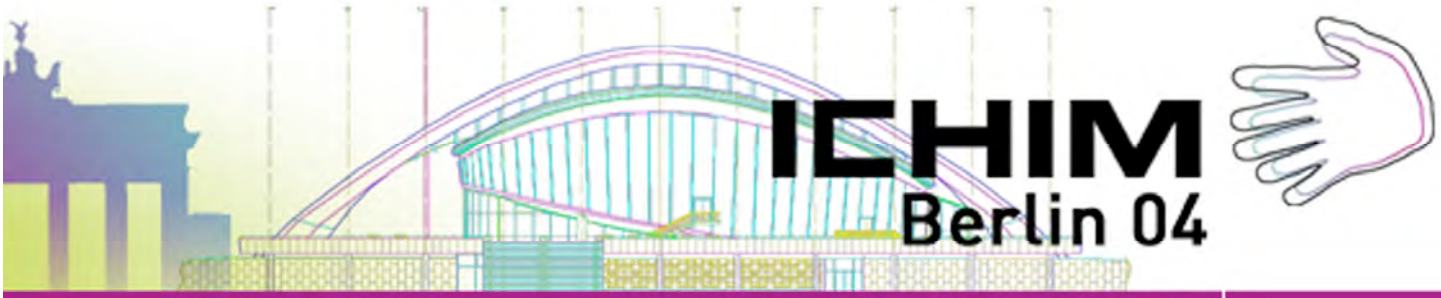

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"SHOOTING THE CAVES: A REVIEW AND HISTORY OF THE TECHNIQUES DEVELOPED BY NORTHWESTERN UNIVERSITY, AND THE DUNHUANG RESEARCH ACADEMY FOR THE MELLON INTERNATIONAL DUNHUANG ARCHIVE FOR DOCUMENTING THE MOGAO CAVE SHRINES"

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Abstract

For the past four years Northwestern University, in a project funded by the Andrew W. Mellon Foundation, in co-operation with Dunhuang Research Academy, has photographically documented the interiors of thirty-nine grottoes located at Mogao Cu, and one at Yulin Cu. This effort to document the grotto interiors has followed a two-pronged effort, coverage photography involved acquisition of high resolution images of the interior surfaces to capture the essentially two-dimensional mural surfaces, and QTVR photography that is designed to record the three dimensional nature of the mural surfaces in-situ within the architecture of the grottos. This paper will describe the evolution of the photographic techniques as they occurred in the process, in a cave-by-cave, shoot-by-shoot process, starting in June 1999 with the acquisition process of CAVE 196 and culminated in April 2002 with a 20 cave QTVR shoot. Our coverage process has gone from an analog image acquisition mode on a stationary camera platform, to a highly efficient, wholly custom designed and fabricated digital photographic system with a sophisticated camera motion control system that is designed to provide an accurate and speedy tiled image acquisition technique. These photographic techniques, in conjunction with a corresponding Andrew W. Mellon Foundation sponsored training program, have the potential to form the basis for a systematic and comprehensive photographic documentation effort that will create a lasting archive for scholars and conservationists.

Keywords: Dunhuang, Cave Shrines, Digital photography, Field Acquisition of Cultural Treasures..

Zusammenfassung (DE)

In den vergangenen vier Jahren hat die Northwestern University in einem Projekt, das von der Andrew W. Mellon Stiftung gefördert wurde, in Zusammenarbeit mit der Dunhuang Reserach Academy die Innenseite von 39 Grotten in Mogao Cu und einer in Yulin Cu fotografisch dokumentiert. Dies verlangte einen doppelten Aufwand: Die Berichterstattungsfotografie einerseits involvierte die Erfassung von Bildern mit einer hohen Auflösung von den inneren Oberflächen um die hauptsächlich zwei-dimensionalen Maueroberfläche festzuhalten, andererseits die Quick Time Virtual Reality (QTVR) Fotografie, die dafür entwickelt wurde die

