LABORATORY WORKPLACE FOR OPTICAL 3D MEASUREMENTS AND VISUALIZATION

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Abstract: Utilization of optical three-dimensional measurements and spatial visualisation are widely spreading into industrial and other commercial applications. Therefore it is important to have an appropriate educational tool for training new engineering specialists in this field. This article introduces new laboratory workplace created for exercising and demonstration of triangulation techniques with stereo camera in computer vision classes.

Keywords: 3D, reconstruction, visualisation, stereoscopy, CUDA

1. INTRODUCTION

Technology improvements over the past decade allow more and more complex task to be solved automatically by computers. This leads to further extension of the ability to highly support or even completely replace human workers by automated computer systems in many tedious and exhausting (both mentally and physically) work assignments.

One of the most difficult human skills to emulate or even substitute is the capability to perceive and react to surrounding environment, where the major amount of information comes from sight. Today the computer vision systems are able to exceed human abilities in many ways. This includes also accurate optical 3D measurements and shape reconstruction.

However the area of multidimensional data processing, computer vision, 3D shape reconstruction and spatial measurements is in general a highly involved subject. It is very important to have appropriate and at the same time intuitive and easy to understand ways of teaching the underlying theory and demonstrating its applications and results. To address this issue we have created new laboratory workplace for teaching computer vision and its applications. It is aimed at passive and active triangulation methods and includes camera stereo-pair with powerful 3D visualization and computational system.

This paper is organised as follows: After this introductory section a brief overview of currently available 3D optical measurement and visualisation techniques is given including related HW components and proprietary solutions. Afterwards the structure and features of the created laboratory workplace is described. The subsequent section of the paper is dedicated to utilization of the acquired laboratory equipment for educational purposes. And finally the results and contribution of our work is summarized in the conclusion section.

2. METHODS AND TECHNOLOGY

2.1. OPTICAL THREE-DIMENSIONAL MEASUREMENT TECHNIQUES

There is a wide range of different approaches to image based shape evaluation and spatial measurements. They can be divided into three groups according to their fundamental principle [1]. These are: Interferometry, Time-of-flight measurements and Triangulation. Further reference for the below mentioned methods can be found for example in [1, 2].

The first group of techniques is based on white light interferometry. This way coarseness of surfaces can be evaluated in large detail. An obvious disadvantage of this method is the rather narrow measuring range of depth which is generally restricted by the wavelength of the light.

The time-of-flight measurement overcomes the disadvantage of interferometry by modulating the projected light beam using for example pulses, continuous waves or white noise signals. This approach has a potential for measurements with wide range of depth. However, in order to get spatial data of a whole object, a step-by-step measurement procedure has to be applied, which makes it difficult to record non-static processes.

Specific features of the two previously mentioned groups make them suitable for only a small fraction of practical problems, leaving the rest of the 3D measurements and reconstruction tasks to the triangulation techniques.

The triangulation techniques utilize characteristic features of triangles and trigonometry rules. This group encompasses theodolite measurements (highly accurate, point-by-point evaluation of large objects), focusing and shape from shading techniques followed by active and passive triangulation. Active and passive triangulations are the most common ones. They reconstruct the lost depth information by capturing the scene from several points of view utilizing several independent cameras or movement of the camera or the object and in case of active triangulation the known properties and position of a source of structured light (Microsoft Kinect). This ensures that triangulation methods can be used to record spatial data of large objects (aerial photogrammetry) as well as very fine features of surfaces. This can be done at high frame rates which allows capturing fast changing processes. Although the image data can be easily saved for more complex evaluation in the future, growth of computational power and development of computer algorithms allows to even evaluate them in real-time.

Another very interesting but also rather novel approach to capturing spatial properties of a scene is the digital light field photography, which can be also included to triangulation techniques. This method records not only the intensity but also the incidence angle of incoming light during a single exposure of digital light field device [3].

2.2. THREE-DIMENSIONAL VISUALISATION

Finding the best way to visualise 3D data, which would create an illusion of space is today a rather popular and heavily discussed topic. An interesting overview of currently available techniques is given in [5], where following display segmentation is introduced:

- Stereoscopic – two images (each for one eye);
- Multiview – 5-9x 2 images – each image pair visible from different viewing angle;
- Integral Imaging – multiview with vertical parallax;
- Volumetric – moving components, 20 slices and more;
- Light-field – multiview with near continuous or continuous parallax;
- Holographic displays – pure holographic solutions.

Today only the stereoscopic method can be called widespread and easily available. There is a wide range of commercial devices supporting stereoscopic visualisation. Most of them require from user to wear some kind of glasses which carry out the image separation. The most common separation techniques use wavelength separation (anaglyphic images), polarisation (linear or circular) and time multiplex (requires active shutter glasses). Glasses-free technologies are often called auto-stereoscopic. Their common representative is lenticular lens based display which usually offers multiview visualisation.

3. DESIGN & REALIZATION

Our goal was to create a laboratory workplace that will allow teaching the basic principles of computer vision focusing on the most common 3D measurements applied to practical problems and at the same time increase the attractiveness of such a task by introducing modern visualization technology. This effort resulted in the setup shown in Figure 1.

