出國報告（出國類別：考察）

出席 IEEE 影像處理國際學術研討會

服務機關：國立中正大學
姓名職稱：林惠勇副教授
派赴國家：埃及
出國期間：11/6/09 – 11/15/09
報告日期：1/27/10

摘要

本次出席在埃及所舉行的 IEEE 影像處理國際學術研討會，發表由國科會所補助的專題研究計畫之研究成果，報告內容詳述參加會議的經過以及與會心得，並以附加相關資料於附錄。

參加會議經過

本次出席的國際會議 2009 IEEE International Conference on Image Processing (ICIP 2009) 為影像處理相關研究領中相當重要且知名之國際會議，此一會議為 IEEE Signal Processing Society主要贊助之國際會議並依循慣例每年舉辦一次。本屆的影像處理國際研討會於埃及的首都開羅舉行，時間安排在十一月七日至十一月十日共四天。由於這是本研討會首次於非洲大陸舉行，並安排在埃及的旅遊旺季，因此吸引了相當多的人士與會。本次會議發表的論文多達一千一百多篇，保守估計應有兩三千人參與此一盛會，這些人員大多來自世界各先進國家在各個領域的工程師、專家、學者以及部分的軍方人士，其中亦不乏相當知名的國際學者。歷年來 ICIP 皆為相當大規模且相當高品質的研討會，今年更吸引了兩千四百多篇的論文投稿。由於會議的規模龐大且涵蓋的領域相當廣，因此除了 poster section 與 oral section 同時進行之外，oral section 亦分為個同時段不同地點的 parallel section。

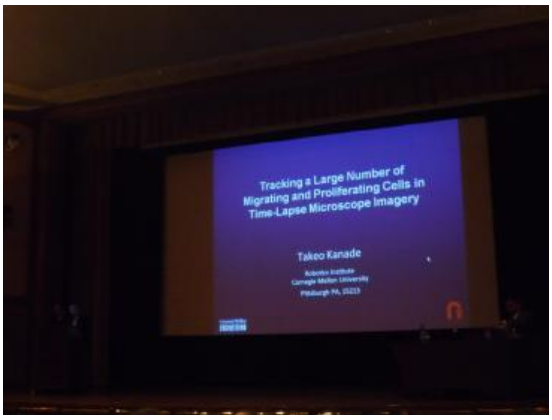
本屆會議國內學者約有二十篇以上的論文發表，再加上舉辦地點埃及的食宿、交通與各項活動便利性的考量，故委由熱心的同仁聯絡旅行社代為辦理前往埃及的行程規劃，也因此組成了包括多所大學、中研院、工研院在內的二十多位同仁的開羅國際學術會議參訪團。一行人於十一月六日由台北出發經曼谷，於十一月七日上午飛抵開羅。當天除了會議中需額外付費的 tutorial 之外並無議程，當地導遊帶領著大家參觀了開羅當地著名的埃及博物館與吉薩金字塔區等著名景點，並介紹了埃及從古法老時代歷經希臘人、羅馬人統治，至現今伊斯蘭國家的演變過程。

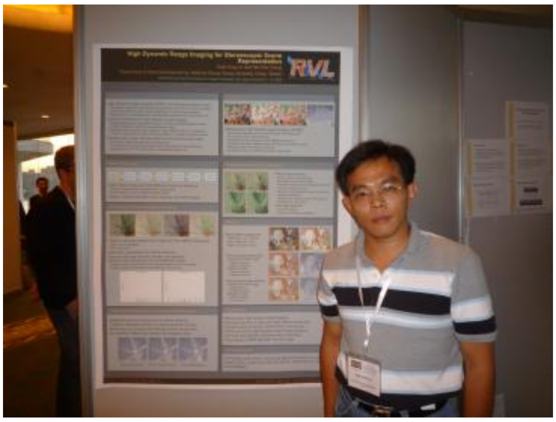
接下來的三天（十一月八日至十一月十日）為本次研討會的主要議程，除了抽空至市區附近感受阿拉伯人的日常生活之外，絕大部分的時間都待在會場聆聽 oral section 的 presentation，觀看 poster presentation 的海報以及與與會學者互動討論。研討會第一天的 Keynote speaker 由埃及古文物部的秘書長 Dr. Hawass 就埃及考古的發現給了精采的介紹，並說明了影像處理與機器人學等現代科技如何成功地協助考古工作的進行。另一個 keynote speech 則由電腦視覺領域相當著名的學者 Kanade 教授，針對顯微影像中細胞的成長、合併、分裂的追蹤技術進行說明。在三天緊湊的研討會議程結束之後，國內與會的學者一同順道參觀埃及散落各地的古文明，並於十一月十四日返國。