drei-dimensionale Natur der Maueroberfläche an Ort und Stelle zu erfassen.
Dieser Vortrag wird die Entwicklung der fotografischen Techniken beschreiben, wie sie im Prozess, einem Höhle-nach-Höhle, Aufnahme-nach-Aufnahme Prozess, aufgetreten sind, der im Juni 1999 mit dem Erfassungsprozess der Höhle 196 begann und im April 2002 in einer QTVR Aufnahme von 20 Höhlen kumulierte. Unser Erfassungsprozess hat sich von einem analogen Bilderfassungsmodus auf einer stationären Kameraplattform zu einem höchst leistungsfähigen, gänzlich anwendungsspezifisch gestalteten und hergestellten, digitalen fotografischem System mit einer technisch ausgefeilten Bewegungskontrolle entwickelt, die zur Unterstützung einer genauen und schnellen Bilderfassung entworfen wurde.
Diese fotografischen Techniken haben, in Verbindung mit einem entsprechenden von der Andrew W. Mellon Stiftung gesponserten Trainingsprogramm, das Potential eine Basis für eine systematische und umfassende fotografische Dokumentation zu bilden, welche ein dauerhaftes Archiv für Studenten und Wissenschaftler sowie für Natur- und Umweltschützer hervorbringen wird.

Schlüsselwörter: Dunhuang, Höhle, Grotte, digitale Fotografie, Felderfassung von kulturellen Schätzen.

Résumé (FR)

Ces quatre dernières années *Northwestern University*, dans un projet financé par la Fondation Andrew W. Mellon, et en coopération avec la *Dunhuang Research Academy*, a documenté photographiquement l'intérieur de trente-neuf grottes situées à Mogao Cu, et une à Yulin Cu. Cette campagne de documentation a mis en œuvre à la fois des captations 2D en haute résolution d'images des surfaces murales, et des scènes QTVR (*QuickTime VR)* enregistrant la nature tridimensionnelle de ces surfaces murales in-situ dans l'architecture des grottes. Cet article décrit l'évolution des techniques photographiques pendant la campagne de captation, dans un processus caverne-par-caverne, prise de vue par prise de vue, commençant en juin 1999 avec la caverne 196 et se terminant en avril 2002 par une scène QTVR de la caverne 20. Notre méthode de prise de vues est partie d'un mode analogique de captation classique avec un appareil sur pied, jusqu'à un très efficace système numérique conçu et développé spécialement, avec un dispositif sophistiqué de pilotage des mouvements de l'appareil photo produisant rapidement des images avec une

technique de recouvrement précise (tuilage pour la fabrication des scènes QTVR). Ces techniques photographiques, en conjonction avec un programme de formation spécifique financé par la Fondation Andrew W. Mellon, sont les clés pour une campagne photographique systématique et exhaustive qui produira des archives de référence durables pour les érudits et les conservateurs.

Mots-clés : Dunhuang, Cavernes Shrines, Photographie numérique, QTVR, Captation sur site des trésors culturels.

I. PAPER

In June 1999, Northwestern University, in a project funded by the Andrew W. Mellon Foundation and in cooperation with the Dunhuang Research Academy, began a four-year project to photographically document the Mogao Grottos. At the end of that period, in April 2004, thirty-nine grottos at Mogao, and one grotto at Yulin were complete. This effort was designed to produce a series of extremely high-resolution photographic textures and panoramic photography for inclusion in the Mellon International Dunhuang Archive component of ARTSTOR. This comprehensive photographic effort brought a unique set of resources to the site, one that was able to build on, and augment the ongoing photographic efforts at Mogao by the Dunhuang Research Academy. This paper describes and catalogues the effort of the Northwestern Team working in cooperation with Dunhuang Research Academy. Work in this area of documentary photography has been in process by the Academy since its earliest days. Research in areas of digital acquisition production has been in progress since at least 1993, five years before our work began. The efforts detailed here need to be seen in context; a four-year effort in a continuum that has gone on for 100 years. Our group has had a privileged relationship and access to the site, because of our special relationship with the stewards of the Mogao grottos, and should be seen as such. The efforts and developments described here are collaborative and cooperative. This was a brief period of involvement by one of many foreign groups that are working at the site with the DRA. There has been an ongoing process of documenting the Mogao grottos for about 100 years. A couple of notorious foreigners, Aurel Stein and Paul Pelliot conducted the first systematic photographic efforts at the site in the first decade of this century. Aurel Stein writes of his early efforts:

> "As already stated, the best preserved and manifestly oldest frescoes were to be found within the large cellas, and just there the conditions of lighting were such as to render photographing particularly difficult. Only during certain hours of the morning could adequate light be obtained for particular portions of the painted wall surfaces. Even then the work was often seriously interfered with or stopped by the dust-haze left behind by the violent gales which after some day's intervals used to blow up the desert valley from the north and northeast. Thus it cost no small amount of time and effort to secure the dozens of photographic negatives by which, in combination with detailed notes, I endeavored to bring away some record of the most characteristic schemes of mural decoration to be found in these grottoes"

- Sir Aurel Stein, *Ruins of Desert Cathay*, pg.225

This project was able to bring to bear through the support of the Mellon Foundation the latest in acquisition and custom built equipment. The environmental conditions, hostile to humans but good for the preservation of wall murals, are little affected by such support and commitment. We still suffered under many of the same problems endured by Stein, especially during our acquisition trips in the "yellow sky" season of early April. This effort had a dual objective; 1) coverage photography that involved acquisition of high-resolution images to capture the essentially two-dimensional mural surfaces and 2) QTVR photography that is designed to record the three-dimensional nature of the mural surfaces in situ. QTVR (QuickTime Virtual Reality) is a form of user navigable panoramic photograph. It provides a mechanism that allows a user to explore the image by panning, and zooming in a three hundred and sixty degree panorama. Both of these paths were composed of unique acquisition techniques, and unique processing techniques that worked together, and informed each other. Our coverage process has gone from an analog image acquisition mode on a stationary camera platform to a highly efficient, custom designed and fabricated digital photographic system with a sophisticated camera motion control system that is designed to provide an accurate and rapidly-tiled image acquisition technique. The unique environmental obstacles of the Mogao grottos meant the success of the effort was, from beginning to end, an exercise in flexible thinking. While there is a core narrative to the development of the techniques used, and a certain refinement of the actual documentary approaches, the ability to address the unique aspects of the different physical geometry of the grottos was the key to the results that we achieved. In almost every situation, the issues presented to us by an individual grotto was unique, requiring special adaptations to our established systems, and continually tuning our equipment and techniques to provide the highest possible results from each situation. This paper describes the general history of the acquisition process, and then uses one particular grotto, cave 365, as a detailed example of how the various techniques were used, and adapted to a specific shooting environment. The development of the photographic techniques for documenting the grottos can be divided into three phases; discovery, research, and production (*appendix:figure 1*).

The discovery and research phase of the project involved preparation in anticipation of our first

attempt, and then the first three acquisition trips that took place in June and November 1999, and March of 2000. Several attempts were made to construct replica environments in the studio to test out various shooting techniques before the first trip abroad. The June 1999 trip was unique in several ways. To begin with, the photographic team had never experienced the grottoes and this trip was as much a scouting venture, as an attempt to successfully capture an entire grotto. This was the only trip that all of the photography was taken as analog imagery, that is it was shot on 100 speed Kodak echtachrome film. A NIKON F5 camera body was used with a variety of fixed focal length lenses and the resulting exposed film was then carried back to the Unites States unprocessed. The entire first grotto, CAVE 196, was shot without seeing a single processed image of any of the 2000 odd source images that we photographed before we left China. Upon arrival back in the United States the images were all processed and transferred to Kodak PhotoCD. The camera platform for supporting and manipulating the photographic equipment was crude. We adapted a set of standard steel scaffolding with auto poles, iron bars and super clamps. To facilitate moving the structure in CAVE 196 we mounted the entire structure on casters. Illumination was provided by a portable battery powered LUMEDYNE system. This strobe-based illumination was the only aspect of our acquisition system to remain consistent throughout the entire process. Within one year, our process would completely evolve from an analog/film-based methodology using off-the-shelf scaffolding into one based on a custom designed and fabricated camera platform and an image acquisition system almost entirely dependent on digital camera devices.

