

GREGORY FRANCIS WELCH

Curriculum Vitae—November 20, 2009

CONTACT INFORMATION

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EDUCATION

Dec 1996 **Ph.D., Computer Science**
University of North Carolina at Chapel Hill, Chapel Hill, NC
Under the direction of Gary Bishop

May 1995 **M.S., Computer Science**
University of North Carolina at Chapel Hill, Chapel Hill, NC

May 1986 **B.S. with *Highest Distinction*, Electrical Technology**
Purdue University, West Lafayette, IN

PROFESSIONAL EXPERIENCE (SUMMARY)

University of North Carolina at Chapel Hill

2001–present Research Associate Professor, Computer Science

2005–present Adjunct Associate Professor, Applied & Materials Sciences

2000–2003 Adjunct Assistant Professor, Applied & Materials Sciences

1996–2001 Research Assistant Professor, Computer Science

Renaissance Sciences Corporation

2007–2008 Principal Investigator II

1990–1992 **Northrop Defense Systems Division**
Senior Engineer, Airborne Electronic Countermeasures, Digital Systems Group

1987–1990 **NASA Jet Propulsion Laboratory (California Institute of Technology)**
Member Technical Staff, Voyager Spacecraft Project,
Flight Command and Data Management Section

 ACTIVITIES AND HONORS

- IMMERSCOM 2009 panel member with Randy Harrell (CISCO), Jaron Lanier (Microsoft), Frantz Lohier (Logitech), William C. Wickes (Hewlett Packard), and Zhengyou Zhang (Microsoft); May 29, 2009
- Keynote speaker, RAVE 2009 workshop (Real Action, Virtual Environments), Barcelona, Spain, March 4, 2009
- Keynote speaker, D2D 2008 workshop (Digital City Monitoring and Emergency Management), Shenzhen, China, October 25, 2008
- Keynote speaker, 14th Eurographics Symposium on Virtual Environments (EGVE 2008), Eindhoven, The Netherlands, May 29, 2008
- *Excellence in Teaching* award, UNC-Chapel Hill, Computer Science Student Association, for 3D Computer Modeling and Animation, Spring 2007
- *Best Paper*, ACM Symposium on Virtual Reality Software and Technology 1999 (VRST 99)
- Internationally-recognized Kalman filter web site (<http://www.cs.unc.edu/~welch/kalman/>)
- Graduated with *Highest Distinction* from Purdue University (among three-tenths of the baccalaureate graduates having the highest graduation indexes)
- *Outstanding Senior Design Project*, “The Easy Chair: A Microprocessor-Controlled Wheelchair for Children With Muscular Disorders,” E.T., Purdue University, 1986
- *Distinguished Student*, Purdue University, 1982–1986 (all semesters)
- Residence Hall Counselor, Purdue University, 1985–1986
- President, UNC-Chapel Hill Computer Science Student Association, 1994–1995
- Boards and Committees
 - UNC-Chapel Hill Committee on Student Conduct (COSC)
 - UNC-Chapel Hill Computer Science Committee on Undergraduate Service Courses
 - Board of Directors, HiBall Tracker, Inc. (<http://www.3rdTech.com>)
- Reviewer, Committee, and Editorial Activity
 - Presence: Teleoperators and Virtual Environments (Associate Editor)
 - International Journal of Virtual Reality (Editorial Board)
 - International Symposium on 3D Data Processing, Visualization, and Transmission (3DPVT)
 - ACM: International Conference on Graphics and Interactive Techniques (SIGGRAPH); Symposium on Virtual Reality Software and Technology (VRST); Symposium on Interactive 3D Graphics; Multimedia; User Interface Software and Technology (UIST); Transactions on Mathematical Software;
 - IEEE: Computer Graphics and Applications (CG&A); International Symposium on Mixed and Augmented Reality (ISMAR)—Area Chair; Virtual Reality (VR); Transactions on Visualization and Computer Graphics; Transactions on Aerospace and Electronic Systems; Conference on Computer Vision and Pattern Recognition (CVPR)
 - IEEE/ACM International Symposium on Wearable Computers
 - EURASIP Journal of Applied Signal Processing; Transactions on Automatic Control
 - Journal of Optimal Control Applications and Methods
 - Eurographics Workshop on Virtual Environments
- Developer of popular Mac OS X Mail plugins MailFollowUp and MailRecent
- Consultant and Expert Witness

ACTIVITIES AND HONORS (CONTINUED)