心得及建議

ICIP 為 IEEE 所直接贊助每年一度的大型國際研討會，其論文的品質一向非常整齊且優良，在影像處理領域有著相當的影響力，而眾多的大師級學者也必親自與會。本屆會議由國內前往參加的包括了台大、清大、交大、成大、中央、中正、海洋、台科大、東方、中研院、工研院等單位的教授，因此除了可以在短暫的研討會期間接觸到世界各地的研究近況，亦得以與國內學者詳談並了解國內的研究趨勢與優勢。在會場上與會人員直接與論文作者的討論與互動，以及積極參與的態度相當值得我們學習。

本次研討會最大的收穫可以算是兩個 plenary speeches 的部分，除了 Dr. Hawass 說明了影像處理在考古研究的貢獻之外，Kanade 教授也提出了在顯為影像上對於大量細胞追蹤的技術。在這一方面的研究上他認為已有突破性的進展，並得以為人類在醫學上的研究作出進一步的貢獻。相較於他早期在電腦視覺上與生活與娛樂相關的研究，此一改變或可察覺到未來在影像方面的研究趨勢。整體而言，除了四天的行程無法涵蓋研討會全程之外，其收穫可以說是相當豐富。





左圖為 Kanade 教授演講題目，右圖為論文發表所張貼之海報。

附件

1. 會議相關資料
2. 發表之論文

2009 IEEE International Conference on Image Processing

ICIP 2009

Program Guide

November 7–10, 2009
Grand Hyatt Cairo
Cairo, Egypt

SPONSORED BY

INSTITUTE FOR ELECTRICAL AND ELECTRONICS ENGINEERS
IEEE SIGNAL PROCESSING SOCIETY

Schedule at a Glance

Saturday, November 7

09:30 – 12:30	Tutorials
10:50 – 11:10	Break
12:30 – 13:30	Lunch (On your own)
13:30 – 16:30	Tutorials
14:50 – 15:10	Break
18:00	**Buses leave for reception**

Sunday, November 8

08:30 – 10:00	**Opening Remarks and Plenary Talk: Dr. Zahi Hawass**
10:15 – 11:35	Technical Sessions (First Half)
11:35 – 12:05	Break
12:05 – 13:25	Technical Sessions (Second Half)
13:25 – 14:45	Lunch (On your own)
13:35 – 14:35	*Meeting: Image, Video and Multidimensional Signal Processing TC Luncheon*
14:45 – 16:05	Technical Sessions (First Half)
16:05 – 16:35	Break
16:35 – 17:55	Technical Sessions (Second Half)
18:00 – 19:00	*Meeting: Publications Board Dinner*
19:00 – 23:00	*Meeting: Publications Board Meeting*

Monday, November 9

08:30 – 09:50	Technical Sessions (First Half)
09:50 – 10:20	Break
10:20 – 11:40	Technical Sessions (Second Half)
11:30 – 13:30	*Meeting: Executive Committee Luncheon*
11:40 – 13:00	Lunch (On your own)
11:50 – 12:50	*Meeting: Information Forensics and Security TC*
13:00 – 14:20	Technical Sessions (First Half)
13:30 – 16:30	*Meeting: ExCom Strategic Planning Retreat*
14:20 – 14:50	Break
14:50 – 16:10	Technical Sessions (Second Half)
16:45	**Buses leave for banquet**

Tuesday, November 10

08:30 – 09:30	**Plenary Talk: Takeo Kanade**
09:45 – 11:05	Technical Sessions (First Half)
11:05 – 11:35	Break
11:35 – 12:55	Technical Sessions (Second Half)
13:05 – 14:05	*Meeting: IEEE Transactions on Image Processing Editorial Board*
13:05 – 14:05	*Meeting: ICIP to ICIP*
12:55 – 14:15	Lunch (On your own)
14:15 – 16:05	Technical Sessions (First Half)
16:05 – 16:35	Break
16:35 – 17:25	Technical Sessions (Second Half)
18:00 – 19:00	Student Reception
18:00 – 19:00	*Meeting: Conference Board Dinner*
19:00 – 23:00	*Meeting: Conference Board Meeting*

Wednesday, November 11

08:00 – 09:00	*Meeting: Board of Governors Breakfast*
09:00 – 17:00	*Meeting: Board of Governors Meeting*
12:00 – 13:00	*Meeting: Board of Governors Luncheon*

Welcome Message from the General Chair

Ahlan Wa Sahlan

These are the first words that guests in Egypt are greeted with. In Egyptian slang, ahlan wa sahlan means welcome to your family. You will feel the warmth, kindness, and comfort of a family. So, enjoy your big family in Cairo. On behalf of ICIP 2009 and IEEE Signal Processing Society (SPS), I welcome you to Cairo, the land of pixels.

By attending ICIP 2009, you are taking part and participating in history in the making:

- This is the first time that ICIP will be held in the Middle East and only the second time that any major IEEE SPS conference—ICASSP or ICIP—is taking place in this region.

- ICIP 2009 is one of the main SPS initiatives to reach out and have global impact. This year, we received papers from countries which have never participated in ICIP before. Also, we have more papers from countries that used to have very few. Papers have been submitted from about 50 countries.

