


A Brief Introduction of the Achievements of Key Project Image-based Modeling and Rendering for Virtual Reality Applications

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1. Background

The virtual reality (VR) technology is now at the frontier of modern information science. VR is based on computer graphics, computer vision, and other fresh air topics in today's computer technology. Nowadays the VR technology has been applied successfully in a variety of fields such as military simulation, industry, medical training and visualization, environment protection and entertainment.

The key problem studied in VR is how to generate a stereo view of high realistic virtual environment in real time. In traditional Computer Graphics the process of image generation consists of the following steps: 3D object model generation by using geometry modeling software; projective transformation of 3D model into image space by using perspective transformation and rendering procedures in image space. Today the advanced graphics hardware is able to generate realistic images with relative complex objects in a short time, but there is still a big gap to generate photo-realistic images with complex objects in real time. Therefore the model complexity, rendering quality and speed became the key issues of real time generation of photo-realistic images. Consequently these key issues are restricting VR applications further. In order to solve these key issues, a new technology called Image- based Modeling and Rendering (IBMR) was proposed in recent years. IBMR is an interdisciplinary research direction jointed by Computer Graphics, Computer Vision, Image Processing and Photogrammetry etc. IBMR technology possesses the advantage for solving the inter-restrain problem among the above key issues, because it does not use geometry modeling, but instead use a set of photos taken in real world to generate novel views of the scene. So IBMR is a technology based on samples taken in real world to represent or render the new view of the environment. The realistic pictures used contain plenty of details and colors of objects to ensure generating photo images. Also the rendering speed of the IBMR technology does not depend on the scene complexity. It does depend on the display resolution only. IBMR technology provides a possible solution of real time rendering of a very complicated virtual environment. IBMR research started in the early 90s of the last Century. It grew up quickly and became a popular and hot field of Computer Graphics. IBMR research of Chinese Computer Graphics Community can be traced back to February 1997, and just at that time, a Workshop on IBMR sponsored by NSFC was held in Kunming, Chinese Computer Vision Community is very active in IBMR work. The NSFC key project - "Image- based Modeling and Rendering for Virtual Reality Application (No. 60033010)" was officially initiated in 2001. The key project was jointly carried out by Institute of Automation CAS, Institute of Software CAS and Zhejiang University. The key project proposed to use image-based modeling instead of traditional geometry modeling and to use image-based rendering instead of traditional graphics rendering pipeline to meet the high requirements of visual modeling complexity, rendering quality, and speed of VR applications, and to solve object interactive issues in traditional Computer Graphics. Therefore IBMR technology could provide an efficient scheme to generate photo-realistic images with complex objects in real time. The key project's fundamental task is to study the basic theory and algorithms of IBMR and to develop IBMR software prototype systems with potential applications.
2. Main Research Achievements of the Key Project

(1) The PnP problem is a technique to determine the extrinsic parameters of a camera. There are two basic problems in the PnP problem study. The one is to determine the number of possible solutions; the other is to assess the stability of solutions. In this project, we showed that the distance-based PnP problem is in fact not equivalent to the transformation based PnP problem, a viewpoint held for years in literature. In addition, we proved that it is not possible to have an affine reconstruction from a pair of images captured by a translating camera if the intrinsic parameters are subjected to changes. This wrong viewpoint was existent for 10 years in literature. Besides, several new theories and algorithms on active vision based camera calibration have been proposed. Our findings have been published by IEEE Trans. PAMI, Pattern Recognition Letters, Image and Vision Computing, as well as by some domestic first-level computation journals.

(2) For the first time, we solved a challenging problem on automatic reconstruction of geometric models for highly complex environments expressed by a set of depth images. In the solution, the representation for the model reconstruction is a hybrid model in terms of points and plans. A series of innovative algorithms were proposed in the reconstruction procedure. For example, an automatic pixel sorting algorithm was put forward to classify pixels into point models and plan models: Jacobi matrix based sampling dense comparison was employed to pick up best textures, and hole analysis and prefilling algorithm were used for reconstructing plan models: an efficient real-time walkthrough algorithm was designed for objects with hybrid point—and-plane based representation. The research result and its rendering demonstrated its leading work in this topic, and as a result, the related system design was invited as a chapter of the monograph "Integrated Image and Graphics Technology" published by Kluwer Academic publisher in January 2004.

(3) A framework for digital geometry processing has been proposed by the key project. This framework provides a solution for parameterization of mesh model onto sphere (or plane). Under this framework all existed digital image-processing technologies may be applied for 3D geometry processing. The paper on this framework laid a firm theoretical foundation for later application research and promotes the integration of two subject areas—Computer Graphics and Image Processing, at levels of both data presenting and data processing. Based on this framework an efficient method for surface filtering was proposed. Our contribution consists of a two-step method of spherical parameterization. The papers related with this topic were published in international journal of Computer Aided Design and domestic Journal of Computer Science and Technology.

