


Flood Management System

Xiaoming Xu, Guenther Lorber, Graz

Abstract

What happens if deluge of level x were passing through the city? How many inhabitants have to be evacuated? How many kindergartens, schools, hospitals, residential and others public buildings were involved? How many people were inside the buildings? If the flood burst the river banks, where were most possible dangerous locations? How big was each of the gaps? If the traffic system were under water, say from A to B, where was the optimal route for fire bridge vehicles? After the flood, what the tangible damages either in agriculture, industrial or residential/commercial areas might look like? To answer all these practical questions, one hybrid system combined of hydrodynamic system and GIS was developed jointly by Graz University of Technology and City of Graz for about three years. The characteristic features of the system design are described. Especially, database design, adoption of the results from hydrodynamic system into database, data fusion and analysis subsystems are delineated in detail. Most distinctive features of the system are following: a) Results of different hydrodynamic systems can be adopted into the system; b) The requirement of basic data, either from hydrology or geoinformation, is scalable. If the minimal requisite of the data source is available, the system is operational, even the more data sources are the more extensive analysis resulted; c) Comparing to other flood hazard maps, the system can be used as tools before, during and after the flood disaster happening. It delivers not only graphical overview of the deluge scope, but also suggests the rescuers with numerical analyzed results interactively. For decision maker, water related authorities, fire brigades or other disaster rescuers, and insurance companies the system gives either generated damage scopes or detailed numerical information; d) The developing platform is based on one of most up-to-date GIS system. Two forms of the system may be implied, as plugin solution of ArcGIS 9.x© or as stand along solution based on ArcEngine9.x© library. Since 2005 this system is tested and implicated along the river Mur in Graz city area. The application by the city fire brigade and annual adjusted results are presented.

Keywords: Floods, GIS, Disaster, Monitoring, Development, Systems, Three-dimensional, Database

Kurzfassung

Was geschieht, wenn Hochwasser mit einem bestimmten Pegel durch die Stadt fließt? Wie viele Einwohner müssen evakuiert werden? Wie viele Kindergärten, Schulen, Krankenhäuser, Wohn- und andere öffentliche Gebäude sind betroffen? Wie viele Leute befinden sich innerhalb von Gebäuden? Wo sind mögliche gefährdete Gebiete, wenn das Hochwasser über die Ufer tritt? Wie groß sind diese Bereiche? Wo ist der optimale Weg für Fahrzeuge der Feuerwehr, wenn Verkehrswege überflutet sind? Wie hoch sind die abschätzbaren Schäden, die in der Landwirtschaft bzw. in Industrie-, Wohn- oder Bürogebieten entstehen könnten?

Um alle diese Fragen beantworten zu können, wurde über einen Zeitraum von 3 Jahren von der Technischen Universität Graz und der Stadt Graz gemeinsam ein hybrides System entwickelt, das aus einem hydrodynamischen System und einem Geoinformationssystem (GIS) kombiniert ist. Die charakteristischen Eigenschaften des Systemdesigns werden in der Folge beschrieben. Im Besonderen wird dabei auf das Datenbankdesign, die Überführung der Ergebnisse des hydrodynamischen Systems in die Datenbank, die Datenfusion und die Analyse der Teilbereiche eingegangen.

Schlüsselwörter: Hochwasser, hydrodynamisches System, Überflutungsbereiche, Routenplanung, Evakuierung

1. General

1.1 General Instructions

More and more cities and towns are interested in the modern technology which can be applied in monitoring, forecasting and prevention of catastrophic events. Based on hydrological, hydrodynamic and GIS information, one system was developed for flood events management in Graz, Austria. If the flooding levels can be simulated in the natural way, many questions as mentioned in above abstract might be answered by this system. The general purpose of this system may be summarized in one sentence: if flooding of certain level is forecasted the system can be implied to tell the user what happens in the city in form of graphics and quantities analysing results.

1.2 The problem and background

After several floods happened in recent years, as it is in many other cities and towns in Europe, the disaster prevention centre, the rescuing forces and fire brigade of Graz are working on an improvement of flooding arrangement plan. The traditional plans show the corresponded actions on printout papers. By any variation of either topographic or man-made objects are they out-of-date. Another decided shortcoming is the absence of quantitative information and their inflexible forms. Since 2003, the City of Graz has engaged in the development of a system which should be based on the up-to-date technology, and first of all it should meet the needs of the authorities, e.g. accurate and quantitative analysing results, flexible and easy up to date, mobile and practical application for end users.

