QUALITY PARAMETERS OF THE OPTICAL DATA CHANNEL USED IN IMPACT TESTS

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ABSTRACT
The German automobile industry intends to revise the existing ISO standard for measuring techniques in impact tests on road vehicles. The revision is an improvement of the ISO standard with regard to the application of three-dimensional analysis and of digital high-speed cameras. It is also however an extension of the reproducibility of the results for analysis. For this purpose the entire operational sequence of an impact test on road vehicles must be regarded first, i.e. the design of the photogrammetric network and its evaluation from a theoretical point of view. This work is part of a project between the Institute of Photogrammetry and GeoInformation (IPI), University of Hannover and the German automobile industry.

1. INTRODUCTION

In the German automobile industry new developments in digital high-speed-cameras and three-dimensional analysis of the impact tests have recently started to be used. The problem is, that the impact tests on road vehicles are not only carried out by the automobile firms themselves but also by external service providers. To compare the results of these service providers with other results and to be sure that the impact tests and their analysis are carried out reliably, the ISO standard 8721: *Road vehicles – Measurement techniques in impact test – Optical instrumentation* (ISO, 1986) was developed in 1986. Many new developments are not however included within this standard. Thus the German automobile industry has begun to revise this ISO standard 8721 encompassing the new developments. This revision of the ISO standard is part of a project between the German automobile industry and the Institute of Photogrammetry and GeoInformation (IPI), University of Hannover.

Due to the revised version of the ISO standard the new execution of impact tests and the results of the analysis become comparable. The quality of the execution is also of special interest. Therefore the quality of the network design and the other components of the impact test have to be evaluated. Generally the quality of a network design is defined by the standard deviation of the computed three-dimensional object coordinates, derived by error propagation. Influences such as improper illumination or unsuitably small targets are usually only captured in the used measurement accuracy.

In this article a more detailed possibility for the estimation and optimisation of the quality of the used network design will be presented. Simulations will be carried out in the preliminary phase of the real impact test. Thus there is the possibility to pre-estimate the accuracy of the determination of three-dimensional object points and to change the network design if necessary. In the following paragraphs the network design and the results of the analysis will be called the optical data channel.

2. OPTICAL DATA CHANNEL

2.1 Definition

The optical data channel is defined as the network design and the results from the analysis of the impact test on road vehicles. The term optical data channel has its origin in two different fields of activity, optical measurement techniques and quality management.

2.2 Validation of the optical data channel

The optical data channel consists of different processes, which affect each other mutually (Fraser, 2001). In order to be able to give a statement about the entire optical data channel, it will be divided into its components. Each of the components will be investigated with regard to its quality (Wiggenhagen, Raguse, 2003). Subsequently, the quality of every related component will be described by a criterion. To structure the whole task, the components will be divided into two groups. The first group comprises all image-related components. This group contains components, which describe only one image. In the other group the model-related components are combined. These components define the relationship between the images forming the models. The grouping of the components corresponds to the processing sequence. First, each image will be investigated, then all images will be assessed as model and/or block (Raguse, Wiggenhagen, 2003).

3. COMPONENTS OF THE OPTICAL DATA CHANNEL

3.1 Image-related components

Image-related components are for example the properties of the targets. These target properties are crucial for the results of the analysis. In most applications the measurement of a target's image coordinates is carried out automatically. The accuracy of the derived image coordinates typically lies between 0.02 and 0.2 pixel, depending on the used algorithm. In order to be able to obtain this accuracy some requirements on the signalisation of the targets in the images have to be fulfilled. An example of this is that the diameter of the targets must have a given target type-related minimum size (see Figure 1).

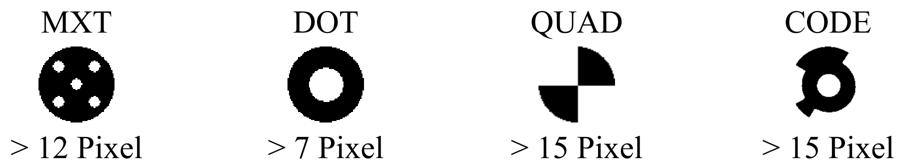

Figure 1. Minimum target diameter of different target types (Falcon, 2003)

The distribution of the targets in the image is also critically important. This distribution of the targets is described by counting the number of points in different image sections and by the determination of the area which is formed by the control points.

A further element of this group of image-related components deals with the camera calibration. There are special requirements for the camera calibration to obtain the parameters of interior orientation. These requirements are comprised of the structure of the calibration field and the network design used during the camera calibration (AICON, 2002; Luhmann, 2000)

3.2 Model-related components

Model-related components are for example the network design. Normally an optimal network design (see Figure 2) with different height levels and a circular setup is used to obtain a robust geometry for the determination of three-dimensional object coordinates (Rautenberg, Wiggenhagen, 2003). This is the optimal configuration and meets the requirements with regard to the accuracy and reliability of the application. However the effort needed may be to high to be justified in an operational setup. Through simulation of the impact tests the camera stations and the number of acquisitions as well as the camera lens combinations can be carried and adapted to the desired requirements and the available resources (Fraser, 2001).