- Professional Societies
 - Association for Computing Machinery (ACM)
 - Institute of Electrical and Electronics Engineers (IEEE) Computer Society
 - Society for Simulation in Healthcare (SSIH)
- Event Organization Activity
 - VR 2007 Research Demos Co-Chair, IEEE Virtual Reality 2010 (Waltham, MA, USA), with Yoshifumi Kitamura (Osaka University, Japan), Laura Monroe (Los Alamos National Laboratories, USA), Dirk Reiners (University of Louisiana at Lafayette, USA), and Simon Richir (Laval Virtual, France)
 - Dagstuhl Seminar on “Virtual Realities” (Seminar 08231), co-organized with Guido Brunnett (TU Chemnitz, Germany) and Sabine Coquillart (INRIA Rhône-Alpes, France), June 1–6, 2008, The International Conference and Research Center for Computer Science, Dagstuhl, Germany
 - VR 2007 Local Arrangements Co-Chair, IEEE Virtual Reality 2007 (Charlotte, NC, USA), with Zachary Wartell (UNC-Charlotte, USA), Sabarish Babu (UNC-Charlotte, USA), and Regis Kopper (Virginia Tech, USA)
 - ISMAR 2006 Workshops/Tutorials Chair, 5th IEEE and ACM International Symposium on Mixed and Augmented Reality (Santa Barbara, CA, USA)
 - ProCams 2006 Co-Chair, IEEE CVPR 2006 International Workshop on Projector-Camera Systems, (New York, NY, USA), with Chris Jaynes (University of Kentucky)
 - 3DPVT 2006 Organizing Committee, Third International Symposium on 3D Data Processing, Visualization and Transmission (Chapel Hill, NC, USA)
 - EDT 2006 Co-chair, IEEE Virtual Reality 2006 International Workshop on Emerging Display Technologies (Alexandria, VA, USA), with Mark Bolas (USC and Fakespace Labs) and Andreas Simon (FH-Aargau)
 - ICAT 2005 Program Co-Chair, 15th International Conference on Artificial Reality and Telexistence (Christchurch, New Zealand), with Sang Chul Ahn (KIST, Korea), and Haruo Noma (ATR, Japan)
 - ProCams 2005 Posters Chair, IEEE CVPR 2005 International Workshop on Projector-Camera Systems (San Diego, CA, USA)
 - EDT 2005 Co-chair, IEEE Virtual Reality 2005 International Workshop on Emerging Display Technologies (Bonn, Germany), with Mark Bolas (USC and Fakespace Labs) and Andreas Simon (Fraunhofer IMK)
 - I3D 2001 Registration Chair, ACM Symposium on Interactive 3D Graphics (Chapel Hill, NC, USA)

INVITED TALKS (SELECTED)

- “Virtual Artifacts and Experiences in Real Environments,” second RAVE 2009 workshop (Real Action, Virtual Environments), Barcelona, Spain, March 4, 2009
- “A Living, Breathing, Dynamic Digital City,” D2D 2008 workshop (Digital City Monitoring and Emergency Management), Shenzhen, China, October 25, 2008
- “VR Research at UNC-CH: A Sampling,” with Henry Fuchs, Daimler AG, Ulm, Germany, June 10, 2008
- “Immersive Display Research at UNC-CH: A Sampling,” with Henry Fuchs, Max Planck Institute, Tübingen, Germany, June 9, 2008.
- “Motion Tracking as an Epic Battle Between Information and Uncertainty,” Keynote address, 14th Eurographics Symposium on Virtual Environments (EGVE 2008), Eindhoven, The Netherlands, May 29, 2008.
- “Hardware Information Optimization in the Design of Systems for the Sensing of Human Motion,” University of California at Riverside, Riverside, CA, USA, October 23, 2006.
- “Improving, Expanding and Extending 3D Telepresence,” International Workshop on Advanced Information Processing for Ubiquitous Networks, with ICAT 2005, Christchurch, New Zealand, December 8, 2005.
- “Differential Imaging/Setups,” 1st Computer Vision for Interactive and Intelligent Environments (CV4IIE) workshop, University of Kentucky, Lexington, KY, November 17–18, 2005.
- “3D Medical Consultation,” Naval Postgraduate School/MOVES Institute guest lecture, Monterey, CA, November 10, 2005.
- “Multi-Projector Displays,” US Army sponsored workshop on “Displays for Immersive Education and Training,” Institute for Creative Technologies, University of Southern California, Marina del Rey, CA, October 24–25, 2005.
- “3D Telepresence for Off-Line Surgical Training and On-Line Remote Consultation,” 2nd CREST Symposium on Telecommunication, Teleimmersion and Telexistence, University of Tokyo, December 9–10, 2004.
- “Immersive Telepresence for Surgical Teaching and Remote Consultation: Extending Medical Expertise Over Time and Space,” University of Florida, Department of Computer and Information Science and Engineering, “Geometry, Graphics, Vision, Visualization/ Simulation (G2V2)” seminar series, October 17, 2003.
- “Sensor Information Efficiency for Pose Estimation,” University of Rochester, Department of Computer Science, April 13, 2001.
- “Inside the HiBall Tracking System,” Siemens Corporate Research, Imaging and Visualization Department, Princeton, NJ, October 25, 2000.
- “Tracking for Interactive Computer Graphics: To the Hallway and Beyond,” the Boeing Corporation, Virtual Reality Group, Seattle, WA, April 21, 1999. (Also presented at Microsoft Research, Seattle, WA, April 21, 1999.)
- “Spatially-Augmented Visualization,” Walt Disney Imagineering, Virtual Reality Studio, Burbank, CA, September 1998.
- “An Introduction to the Kalman Filter,” NSF Graphics and Visualization Science and Technology Center Lecture Series. Guest lecture with Gary Bishop, 1995 and 1997.
- “Computers, Ethics, and Whistle Blowing,” COMP 096, Computers and Society, University of North Carolina at Chapel Hill. Guest lectures, 1994–2003.