1.3 The Project space and time scope

The application area of Graz is about 146 km^2 and 250,000 inhabitants. Altogether there are about 34,000 registered buildings and among them about 200 are special buildings, for example, kindergarten, school, hospital and other public institutions. Figure 1 shows the city position in Austria. The object of this project is the 18 km long river Mur in the city area of Graz. There are several hydrological observation stations nearby and in this part of the river.

Fig. 1: Position of Graz in Austria

Fig. 2: The river Mur in the city area

From 2003 to 2006, the project could be divided into three major phases, phase one: p1.1) investigation of existed data, which kinds of data might be useful, and what kinds of data may have to be collected; p1.2) research and analysing the systems on the market, to find out if a suitable system may be applicable; phase two: p2.1) developing application based on ArcGIS© platform. p2.2) implementation of hydrological data and computation of flood simulation from level to level; phase three: p3.1) calibration of simulation results; p3.2) checking the simulation by flooding records; p3.3) application by local authorities.

2. The system

The major functional parts of the system can be divided into following: a) data management which includes the taking over of 2D hydrodynamic flow model into GIS database; b) establishing analysing model. Along most important rivers, especially those flowing through cities with dense population, there should be observation stations for hydrological data for years. As many other flux simulation systems, the more detailed digital terrain model (DTM), the much more similar are the results to the natural occurrences. In our case, we integrated not only the buildings, but also each element, like river banks, man-made objects etc. which may influence the simulation behaviours in the DTM.

2.1 Development environment

ArcGIS 9.x© might be the widely used GIS platform in public institutes in Austria. MS visual basic 6.0 was selected as working language due to the multitudinous subroutines and examples from ESRI developer supporting forum and also from third parties. In order to use its comprehensive functions without bonding to ArcGIS Desktop©, ArcEngine9.x© was also implemented to produce a standalone application.

2.2 Methodology

It is normal to get an inundation map for one city, but the questions are: What can be done before the flooding happens to some dangerous locations? What happens during and after the flood events? With flood simulation systems, like MikeFlood© that we applied in our project, it is possible to get out the flux vector at each grid point. We merge that information into the existed GIS data for the further analysing works.

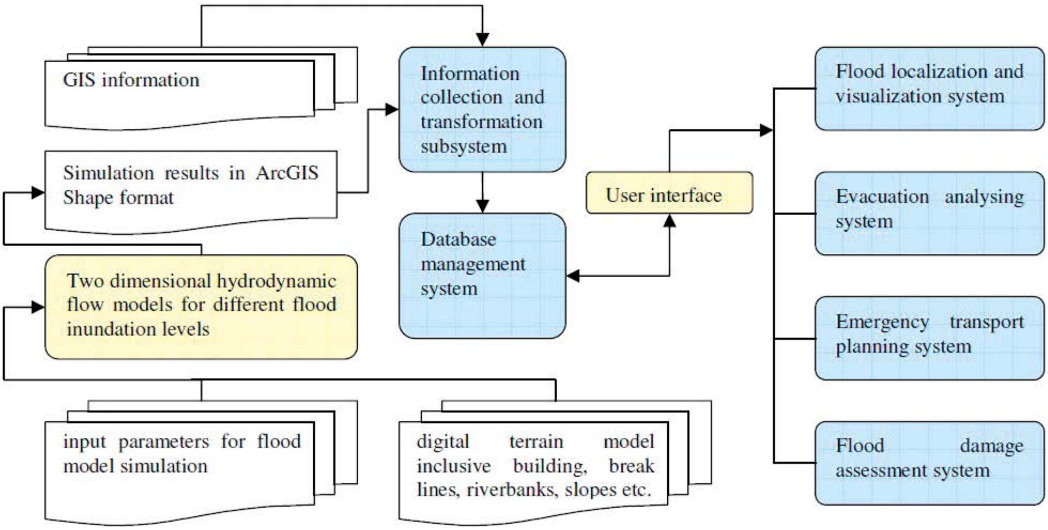

Fig. 3: System overview

2.3 The subsystems

Altogether this system consists of six subsystems as they are shown in figure 3 (blue background).