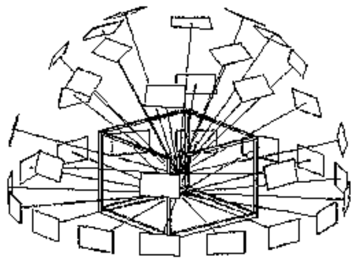

Figure 2. Optimal network design with different height levels and a circular setup

4. REVISION OF THE ISO STANDARD

4.1 General

The existing version of the ISO standard 8721 (ISO, 1986) determines a value for the quality validation of the optical data channel. This value is called the distortion index. This is not the same as the distortion index in the revised version of the standard. The previous distortion index does not give the user the possibility to look for the cause of an error in the optical data channel. The component which causes this error cannot be found directly. An appropriate standard for the American automobile industry is the SAE J211/2: *Instrumentation for impact test – part2: Photographic instrumentation* (SAE, 2001). The scope of this standard says, that the purpose of this SAE Recommended Practice is to define criteria of performance for an optical data channel when numerical time and space data are taken from the images to analyse results of an impact test. The basic concept of the SAE to determine the quality of the optical data channel from the quality of the divided components should be used in the revision of the ISO standard. Thus the revision of the ISO standard 8721 is a combination out of the old ISO 8721 and the SAE J211/2.

Also, there are a few requirements for the performance verification of an optical three-dimensional measuring system (Schwenke et al., 1998; Luhmann, Wendt, 2000), which should be recognised. A testing procedure has to meet the following aspects:

- sensitive to all system-specific error components,
- easy to interpret,
- cheap, easy and fast to handle,
- conformity with existing standards and guidelines,
- provide traceability (link to the definition of the unit “meter”),
- global ok / false decision.

These requirements can be best fulfilled by the use of a calibrated reference object.

4.2 Realisation of the revision

The already mentioned requirements for the performance verification of the optical three-dimensional measuring system should be recognised by the revision of the ISO 8721. All six requirements are implemented in the current revision of this standard. The length measurement error of the calibrated reference scale is used to verify the optical data channel because all of the system-specific error components are reflected in this value. The testing procedure for every component takes place on the basis of simple functional and geometrical connections , so it is easy to interpret. There is no special equipment needed for this testing procedure, so it is cheap easy and fast to handle. The quality decision of every components leads to an ok/false decision. To come to a global ok/false determination of the optical data channel all decisions of the components will be combined. Calibrated reference scales are used during the analysis to provide the traceability. By the use of these scales the conformity with existing standards and guidelines is ensured. In VDI/VDE – Guideline 2634 Part1 (VDI, 2002) the definition of the quality parameter length measurement error is used for the verification of optical three-dimensional measuring systems. This length measurement error is also used in a modified form in the revised version of the ISO standard 8721. The absolute length measurement error will not be used because the relationship between the reference scale and the object size is not defined. Thus the relative length measurement error is used to verify the measuring system in this case.

The recommendation for the verification of optical three-dimensional measuring systems is the use of the principle of substitution (Schwenke et al., 1998). This principle should be used instead of the principle of error budget, because the correlation between the different components of the optical data channel are not known at the moment. So the error budget could not be set up correctly. In the principle of substitution the individual influences of every component are reflected together in the length measuring error of the calibrated reference scales. Therefore the lengths of the calibrated reference scales has to be measured with an accuracy ten-times higher then the required accuracy of the optical data channel.

4.3 Indices of the optical data channel

In the revision of the ISO standard the principle of substitution is used for the verification of the optical data channel as mentioned above. The influences of the components are all reflected in the length measuring error of the calibrated reference scale. Due to this fact there is no reason to divide the optical data channel into its components and to verify every components individually. The benefit of this modification is the possibility to find and eliminate weak points in the optical data channel directly. So, for every component of the optical data channel there is a statement about its quality. This quality statement is called a performance index. In the following Table 1 all the performance indices of the optical data channel, which are used in the current version of the revision of the ISO standard, are listed.

There are many more components of the optical data channel than the listed indices. But for the most important influencing variables of the optical data channel there is at least one index. The main influencing variables of an optical three-dimensional measuring system as the optical data channel in impact tests are for example the camera, algorithms of image processing and network design.

