

# GRAND CANAL IN SCAN- AND IMAGE DATA

## Mobile Laser Scanning in Venice

High measurement rates and centimetre precision point-clouds are state-of-the-art in mobile laser scanning. The introduction of photogrammetric features as next logical step considerably expanded the horizon of potential applications. Digital 3D documentation of Venetian cultural heritage as represented by the Grand Canal has until recently been achieved only for a few individual buildings. Now, in a collaborative project carried out by Università IUAV di Venezia and mobile-scanning system VMX-250 manufacturer RIEGL Laser Measurement Systems, the entire Grand Canal area has been registered in time-stamped image and scan data, complete with precise location and position data.

The IUAV CIRCE Photogrammetry Lab presented its project idea to RIEGL following contacts with the company's Italian distributor, Microgeo srl. After considerable R&D efforts, a new, modular camera system was integrated into the RIEGL VMX-250 in September 2010. The Venice project was an exciting and testing setup for simultaneous acquisition of 3D point-clouds and high-resolution images. By exemplary processing of single facades, the quality of the coloured point-clouds was to be proved and their appropriateness confirmed as a basis for further mono-plotting processing, and 2D and 3D CAD maps.

### Mission Planning

Meticulous planning is a matter of utmost importance in mobile-scanning campaigns. In Venice this involved gaining a thorough impression of the scene, local conditions and resources at our disposal. The Grand Canal is a waterway of approximately 4km in length and 40 to 70 metres in width, frequented by heavy right-hand side traffic. With the exception of some Vaporetto stops, free views are afforded on either side of facades of 20 metres maximum height. In order to convert the acquired data into 1:100 scale it was necessary to achieve 1-cm point-to-point spacing on the object. The duty boat was rented, 20m long and complete with crew and crane. According to forecasts concerning the days we were looking at in early November, reception of signals from seven to ten satellites could be expected: ideal preconditions for gaining a precise trajectory. The national reference system 'Gauss Boaga', an orthophoto and a 1:2000-scale 2D CAD map of Venice provided further information. Weather remained the one big unknown.

### On Schedule

IUAV team members Francesco Guerra, Paolo Vernier and Andrea Adami; Simone Orlandi of Microgeo; Gerold Eßer, Jan Kanngießner and Mathias Ganspöck of EKG Baukultur; and RIEGL's Nikolaus Studnicka and Philipp Amon met up in Venice on 10th November 2010. Despite high water, rain and fog, the project started on schedule. Theoretically, one single measurement day would have been sufficient. But bad weather led the team to decide to carry out scanning trips over three days, under differing conditions.

Taking into account the right-hand traffic, two camera positions had been predetermined. Visual occlusion of facades by water-bus stops was reduced to a minimum by mounting the scanning system at three metres height on a scaffold (Figure 2). Passage height of bridges (7m) and driving speed (5km/h) presented no problems. Daily on-scene data processing for data checking purposes confirmed the scanning parameters applied, and proved the trajectory precise and the initialisation process ideal.

### The System

The VMX-250 consists of two RIEGL VQ-250 'Full Circle' laser scanners, an inertial navigation system (INS) combined with global navigation satellite system (GNSS) establishing the INS-GNSS unit, and an operating computer in a portable box. The INS-GNSS unit comprises electronics for real-time kinematic (RTK) data processing and three sensors: an inertial measuring unit (IMU), a distance measuring indicator (DMI), and a GNSS receiver including antenna. The scanners and the INS-GNSS unit are mounted tightly coupled on and within a rigid sub-mount, intended to be carried by a vehicle. A single cable connects the acquisition platform and the compact box placed inside this vehicle. The box contains power supply, an embedded computer running acquisition software, removable storage disks, and a handy touch-screen providing a comfortable control interface for the operator. Both laser scanners are operated synchronously during a survey, achieving 600,000 measurements per second in combined action, for extremely fast, efficient and highly accurate 3D mapping.

The VMX-250-CS6 camera option, supporting up to six industrial cameras with global electronic shutter, completes the system. Each

camera is protected by a sealed and heated housing. An additional PC embedded in the control unit controls image acquisition, and resulting data is stored on three additional hard disks. Flexible and modular design allows mounting and tilting of the cameras according to need.

### Setting Parameters

For the Venice project, two 5-Megapixel cameras with 12-mm lenses were mounted in portrait format, with overlapping field of view (FOV). This setup results in an effective vertical FOV of 70°, corresponding to pixel footprint of 15mm at 20m distance. Corresponding to the travelling speed of 5km/h, both cameras were triggered every 1.5 seconds.

Based on the input of vehicle speed and target distance, the acquisition software RiACQUIRE calculated the ideal scanning parameters for each scanner and each trip in terms of a certain point pattern on the surfaces. In the case of the Venice project, an overlay of three trips was necessary for the required point density of an orthoplan: the orthogonal representation of the scanned point-cloud. Ideally, the required point density of 10,000 points/m<sup>2</sup> should be gained in one single pass. However, this would demand an even higher measurement rate, slower travelling speed and shorter distance between boat and façade.

### Data Processing

As the most important traffic artery of Venice, the Grand Canal describes a broad loop through the entire urban area. The three bridges, Ponte degli Scalzi next to the train station, the Rialto Bridge, and Ponte dell'Accademia in the south, served as reference for splitting the project area into four sections for data acquisition. The focus during post-processing was set on Section 3, the area between the Rialto and Scalzi Bridge. All datasets recorded were used for scan-data adjustment. For this purpose, suitable segments of planar surfaces on the facades, called 'tie planes', were defined in the scan data using RiPROCESS software. Before adjusting scans to each other, the heading angle had to be optimised. The automatic adjustment function in the software package provided all required heading correction values for the trajectory along this section of the Grand Canal, for all scans. In a second step, based upon the already defined planes, minor corrections of position in latitude, longitude, and altitude were determined, serving an optimal correspondence of the single scans from different days.

As a result of these two steps of adjustment, the residual standard deviation was 0.0137m, taking into account the 95 linked tie planes, which corresponds to 16,771 observations for the least-squares adjustment algorithm. Once the point-cloud was optimised, image data were adjusted. For this task, single passes were evaluated and only those up- and down passes with pictures from both cameras best suited for white balance were optimised according to light conditions and then brought into congruent matching. By clicking on distinctive points in an image and the corresponding ones in the point-cloud, the external calibration of the cameras was determined. This task accomplished, it became possible to precisely synchronise navigation and measuring in both image and scan data. A few mouse-clicks later, and the point-cloud was coloured and a photo-realistic 3D point-cloud permitted a first breathtaking virtual trip through Grand Canal.

The quality of the final point-cloud at our disposal in the WGS84 coordinate system was assured through externally surveyed control points. To be able to perform further processing in the local Italian coordinate system (Monte Mario / Italy Zone 2), the project was accordingly transformed by the RIEGL Software tool GeoSysManager for data export into the widely used LAS- format.

### Photogrammetric Analysis

Based upon the orthogonal projection of the point-clouds, EKG Baukultur and Phocad drew 2D-CAD plans and orthophotos (Figure 4). Data quality proved extremely sufficient to produce 1:100-scale plans of the facades. Internal evaluation of the data revealed that the precision of the CAD drawings complied approximately with Degree 2-1 of the Austrian ÖNORM standard A6250, while information density complied with Degree 3 of the quoted standard. Deformation, as well as settlement and other damage to structure were distinctly recognisable.