2.3.1 Information collection and transformation

Detailed DTM information including riverbanks is collected. The positions and heights of buildings in the city area are integrated into the DTM. Each flood level is computed with hydrodynamic observation data. The output results of the hydrodynamic system are the flow vectors on each grid point in shape format. By including other GIS data sources, like building information, traffic networks, agriculture/green, industrial, and/or commercial area etc., all the available information are transmitted into a geodatabase by means of semi/automatic conversion/input subroutines. Some data management works have to be done manually, e.g. vertical area detection of overflow locations, building including basement garage identification with corresponding priority.

2.3.2 Database management

Fusion of information derived from hydrodynamic system to geoinformation in third dimension is one of the key challenges of database design. In case the flood at level x bursts the riverbanks, the system should not only output the dangerous locations along both sides of the river, but also hand out the vertical area of each gap. In this way the water related authorities may know where the week positions along the river at flood level x are and how many materials may be necessary to stop the gaps in that situation.

2.3.3 Transport planning for emergency situation

The transport route may be computed by inputting of two addresses listed from database or graphically on the interactive display by mouse button press. As reference parameter is the water height which rescue vehicle may be able to pass through. The outputs, like the driving distance, name and distances of streets to be followed, driving time etc. are generated and can be print out if necessary.

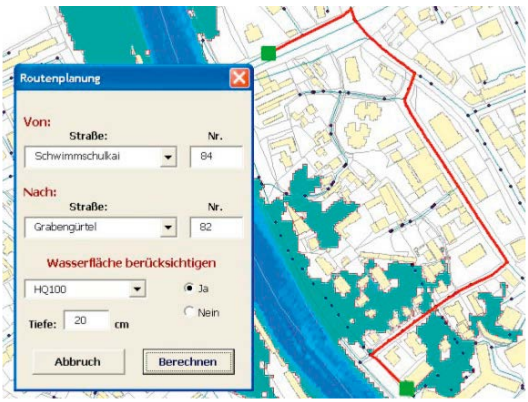

Fig. 4: Transport route with consideration of water height

2.3.4 Flood inundation prediction and events management

The accuracy of flood simulation depends on various factors. Two basic data sources might be the most important, i.e. accurate DTM and hydrological observations for years from different stations along the river. We integrated buildings as bodies in our DTM. This makes the simulation as natural as possible. 5 flood levels were simulated. The hydrological input parameters were gathered until flood level of 30 years. The remaining two levels were computed by extrapolated curvature.

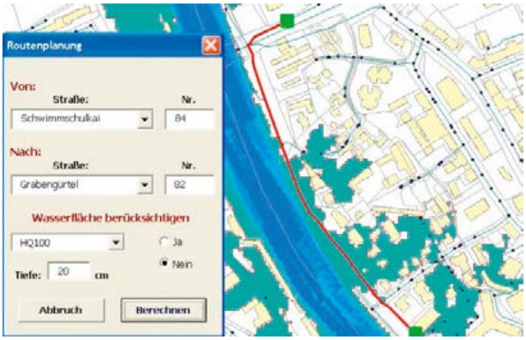

Fig. 5: Transport route without consideration of water depth

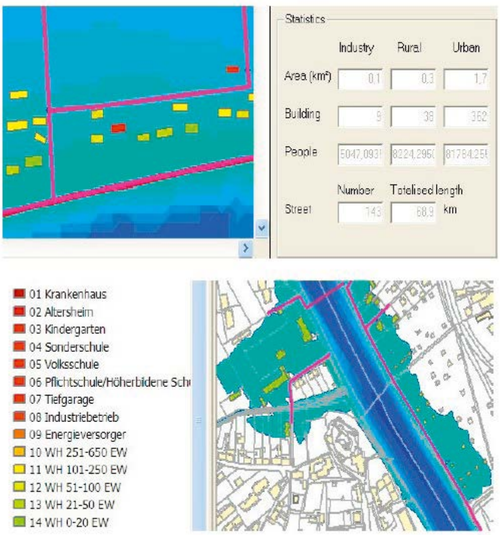

Fig. 6: Statistic (upper) and classification functions in "evacuation analysis" subsystem

2.3.5 Evacuation analysis

Which parts of the city may be touched by flood, inside these areas how many buildings with priority including the number of people may be created either graphically or statistically. For all of these building types, 15 priorities are indicated with different colours. During the emergent situation, the rescuers can follow the priority colours and know the number of the people inside the evacuated building. Another tool in this subsystem is the statistic function, which gives a general view of the disaster scope for each flood level. It is shown in figure 6.