The new workplace allows complex solution of 3D measurements and reconstruction which begins with capturing images using stereo configuration of industrial color cameras, followed by image processing and 3D visualization of results.

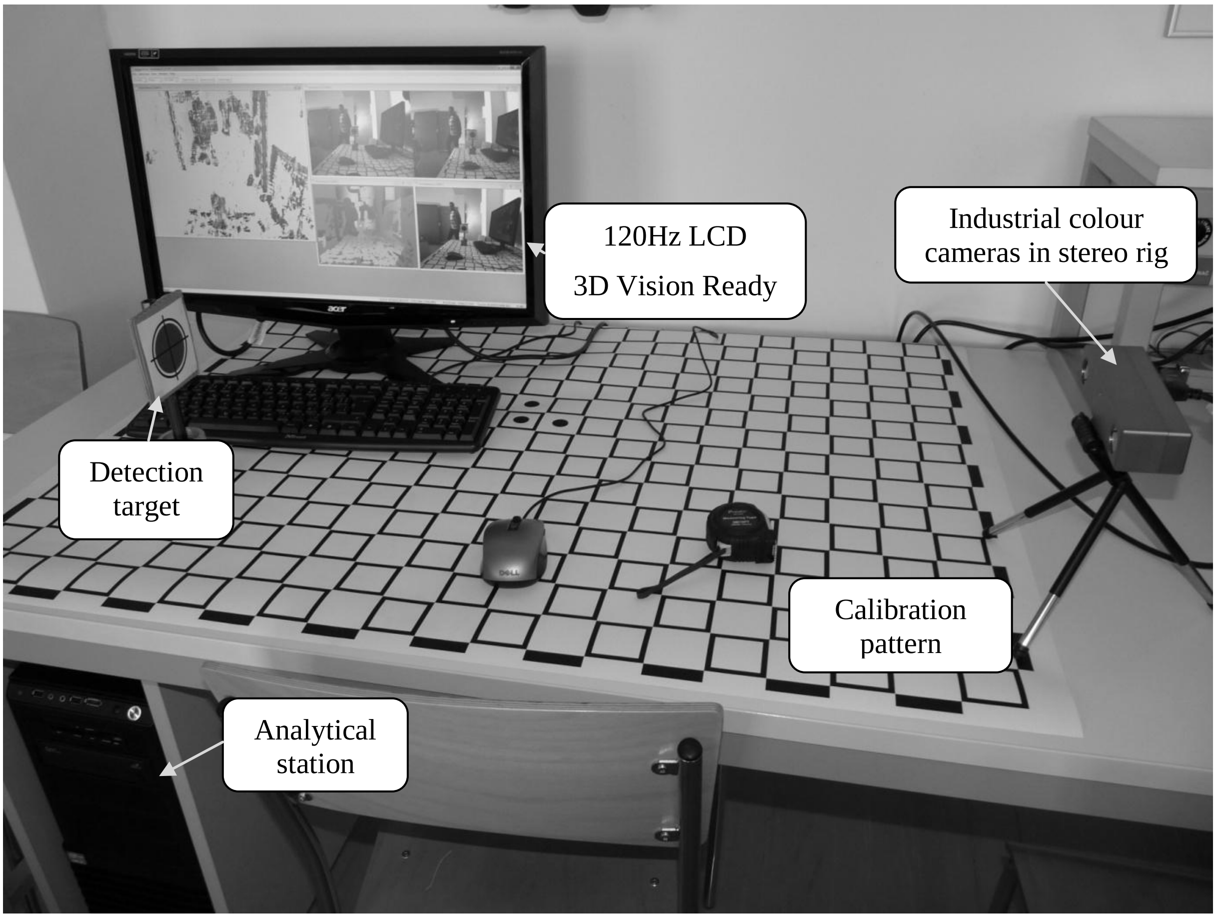

Figure 1: Arrangement of the created laboratory workplace

3.1. THREE-DIMENSIONAL ACQUISITION

The most important part of the workplace is the stereo combination of two industrial cameras compiled to a compact solution called “Bumblebee2” (see Figure 2 left) by Point Grey Research, Inc.

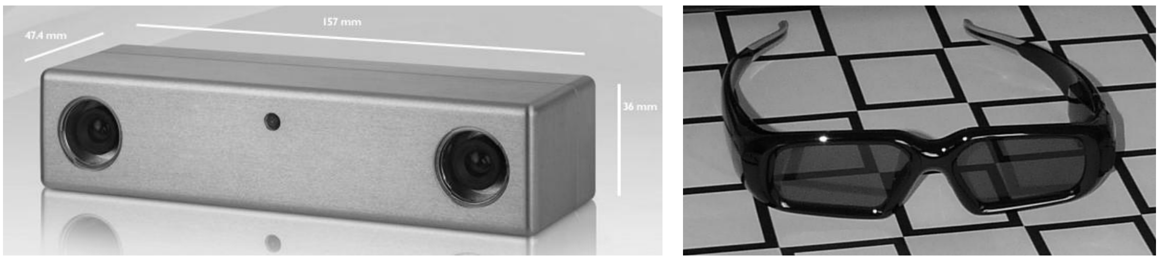

Figure 2: Left: Bumblebee2 - Point Grey stereo-camera [4], Right: NVIDIA stereoscopic glasses (active)

Each camera has a 1024x768 color CCD chip with maximum of 15 frames per second. Communication requires FireWire cable connection with the computer. Camera's compact dimensions make it suitable for desk close range application and therefore ideal for instructional and educational purposes.