The next two trips, November 1999 and March 2000, was the basis of all of the core innovations that were implemented in the production and completion phases to come. The two significant changes that occurred in our acquisition efforts in November 1999, CAVE 148, involved the introduction to our process of high-resolution digital camera acquisition devices, specifically the KODAK DCS 660, and the use of high intensity HMI lighting instruments for the QTVR illumination of the entire cave at one time. The use of the DCS 660, one of the first high resolution digital field cameras gave us the benefits that everyone is now familiar with, the ability to preview the image as it is acquired. In the field, seven thousand miles away from your photographic processing laboratory, the value of digital acquisition cannot be overstated. It is invaluable in as much as the process of seeing the image is instantaneous, and decisions can be

immediately made about the value of the photography. The post processing of the separate tiled images can not only be seen immediately, but can also be stitched together in the cave to verify the quality of the image, the exposure and focus, the geometry of the image sequence, the order and spacing, and it can be assembled into the final textures in the field.

Cave 148 was the first of the grottos that we also brought in high intensity HMI style lighting to do a full cave illumination for the QTVR photography. This enabled us to present the three-dimensional nature of the grotto interiors in a fashion that would most closely replicate the experience that a visitor would encounter by actually standing in the grotto. The HMI lights were pointed at bounce cards, which were placed on the floor. The light "bounce" from the cards would then fill the interior space with light that would closely mimic the experience of exterior daylight coming in corridors from the south, but which could be completely controlled, and images could be acquired independently of the vagaries of actual daylight.

Cave 16 & 17 were shot in March 2000. The final major piece of research and development that was implemented in this acquisition trip was the use of track and rollers to create a robust, yet adaptable motion control system for the camera platform. Due to its size, Cave 17 could only be shot by hand and tripod, as the tiny dimensions of the library cave prohibited any more elaborate solutions. In contrast, the extremely large dimensions of cave 16 required the implementation of something new. A system of accurately controlling the movement of the camera, while also allowing quick adjustment was necessary. The relationship between the post-production stitching efforts to create single unified textures, and the irregular movement of the camera taking the tiled images needed to be addressed. We required a technique where the camera movement was constrained and controlled, so the results would be easier to assemble into the final stitched composites. This rolling adjustable scaffold allowed the camera to be moved in precise increments and also increased the speed of the acquisition process. Custom aluminum and steel work was fabricated for mounting wheels on precision track to create a flexible rolling scaffolding system that both controlled the camera movement across the front of a wall mural, and incrementally raised the platform in defined, controlled and measurable parameters. These pieces were the final core innovations that were implemented into our photographic acquisition techniques.

With the acquisition trip of October 2000, the process moved into a high production mode. This trip, a little over three weeks in length, acquired complete imagery from three grottos, doubling the quantity of caves shot during the entire first year of production. These three grottos, 249, 285, and 158, were completely captured in three weeks, one week less than it took to capture just one cave in June 1999. Material process improvement occurred with the addition of another complete set of rolling scaffolding, further refining the elements needed to speed up our work and increase our accuracy. This provided us with enough equipment to provision two complete 2-D mural photography teams working in two different caves. A third team working in a third cave shot the QTVR photography. In this way, through the organization of the cave shooting order, and the organization of the camera teams, we doubled the production of the entire first year of the project. At this point manpower was a key issue, and members of the DRA staff worked within each of our groups promoting the speed and efficiency of our efforts. Without the participation and collaboration of the DRA leadership and staff as an integral part of our process, handling both the administration and also doing the work in the grottos with us, our work could not have been as successful as it was.

This model defined the work mode for the next two years. A series of three week - three grotto shoots followed; April 2001, grottos 45, 61, and 254, August 2001, grottos 329, 419, 428, October 2001, grottos 156, 322, 420. In August 2001, we upgraded our digital acquisition devices. A significant time period had elapsed since the release of the KODAK DCS660. These cameras were almost two years old, and the technology advances over this period were significant. Two Hasselblad ELP camera bodies with the KODAK ProBack acquisition model were added to our camera arsenal. This camera allowed us to capture individual frames at much higher resolution, essentially three times more data, thereby decreasing the amount of frames that we needed to shoot to cover a specific wall mural, and also making the post-production assembly of the images quicker. In April, 2002, we shot five grottos in slightly longer than three weeks, 9,14, 303, 363, and 427. We were able to do this because we had established a core group of American and Chinese crewmembers that were completely facile with the acquisition techniques. We had also accumulated enough equipment on the site that we could have four shooting teams working simultaneously. Our last trip to capture high-resolution wall mural images occurred in July of 2003. We shot two Grottos, in Dunhuang grotto 465, the Tantric grotto and in Yulin Cu,

