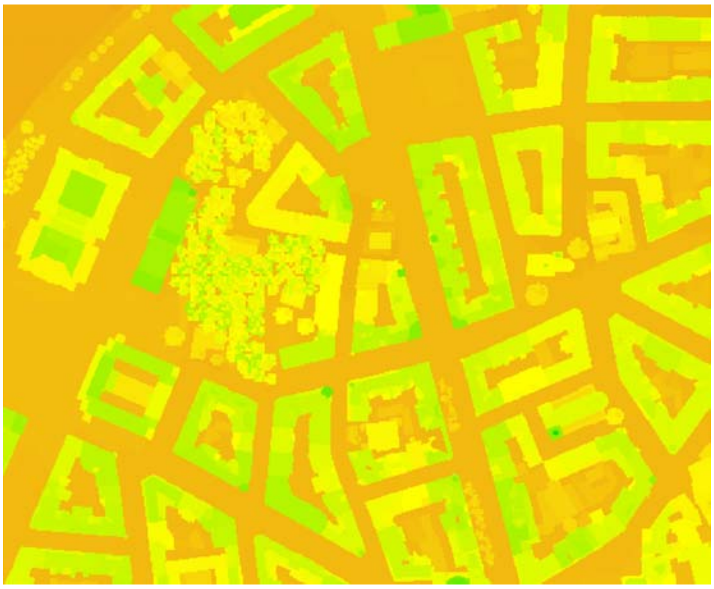

fig. 4: Detail of output 1m grid (combination of terrain, buildings, green)

Modelling viewsheds using the surface model instead of simple terrain model makes model results useful for practical implementation. In real world the visibility of objects depends on many other temporary and fuzzy aspects, i.e. seasonal state of green, fences, street objects and many others, however, the decisive influence have the built up structures covered very successfully with the model. The current representation of green leads to overestimating of its sight blocking effect, therefore, viewshed analyses are usually provided both with and without green influence.

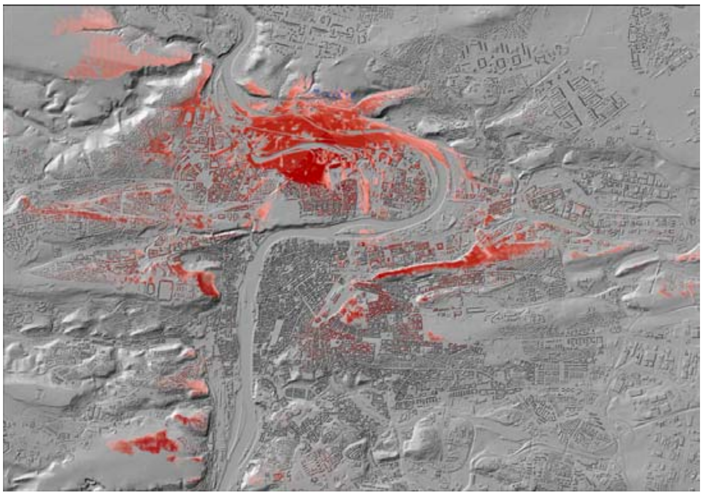

fig. 5: Example of large-scale viewshed analysis

As a side effect of surface model preparation it has been developed also an additional map product – hillshade structure map of city. The map has been generated by hillshade function with shadow rendering option. Detail building structures are well displayed in 1 m resolution, while 5 meters grid without shadow rendering is ideal for explaining and presenting the town structures in a city-wide level.

fig. 6: Detail of 1m hillshade grid with shadow rendering

3 MODELLING THE TOWN CENTRAL PLACES

Transformation of the classified vector data into grid opens the door for detail examination of location within the polygon boundaries. So far, the whole area of a single polygon was treated as homogeneous piece of space, while we can find many different qualities which representation by strict vector objects is a bit limping. For example density of population, expressed by the census units often does not reflect the substantial differences in density distribution within this zones. Also, discussed travel distances cannot be reliable when applied to the polygons of development sites.

Need to overcome the limits of vector representation for analyses of detail spatial and functional structure of the city, led in Prague to use grid models also for analysis of master plan land use data. The task was to search for the places in the city, which spatial and functional location has the physical attributes of the city centre location. Behind the task there was need to look at the city structure with a new perspective and try to find out the nature of relation between real town centres and geographically central places in a city. The results of analysis were then used for modelling one aspect of investment attraction.

The subject of analysis was evaluation of rate describing how centrally within built-up structure the place is located as well as how many central functions the location carries. As central functions were considered functions and services usually located in a city centres, as banks, offices, retail and high-density housing. On the other side, disturbing functions as industry, warehouses, transportation and logistic terminals etc. were treated as "anti-central" functions with a negative impact to the neighbourhood from the point of view of their chance to become an attractive town centre.

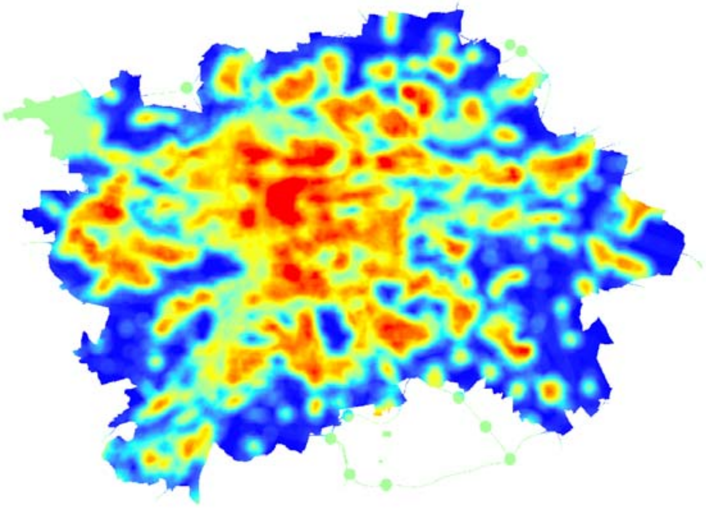

fig. 7: Grid representing index of functional centrality (400 m resolution)

Master Plan functional regulation zones data has shown as ideal input to the evaluation, as functional regulation is in fact synthesis of spatial typology and functional role of the place. The level of central functions is reflected by so-called mixed use-functions differentiated according to the intensity and structure of individual mostly public service sub functions. For the analysis elaboration, to each functional regulation class (type) the value form –10 to +10 was matched according to its supposed centrality potential. The pure residential zones were considered as of weak positive potential, while potential of industrial and natural zones was assessed as negative.

Using this value, grid of 20 m resolution was generated. Evaluation of centrality was based on evaluation of average value of centrality potential within 400 m neighbourhood area. The size of neighbourhood was defined as the walking distance to the local centres. Calibration of the model using by neighbourhood from 200 to 2000 meters proved that analysing of larger neighbourhood leads to excessive generalisation and scrapping of the local differences, while smaller neighbourhood size is not sufficient for generation local core spots.

The method was the starting point for further steps toward more complex town development model.

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