As the camera's construction indicates, its main field of application is passive triangulation techniques (see section 2.1 of this paper). However, if combined with an appropriate source of structured light (e.g. projector) a powerful system for active triangulation can be also created.

3.2. DATA PROCESSING

The purchased Point Grey stereo camera comes with a software development kit for C++ language. It allows to control the image acquisition hardware, includes fast algorithms for image preprocessing (rectification, edge detection). Additional Triclops software library supplies data types and procedures for complete solution of on-line 3D reconstruction.

The analytical station is equipped with NVIDIA graphics processing unit (GPU) GTX 570, which, thanks to its 480 CUDA cores, has an outstanding potential for parallelization and acceleration of demanding computing tasks.

3.3. VISUALIZATION SYSTEM

As was mentioned above the 3D data acquisition and processing parts of the workplace are complemented by a 3D capable visualization system. This includes the above introduced NVIDIA GPU (GTX570) and NVIDIA 3D vision compatible 120Hz LCD display. In order to perceive the 3D image properties, user has to wear active shutter glasses (see Figure 2 right), where each of the lens is actually a LCD display and their transparency is synchronized with the images being displayed on the monitor screen in time multiplex.

4. CONTRIBUTION TO TEACHING

At present two laboratory exercises have been designed for the new workplace. The first assignment is focused on an object 3D localization using calibrated stereo-pair (see Figure3). The second task works with stereo images of the scene in order to create anaglyphic and full colour stereoscopic images. The used equipment serves also for student projects, bachelor's and master's thesis, which currently include object 3D trajectory tracking, GPU stereo image processing and GPU acceleration of differential evolution.

Figure 3: Object's 3D position localization

Further contribution of the workplace lies in the ability to introduce optical 3D data acquisition and processing using an attractive and easy to understand visual representation of shape reconstruction results. For this purpose the demonstrational application (see Figure 4), which is part of the Point Grey SDK, is very well suited.

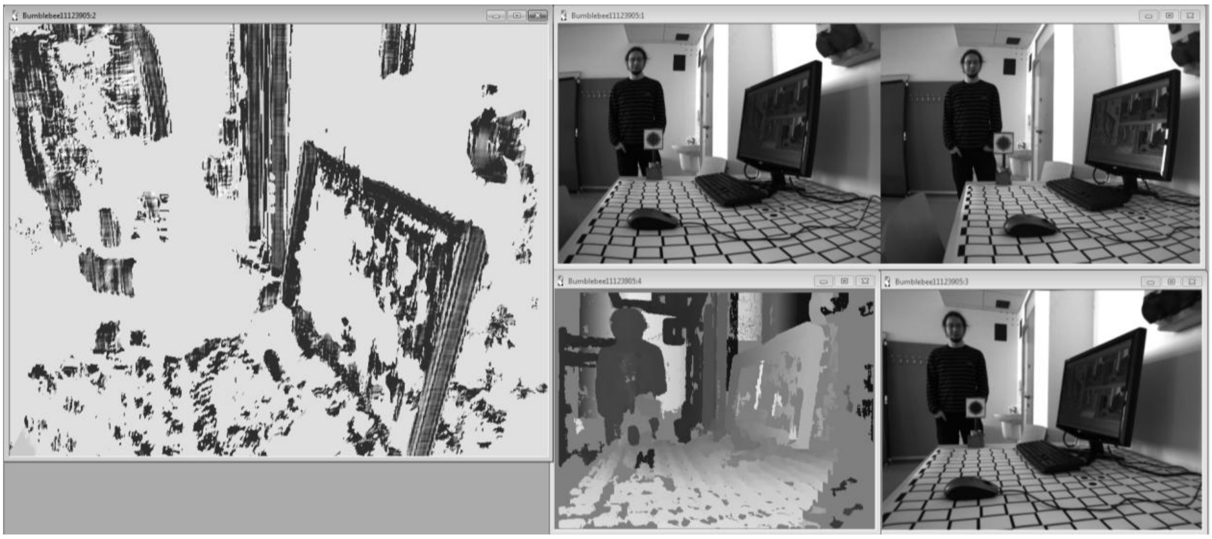

Figure 4: Demonstrational software application

5. CONCLUSION

The created laboratory workplace facilitates education and practical application of knowledge for computer vision courses with particular aim at optical triangulation and 3D shape reconstruction from images. Utilization of modern computing and visualisation technologies makes it more attractive and easier to understand. Thanks to these properties it is also a suitable object for public presentations and propagation of our department.

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