Qifa Ke

Carnegie Mellon University
Computer Science Department
Pittsburgh, PA 15213

Tel.: (412)370-7467
E-mail: ke@cmu.edu
http://www.cs.cmu.edu/~ke
Visa status: Permanent Resident

EDUCATION

CARNEGIE MELLON UNIVERSITY — Pittsburgh, PA, USA

Ph.D. in Computer Science, 2003
Advisor: Prof. Takeo Kanade

INST. OF AUTOMATION, CHINESE ACADEMY OF SCIENCES — Beijing, China

M.S. in Pattern Recognition and Artificial Intelligence, 1997
Advisor: Prof. Songde Ma

UNIVERSITY OF SCIENCE & TECHNOLOGY OF CHINA — Hefei, Anhui, China

B.S. in Electronic Engineering, 1994

RESEARCH INTERESTS

Computer vision, machine learning, image/video analysis, signal processing, human computer interaction, vision for robotics, computer graphics.

SKILLS SUMMARY

- Expert in structure from motion (SFM), multi-view geometry, 3D reconstruction, image based modeling and rendering, image/video mosaicking, feature tracking, image/video processing and analysis, and convex optimization.
- Expert in architecting, designing, implementing, testing, and deploying computer vision systems to handle large amount of video data.
- Strong background in computer vision, machine learning, pattern recognition, computer graphics, numerical optimization, probabilistic inference and statistical analysis.
- Experienced in coordinating a team of people to prototype working computer vision systems in a timely manner for sponsors (DARPA and U.S. Air Force).
- Experienced in computer networking, with focus on wireless mobile ad hoc networks.
- Proficient in numerical algorithm programming and in C, C++, and Matlab.
- Strong system builder, experienced presenter, and team player.
- Independent, creative, and rigorous thinker.

PROFESSIONAL EXPERIENCE

2003/8–current — **Systems Scientist** — Department of Computer Science, CMU

Technical lead for projects funded by DARPA and U.S. Air Force:

- Robust Quasiconvex Optimization for Geometric Reconstruction;
- Robust 3D Vision System for Small and Micro Aerial Vehicle (feature tracking, motion estimation, 3D reconstruction, navigation and control);

A summary of my research activities at CMU and elsewhere begins on page 5.

1997/8–2003/7 — **Research Assistant** — Department of Computer Science, CMU

Major projects include:

- Doctoral thesis: subspace approach to layered-based video analysis. Apply to video segmentation, object tracking, 3D scene reconstruction, video mosaicking, and video compression;
- Ground plane detection for safe driving;

- Visual inspection of printings on non-planar surface;
- Emulation of multi-hop wireless networks.

Summer 1998 (May–Sept.) **Research Intern** Microsoft Research, Redmond, WA

Summer research internship (worked with Dr. Harry Shum and Dr. Zhengyou Zhang):

- Efficient bundle adjustment for multi-frame Structure from Motion;
- Image based rendering using ConCentric mosaics.

1994/9–1997/7 **Research Assistant** Chinese Academy of Sciences, China

Graduate research assistant at National Laboratory of Pattern Recognition.
Major projects include:

- 3D structure and motion reconstruction by efficient reactive Tabu search;
- Road extraction from satellite images, and blood vessel extraction from medical images;
- Low-level image feature and geometric primitive detection.

1992/9–1994/7 **Research Assistant** Univ. of Science & Technology of China

Undergraduate research assistant at Networking and Multimedia Communications Lab.

TEACHING EXPERIENCE

Students I work with closely (co-supervise) at CMU:

2004 – Myung Hwangbo, Ph.D. student in Robotics, project "Vision-based MAV Navigation and Control".

2005 – David Lee, Master student in ECE, project "Quantitative Performance Evaluation of 3D Reconstruction for MAV Applications".

Summer 2005 Kelvin Goh, Master student in ECE, project "Ground Layer Detection for Vehicle Navigation".

Teaching Assistant:

1999 CMU undergraduate course 15-412, *Operating Systems: Design and Implementation*
Assisted with the design and grading of homework, exams, and projects. Held office hours.

2001 CMU undergraduate course 15-385, *Computer Vision*
Design and grading of homework, exams, and projects. Held office hours. Some lectures. Assisted with course design.

PUBLICATIONS

Refereed Papers:

[1] **Q. Ke** and T. Kanade, "Uncertainty Models in Quasiconvex Optimization for Geometric Reconstruction", to appear in *IEEE Conf. on Computer Vision and Pattern Recognition (CVPR 2006)*, June, 2006.