Validation index	Assertion
Scale index	Availability of enough independent reference scales to control the system scale
Focal length index	Validation of the focal length of the used camera
Distortion index	Validation of the distortion parameters of the interior orientation of the used camera
Target index	Size of the signalized points
Blur index	Blurring in the image with respect to the aperture (Depth of field)
Motion blur index	Blurring in the image with respect to the exposure time and the object motion
Point motion index	Allowed point motion between two successive images of one sequence
Control point distribution index	Distribution of the control points in the image
Time base index	Accuracy of the used time base
Timer origin identification index	Accuracy of the used time origin identification device
Intersection index	Intersection geometry of the rays (Network design)
Synchronism index	Synchronous image recording

Table 1. Performance indices of the optical data channel

4.4 Testing procedure for ISO conformity

The validation pattern of the optical data channel, as it is described in the revised version of the ISO standard 8721 is shown in Figure 3. The validation process can be interpreted in the following way. To obtain one quality value, called performance value, for the entire optical data channel both types of components, the image-related and the model-related, have to be combined. This value must be regarded as a tolerance value, describing the worst case scenario. Apart from the performance value another value is required to evaluate the obtained results. It is called the accuracy value of the optical data channel. Both values, the performance and the accuracy value, have to be positive for an ISO conforming execution of the test. To check them, they are compared with given thresholds. For example for the performance value a threshold of 0.8 is defined. This means, that the global ok/false decision of 80 percent of the performance indices has to checked positive. These thresholds are general rules-of-thumb, which have to be checked through experiments in the context of the project with the German automobile industry.

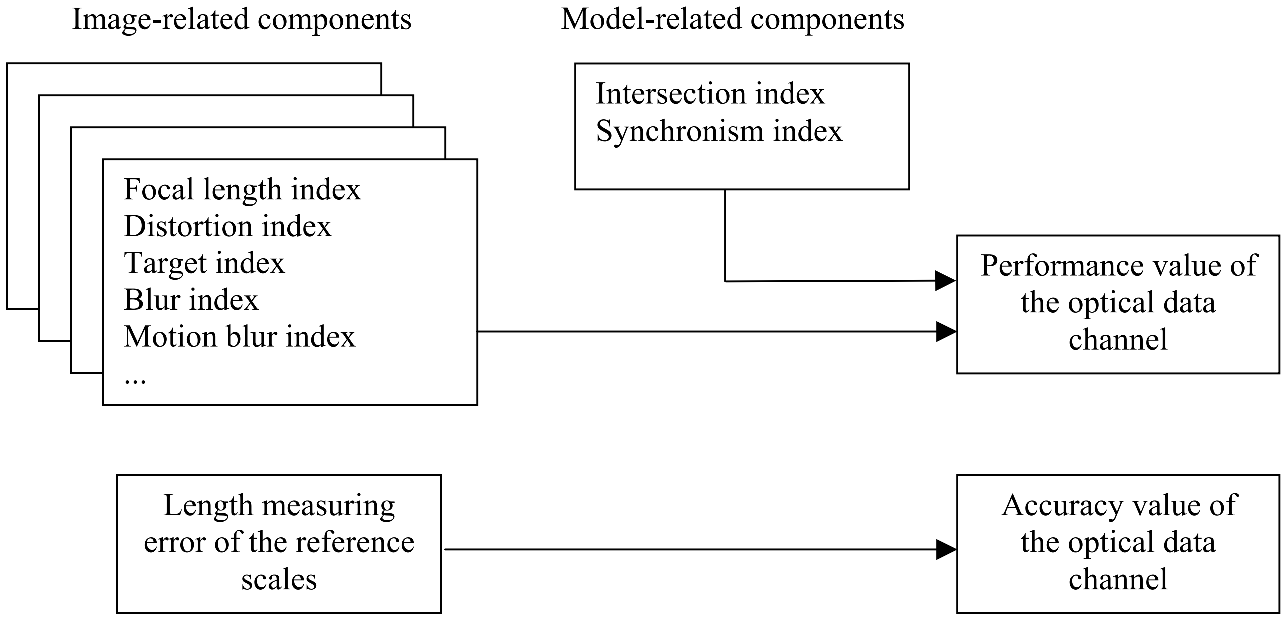

Figure 3. Validation pattern of the optical data channel

5. CONCLUSIONS

The article describes the current results in the revision of the existing ISO standard. The aim of the revised version of the ISO standard is to take new developments into consideration. Due to the new version the user has the possibility to look for the cause of occuring errors in the rusults from analysis of the optical data channel. The devision of the optical data channel into its components and the validation of every component allows weak points in the optical data channel to be found. These weak points can then be eliminated directly.

The revised form of the ISO standard 8721 is based on the older standards in the area of impact tests, the ISO standard 8721 and the existing standard for the American automobile industry SAE J211/2. It also takes elements from some existing standards for optical three-dimensional measuring systems, the German VDI/VDE-Guideline VDI/VDE 2634 Part 1. Thus the acceptance of the users to this revised standard will be greater.

The verification of the quality determination for the optical data channel is converted into practice through experiments in the project with the German automobile industry. Furthermore it is examined whether those components, which were consulted in this version of the standard are sufficient, or whether further components should be added.

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