STUDENT ADVISEES

Adrian Ilie (current); Tao Li (current); Peter Lincoln (current); Tianren Wang (current); Jinghe Zhang (current); Hua Yang (2008, Ph.D., Kitware); Danette Allen (2007, Ph.D., NASA Langley Research Center); Vincent Noel (2006, M.S., Google); Michael Noland (2006, M.S., Emergent); Aditi Majumder (2003, Ph.D., University of California at Irvine); Ruigang Yang (2003, Ph.D., University of Kentucky); and Ramesh Raskar (2001, Ph.D., MIT Media Lab).

STUDENT COMMITTEES

Monika Schaeffer (current, Duke University); Brian Clipp (current); David Gallup (current); Drexel Hallaway (current, Columbia University); Tyler Johnson (current); Seon Joo Kim (2008, Ph.D., UNC-Chapel Hill); Patrick Quirk (2006, M.S.); Kok-Lim Low (2005, Ph.D., National University of Singapore); Michael Rosenthal (2005, Ph.D., Residency: Brigham-Harvard, Radiology); Benjamin Lok (2002, Ph.D., University of Florida); Nicholas Vallidis (2002, Ph.D., National Robotics Engineering Consortium); Gopi Meenakshisundaram (2001, Ph.D., University of California at Irvine); Mark Livingston (1998, Ph.D., Naval Research Lab); and Hans Weber (Sports Media Technology Corporation).

TEACHING EXPERIENCE

- *3D Computer Modeling and Animation*, First Year Seminar, UNC-CH, 2003–2007. Conceived of and created the course, which was chosen by UNC from among competing First Year Seminar proposals. Awarded Computer Science Student Association *Excellence in Teaching* award, Spring 2007
- *Introduction to Programming (Java)*, UNC-CH, 2002–2003
- *Team Software Engineering*, UNC-CH, 2001 (Spring)
- *Exploring Virtual Worlds*, UNC-CH, 1997 and 1998
- NSF STC Center-Wide Lecture Series, coordinated within the Center, 1997
- Kalman Filter Seminar, UNC-CH, with Gary Bishop, 1996
- *Computers: Power Tools for the Mind*, UNC-CH, 1995

BOOKS CHAPTERS/SECTIONS

- Greg Welch and Larry Davis. Tracking for Training in Virtual Environments: Estimating the Pose of People and Devices for Simulation and Assessment. In J. Cohn, D. Nicholson, and D. Schmorrow, editors, *The PSI Handbook of Virtual Environments for Training and Education: Developments for the Military and Beyond*, chapter 30. Praeger Security International, 2008.
- Greg Welch, Ruigang Yang, Bruce Cairns, Herman Towles, Andrei State, Adrian Ilie, Sasch Becker, Dan Russo, Jesse Funaro, Diane Sonnenwald, Ketan Mayer-Patel, Bonnie Danette Allen, Hua Yang, Eugene Freid, Andries van Dam, and Henry Fuchs. 3D Telepresence for Off-Line Surgical Training and On-Line Remote Consultation. In S. Tachi, editor, *Telecommunication, Teleimmersion and Telexistence II*, pages 113–152. IOS Press (English) and Ohmsha (Japanese), 2005.

SHORT COURSES AND PANELS

- Greg Welch, Gerhard Reitmayr (Graz University of Technology), Vincent Lepetit (Swiss Federal Institute of Technology), and Brian Clipp (UNC-Chapel Hill), “Tracking for AR Tracking Researchers,” International Symposium on Mixed and Augmented Reality (ISMAR 2009), October 19, 2009.
- Henry Fuchs, Bernd Fröhlich (Bauhaus-Universität Weimar), and Greg Welch. “Display Technology,” 14th Eurographics Symposium on Virtual Environments (EGVE 2008), Eindhoven, The Netherlands, May 30, 2008.
- Barbara Hayes-Roth, Austin Henderson, Ramesh Jain, Lev Manovich, Greg Welch, and Gopal Pingali. “Experiential Telepresence: How Can Telepresence Research be Guided Towards Better End User Experience?” ACM SIGMM 2003 Workshop on Experiential Telepresence 2003 (ETP 2003) panel, November 7, 2003, Berkeley, CA USA.
- Greg Welch and Gary Bishop. “An Introduction to the Kalman Filter,” ACM SIGGRAPH 2001 tutorial, August 12, 2001, Los Angeles, CA USA.
- B. Danette Allen, Gary Bishop and Greg Welch. “Tracking: Beyond 15 Minutes of Thought,” ACM SIGGRAPH 2001 short course, August 12, 2001, Los Angeles, CA USA.