- ICIP 2009 has achieved record submissions; more than 2400 papers were received . This was about a 40% increase over the average submission of previous ICIPs. More important, there was a wide geographical diversity in paper submission.

Lina Karam and Thrasos Pappas, the technical program chairs, and their committees have developed an outstanding, colorful and focused technical program. It is a streamlined, vibrant and friendly program. It includes a record 1101 papers. A rigorously reviewed set of special sessions, focused on emerging technological and research issues. Industrial, academic scholars and developers have teamed up to offer a set of high quality tutorials on several emerging topics in Image Processing. Tutorials have been made more accessible to the Egyptian attendees, especially students. This outstanding technical program is attributed to the excellent contributions and hard work of the technical program committee, the reviewers and, most important, the authors.

One of the main highlights of the conference program is the keynote speakers. We are fortunate to have Dr. Zahi Hawass, who is a worldwide-celebrated Egyptologist. He is the head of the Egyptian Authority of Antiquities. He accompanied U.S. president Barak Obama in his recent visit to the pyramids. He did the same with many presidents and celebrities including Bill Clinton, Jacques Chirac, and Tony Blair.

Prof. Takeo Kanade has a profound impact on humanity. He is directing two centers. The first is at Carnegie Mellon University (USA): Quality of Life Technology Engineering Research Center. The second center is in Tokyo: Digital Human Research Center. Prof. Kanade has been elected to the National Academy of Engineering and the American Academy of Arts and Sciences.

In addition to this stimulating and intellectual technical program, a colorful, cultural and entertaining social program is planned. Two historic landmarks—the Pyramids and Citadel—are the centerfolds of this culture program:

- **A welcome reception at the Citadel, Saturday, Nov. 7th.** The Citadel is a major Islamic landmark. It is overlooking Cairo, it offers great city views and breeze. The program highlights of the impact of Islamic history on music and entertainment.

- **Conference Banquet at the Pyramids, Monday, Nov. 9th.** It's the view of a lifetime. The greatness of its history is lit with you in the picture. You will surf all over Egypt through dancing and music. You will get a taste of each region in Egypt.

The conference hotel, the Grand Hyatt, is one of the finest hotels in Cairo, located on an island in the middle of the Nile. All rooms have a Nile view; it is beyond imagination. You will feel that you are "hugging Cairo on the Nile". Aly Farag and Ayman El-Desouki are working with both U.S. and Egyptian teams to ensure a successful conference.

Many people, colleagues and friends have helped in making this conference a reality. Lina Karam and Rabab Ward came up with the idea; we believed in it and worked hard with all parties to bring it to life. Aly Farag and Ayman El-Desouki have laid down the foundation in the U.S. and Egypt. Samia Mashaly and Amal Zaki have been the front team to decide on the location for the conference 4 years ahead (that is not very common in Egypt). We have formed a real global team among CMS (USA), Wings Tours (Egypt), and the Grand Hyatt (Egypt); they are working for one unified cause: a successful ICIP. Now, Bryan Stewart is an expert in Cairo (especially crossing streets), Lance still keeping his cool after all these visas questions, and Ahmed Glal and Mohamed Aly know the American secrets of organization. Special thanks to John Mathews for his leadership and the SPS office led by Mercy for facilitating all the hurdles of having a conference in this region for the first time. Special thanks to Ed Delp, whom we asked for help and advice quite often. My deep appreciation to my students and dynamic assistant, Cathy Pomier.

We are very proud to be hosting ICIP 2009. We hope that it will be a rewarding, informative and stimulating experience. We look forward to welcoming you in Cairo, where images were invented 7000 years ago! Come and celebrate the vivid images across history with us. All pixels will welcome you.

Prof. Magdy Bayoumi
ICIP 2009 General Chair

Technical Program Chairs' Overview

It is our pleasure to welcome you to the 2009 IEEE International Conference on Image Processing in Cairo, Egypt, one of the most prominent centers of the ancient and modern world. We hope that you will enjoy the exciting and stimulating technical program of the conference, and also take some extra time for sightseeing and exploration.

The 2009 technical program builds on ICIP's tradition and reputation as the world's premier technical conference in the field of image and video processing. This year we had a record 2442 paper submissions (not counting partial and duplicate submissions) from 64 countries, confirming that ICIP is a truly international conference!

Out of the 2442 submitted papers, 2360 papers sucessfully passed the inspection process and were peer reviewed. The Technical Program Committee, consisting of 59 area chairs and 1142 reviewers, includes members of the Image, Video, and Multidimensional Signal Processing (IVMSP) Technical Committee of the IEEE Signal Processing Society, as well as numerous other experts in the field. Given the large number of submissions, we are especially proud of the thorough and impartial review process. An improved and more elaborate ICIP review form was designed and used this year in order to guide the reviewers in providing comments and relevant feedback to the authors and program chairs. Each paper received at least three reviews. The area chairs personally assigned reviewers for each of the submissions according to their technical content, and made careful recommendations based on the reviewer comments and sometimes even on their own reading of the papers. The special session papers underwent the same review process as regular submissions, each receiving three to six reviews.