grotto 25. The last trip of our project was in April 2003, and was designated as a QTVR only shoot. We acquired QTVR data for 20 grottos over the course of the two-week shoot and again upgraded our digital cameras to NIKON D100 bodies mounted on KAIDAN spherical QTVR shooting heads.

The QTVR shooting techniques evolved into a flexible set of parameters that were again changed and adapted by the flexible configurations of the grottos themselves. As a general rule the in-cave illumination was derived from two sources; the large HMI daylight balanced light, bouncing the light off of cards placed on the floor to flood the room, and the LUMEDYNE strobe head in a china ball soft box to raise the level of ambient light immediately surrounding the camera. The balance of these sources both modeled the room, and provided even illumination for murals closest to the camera.

Two surfaces in Grotto 365 can serve as an in depth example of both the range of techniques used to acquire the source imagery, and the type of flexibility required to adapt and improvise on site to accomplish the goals of the project (*appendix: figure 2*). Grotto 365 is at the north end of the cliff scarp, immediately above grotto 16, and it shares the temple like wooden facade of grotto 16. It is a large space, approximately 13 meters wide, and 12 meters deep with a large altar and a tunnel-like circumambulation path that extends completely behind the altar. On the altar, (which projects about 4 meters into the chamber) sit seven seated, fully sculptured, statues of the Buddha. As planned, the north and south walls of the grotto would be shot with a single track placed 2 meters off of the object surface. Not until we arrived in the grotto and had fully set up the shooting rig were we able to discover that the geometry of the altar would obscure a major section of the north and south walls. The section of the altar that extended out in to the main chamber blocked all of the mural painting behind it and prevented a proper parallel camera angle to acquire imagery that was not distorted by perspective. About two thirds of the wall murals on the north and south were thus obscured. That portion of the wall that could be captured with the Hasselblad and ProBack at higher resolution capture was shot in the way anticipated by the plan. The solution for the obscured portion was to set up a section of the track in the 100-centimeter corridor space next to the altar and capture that portion of the wall with same camera but using the lighting and support rig as it had been set up for the DCS 660. The camera lens was changed to a shorter lens and many more images had to be acquired to account for the vastly smaller field

of surface captured. This also affected the postproduction dramatically as it increased the sheer number of files that had to be assembled for a relatively small area. As a comparison - the larger area of the north wall, shot as planned, had 6 rows of 8 images each for a total of approximately 48 usable images to be assembled to create one partial texture covering two thirds of the entire wall. The smaller obscured area, shot at much closer range had 15 rows of 10 images each, approximately 150 usable images for an area that was only one third of the completed texture. The final detail about the process, both at acquisition and throughout post was that each captured image represents forty-eight megabytes of file size. The acquired image data for this one surface, of one grotto, was over 11 gigabytes in size. Merely moving the data, on site in the grotto and later at each of the stages of backing up, sorting, and postproduction was itself a significant task.
The work done in this grotto also demonstrated the use of large format film acquisition (4x5 film on a field camera). This technique was used sparingly, but was required for certain situations where there were large niches, with full sculptural elements. This was done to provide documentation of elements that proved to be too problematic to capture using the high resolution tiled image techniques that were employed for the wall murals. The processed film was then drum scanned and provided the basis of the source imagery to be combined in our photo manipulation efforts. In grotto 365 the plan was to shoot three 4x5 images for combination into a seamless texture of the entire altar with the seven-seated Buddha sculptures. After arriving on site, it again became apparent that the realities of the physical geometry of the space would not allow a capture of the altar as planned. That plan was altered to shoot 7 different setups with 2 different shifts each, providing a source image set of fourteen different 4x5 transparencies. This was determined by the angles of the images that would be needed to capture each of the seven-seated Buddha sculptures in its entirety, and also provide the necessary imagery above and below the figures to assemble them together into a final texture.