REFEREED PUBLICATIONS

- [58] Amela Sadagic, Greg Welch, Chumki Basu, Chris Darken, Rakesh Kumar, Henry Fuchs, Hui Cheng, Jan-Michael Frahm, Mathias Kolsch, Neil Rowe, Herman Towles, Juan Wachs, and Anselmo Lastra. New Generation of Instrumented Ranges: Enabling Automated Performance Analysis. In *Proceedings of 2009 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC-2009)*, Orlando, Florida, U.S.A., November 30–December 3 2009.
- [57] Peter Lincoln, Greg Welch, Andrew Nashel, Adrian Ilie, Andrei State, and Henry Fuchs. Animatronic Shader Lamps Avatars. *Proceedings of 8th IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR'09)*, October 19–22, 2009.
- [56] Hua Yang, Greg Welch, Jan-Michael Frahm, and Marc Pollefeys. 3D Motion Segmentation Using Intensity Trajectory. *Proceedings of the 9th Asian Conference on Computer Vision (ACCV 2009)*, September 23–27 2009.
- [55] Peter Lincoln, Andrew Nashel, Adrian Ilie, Herman Towles, Greg Welch, and Henry Fuchs. Multi-View Lenticular Display for Group Teleconferencing. *Proceedings of IMMERSCOM 2009*, 27–29 May 2009.
- [54] Greg Welch, Diane H. Sonnenwald, Henry Fuchs, Bruce Cairns, Ketan Mayer-Patel, Hanna M. Söderholm, Ruigang Yang, Andrei State, Herman Towles, Adrian Ilie, Manoj K. Ampalam, Srinivas Krishnan, Vincent Noel, Michael Noland, and James E. Manning. 3D medical collaboration technology to enhance emergency healthcare. *J Biomed Discov Collab*, 4:4, 2009.
- [53] Tyler Johnson, Greg Welch, Eric Laforce, Herman Towles, and Henry Fuchs. A distributed cooperative framework for continuous multi-projector pose estimation. *Proceedings of IEEE Virtual Reality 2009*, Mar 14–18, 2009.
- [52] Greg Welch. HISTORY: The Use of the Kalman Filter for Human Motion Tracking in Virtual Reality, *Presence: Teleoperators and Virtual Environments*, 18(1), 2009.
- [51] Adrian Ilie, Greg Welch, and Marc Macenko. A Stochastic Quality Metric for Optimal Control of Active Camera Network Configurations for 3D Computer Vision Tasks, in *Proceedings of ECCV 2008 workshop on Multi-camera and Multi-modal Sensor Fusion Algorithms and Applications*, Marseille, France, October 18 2008. European Conference on Computer Vision (ECCV).
- [50] Guido Brunnett, Saine Coquillart, and Greg Welch, “08231 abstracts collection – virtual realities,” in *Virtual Realities* (Guido Brunnett, Sabine Coquillart, and Greg Welch, eds.), no. 08231 in *Dagstuhl Seminar Proceedings*, (Dagstuhl, Germany), Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, Germany, 2008.
- [49] Hanna M. Söderholm, Diane H. Sonnenwald, James E. Manning, Bruce Cairns, Greg Welch, and Henry Fuchs. Exploring the Potential of Video Technologies for Collaboration in Emergency Medical Care. Part II: Task Performance, *Journal of the American Society for Information Science and Technology (JASIST)*, 59(14):2335–2349, 14 August 2008.
- [48] Diane H. Sonnenwald, Hanna M. Söderholm, James E. Manning, Bruce Cairns, Greg Welch, and Henry Fuchs. Exploring the Potential of Video Technologies for Collaboration in Emergency Medical Care. Part I: Information Sharing, *Journal of the American Society for Information Science and Technology (JASIST)*, 59(14):2320–2334, 14 August 2008.