Based on the input from the reviewers and area chairs, we accepted 1101 papers that were organized into 7 special sessions, 23 lecture sessions, and 70 poster sessions, covering a wide range of image and video processing research. While organizing the lecture and poster sessions, the technical program chairs looked at all the papers, independent of the topics (EDICS) under which the papers were originally submitted, and attempted to group the papers into thematic sessions. Following the ICIP tradition, the allocation of the papers into oral and poster sessions was based on topic, and not on quality.

On behalf of the entire ICIP community, we would like to thank all of those who generously volunteered their time and effort to ensure the excellence of the technical program.

The ICIP 2009 technical program includes two plenary lectures highlighting exciting and timely topics that complement the topics covered in the sessions. We are grateful to the plenary chair, Rabab Ward, and the general chair, Magdy Bayoumi, for selecting the distinguished plenary speakers: Dr. Zahi Hawass, Secretary General of the Supreme Council of Antiquities, Egypt, and Takeo Kanade, Robotics Institute, Canegie Mellon University, USA.

The conference begins on Saturday, November 7, with 8 tutorials that were selected by the tutorial chairs, Eli Saber and David Taubman. The tutorials were selected from 19 proposals that were submitted in response to the Call for Tutorials and were reviewed by a team of experts under the coordination of the tutorial chairs. The tutorials offer overviews of the state of the art in several key areas of both theoretical and practical interest to researchers in the field. The tutorial topics and their presenters are: 1) Nonlocal Image Processing Techniques presented by Vladimir Katkovnik (Tampere University of Technology, Finland), 2) Shape Representation and Registration using Different Implicit Spaces presented by Aly Farag (University of Louisville, USA) and Hossam Abdelmunim (Ain Shams University, Egypt), 3) Color in Image/Video Processing Applications presented by Theo Gevers (University of Amsterdam, The Netherlands) and Joost van de Weijer (Universitat Autònoma de Barcelona, Spain), 4) Video Processing Techniques for 3-D Television presented by Yo-Sung Ho (Gwangju Institute of Science and Technology, South Korea), 5) Multiresolution Analysis for Imaging on Reconfigurable Hardware presented by Abbes Amira (Brunel University, UK), 6) Image Fusion for Image and Video Quality Enhancement presented by Jan Flusser, Filip Šroubek and Barbara Zitová (Institute of Information Theory and Automation of the ASCR, Czech Republic), 7) Perceptual Metrics for Image Quality Evaluation presented by Sheila Hemami (Cornell University, USA) and Thrasos Pappas (Northwestern University, USA), 8) Introduction to Image Registration presented by William Wells (Massachusetts Institute of Technology, USA) and Lilla Zollei (Massachusetts General Hospital, USA).

The ICIP 2009 technical program also includes 7 special sessions covering a broad spectrum of topics that highlight emerging areas of research and new perspectives to existing topics. Special session chairs Sheila Hemami and Moumen Elmelegy coordinated a thorough review of both the special session proposals and the individual papers submitted to each of the selected sessions. This year’s special sessions and their organizers are: 1) Digital Imaging in Cultural Heritage organized by Patrick Ndjiki-Nya (FhG Heinrich-Hertz-Institut, Germany), Peter Schallauer (Joanneum Research Forschungsgesellschaft mbH, Germany), Bogdan Smolka (Silesian University of Technology, Poland), Konstantinos Plataniotis (University of

Toronto, Canada), M. Emre Celebi (Louisiana State University, USA), and Vito Cappellini (University of Florence, Italy), 2) Reconfigurable Video Coding organized by Ihab Amer and Marco Mattavelli (Ecole Polytechnique Federale de Lausanne, Switzerland), 3) Sparsity Tour of Inverse Problems organized by Jean-Luc Starck (CEA, France) and Jalal Fadili (Caen University, France), 4) Adaptive Morphology organized by Petros Maragos (National Technical University of Athens, Greece) and Corinne Vachier (ENS Cachan, France), 5) Next Generation Image and Video Coding through Texture Analysis and Synthesis organized by Patrick Ndjiki-Nya (FhG Heinrich-Hertz-Institut, Germany), Thomas Wiegand (FhG Heinrich-Hertz-Institut, Germany) and Dave Bull (University of Bristol, UK), 6) Visual Attention: Models and Applications in Image and Video Processing organized by Patrick Le Callet (Nantes University, France) and Olivier Le Meur (Thomson R&D, France), 7) Advances in Remote Sensing Image Processing organized by Gustavo Camps-Valls (Universitat de València, Spain), Devis Tuia (University of Lausanne, Switzerland), Riadh Abdelfattah (URISA, SUP'COM, Tunis, and ITI, TelecomBretagne France), and Mehrez Zribi(IRD-CESBIO, France).

