ZEISS SYMPOSIUM
OPTICS IN THE
DIGITAL WORLD

WHITE PAPER ON LARGE DATA IN OPTICS AND VIRTUAL / AUGMENTED REALITY

Based on presentations and discussions during the respective workshop on 23 June 2016 in Oberkochen, Germany

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Preface and introduction

The intention of this white paper is to give a short summary of the workshop on "Large Data in Optics and AR/VR". First, we will summarize some of the key aspects of the talks that were given during the main part of the workshop, and we will present the participants' answers to the questions after each session. Second, feedback and answers to the guiding questions of the workshop will be presented. The guiding questions cover three aspects: the latest developments in the field, open issues and ideas for actions. They are intended to push advances in commercial implementation and research in the field of Large Data and AR/VR.

Latest developments

Guiding question: What are the main latest developments and trends that have benefited AR/VR and Large Data?

AR / VR: Advances in optical technology, computational hardware as well as algorithms have led to a significantly growing interest in AR and VR over the past few years. On the hardware side mainly the availability of new sensors, but also new display technology and advances in mobile hardware foster a revival boom of AR / VR concepts. This is predicted to be only the beginning as David Bohn from Microsoft pointed out in his plenary talk at the Symposium.

Consumer depth sensors such as Kinect/ToF and enhanced processing have pushed dense real-time 3D reconstruction and can be used for mapping, localization and tracking. There has been significant progress in the latter fields during the last few years. In the display domain, OLEDs offer ever-increasing brightness while exhibiting low power consumption. New technologies like transparent OLEDs or bidirectional OLEDS allow for new optical system concepts. Advances in the miniaturization of optical components make new compact HMDs (head mounted displays) with small form factors possible. One example is 3D-printed free-form micro lenses presented by Harald Giessen from the University of Stuttgart.

Aiming for the consumer market, Microsoft has published its first version of the HoloLens using a stereoscopic waveguide-based display and depth sensors for gesture recognition and real-time dense mapping. Computation and rendering is done completely on the device.

In the industrial sector, Volkswagen is using AR devices for technical documentation and assistance. They superimpose virtual objects like motors or assembly instructions onto real objects like cars in real-time. Facebook's Oculus Rift currently sets the technical benchmark for VR devices and other companies have followed their initiative.

Large Data: The amount of digital data doubles every two years and is expected to reach 40 zettabytes in 2020. New developments in high-performance computing and cloud computing have become broadly available and help to process and analyze the data, which usually originate from many different sources. Following this trend in optics as well, sensor fusion and multimodal imaging is becoming increasingly important. The correlation of multimodal data yields comprehensive information on the objects under investigation.

Progress in compressive sensing/ imaging lays the foundation to handle efficiently the huge amount of data. Computational methods like SVD, MUSIC and PCA permit the identification of important parts of the data, while simultaneously allowing noise to be filtered. Especially in QA/QC applications, information theoretic approaches (e.g. Fisher information) and the use of a priori information help to analyze large amounts of data efficiently.

Machine Learning is a natural match for Large Data. For one thing there is an increasing demand for powerful and efficient learning-based algorithms that analyze ever-increasing large data volumes. Conversely, Machine Learning methods benefit strongly from large data volumes and multimodal signals, both of which can help to avoid the overfitting problem. As of late, Deep Learning methods have been applied across different fields of computational problems and require huge training datasets from which they automatically derive suitable features. Ingmar Posner gave interesting examples on self-driving cars in one of the Symposium keynotes. These methods have proven to be highly efficient at test time, which makes them especially well-suited for Large Data scenarios, e.g. in the segmentation of microscopy images. Closing the loop to AR/ VR, the increasing availability of large 3D datasets, e.g. from microscopy, CT images or 3D / 360° cameras, have created a high demand for 3D virtualization methods. Timo Bernthaler from FH Aalen (Aalen University) demonstrated this with his virtual walkthrough of scanned and analyzed materials.

Open issues

Guiding question: What do you consider the most crucial issues and questions in AR/ VR and Large Data (technology/application/market)?

AR / VR: The traditional conflict between the physical ergonomics and visual ergonomics of AR/VR devices is still a challenge. On the one hand, the HMD has to be lightweight and compact to be worn conveniently for hours. In addition to that the design should be attractive enough for wearing in public (keyword: 'social acceptance'). On the other hand, most applications require a natural field of view (i.e. for the human eyes this would mean more than 150 degrees), a huge eye-box (for a robust projection of the image into the eye even under everyday user conditions) and high optical performance (for brilliant and crisp 3D images). Even though there are solutions for a restricted set of these specifications, up to now there is no concept that meets all these contradictive requirements at once.