2.3.6 Flood damage estimations are to be depicted with examples in figures and video films

The analyzing works of this part depend on the data model which is available for the city. Due to intensive costs, parts of data model from European neighbour countries are implied for our study. Another problem was the border definition of different area types, like those one of agriculture/vegetation, industrial and inhabitant/commercial. This may be quite different for countries in diverse continents. This research, as also the application of this system to river networks, including undergrounds drainage system may be left for the forthcoming works.

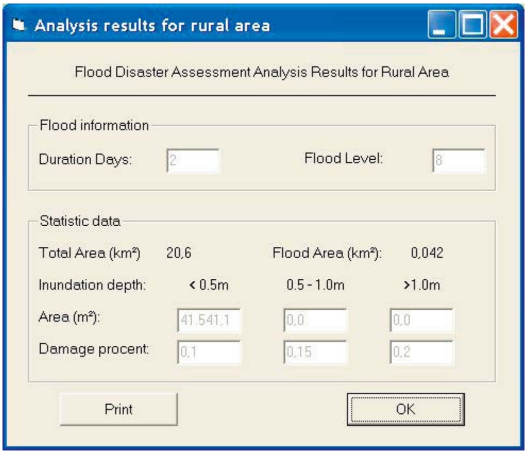

Fig. 7: Statistic table for disaster damage assessment

2.4 Data sources

The simulation results in shape file format for 5 flood levels were transferred into a Geodatabase. As input parameters for flood simulation are following data sources necessary:

- flux
- gauge height
- smoothness coefficients
- cross profiles of river channel
- slope edges
- digital terrain model (DTM)

- building data, not only the position, but also the height

We need additional data for analysing the model:

- register data
- cadastral data
- address data
- buildings information
- streets information
- priority data, this data was predefined by rescue forces for classification of rescuing procedure.
  - hospital/sanatorium
  - nursing home/ house for handicapped
  - kindergarten
  - special school
  - elementary school
  - compulsory school
  - underground garage
  - industrial plant
  - power utilities
  - Inhabitants above 250
  - Inhabitants 101-250
  - Inhabitants 51-100
  - Inhabitants 21-50
  - Inhabitants 0-20

2.5 The user interfaces

The end user of this system might be disaster management authorities, national and local rescuing forces, local fire brigade etc. The user interfaces should be designed as simple and direct as possible. This request implies that most of the pre-processing procedures have to operate semi/automatically.

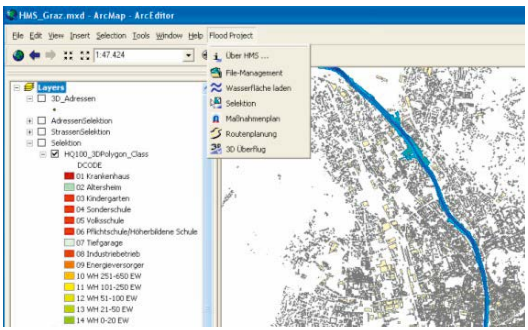

Fig. 8: User interfaces in form of plugin of ArcMap(TM)

The advantage of a standalone solution is the independence. This may be even more important for the management during disaster phase. For systems with wide range users it is more economical than a plugin solution.

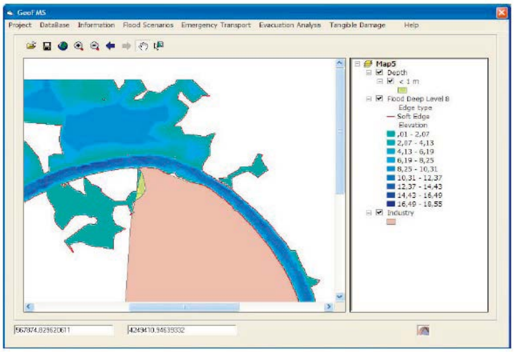

Fig. 9: Standalone solution based on ArcEngine(TM)

3. The Results and calibration

For the river Mur there are altogether 5 levels of flood that have been simulated, i.e. Q10, 30, 50, 100, 200. The rest analysing results depend on the accuracy of these simulation results. So the first step before analysing is to calibrate the simulation results.