We would like to extend our deepest appreciation to the plenary speakers, tutorial presenters, special session organizers and presenters, and above all, all the authors who submitted their papers to ICIP. We wish to thank the Technical Program Committee, the Special Session Chairs, the Tutorial Chairs, and the Plenary Chair for an outstanding technical program, and of course the General Chair and General Co-Chairs and the rest of the Organizing Committee for making such a great event possible. We would also like to thank the staff of Conference Management Services, Inc. (CMS), and in particular, Ms. Billene Mercer, for their expert guidance in organizing a conference of this size. Special thanks to Mr. Lance Cotton of CMS, whose tireless day-to-day expert support over the past year, was indispensable for the success of ICIP.

We would like to thank the IEEE Signal Processing Society, the US National Science Foundation, and Qualcomm, for providing generous authors' and students' travel grants, without which some authors would not have been able to attend and present their work at ICIP 2009. We would like to thank the members of the travel grant committee, Khaled El-Maleh, Sheila Hemami and Ahmed Tewfik, for coordinating the review of the travel grant applications and for selecting the travel grant awardees.

We are looking forward to welcoming you in Cairo and offering you a rewarding, exciting, and memorable experience.

Lina Karam and Thrasos Pappas
ICIP 2009 Technical Program Chairs

(Continued from previous page.)

15:35 - 16:05 BREAK

16:05 - 17:25

TP.PI.7b **STEREOSCOPIC VIDEO ERROR CONCEALMENT FOR MISSING FRAME RECOVERY USING DISPARITY-BASED FRAME DIFFERENCE PROJECTION**
Yibin Chen, Canhui Cai, Huaqiao University, China; Kai-Kuang Ma, Nanyang Technological University, Singapore

TP.PI.8b **SHAPE FROM FOCUS USING KERNEL REGRESSION**
Muhammad Tariq Mahmood, Tae-Sun Choi, Gwangju Institute of Science and Technology, Republic of Korea

TP.PI.9b **OVERLAP ELIMINATION FOR REGISTERED RANGE IMAGES**
Xiaokun Li, DCM Research Resources LLC, United States; William G. Wee, University of Cincinnati, United States

TP.PI.10b **PARALLEL HIGH RESOLUTION REAL-TIME VISUAL HULL ON GPU**
Wolfgang Waizenegger, Ingo Feldmann, Peter Eisert, Peter Kauff, Heinrich-Hertz-Institute, Germany

TP.PI.11b **HIGH DYNAMIC RANGE IMAGING FOR STEREOSCOPIC SCENE REPRESENTATION**
Huei-Yung Lin, Wei-Zhe Chang, National Chung Cheng University, Taiwan

TP.PI.12b **3-D STRUCTURE RECOVERY FROM 2-D OBSERVATIONS**
Huiyu Zhou, Queen's University Belfast, United Kingdom; Gerald Schaefer, Loughborough University, United Kingdom; Tangwei Liu, Faquan Lin, Guangxi Medical University, China

HIGH DYNAMIC RANGE IMAGING FOR STEREOSCOPIC SCENE REPRESENTATION

Huei-Yung Lin and Wei-Zhe Chang

Department of Electrical Engineering
National Chung Cheng University
Chia-Yi 621, Taiwan
E-mail: hylin@ccu.edu.tw, ilct0308@hotmail.com

ABSTRACT

This paper presents a method for generating high dynamic range and disparity images by simultaneously capturing the high and low exposure images using a pair of cameras. The proposed stereoscopic high dynamic range imaging technique is able to record multiple exposures without any time delay, and thus suitable for high dynamic range video synthesis. We have demonstrated that it is possible to construct the camera response function using a pair of images with different amount of exposure. The intensities of the stereo images can then be normalized for correspondence matching. Experiments using the Middlebury stereo datasets are presented.

Index Terms— high dynamic range image, stereoscopic

1. INTRODUCTION

High dynamic range imaging (HDRI) is an emerging research topic, especially in computer vision, computer graphics and imaging science communities. The objective is to capture, represent and display the significant amount of luminance variation of the real-world scenes. This problem commonly arises from the limited dynamic range capability of current imaging devices, compared to the much wider perception range of the human visual system. Since the HDRI is aimed to span a large luminance range for vivid image representation and reproduction, it has many applications on, for example, cinematography, photography, computer graphics and visualization, etc.

The most intuitive way of capturing HDR images is to adopt special light detecting sensors capable of recording images with extended intensity range. However, commercially available HDRI systems are usually very expensive and still only accessible to the professional users. For this reason, many researchers have proposed various HDRI techniques using low-cost imaging devices [1]. The most popular approach is to synthesize an HDR image using several image captures under different amounts of exposure [2, 3]. Although easy to implement, one major drawback of this method is that the ghost phenomenon may be present in the synthesized HDR image. This is usually inevitable especially for fusing multiple exposures of a dynamic scene [4].