- [47] Brian Clipp, Rahul Raguram, Jan-Michael Frahm, Greg Welch, and Marc Pollefeys, A Mobile 3D City Reconstruction System, IEEE Virtual Reality 2008 workshop on Cityscapes, March 9, 2008, Reno, Nevada, USA
- [46] Marc Pollefeys, David Nistér, Jan-Michael Frahm, Amir Akbarzadeh, Philippos Mordohai, Brian Clipp, Chris Engels, David Gallup, Seon Joo Kim, Paul Merrell, C. Salmi, Sudipta Sinha, Brad Talton, Liang Wang, Qing-Xiong Yang, Henrik Stewénius, Ruigang Yang, Greg Welch, and Herman Towles, Detailed Real-Time Urban 3D Reconstruction From Video, International Journal of Computer Vision (IJCV), special issue on “Modeling Large-Scale 3D Scenes, 2007.
- [45] Hanna M. Söderholm, Diane H. Sonnenwald, Bruce Cairns, James Manning, Greg Welch, and Henry Fuchs, The Potential Impact of 3D Telepresence Technology on Task Performance in Emergency Trauma Care, proceedings of the ACM Group 2007 Conference, November 4–7 2007.
- [44] Brian Clipp, Greg Welch, Jan-Michael Frahm, and Marc Pollefeys, Structure From Motion via a Two-Stage Pipeline of Extended Kalman Filters, in Proceedings of the British Machine Vision Conference (BMVC 2007), September 10–13 2007.
- [43] Hua Yang, Marc Pollefeys, Greg Welch, Jan-Michael Frahm, and Adrian Ilie, Differential Camera Tracking Through Linearizing the Local Appearance Manifold, in Proceedings of the 2007 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR’ 07), 2007.
- [42] Philippos Mordohai, Jan-Michael Frahm, Amir Akbarzadeh, Brian Clipp, Chris Engels, David Gallup, Paul Merrell, C. Salmi, Sudipta Sinha, Brad Talton, Liang Wang, Qing-Xiong Yang, Henrik Stewénius, Herman Towles, Greg Welch, Ruigang Yang, Marc Pollefeys, and David Nistér, Real-time video-based reconstruction of urban environments, in Proceedings of the ISPRS Working Group V/4 Workshop 3D-ARCH 2007: 3D Virtual Reconstruction and Visualization of Complex Architectures, (ETH Zurich, Switzerland), July 12–13 2007.
- [41] Greg Welch, B. Danette Allen, Adrian Ilie, and Gary Bishop, Measurement Sample Time Optimization for Human Motion Tracking/Capture Systems, Proceedings of Trends and Issues in Tracking for Virtual Environments, Workshop at the IEEE Virtual Reality 2007 Conference (Charlotte, NC USA) (Gabriel Zachmann, ed.), Shaker, March 11 2007.
- [40] Greg Welch, Michael Noland, and Gary Bishop, Complementary Tracking and Two-Handed Interaction for Remote 3D Medical Consultation with a PDA, Proceedings of Trends and Issues in Tracking for Virtual Environments, Workshop at the IEEE Virtual Reality 2007 Conference (Charlotte, NC USA) (Gabriel Zachmann, ed.), Shaker, March 11 2007.
- [39] Diane H. Sonnenwald, Hanna Maurin, Bruce Cairns, Eugene Freid, James Manning, Greg Welch, and Henry Fuchs. Experimental Comparison of the Use of 2D and 3D Telepresence Technologies in Distributed Emergency Medical Situations. In Proceedings of the American Society of Information Science and Technology (ASIS&T 2006), Austin, Texas, November 3–9, 2006.
- [38] Hua Yang and Greg Welch. Illumination Insensitive Model-Based 3D Object Tracking and Texture Refinement. In Proceedings of the Third International Symposium on 3D Data Processing, Visualization and Transmission (3DPVT 2006), The University of North Carolina at Chapel Hill, Chapel Hill, NC USA, June 14-16, 2006.
- [37] Ruigang Yang, Liang Wang, Greg Welch, and Marc Pollefeys. Stereovision on GPU. In Proceedings of the 2006 Workshop on Edge Computing Using New Commodity Architectures (EDGE 2006), May 23–24 (Chapel Hill, NC, USA).