In addition, AR devices are even more challenging because the virtual digital content has to be aligned and displayed in 3D over objects of the real world. Werner Schreiber from Volkswagen addressed in his talk the following practical issues of AR-systems that need to be improved. Many of these also apply to VR systems:

- Large field of view to support immersion
- Solution for vergence accommodation conflict
- Easy way for ophthalmic correction, especially also for presbyopic persons
- Bright, high resolution displays for use under daylight conditions
- Virtual overlay, e.g. virtual image distance has to fit to the real object distance
- Latency issues
- Realization of short virtual imaging distances
- Variable focal length/ light field for 3D AR/VR
- Precise environmental tracking without extensive training of the tracking system
- Runtime for one working day (>8h)
- High mobile calculation power for photorealistic real-time rendering/imaging

Even assuming all these technical issues were to be solved, there is still no clear answer concerning the range of applications. Certainly gaming is the driving force for VR and related applications are likely to follow: entertainment like 3D sports broadcasts, virtual tourism, education, architecture and even social networking if Facebook’s plan succeeds.

For AR the answer is not so clear. Certainly applications like guiding and teaching in a professional environment are attractive, but the answers to the fundamental questions are still open: For which applications does AR provide the real differentiator? What are the mainstream applications addressing a huge market?

Large Data: The usefulness and potential of Large Data crucially depends on efficient handling and streaming strategies. The preparation and condensation of the datasets from different sources, the subsequent overlay and augmentation of this various information to meaningful and helpful displays for the user is one of the biggest challenges for Large Data. The huge amount of data that is gathered by optical tools and other sources boost the need for a combined 3D virtualization of the datasets.

Also the demand for analyzing, qualifying and for doing measurements on the data content increases. Better assistance and workflows for user interaction are needed to handle the data and to increase productivity. The increasing size and the diversity of the datasets makes intelligent screening and evaluation algorithms like Deep Learning indispensable. The integration of machine learning concepts (libraries, modules) for detection and classification of structures, geometries, morphologies pave the way from conventional optics to smart systems. The exchange with different software platforms and applications has to be facilitated. Open source approaches and the standardization of interfaces are the consequence.

Ideas for action

Guiding question: Where do you see ideas and significant potential for collaborative action?

AR / VR and Large Data: In the course of the workshop discussion, potential action was addressed on different levels.

The most popular level was to foster innovation and research programs in the direction of AR / VR and Large Data. Especially on a European level, existing programs such as the Horizon 2020 (and following programs) or the Marie Skłodowska-Curie research fellowship programs could be supported to focus on research in AR / VR and Large Data. Companies with a large industrial impact such as ZEISS could play their part in shifting the focus of such programs towards these key technologies. Similar initiatives can be addressed on a national level.

A second level that was discussed is to provide platforms with publicly available datasets and programs that encourage and facilitate development in the field of AR / VR and Large Data and that represent platforms for field experiments, especially with regard to practical applications that can be used to test acceptance and gather data at the same time. The platforms provide the framework for field experiments, especially with regard to practical applications and can be used to test user's acceptance and gather data at the same time. One example is RETIPLUS, a Big Data platform dedicated to low vision pathologies (AMD, glaucoma, retinitis, etc.) with an AR smartglass for enhancing quality of life and autonomy of low vision patients. In this context, workshop participants saw a growing future demand for machine learning algorithms especially in the form of libraries that can be easily incorporated into analysis workflows.

A third aspect pointed out by the participants concerned interdisciplinary cooperation. To account for the impending digitalization in optical subjects, interdisciplinary synergies should be leveraged more in order to foster cooperation between the fields of optics, information technologies and electronics. Many participants agreed that this should start early on a fundamental educational level: universities and schools should start efforts for bringing together optical and computational disciplines by combining paradigms in teaching and respective technical concepts that are unique to each field.

As a final note, the workshop showed that each of the discussed fields, Augmented Reality and Virtual Reality as well as Large and Big Data, come with such fundamental questions and far reaching technical implications on many different levels that there is a strong need for disruptive rethinking of implied technologies and applications especially from the data and algorithm perspective.