As it can be interpreted from figure 10, the maximum gauge height differences between simulation and observation are located during the flooding period in July und August 2002, about 0.2 meter. In order to get clear curves, the differences are enlarged with factor two. Another checking index is flux at observation station x. As shown in figure 11, the flux amounts are also enlarged by factor 2, and the maximum differences (about 300 m^3/s) happened also during the flooding period in 2002.

3.1 Practical checking by flooding events

During summer 2005, flooding in level about 10 years happened in the city area. According to simulation results, the dangerous positions where overflow may occur were verified. The following figures show the theoretical and practical results: About five hours after the flood peak, the simulated overflow locations were checked with the correspondent simulated flood level. The scopes of the overflow are relevant to the theoretical values, as it shows in figure 12. There were some other locations, where simulation was not exactly the same as the reality. The reason was the slope error of the river banks.

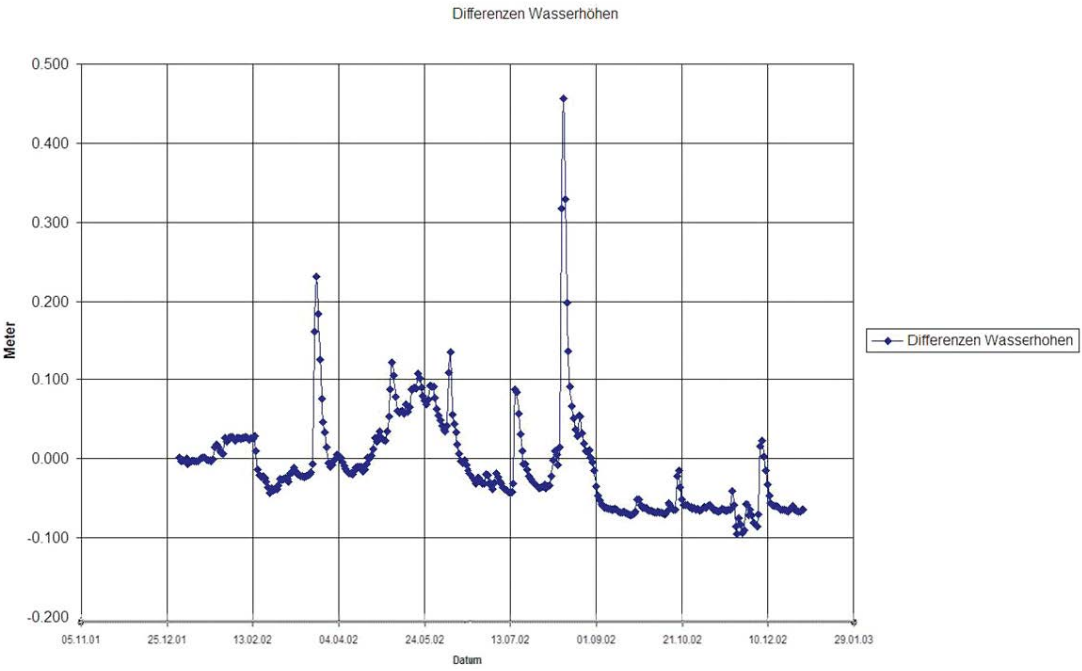

Fig. 10: Gauge height differences of simulation and observation results at station X

