MOBILE MAPPING WITH A STEREO-CAMERA FOR ROAD ASSESSMENT IN THE FRAME OF ROAD NETWORK MANAGEMENT.

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ABSTRACT:

The management of existing road networks and their cost-efficient maintenance is of increasing importance, especially there where networks are almost completed. Road monitoring for the assessment of the state of the network is an integral part of road management. A major step in road management is the making of an inventory of the network. Often the geometry of the roads and all kinds of quantitative properties are included in the database. The evaluation of the quality of the road network also includes the determination of the state of deterioration of the road surface and a rough quantification of the surface area affected by deficiencies.

We will present an approach of road monitoring using a mobile mapping system with stereo-camera. The main motivation for the use of a pair of cameras is the possibility to measure objects in the image pairs. The objective is to identify particular objects, to determine the size of objects or the distance between objects. This objective is to be matched in a semi-automatic way, by post-processing of the images taken on the field.

In our contribution we will describe the set-up of the tested configuration of a stereo-camera on a vehicle, we will report on the execution of an experiment in a suburban environment and we will present some results of the interpretation of the images.

1. INTRODUCTION

The management of a road network needs efficient ways for assessment at minimal costs. This contribution describes an approach oriented to the specific needs of road assessment making use of a mobile mapping system consisting of a stereo-camera on a vehicle. Our concern for the precision of the measurements is the key motivation for the work reported here.

The context of the application domain for stereovision addressed here is given in Section 2. This includes some references to existing techniques other than by cameras as well as to reported usage of a stereo-camera approach for road assessment. In Section 3 an experiment with a stereo-camera of the University of Ghent on a road assessment vehicle of the BRRC is described. The set-up of the tests and also the calibration procedure for the cameras are discussed. In Section 4 the experiment is evaluated and some results of the interpretation of the image pairs are presented.

2. CONTEXT: ROAD SURVEYS

2.1 Importance of road management

Now and then everyone is confronted with repair works on the road. Often national, regional or communal official instances are the network managers and they decide on the execution of the maintenance works. Pavement management systems (PMS) assist them in their quest for a cost-efficient investment policy. A PMS is built on top of a database of all roads in the network. In a first step the network has to be inventoried. Interventions on the road can be undertaken by numerous actors (for example by gas and electricity companies or by telecom operators), and hence the content of the database must be checked regularly against the real state on the terrain. Another valuable input for the PMS is delivered by road assessment procedures for detection of deficiencies or deteriorations of the road structure itself. The most inexpensive assessment giving a good first impression of the state of a road is the visual inspection of the road surface.

For maintenance planning the road network manager needs adequate information on the state of the road surface: presence of cracks, potholes, rutting, etc.. Sometimes results of a visual inspection suggest possible structural problems. In such a case the road network manager can decide for further investigations on project level. The whole setup of assessment and PMS helps the road manager in his choice to undertake well-oriented actions for the improvement of the safety and user-friendliness of the network.

2.2 Objectives of the road survey

Two advantages of camera technology for road network assessment can be put forward. Rather than interpreting everything on the road, the camera on a vehicle allows collecting the data fast on a clear day while interpretation of the

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images can be done safely in the office. The use of a stereo-camera allows treating the image pairs for the measurement of objects in the images. Whereas measurements in situ are limited in number due to lack of time and are done rather inaccurately due to the difficult or dangerous access to a road lane, computer driven interactive measurements in the images are fast, safe and sometimes much more precise. Due to limitations on the field, the inaccuracy of measures with a “distance measuring wheel” can rise up to 15 cm.

For road surveys, many objects are relevant. The road signs must be visible, their minimal size and the height of their placement is regulated. Road signs are easily detected in images due to their standard shape but may be harder to detect when damaged. Three-dimensional information may help detecting such damages. Note that the measurement of size and height of road signs needs high precision. Also horizontal signalisation is regulated. For instance, the width and the orientation of the crossings for pedestrians and the size of the lines delimiting cycle tracks are prescribed. A database of a road network often contains the presence and width of lanes, sidewalks and cycle tracks, the presence and size of traffic signalisation and traffic lights, the type of material used for the road, and in case of concrete roads this also includes the size of the concrete slabs. For safety of and serviceability to the end-users of the road network, information about the space left for pedestrians and wheelchair users around obstacles like bus shelters or light poles on the sidewalk is of interest to the road manager. The presence of manhole covers and gully holes and their relative position to the middle of the road is of practical use for the execution of road works.

2.3 Existing techniques

The most commonly used traditional approach to road assessment simply is the use of a piece of paper and pen by an operator going around on foot. Variants on this approach try to simplify the task of the operator, proposing various recent technologies. These include the use of dedicated software running on a computer on board of a slowly moving vehicle (e.g. the touch screen software of “SAND” of the BRRC and of the Scandinavian data collection software “CamSurvey”) and the introduction of GPS and cartographical data in order to improve the absolute positioning of the observations.