[2] **Q. Ke** and T. Kanade, "Quasiconvex Optimization for Robust Geometric Reconstruction", *Tenth IEEE International Conference on Computer Vision (ICCV 2005)*, vol. 2, pp. 986-993, October, 2005. (oral presentation)

[3] **Q. Ke** and T. Kanade, "Robust L_1 Norm Factorization in the Presence of Outliers and Missing Data by Alternative Convex Programming", *IEEE Conference on Computer Vision and Pattern Recognition (CVPR 2005)*, vol. 1, pp. 739-746, June 2005.

[4] R. Prazenica, A. Watkins, A. Kurdila, **Q. Ke**, T. Kanade, "Vision-Based Kalman Filtering for Aircraft State Estimation and Structure from Motion", *AIAA Guidance, Navigation, and Control Conference (GNC 2005)*, pp. 1-13, August 2005.

[5] T. Kanade, O. Amidi, and **Q. Ke**, "Real-Time and 3D Vision for Autonomous Small and Micro Air Vehicles", invited paper, *IEEE Conf. on Decision and Control (CDC 2004)*, pp. 1655-1662, Dec. 2004.

[6] **Q. Ke** and T. Kanade, "Robust Subspace Clustering by Combined Use of kNND Metric and SVD Algorithm", *IEEE Conference on Computer Vision and Pattern Recognition (CVPR 2004)*, vol. 2, pp. 592-599, June 2004.

[7] **Q. Ke** and T. Kanade, "Transforming Camera Geometry to A Virtual Downward-Looking Camera: Robust Ego-Motion Estimation and Ground-Layer Detection", *IEEE Conference on Computer Vision and Pattern Recognition (CVPR 2003)*, vol. 1, pp. 390-397, June 2003.

[8] **Q. Ke** and T. Kanade, "A Robust Subspace Approach to Layer Extraction", *IEEE Workshop on Motion and Video Computing (Motion 2002)*, pp. 37-43, December 2002.
Lockheed-Martin Best Paper Award

[9] **Q. Ke** and T. Kanade, "A Subspace Approach to Layer Extraction", *IEEE Conference on Computer Vision and Pattern Recognition (CVPR 2001)*, vol. 1, pp. 255-262, December 2001. (oral presentation)

[10] **Q. Ke**, D. Maltz, and D. B. Johnson, "Emulation of Multi-Hop Wireless Ad Hoc Networks", *Seventh International Workshop on Mobile Multimedia Communications (MoMuC 2000)*, October 2000.

[11] H. Shum, **Q. Ke**, and Z. Zhang, "Efficient Bundle Adjustment with Virtual Key Frames: A Hierarchical Approach to Multi-Frame Structure from Motion", *IEEE Conference on Computer Vision and Pattern Recognition (CVPR 1999)*, vol. 2, pp. 538-543, June 1999.

[12] **Q. Ke**, G. Xu, and S. Ma, "Recovering Epipolar Geometry by Reactive Tabu Search", *Sixth IEEE International Conference on Computer Vision (ICCV 1998)*, pp. 767-771, January 1998.

[13] **Q. Ke**, L.Wang, and S. Ma, "The Design and Application of Multi-Scale Differential Filters", *Chinese Journal of Computers*, Vol. 21(3), pp.234-244, 1998.

[14] G. Cong, **Q. Ke**, and S. Ma, "Curvatures in Scale Space for Corner Enhancement", *Chinese Journal of Computers*, Vol. 21(4), 1998.

[15] **Q. Ke**, T. Jiang, and S. Ma, "A Tabu Search Method for Geometric Primitive Extraction", *Pattern Recognition Letters*, Vol.18(14), pp.1443-1452, December 1997.

[16] **Q. Ke**, J. Xiao, Z. Yang, and S. Ma, "Energy-Based Method for Road Extraction from Satellite Images", *IAPR Workshop on Machine Vision and Applications (MVA 1996)*, Tokyo, Japan, 1996.

[17] **Q. Ke** and S. Ma, "Differentiation Filter Design: Theories and Applications", *The 4th International Conference on Control, Automation, Robotics and Vision (ICARCV 1996)*, Singapore, 1996.
(**Finalist for the Best Paper Award**)

Technical Report:

[18] **Q. Ke**, "A Robust Subspace Approach to Extracting Layers from Image Sequences", *Doctoral Thesis, Tech. Report CMU-CS-03-173*, Computer Science Department, Carnegie Mellon University, August 2003.

[19] **Q. Ke** and T. Kanade, "Robust Subspace Computation Using L_1 Norm", *Tech. Report CMU-CS-03-172*, Computer Science Department, Carnegie Mellon University, 2003.