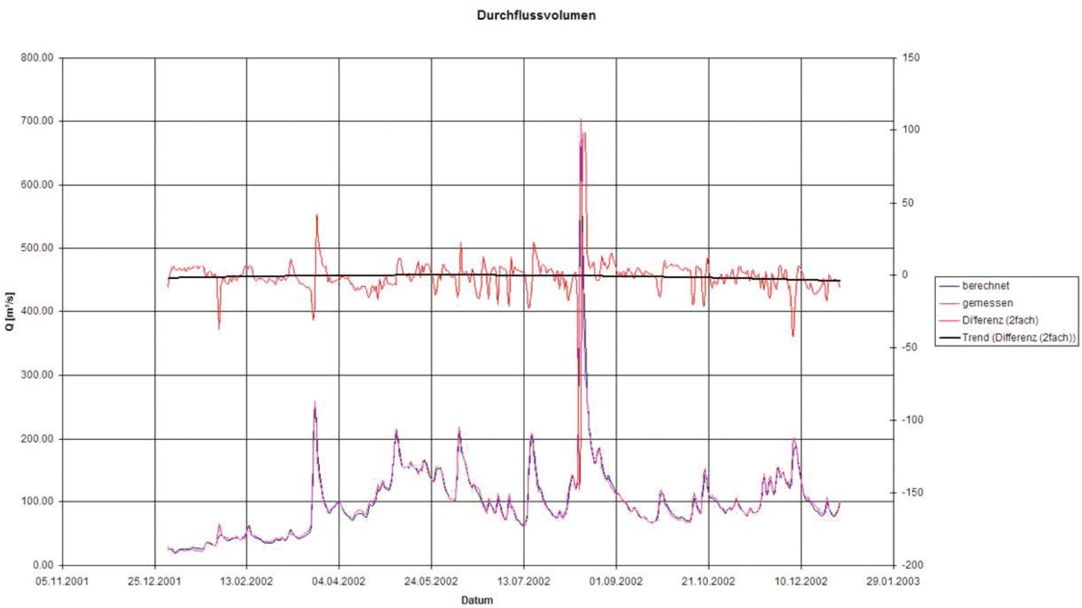

Fig. 11: Flux differences of simulation and observation at station x

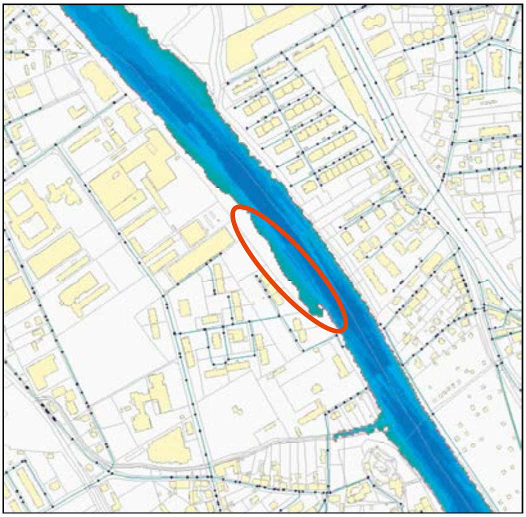

Fig. 12: *Simulated (upper) and practical checking overflow areas at flood level 10*

4. Forthcoming works

4.1 More data sources

The surficial area data of either rivers or streams should be included and simulated by networking methods. But due to lack of observations none of the streams in Graz was included in the simulation and followed network analysis. For some areas the canal overflow may influence the surficial model too, but in this project they were not immersed.

4.2 Rainfall radar may be integrated into the system for Real-time forecasting

The system will tell us what happens in next time when the flood level x is forecasted in time. This task may be difficult for city areas where not enough rainfall or flux observation stations are installed, and for streams it is also uneconomical to install such a station along each stream. One thinkable solution is to install rainfall radar which covers the whole city area.

4.3 Internet presentation

The data protection regulations are varying from country to country. The sensitive data, like building information, inhabitant number, its distribution and other relevant information may be the fundamental barricade for the system to be published on internet. The future works may be concentrated on the aspects how to adjust the application according to the local or national law regulations.

5. Conclusion

One system either as plugin for ArcGIS(TM) or as standalone application based on ArcEngine(TM) with study area in Graz is presented. Different scenarios were simulated by MIKE21 from DHI Group, and the results were imported into the system for visualization and analysis of the diverse flood events. The improvement of DTM with integrated buildings and other man-made objects in the city area made the inundation more accurate and natural. The analysis of various flood scenarios based on the two-dimensional hydrodynamic flow model has shown its practical application potentiality in different disaster management fields.

References

HJ.Booysen, et al.: Methodology for the calculation of industrial flood damage and its application to an industry in Vereeniging, http://www.wrc.org.za (1998), pp 41-46

X.Xu: Hochwassermanagement, Esri-User-conference, 2007, Erfurt, Germany

X.Yang, et al.: Predicting flood inundation and risk using geographical information system and hydrodynamic model: a technical report on the case study at Eskilstuna, University of Gävle, 2001, Sweden

Yangtze River Flood Control and Management Project, Yangtze general planning, http://www.ccol.tv, 2003, China

Contact

Dr. Xiaoming Xu, Magistrat Graz, Stadtvermessungsamt, Europaplatz 20, A-8020 Graz, Austria.

E-mail: xu@stadt.graz.at

DI. Günther Lorber, Magistrat Graz, Stadtvermessungsamt, Europaplatz 20, A-8020 Graz, Austria.

E-mail: guenther.lorber@stadt.graz.at