- [36] Greg Welch, Hua Yang, Andrei State, Vincent Noel, Adrian Ilie, Ruigang Yang, Marc Pollefeys, and Henry Fuchs. GPU-Based View Synthesis Using an Orbital Reconstruction Frustum. In Proceedings of the 2006 Workshop on Edge Computing Using New Commodity Architectures (EDGE 2006), May 23–24 (Chapel Hill, NC, USA).
- [35] Greg Welch, Diane Sonnenwald, Ketan Mayer-Patel, Ruigang Yang, Andrei State, Herman Towles, Bruce Cairns, and Henry Fuchs, Remote 3D Medical Consultation. In Proceedings of *BROADNETS: 2nd IEEE/CreateNet International Conference on Broadband Networks*, (Boston, MA, USA), pp. 103-110, Omnipress, October 2005.
- [34] B. Danette Allen and Greg Welch. A general method for comparing the expected performance of tracking and motion capture systems. In *VRST '05: Proceedings of the ACM symposium on Virtual reality software and technology*, (Monterey, CA, USA), pp. 201–210, ACM Press, New York, NY, USA, November 2005.
- [33] Adrian Ilie and Greg Welch. Ensuring Color Consistency Across Multiple Cameras. In Proceedings of the 2005 International Conference on Computer Vision (ICCV 2005), October, 2005 (Beijing, China).
- [32] Greg Welch, Ruigang Yang, Sascha Becker, Adrian Ilie, Dan Russo, Jesse Funaro, Andrei State, Kok-Lim Low, Anselmo Lastra, Herman Towles, Bruce Cairns, M.D., Henry Fuchs, and Andy van Dam. Immersive Electronic Books for Surgical Training. *IEEE Multimedia*, 12(3):22–35, July–September 2005.
- [31] Ruigang Yang, Marc Pollefeys, Hua Yang, and Greg Welch. A Unified Approach to Real-Time, Multi-Resolution, Multi-Baseline 2D View Synthesis and 3D Depth Estimation Using Commodity Graphics Hardware. *International Journal of Image and Graphics (IJIG)*, 4(4):1–25, 2004.
- [30] Adrian Ilie, Kok-Lim Low, Greg Welch, Anselmo Lastra, Henry Fuchs, and Bruce Cairns. Combining Head-Mounted and Projector-Based Displays for Surgical Training. *Presence: Teleoperators and Virtual Environments*, 13(2), April 2004. This is an invited (but refereed) extended version of [28].
- [29] Ruigang Yang, Marc Pollefeys, and Greg Welch. Dealing With Textureless Regions and Specular Highlights—A Progressive Space Carving Scheme Using a Novel Photo-Consistency Measure. In Bill Triggs and Andrew Zisserman, editors, *Proceedings of 9th International Conference on Computer Vision*, pages 576–584, Nice, France, 2003. IEEE Computer Society.
- [28] Kok-Lim Low, Adrian Ilie, Greg Welch, and Anselmo Lastra. Combining Head-Mounted and Projector-Based Displays for Surgical Training. In *Proceedings of the IEEE Virtual Reality 2003*, pages 110–117. IEEE Computer Society, 2003.
- [27] Ruigang Yang and Greg Welch. Real-time consensus-based scene reconstruction using commodity graphics hardware. *Computer Graphics Forum* (invited submission), 22(2):207–216, 2003.
- [26] Greg Welch and Eric Foxlin. Motion Tracking: No Silver Bullet, But a Respectable Arsenal. *IEEE Computer Graphics and Applications*, 22(6):24–38, 2002.
- [25] Ruigang Yang, Greg Welch, and Gary Bishop. Real-Time Consensus-Based Scene Reconstruction Using Commodity Graphics Hardware. In *Proceedings of Pacific Graphics 2002*, Tsinghua University, Beijing, China, October 9–11 2002.
- [24] Rich Superfine, Gary Bishop, Jeremy Cummings, Jay Fisher, Kurtis Keller, G. Matthews, D. Sill, Russell M. Taylor II, Leandra Vicci, Chris Weigle, Greg Welch and Benjamin Wilde.

- Touching In Biological Systems: A 3D Force Microscope. MSA—Microscopy and Microanalysis 2002, Quebec City, Canada. published in Proceedings of MSA—Microscopy and Microanalysis 2002.
- [23] Ruigang Yang and Greg Welch. Fast Image Segmentation and Smoothing Using Commodity Graphics Hardware. *J. Graph. Tools*, 7(4):91–100, 2002.
- [22] Ruigang Yang and Greg Welch. Automatic Projector Display Surface Estimation Using Everyday Imagery. In *Proceedings of the 9th International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision 2001*. Plzen, Czech Republic, 2001.
- [21] Greg Welch, Gary Bishop, Leandra Vicci, Stephen Brumback, Kurtis Keller, and D’nardo Colucci. High-Performance Wide-Area Optical Tracking: The Hiball Tracking System. *Presence: Teleoperators and Virtual Environments*, 10(1):1–21, 2001. This is an invited (but refereed) extended version of [10].
- [20] Ramesh Raskar, Greg Welch, Kok-Lim Low, and Deepak Bandyopadhyay. Shader Lamps: Animating Real Objects with Image-Based Illumination. In S. J. Gortler and K. Myszkowski, editors, *Rendering Techniques 2001, Proceedings of the Eurographics Workshop in London, United Kingdom*, pages 89–102. Springer, NewYork, University College London (UCL), London, England, 2001.
- [19] Aditi Majumder and Greg Welch. Computer Graphics Optique: Optical Superposition of Projected Computer Graphics. In *Fifth Immersive Projection Technology Workshop, in conjunction with the Seventh Eurographics Workshop on Virtual Environments*, Stuttgart, Germany, 2001. Springer-Verlag.
- [18] Kok-Lim Low, Greg Welch, Anselmo Lastra, and Henry Fuchs. Life-sized Projector-Based Dioramas. In *Proceedings of the ACM Symposium on Virtual Reality Software and Technology*, page 8. ACM SIGGRAPH, AddisonWesley, Banff Centre, Banff, Alberta, Canada (November 15–17, 2001), 2001.
- [17] Greg Welch and Gary Bishop. An Introduction to the Kalman Filter: SIGGRAPH 2001 course 8. In *Computer Graphics, Annual Conference on Computer Graphics & Interactive Techniques*. ACM Press, Addison-Wesley, Los Angeles, CA, USA (August 12–17), SIGGRAPH 2001 course pack edition, 2001.
- [16] Bonnie Danette Allen, Gary Bishop, and Greg Welch. Tracking: Beyond 15 Minutes of Thought: SIGGRAPH 2001 course 11. In *Computer Graphics, Annual Conference on Computer Graphics & Interactive Techniques*. ACM Press, Addison-Wesley, Los Angeles, CA, USA (August 12–17), SIGGRAPH 2001 course pack edition, 2001.
- [15] Gary Bishop and Greg Welch. Working in the Office of ‘Real Soon Now’. *IEEE Computer Graphics and Applications*, 20(4):76–78, July/August 2000.
- [14] Wei-Chao Chen, Herman Towles, Lars Nyland, Greg Welch, and Henry Fuchs. Toward a Compelling Sensation of Telepresence: Demonstrating a Portal to a Distant (Static) Office. In *Proceedings of IEEE Visualization 2000*. IEEE Computer Science Press, Salt Lake City, UT, USA (October 8–13), 2000.
- [13] Aditi Majumder, Zhu He, Herman Towles, and Greg Welch. Color Calibration of Projectors for Large Tiled Displays. In *Proceedings of IEEE Visualization 2000*. IEEE Computer Science Press, Salt Lake City, UT, USA (October 8–13), 2000.