In addition to the increasing demand of high quality reproduction of real-world scenes, there is always a need for stereoscopic image representation for the binocular human visual system. The objective is to provide us the depth perception ability using stereo image disparities. Thus, there are many advantages and a large application domain available from combining HDRI with stereo vision. For example, this so-called *stereoscopic HDRI* or *SHDRI* can be used to generate the content of 3D TV, video games, augmented reality, or used for advanced video surveillance.

In this work, we propose an SHDRI technique by simultaneously capturing the high and low exposure images using a pair of cameras. Since the stereo image pair can be acquired without any time delay in this approach, the ghost phenomenon introduced by dynamic scene HDR image synthesis is mitigated. Furthermore, the disparity maps associated with the HDR images can be obtained by some readily accessible stereo matching algorithms. To facilitate the correspondence searching with comparable stereo image brightness and display the HDR images on low dynamic range (LDR) devices, a tone-mapping algorithm based on the estimated camera response function is presented.

Although there is a fairly large amount of literature related to the HDRI research, to the authors' best knowledge no previous work on stereoscopic HDRI has been addressed. We demonstrate in this research that it is possible to construct the camera response function using a stereo image pair with different amount of exposure. The HDR and disparity images can then be obtained based on the derived camera response function. Experimental results using the Middlebury stereo datasets [5] have illustrated the feasibility of our approach.

2. HDRI BACKGROUND

Due to the limited dynamic range of conventional imaging sensors, it is not possible to fully capture a high contrast scene

The support of this work in part by the National Science Council of Taiwan, under Grant NSC-96-2221-E-194-016-MY2 is gratefully acknowledged.

with a single exposure using standard cameras. One simple way to create an HDR image is combining several LDR exposures based on the knowledge of the camera response function. In general, the camera response characteristics are not provided by the manufacturers. Thus, we adopt the classic method proposed by Debevec and Malik [2] to derive the intensity response curve, with some modifications on sample point selection as described in the following section. The unknown scene radiance can then be recovered using the intensities of the acquired images and the associated camera exposure settings.

The HDR image generated from multiple LDR exposures usually suffers from noise, blurring, and ghost phenomenon, etc. In the previous work, Grosch proposed a ghost removal algorithm by eliminating the moving object in the scene based on the difference of median threshold bitmaps of two consecutive exposures [6]. Since the noise can easily affect the threshold result, especially for the images with low exposure, the method usually requires to set the threshold manually. Akyuz and Reinhard presented a noise reduction method by replacing the low exposure images with multiple weighted high exposure ones [7]. Different from the previous approaches, except for the issue on noisy image captures under low illumination conditions, we will also have to deal with the ghost image problem of SHDRI due to stereo mismatches.

Although the HDR radiance map can be used to represent an HDR image, most of the existing display devices and media are not capable of covering the full dynamic range. Compressing the HDR images for a LDR display is known as the tone-reproduction or tone-mapping problem, and there is a number of techniques with remarkable performance. In this work, the algorithm proposed by Drago [8] is used to generate the tone-mapped images for display and correlation-based stereo matching.

3. THE ALGORITHM

This section presents the proposed technique for stereoscopic high dynamic ranging imaging. Two cameras placed side-by-side as a conventional stereo configuration are used for image acquisition. Each stereo image pair acquired with different shutter speed is used for HDR image synthesis and stereo disparity computation.

3.1. Deriving the Camera Response Function

To derive the camera response function from a single viewpoint with multiple exposures, it is necessary to obtain the intensities associated with the same image pixel. In the stereoscopic high dynamic range imaging, however, a scene point is not necessarily projected to the same pixel for two images. Thus, it is mandatory to find the feature correspondences between the images and then used as the sample points for camera response function derivation. In this work, the SIFT descriptor [9] is used to select the sample points for camera response curve modeling. An example of the correspondence feature extraction is shown in Fig. 1.

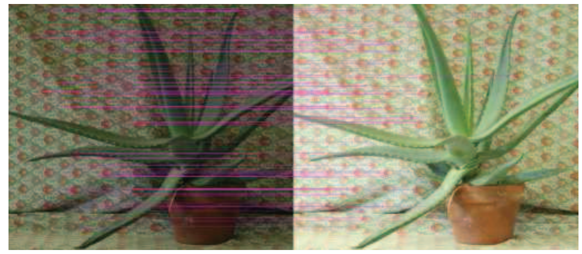


Fig. 1. Correspondence feature extraction using SIFT.