A component of this project, which it is important to highlight, was the separate training activities associated with this effort. Through the entire sequence of image acquisition trips over the four-year duration of this project, the Andrew W Mellon Foundation, Northwestern University, the Dunhuang Research Academy and the Beijing Cultural Relics Bureau established a parallel training track. Essentially one training mission was designed to occur independent of each of the acquisition trips through August of 2001. Side-by-side shooting teams, one crewed

by MIDA personnel with DRA support and one DRA only crew worked in tandem on different grottos. In this way, a set of Chinese personnel skilled in the techniques of the acquisition efforts were assembled, that would be able to apply these techniques after the current MIDA sponsored project was completed in Dunhuang, as well as in other sites in China. The Beijing team has had training in applying these techniques in freestanding temples at Pilu Si, Hebei Province and Guang Sheng Si, in Shanxi Province. The DRA team has shot three grottos and other projects associated with the preservation of large mural paintings. The dissemination of these jointly developed photographic techniques into areas that may provide documentation and preservation of the vast cultural resources of China will hopefully be the final legacy and result of this project.

The driving motivation behind this project, executed to this depth and detail was the desire on behalf of Andrew W Mellon foundation to propagate the Mellon International Dunhuang Archive (MIDA) component of ARTSTOR with original documentary photography of the Mogao grottos. This effort was only one component of the MIDA archive project. Other collections and institutions from around the world participated in its development by contributing digitized representations of objects that originated from the library cave, grotto 17. In this way the work provides a new and fundamental grounding in the study of mural painting and culture that created the original work. The Dunhuang Research Academy was supported in a related follow up to this project to explore the application of these high-resolution images as a component of a proposed visitor center. The high-resolution images were used as a basis of an exploration in both 2-D and 3-D presentation models to create prototypes of narrative presentations that could be used as part of an educational program. This project will hopefully lead to other explorations of the way that imagery of this resolution and quality can be used both in research and education, and form the basis of new ways to explore, understand and preserve similar sites.

Without a doubt, the painting and sculpture seen in the grottos is the product of the devotion of artists going to great lengths to create some of the most beautiful interior spaces in the world. The span of time that the painted murals represent is almost a thousand years, and in those thousand years many of the narrative motifs and structures are repeated. Jataka tales, and Sutras are depicted, copied and changed throughout the dynasties. Our team had the privilege of working in these spaces an arms length away form the murals themselves. In many cases we had the same perspective that those who originally worked creating these grottoes as they were applying the

paint to the walls. The work that we have done in these caves has extended their efforts, through the use of digital cameras and the digital on line archive into a new realm. No longer linked physically to the living rock of the cliff scarp, these digital impressions of the murals have found a new architecture to continue the tradition, repeating the narrative motifs and structures again. These images extend their original work in new ways. The technology, and presentation of these digital images allows viewers to see the murals in ways that cannot be replicated, even in the actual caves. The lighting and detail present in the on-line imagery provides a privileged view, one experienced by those of us that had the experience of acquiring these photographs, and perhaps in a small way, the view of those that originally created them.

The efforts detailed here are one part of a comprehensive effort, and as such represent the work of a complex and varied team. This project could not have happened without the vision, support and guidance of William G. Bowen, President of the Andrew W. Mellon Foundation, and Henry Bienen, President of Northwestern University, Director Fan Jin Shi and Vice Director Li Zuixiong of Dunhuang Research Academy. My two direct associates at the Dunhuang Research Academy, Liu Gang and Sun Hongcai, who worked with us and supported and helped develop our efforts at every step were integral in success of this work. The attention and focus of Don Waters, our program officer at the Andrew W. Mellon Foundation was invaluable in the great range of support that was provided to all aspects of this project. My two principal American collaborators on the development of the techniques described here were James Prinz who accompanied me on every single acquisition trip, and Stefani Foster who functioned as one of our principal photographers and trainers. Lastly, this could not have happened without Professor Sarah Fraser, the project's director whose original research on three of these caves was the initial inspiration for this project.