- [12] Greg Welch, Henry Fuchs, Ramesh Raskar, Michael Brown, and Herman Towles. Projected Imagery in Your Office in the Future. *IEEE Computer Graphics and Applications*, 20(4):62–67, July/August 2000.
- [11] Ramesh Raskar, Michael Brown, Ruigang Yang, Wei-Chao Chen, Greg Welch, Herman Towles, Brent Seales, and Henry Fuchs. Mutli-Projector Displays Using Camera-Based Registration. In *Proceedings of the Conference on Visualization 99*, IEEE Visualization, pages 161–168. San Francisco, CA, USA (October 24–29), 1999.
- [10] Greg Welch, Gary Bishop, Leandra Vicci, Stephen Brumback, Kurtis Keller, and D'nardo Colucci. The Hiball Tracker: High-Performance Wide-Area Tracking for Virtual and Augmented Environments. In *Proceedings of the ACM Symposium on Virtual Reality Software and Technology*, pages 1–11. ACM SIGGRAPH, Addison-Wesley, University College London, London, United Kingdom (December 20–23), 1999.
- [9] Ramesh Raskar, Greg Welch, and Wei-Chao Chen. Table-top Spatially-Augmented Reality: Bringing Physical Models to Life with Projected Imagery. In *Second International Workshop on Augmented Reality (IWAR'99)*, pages 64–71. San Francisco, CA, USA, 1999.
- [8] Brent Seales, Greg Welch, and Christopher Jaynes. Real-Time Depth Warping for 3-D Scene Reconstruction. In *1999 IEEE Aerospace Conference*, Snowmass at Aspen, CO USA, 1999.
- [7] Ramesh Raskar, Greg Welch, and Henry Fuchs. Spatially Augmented Reality. In Reinhold Behringer, Gudrun Klinker, and David Mizell, editors, *Augmented Reality; Placing Artificial Objects in Real Scenes Proceedings of the First IEEE Workshop on Augmented Reality (IWAR'98)*, pages 63–72. A.K. Peters Ltd., San Francisco, CA, USA (November 1, 1998), 1998. ISBN 1-56881-098-9.
- [6] Ramesh Raskar, Matthew Cutts, Greg Welch, and Wolfgang Stürzlinger. Efficient Image Generation for Multiprojector and Multisurface Displays. In George Drettakis and Nelson Max, editors, *Proceedings of the Eurographics Workshop in Vienna, Austria*, pages 139–144. Springer Verlag, Vienna, Austria (June 29–July 1), rendering techniques 98 edition, 1998. ISBN 3-211-83213-0.
- [5] Ramesh Raskar, Greg Welch, and Henry Fuchs. Seamless Projection Overlaps Using Warping and Intensity Blending. In *Fourth International Conference on Virtual Systems and Multimedia (VSMM)*, Gifu, Japan, 1998.
- [4] Ramesh Raskar, Greg Welch, Matt Cutts, Adam Lake, Lev Stesin, and Henry Fuchs. The Office of the Future: A Unified Approach to Image-Based Modeling and Spatially Immersive Displays. In Michael F. Cohen, editor, *Computer Graphics, Annual Conference on Computer Graphics & Interactive Techniques*, pages 179–188. ACM Press, Addison-Wesley, Orlando, FL, USA (July 19–24), SIGGRAPH conference proceedings edition, 1998.
- [3] Ronald T. Azuma, Bruce R. Hoff, Howard E. Neely III, Ronald Sarfaty, Michael J. Daily, Gary Bishop, Vernon Chi, Greg Welch, Ulrich Neumann, Suya You, Rich Nichols, and Jim Cannon. Making Augmented Reality Work Outdoors Requires Hybrid Tracking. In *First International Workshop on Augmented Reality*, pages 219–224, San Francisco, CA, USA, 1998.
- [2] Greg Welch and Gary Bishop. SCAAT: Incremental Tracking with Incomplete Information. In Turner Whitted, editor, *Computer Graphics, Annual Conference on Computer Graphics & Interactive Techniques*, pages 333–344. ACM Press, Addison-Wesley, Los Angeles, CA, USA (August 3–8), SIGGRAPH 97 Conference Proceedings edition, 1997.
- [1] Greg Welch. *SCAAT: Incremental Tracking with Incomplete Information*. Ph.D. dissertation, University of North Carolina at Chapel Hill, 1996.