[20] **Q. Ke**, S. Baker, and T. Kanade, "Textureless Layers", *Tech. Report CMU-RI-TR-04-17*, Robotics Institute, Carnegie Mellon University, March 2004.

[21] **Q. Ke** and T. Kanade, "A Subspace Approach to Layer Extraction and Its Application to Patch-Based Structure from Motion and Video Compression", *Tech. Report CMU-CS-01-168*, Computer Science Department, Carnegie Mellon University, 2001.

[22] **Q. Ke**, "Multi-Scale Differential Filters: Theory, Design, and Applications", *Master Thesis, Tech. Report*, National Lab. of Pattern Recognition and Artificial Intelligence, Chinese Academy of Sciences, 1997.

[23] **Q. Ke**, "A Gateway Connecting LAN with PSTN for Sharing Facsimile", *Bachelor Thesis, Tech. Report*, Dept. of Electronic Engineering, Univ. of Sci. & Tech. of China, 1994.

In Submission:

[24] **Q. Ke** and T. Kanade, "Quasiconvex Optimization for Robust Geometric Reconstruction", submitted to *IEEE Trans. on Pattern Analysis and Machine Intelligence (PAMI)*. (Conference version appeared in ICCV 2005).

PATENTS

[1] "Rendering with ConCentric Mosaics", Heung-Yeung Shum, Li-Wei He, and Qifa Ke,
-- International patent number: WO 00/68890, granted November 2000;
-- US patent number: 6750860, granted June 2004.

SELECTED HONORS AND AWARDS

2002	Lockheed-Martin Best Paper Award, IEEE Motion'2002
1997 – 2003	Computer science graduate fellowship, Carnegie Mellon University
1997	"Bao Gang" fellowship of P.R. China (one of the most prestigious graduate fellowships in China)
1996	Best Student fellowship, Institute of Automation, Chinese Academy of Sciences
1995	First-class Elite Fellowship of Chinese Academy of Sciences (for ranking 1st in the grade)
1994	Graduated with Honor, University of Science and Technology of China (USTC)
1990 – 1993	Excellent Student Scholarship, University of Science and Technology of China (USTC)
1989, 1994	"Wen-dou Wang & Shu-jing Wang" Scholarship (awarded by Xiamen City)
1989	Rank 1st in Xiamen City in the national college entrance examination

SERVICES AND OTHER ACTIVITIES

Program committee member:

- IEEE Conference on Computer Vision and Pattern Recognition (CVPR 2005, CVPR 2006)
- European Conference on Computer Vision (ECCV 2006)
- International Conference on Pattern Recognition (ICPR 2006)

Reviewer: CVPR, ECCV, IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI), International Journal of Computer Vision (IJCV), Computer Vision and Image Understanding (CVIU), Graphical Models, Machine Vision and Applications (MVA), Journal of Electronic Imaging (JEI).

Member of IEEE

PROJECT MANAGEMENT EXPERIENCES

Since January 2004, I have been co-leading a team (currently eight members) working on a 3D vision system for the guidance, navigation, and control of small and micro aerial vehicles. I oversee the system design and implementation, integration, and performance evaluation. I am responsible for the design and implementation (C++) of the vision component. The vision component has been used by our project collaborators. I am also responsible for writing funding proposals (two approved, one pending).

REFERENCES

Available upon request.

RESEARCH – COMPUTER VISION

2004 – **Quasiconvex Optimization for Robust Geometric Reconstruction** CMU

My recent research activities focus on geometric reconstruction in computer vision, i.e., estimating the three-dimensional information about the scene and/or the camera motions, given measurements in 2D images. Traditional approaches to geometric reconstruction suffer from the problem of being trapped at *local* optimum solutions.

I have identified an intrinsic *quasiconvex* property of the camera model, based on which I developed a quasiconvex optimization framework for geometric reconstruction, which consists of only a few small-scale convex programs that are well-studied and ready to solve. In contrast to existing approaches, the quasiconvex optimization approach is deterministic and guarantees a *global* optimum solution. Moreover, it can handle *outliers* and *directional uncertainty* in image measurements.

I have applied the reconstruction algorithm to (1) 3D structure and motion estimation in our 3D vision system for vehicle navigation, and (2) homography estimation for image mosaicking. Since quasiconvexity is intrinsic for pin-hole cameras, such algorithm can be applied to many other problems in computer vision, when desirable information needs to be inferred from 2D images.

2000 – **Layer-Based Video Representation and Analysis** CMU

Layered representation approximates the video sequence with several overlapping layers in the image domain, where the pixels within each layer share some common motion model. Such representation has rich applications in computer vision, as it explicitly represents the depth discontinuities and occlusions between objects -- two most difficult issues in many vision problems.