Ideally the camera response curve can be derived using the obtained feature correspondences and the associated image intensities. However, there might exist incorrect correspondences due to noise or stereo mismatch. Based on the SHDRI setting with a conventional stereo configuration, the epipolar, ordering and exposure constraints are used to increase the robustness of correspondence matching. Moreover, the feature points with less intensity variation in the neighborhood are selected as sample points for deriving the camera response curve. A window size of 11×11 pixels is used to calculate the variance associated with each feature correspondence. Only those feature points with variance smaller than a given threshold are qualified as sample points.

To ensure that the camera response curve is well sampled for the full brightness range, the above feature points are further divided into 10 equally-spaced groups based on their intensities, and a fixed number of samples is selected from each group.

3.2. Image Normalization and Correspondence Matching

In this work we adopt the stereo matching algorithm based on belief propagation to derive the disparity map [10]. Since the correlation should be evaluated on the images captured with similar illumination conditions, the stereo image pair captured under different exposures should be normalized prior to the correspondence matching process. Using the camera response function derived from the previous section, one image can be transformed to another with a different exposure setting. Thus, by transforming the image pair to the ones with the same exposure, the stereo matching algorithm can be carried out straightforwardly.

Fig. 2 (left two images) shows the normalized stereo image pairs corresponding to the low, median and high exposures (top, middle and bottom figures). The disparity images obtained from stereo matching using belief propagation are shown in Fig. 2 (right figures) for all three cases. It can be seen that there are no significant differences among the disparity images. This also verifies the correctness of the derived camera response function. Since the disparity of each pixel

(a) Normalized low exposure image pair and computed disparity map.

(b) Normalized median exposure image pair and computed disparity map.

(c) Normalized high exposure image pair and computed disparity map.

Fig. 2. Normalized stereo image pairs and the resulting disparity images.

between the image pair is provided by the disparity map, it is possible to transform one image to align with the other. An HDR image can then be obtained by calculating the radiance map using a weighted sum of these two images.

3.3. Ghost Removal and Tone-Mapping

Due to noise or stereo mismatches, the disparity image does not in general provide correct correspondences for all pixels. Using wrong correspondences to generate the HDR image will cause misalignment of the pixels and result in the ghost phenomenon as shown in Fig. 3 (left figures). Note that this is different from the ghost phenomenon appeared in the conventional HDRI with single viewpoint multiple exposures [11, 12], and therefore moving object detection is not required for ghost removal.

To remove the ghost phenomenon, we first transform the image with the viewpoint for HDR image synthesis to an image under the same exposure with the other image using the camera response curve. If the intensity difference between the corresponding pixels of the two images with the same exposure is larger than a threshold, then the correspondence is classified as a stereo mismatch. In this case, the intensity of the mismatch pixel is given by the newly created image instead of the weighted sum of the stereo image pair. Fig. 3 (right images) illustrates the synthesized HDR image using the proposed ghost removal method.

The final step of HDRI for LDR display is the tone-reproduction or tone-mapping process. Since the tone-mapping stage takes the HDR image as input and is irrelevant to how the image is created, the proposed SHDRI uses the existing techniques for tone-reproduction. The tone-mapped SHDR images in this work are generated using the method presented by Drago [8].

4. RESULTS

The proposed SHDRI technique has been tested using the Middlebury stereo datasets. There are six parallel views with three different exposures in the "art" dataset, and we select two different views with different exposures for SHDRI. Figs. 4(a) and 4(b) show the left and right image with exposures of 1 second and 4 seconds, respectively. The camera response curve derived from the stereo image pair is illustrated in Fig. 4(c). Red, blue and green colored curves correspond to the individual color channels.

Figs. 5(a) and 5(b) show the HDR and disparity images obtained using the proposed methods, respectively. For comparison, the HDR generated using the conventional method with single viewpoint multiple exposures and the disparity image obtained from stereo image pair with same exposure are shown in Fig. 6(a) and 6(b), respectively. The PSNR for the disparity image is 44.65 dB, which indicates the difference between the results obtained from these two implementations is fairly limited.

5. CONCLUSION

In this work, we have presented a method to generate high dynamic range and disparity images using a stereo image pair with different exposures. Although there is a fairly large num-

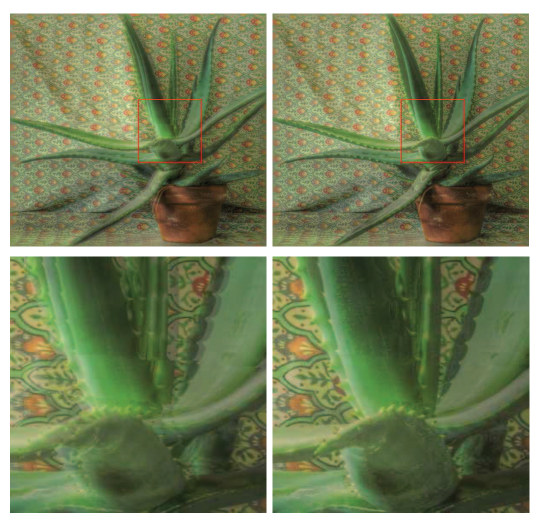
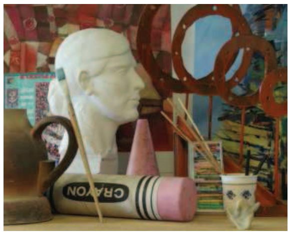
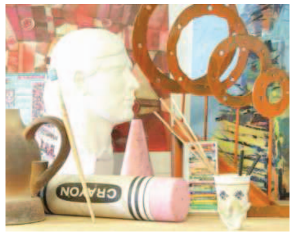