Several researchers announce the use of camera technology for road assessment purposes, like (Tao, 1998), (Gilliéron, 1999) and (Wang, 2006). Some companies already adopt a stereo-camera approach. The Canadian company Géo-3D commercializes the software “Trident 3D Analyst” for the computation of distances in 3D between points in a pair of images made by a horizontally oriented pair of cameras, as described at (Trident, 2006). The Belgian company Sodiplan uses its “Système d’Acquisition Mobile” for the interactive measurement of distances in the stereo-images taken consecutively by the same camera, as described at (SAM, 2006). The GPSVision™ system of the American company Lambda Tech International produces digital stereo-images, as described at (GPSVision, 2006). Their “Feature Extraction Software” allows the determination of the absolute position of a selected point in a pair of images by combining stereo-vision with integrated GPS-INS. At the Flemish ministry MOW the images made with the camera of their A.R.A.N. vehicle and the precision of the measurements in two consecutive images treated with the software “Surveyor” were studied, as reported in (Van Geirt, 2005). Both A.R.A.N. and Surveyor are commercial products of the Canadian company Roadware.
Satellite images or assessment with MAV technology clearly have their application domains. But the camera on a vehicle is a worthy complementary setup between the operator on foot and the flying devices.

3. EXPERIMENTAL SET-UP

3.1 Stereo camera

In our setup, traditional B/W video-cameras in PAL resolution (720 x 486 pixels) are used configured in a stereo geometry (cf. Fig.1). Stereo vision offers the possibility of producing a rich 3D reconstruction by observing the parallax to determine the distance of the cameras to various objects (Faugeras, 1993).

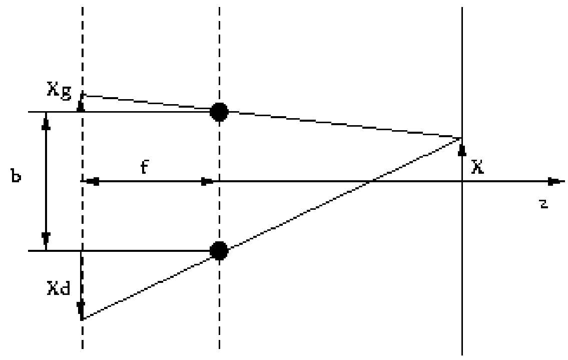

Fig.1: Stereo geometry with baseline b and focal length f.

In order to extract metric information from the images, camera calibration is performed to model the camera parameters (i.e. intrinsic matrix and lens distortion) and the stereo geometry (i.e. baseline and relative orientation of the cameras). For the lens distortion, we have modeled the radial distortion up to third order (cf. Fig.2).

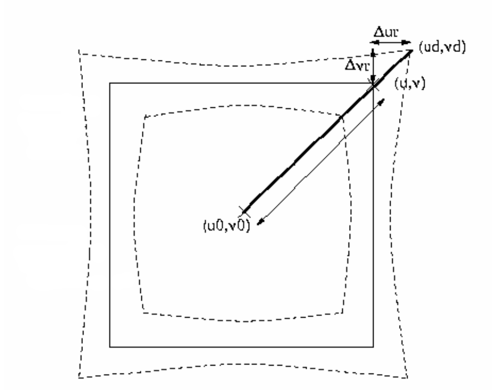

Fig.2: Modelling the camera lens distortion

Since the road assessment has to take place on site sometimes quite far away from the home base of the assessment team, calibration of the stereo camera must partly be done on site. Another advantage of calibration on site is the flexibility with which the camera configuration can be adapted on the fly, allowing several configurations on the same spot on the same day for different applications concerning objects in front of the vehicle or on the side of the road.

A portable frame with grid for calibration had to be designed. For calibration purposes, the size of the grid must be sufficiently big considering the distance range between the cameras from 50 cm up to 2 m. Optimally the grid must be on a perfectly flat surface and the cross points of the grid must be equidistant. Still, the grid has to fit in the vehicle for transportation between home base and assessment site.

3.2 Construction on ARAN

The Belgian Road Research Centre is the proud owner of an Automatic Road Analyser (A.R.A.N.), a multifunctional vehicle for the detection of transverse and longitudinal unevenness of the road surface. A gyroscope and a tool for distance measurement is part of the standard equipment on board. The A.R.A.N. can also be equipped with an integrated GPS system. However, in the experiment an external GPS system of the company Vansteelandt B.V.B.A. was used instead.

Fig.3: A.R.A.N. and stereo-camera

A beam was placed on top of the roof of the A.R.A.N. (cf. Fig.3). At both ends of the beam a support was attached on which a camera can be fixed. The supports can change orientation and the distance between the two supports can easily be modified. This allows changing the relative position and orientation of the cameras on the field: looking sideways and positioned close to each other when concerned with objects on the side of the road, or looking ahead and positioned further away from each other for full lane coverage in the images.