However, conventional methods to layer extraction exploit only the constraints from scene regularities; they either make strong assumptions about the scene, or require a good initial solution that is hard to obtain.

My doctoral thesis research investigated a subspace approach to extracting layers from a given video sequence. While the 2D image motions (e.g., local affine/projective transformations collected from small image patches) across multiple video frames are high-dimensional, I showed that they must lie in a low-dimensional linear subspace. By projecting 2D image motions into the low-dimensional subspace, layers can be simply identified as compact *clusters*. Moreover, the existence of subspace enables us to detect outliers in local image motion measurements.

I have applied the layer-based representation to 2D motion estimation, 3D reconstruction, video compression, moving object detection and tracking, 3D video mosaicking, and ground plane detection for vehicle navigation.

2003 – **Robust 3D Vision System for Micro Aerial Vehicle** CMU

I have developed a vision system for the purpose of Guidance, Navigation, and Control of Micro Aerial Vehicle (MAV). It addresses several challenges posed by MAV: low quality video from a mini video camera, degenerate or near-degenerate camera motion from largely forward flying, and the requirement of sequential estimation (no use of future data as in traditional multi-frame structure from motion). The vision system contains the following major components: (1) robust real-time feature tracker, (2) robust ego-motion estimation, (3) global optimal estimation of 3D scene using quasiconvex optimization, (4) layer-based scene segmentation, and (5) moving ground objects detection and tracking.

The vision system has been released to and used by our project collaborators.

2002 – 2003 **Ground Plane Detection for Automotive Safe Driving** CMU

A vision system capable of detecting pedestrians, obstacles, and other vehicles can greatly improve the safety in driving a ground vehicle. Two important coupled problems in such a vision system are the ground plane detection and the vehicle egomotion estimation. I have developed a robust method to solve the above coupled problems. The method virtually rotates the camera to the downward-looking pose to explicitly exploit the fact that the vehicle is constrained to be on the ground. Such virtual camera rotation can effectively (1) eliminate the ambiguity between rotational and translational ego-motion parameters, and (2) improve the numerical condition in motion estimation. As a result, we are able to reliably estimate the vehicle ego-motion and detect the ground plane.

Summer 1998 (May–Sept.) **Efficient Bundle Adjustment in Structure from Motion** Microsoft Research, Redmond

We developed an efficient hierarchical approach to structure from motion for long image sequences. Our approach contains two key elements: accurate 3D reconstruction for each segment and efficient bundle adjustment for the whole sequence. The image sequence is first divided into a number of segments so that feature points can be reliably tracked across each segment. Each segment has a long baseline to ensure accurate 3D reconstruction. In order to efficiently bundle adjust 3D structures from all segments, we reduced the number of frames in each segment by introducing "*virtual key frames*". The virtual frames encode the 3D structure of each segment along with its uncertainty but they form a small subset of the original frames. Our method achieves significant speedup over conventional bundle adjustment methods.

1997 – 1998 **Visual Inspection of Printings on Non-Planar Surface** CMU

I developed a vision software system for inspecting defects in color printings on non-planar surface (e.g., cans and bottles). I addressed three challenges in this project: (1) reflective lighting conditions due to shinny material, (2) deformation due to non-planar surface, and (3) real-time requirement. The vision system is capable of detecting small printing defects with high accuracy in real time, and has been used in commercial systems.

RESEARCH – IMAGE BASED RENDERING

Summer 1998 (May–Sept.) **Image Based Rendering Using ConCentric Mosaics** Microsoft Research, Redmond

I help in the conception and design of a novel ConCentric mosaic representation (patented) for image based rendering. Concentric mosaics have good space and computational efficiency, and are very easy to capture. Like panoramas, concentric mosaics do not require recovering geometric and photometric scene models. Moreover, ConCentric mosaics provide richer user experience by allowing the user to move freely in a circular region and observe significant parallax and lighting changes.

RESEARCH – COMPUTER/SENSOR NETWORKING

1998 – 2000 **Emulation of Multi-Hop Wireless Ad Hoc Networks** CMU

Sensor networks are often ad hoc since the sensors, when deployed, form a temporary network without any centralized administration. Evaluating a software system in such networks is a challenging task, as it requires either (1) building a real test-bed to deploy the software system, which is expensive and non-repeatable, or (2) re-implementing the software system inside existing network simulators, which is error-prone and infeasible for large-scale software systems. I have developed an emulation system capable of evaluating *unmodified* real software systems in simulated environments (*ns-2* network simulator). The emulation runs in real-time, and is repeatable, detailed, and realistic. The emulator has been integrated into the widely-used *ns-2* simulator, and is publicly available.