(4) In the area of real-time rendering of photo-realistic images based on pre-computing and sampling, we proposed a new rendering method called Spherical Radiance Transport Maps (SRTM). Previous work in this area was restricted to render static objects only. Our method is able to render multiple and dynamic objects to generate soft shadows and inter-reflection effects in real time under environmental illumination. We also proposed a new method for generating illumination dependent textures. It is a real time photo-realistic texture generation method, which is able to show vivid effect of 3D texture under environmental illumination. The papers related to this topic were published in international journals of Computer Graphics Forum and Computers & Graphics.

(5) An optimized method for fusing multiple source images based on correlation coefficients and a linear optimized image fusing method are proposed. We proved that above two optimized methods are equivalent. Also the space-temporal complexity of computation of above two methods has been improved. Considering human vision system (HVS) sensitivity to local image, a new wavelet image fusing algorithm base on HVS has been proposed. The algorithm improved the image fusing results greatly. The related papers were published in the first level Chinese computation journals.

(6) We also developed several IBMR prototype systems with high application potential, such as a prototype system of Series Image Based Modeling system (SIBM) for architectural scenery, and an Image-based Walkthrough prototype system for HU XIUYAN House and LINYIN Temple.

3. Conclusion
The key project is an interdisciplinary research and has great significance for promoting the merging of Computer Graphics and Computer Vision. In the past four years our team published 125 papers. Among them 13 papers were published in top international journals, such as IEEE PAMI, Computers & Graphics, Computer Graphics Forum and Visual Computer. 35 papers were presented at international conferences, and 77 papers were published in the top-level Chinese
journals. Among all the papers, 19 papers were cited by SCI, 54 papers by EI, and 17 papers by ISTP. The project graduated 23 PhDs and 14 masters. Several IBM software prototype systems were developed by our team. These prototype systems have demonstrated the achievements of the project effectively and showed promising application potential in the future.

In the study of fertilization process in the past decade, people learnt that this process is not a simple sperm penetration routine: instead, it contains a series of complicated mutual contexts and delicate interactions between sperm and oocyte. Included stages are separated as: oocyte maturation, sperm capacitation, sperm acrosomal reaction, membrane fusion, meiosis II resumption, oocyte cortical reaction, pronucleus formation, syngamy, and a series of following processes. In the fertilization research, quite a few life secrets were disclosed, however, several problems, such as genetic material transfer and spindle rotation, whether or not sperm receptors locate in the inner surface of zona pellucida, regulation of pronucleus formation, whether or not early round spermatid can be used for fertilization, and the leftovers such as chromosome transfer, germinal vesicle transfer, nucleus-cytoplasm relations etc., all need further in-depth studies. All these researches will provide means to cure infertilities.

feminis. In the process of somatic cell cloning, since the first report of cloned Dolly sheep by Wilmut from Roslin Institute, reports on cloned animals published one after another including those cloned cows in China. These newborn biotechnologies provide new methods and means for the improvement of new livestock species and accelerate livestock breeding.

Through a 20-year study, we explored several frontier hot spots as fertilization mechanism, microfertilization, and animal cloning.

1. Sexual reproduction

1.1 Fertilization physiology

Microfilaments are power source for genetic materials migration and rotation within an oocyte. In the studies of oocyte maturation and zygote formation, we discovered the function of those microfilaments in the processes of chromosome migration, cell division, and polar body emission. In the presence of demecolcine, chromosome migrated from oocyte center to its surface, and induced polarization. When cytochalasin B (CB) was utilized, the meiotic spindle was formed inside oocyte, however, it could not migrate, thus, polarity disappeared. After the elimination of CB, polarity showed up accompanied with the recovery of meiotic spindle migration. This proved that the migration of chromosome was controlled by microfilaments. We also studied the relations between cell cleavage direction and its meiotic spindle. In meiosis I, we used CB to suppress microfilament which directly arrested eggs at meiosis II. Thereafter, we eliminated CB, and then, the division recovered. However, the so-called tetrads were aligned in a line, which totally changed the cleavage direction. Under a microscope view, meiotic spindles of two daughter cells in meiosis I did not rotate but were staid in a line. Thus, the daughters of these two cells divided only from their side directions. This experiment also proved intimate relationship between cleavage direction and meiotic spindle axis. In order to further prove the mechanisms of polar body emission, we used CB at the time when sperm penetrate through zona pellucida, and we found that the polar body could not be discharged. When we transferred this experiment in a normal non-CB culture solution, the second polar body could not be discharged. With the facility of confocal microscopy, we also found a male pronucleus within the zygote cytoplasm, and two female pronuclei separately located on both sides of meiotic spindle. Our experiment proved that CB suppressed the rotation of meiotic spindle. And then, as the rotation phase bypassed, the polar...