4. RESULTS OF TEST RIDE

A test ride was organised in a suburban area, one part in use as industrial area and another part dedicated to habitation. The speed limit in the area was 50 km/h, the road surfaces were made out of asphalt or of block pavements and on the chosen trajectory we encountered bus stops, bridges, traffic lights, a roundabout, etc..

4.1 Execution of test ride

In the experiment, we tried to establish a constant speed of 18 km/h during the whole test ride. Four rounds were made, some with the same and others with different camera orientations. This resulted in camera pictures over a total distance of 34 km. During the day the weather changed from cloudy to quite open and clear conditions. Before each test round, the cameras were oriented to the portable grid calibration frame.

4.2 Difficulties and limitations

As for all approaches with a camera, parked cars, busses and trucks sometimes block the view. During the day local situations changed and at some places the parked obstacle had disappeared at the next passage. This influences the completeness and the repeatability of the measurements. However, compared to a visual inspection on the spot, the risk of overlooking something is reduced since images can be reviewed over and over again in the office and the places where a view is blocked can be identified easily. Whereas the lack of completeness implies a weakness for the setup of an inventory, it does not jeopardise the management of the network afterwards. Often for a PMS it is not necessary to have a complete set of data, since priorities are set on a network level and it is quite reasonable to assume that events are evenly distributed over the network. For detailed evaluation on project level, the road manager will return to the selected area and will apply other techniques of survey with higher precision. The same remark holds for the repeatability of the technique: the influence of the difference on two passages is not relevant for assessment on network level meant for priority setting on road maintenance works.

The determination of relative distances and sizes of objects in the image pairs is an operation depending only on the stereo-camera and its calibration. Absolute positioning linked to the camera images and an accurate determination of the absolute position of an image with respect to a well-drawn map highly depends on the accuracy of the start position (GPS or Lambert coordinates), of the INS system on board and on the relation between the position and orientation of the vehicle and the object in the camera images. Although all necessary systems for absolute positioning were available, the full integration of the setup for the test ride was not good enough for highly accurate results. However, the main objective of the test ride was the measurement of relative distances and sizes.

The combination of the images with other road survey measurements done at the same time with the A.R.A.N. is always based on distance laps rather than time laps. The advantage of distance referencing over time is the possibility to vary the speed of the vehicle. An image recording system based on time implies repeated recording of the same images at standstill, for instance in traffic jams or at a red traffic light.

4.3 Interpretation

In this phase of the work, we investigated if the video data is useful to perform measurements on the image. This means that objects of interest need to be visible with enough contrast and sharpness to be able to identify object borders with high accuracy. At the speed of 18 km/h, objects were visible without motion blur except when taking corners. Contrast proved to be more of a problem since the cameras did not have an auto shutter option. A few examples of objects of interest recorded during the test ride are shown in Fig.4.

Full accuracy assessment could not be made at this time due to the lack of ground truth data. We studied the stability of the stereo setup by examining the epipolar constraint (Faugeras, 1993). This constraint demands that points in one stereo image lie on the corresponding epipolar line in the other one and vice versa. The corresponding epipolar lines are defined as intersection of a plane, containing both optic centers and a given point in the real world scene, with the image planes. The simplest case is when the camera conguration is parallel, i.e., when the image planes are coplanar and the vertical camera coordinate axes are parallel. In this case the vertical component of the disparity vectors is zero and the epipolar lines coincide with the scan lines. A sample is shown in Fig.5. Three points of interest are defined on the image of the left camera, which are useful landmarks to measure lengths. The corresponding epipolar lines of the same landmarks in the image of the right camera fall within a pixel of these points, showing that the calibration of the stereo geometry holds. For more detailed assessment, ground truth data is being collected to assess relative and absolute accuracies.

Fig.4: Sample frames from the test ride with objects of interest

Fig.5: Relative accuracy assessment using epipolar constraint

5. CONCLUSION

From the discussion in this contribution it is clear that the use of a stereo-camera on a vehicle can be of use in the assessment faze for maintenance planning of road networks. The set-up of the configuration of a stereo-camera on a vehicle and the execution of an experiment in a suburban environment described in this contribution allowed us to experience the practical difficulties of the exploitation of stereo-vision for road assessment. We were particularly concerned about the accuracy of the off-line measurements done in the office afterwards. The reported interpretation of results is promising and confirms that the approach applied in the experiment is a valid set-up for road assessment. Objects of interest are clearly visual in the images and the calibration of the camera pair is stable. However, further investigations based on comparisons with ground truth data are necessary and on their way in order to label the measurements in the images with correct accuracy estimations.

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