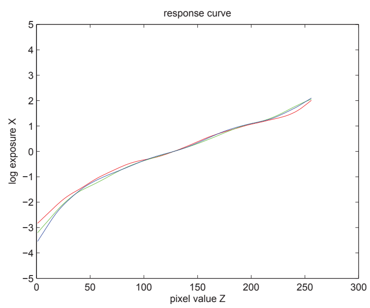
Fig. 3. Ghost phenomenon due to stereo mismatch (left images) and the ghost removal results (right images).



(a) Left image.

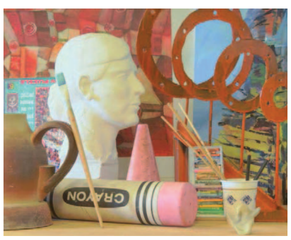


(b) Right image.



(c) Camera response curve.

Fig. 4. Experiment using the "art" images.



(a) Synthesized HDR image.

(b) Disparity image.

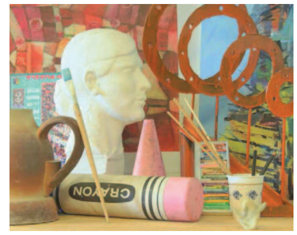
Fig. 5. The results obtained by the proposed SHDRI. Two images with different viewpoints, different exposures are used.

ber of literature related to HDRI research, no previous work on stereoscopic HDRI has been addressed. The camera response function is derived based on the stereo image pair, which is then used to normalize the images for correspondence matching. We have demonstrated the feasibility of the proposed technique using standard stereo image datasets.

References

[1] S.K. Nayar and T. Mitsunaga, "High dynamic range imaging: Spatially varying pixel exposures," in *IEEE Computer Vision and Pattern Recognition*, 2000, pp. I: 472–479.

[2] Paul E. Debevec and Jitendra Malik, "Recovering high dynamic range radiance maps from photographs," in *SIGGRAPH '97: Proceedings of the 24th annual confer-*



(a) Synthesized HDR image.

(b) Disparity image.

Fig. 6. The results obtained by conventional methods. (a) From two images of the same viewpoint with different exposures. (b) From a stereo image pair with the same exposure.

ence on Computer graphics and interactive techniques. 1997, pp. 369–378, ACM Press.

[3] Sing Bing Kang, Matthew Uyttendaele, Simon Winder, and Richard Szeliski, "High dynamic range video," in *SIGGRAPH '03: ACM SIGGRAPH 2003 Papers*, New York, NY, USA, 2003, pp. 319–325, ACM.

[4] Katrien Jacobs, Céline Loscos, and Greg Ward, "Automatic high-dynamic range image generation for dynamic scenes," *IEEE Computer Graphics and Applications*, vol. 28, no. 2, pp. 84–93, 2008.

[5] D. Scharstein and R. Szeliski, "Middlebury stereo vision page," *http://www.middlebury.edu/stereo*, 2002.

[6] T. Grosch, "Fast and robust high dynamic range image generation with camera and object movement," in *Vision, Modeling and Visualization, RWTH Aachen*, 2006, pp. 277–284.

[7] A.O. Akyuz and E. Reinhard, "Noise reduction in high dynamic range imaging," *Journal of Visual Communication and Image Representation*, vol. 18, no. 5, pp. 366–376, October 2007.

[8] F. Drago, W.L. Martens, K. Myszkowski, and N. Chiba, "Design of a tone mapping operator for high dynamic range images based upon psychophysical evaluation and preference mapping," *IS&T/SPIE Electronic Imaging*, 2003.

[9] David G. Lowe, "Distinctive image features from scale-invariant keypoints," *Int. J. Comput. Vision*, vol. 60, no. 2, pp. 91–110, 2004.

[10] J. Sun, N.N. Zheng, and H.Y. Shum, "Stereo matching using belief propagation," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 25, no. 7, pp. 787–800, July 2003.

[11] K. Jacobs, C. Loscos, and G. Ward, "Automatic high-dynamic range image generation for dynamic scenes," *Computer Graphics and Applications, IEEE*, vol. 28, no. 2, pp. 84–93, March-April 2008.

[12] E.A. Khan, A.O. Akyuz, and E. Reinhard, "Ghost removal in high dynamic range images," in *Image Processing, 2006 IEEE International Conference on*, Oct. 2006, pp. 2005–2008.