DISSERTATION

Title: SCAAT: Incremental Tracking with Incomplete Information
Date: October 1996
Advisor: Gary Bishop
Committee: Gary Bishop, Henry Fuchs, Leandra Vicci (née Vernon Chi), Anselmo Lastra, Russell Taylor, and John Poulton
PDF http://www.cs.unc.edu/~welch/media/pdf/scaat_dissertation.pdf

INVITED PUBLICATIONS

- [8] Amir Akbarzadeh, Jan-Michael Frahm, Philippos Mordohai, Brian Clipp, Chris Engels, David Gallup, Paul Merrell, Michael Phelps, Sudipta Sinha, Brad Talton, Liang Wang, Qing-Xiong Yang, Henrik Stewenius, Ruigang Yang, Greg Welch, Herman Towles, David Nistér, and Marc Pollefeys. Towards Urban 3D Reconstruction From Video. In Proceedings of the Third International Symposium on 3D Data Processing, Visualization and Transmission (3DPVT 2006), Chapel Hill, NC, June 2006.
- [7] Andrei State, Greg Welch, and Adrian Ilie. An Interactive Camera Placement and Visibility Simulator for Image-Based VR Applications. In *Proceedings of the Engineering Reality of Virtual Reality 2006 (3D Imaging, Interaction, and Measurement; IS&T/SPIE 18th Annual Symposium on Electronic Imaging Science and Technology)*, San Jose, CA, January 2006.
- [6] Greg Welch, Henry Fuchs, Bruce Cairns, Ketan Mayer-Patel, Diane H. Sonnenwald, Ruigang Yang, Andrei State, Herman Towles, Adrian Ilie, Michael Noland, Vincent Noel, and Hua Yang. Improving, Expanding and Extending 3D Telepresence. In *Proceedings of the 2005 International Workshop on Advanced Information Processing for Ubiquitous Networks*, with ICAT 2005, Christchurch, New Zealand, December 8, 2005.
- [5] Hua Yang and Greg Welch. Model-Based 3D Object Tracking Using an Extended-Extended Kalman Filter and Graphics Rendered Measurements. In *Proceedings of 1st Computer Vision for Interactive and Intelligent Environments (CV4IIE) workshop*, University of Kentucky, Lexington, KY.
- [4] Greg Welch, Ruigang Yang, Bruce Cairns, M.D., Herman Towles, Andrei State, Adrian Ilie, Sascha Becker, Dan Russo, Jesse Funaro, Diane Sonnenwald, Ketan Mayer-Patel, B. Danette Allen, Hua Yang, Eugene Freid, M.D., Andy van Dam, and Henry Fuchs. 3D Telepresence for Off-Line Surgical Training and On-Line Remote Consultation. Susumu Tachi, editor, *Proceedings of ICAT CREST Symposium on Telecommunication, Teleimmersion, and Telexistence*, The University of Tokyo, Tokyo, Japan, December 2004.
- [2] Andries van Dam, Henry Fuchs, Sascha Becker, Loring Holden, Adrian Ilie, Kok-Lim Low, Anne Morgan Spalter, Ruigang Yang, and Greg Welch. Immersive Electronic Books for Teaching Surgical Procedures. In Susumu Tachi, editor, *Proceedings of ICAT CREST Symposium on Telecommunication, Teleimmersion, and Telexistence*, The University of Tokyo, Tokyo, Japan, December 2002.
- [1] Greg Welch. A Survey of Power Management Techniques in Mobile Computing Operating Systems. *ACM Operating Systems Review (SIGOPS-OSR)*, 29(4):47–56, 1995.

POSTER PRESENTATIONS

- [7] Brian Clipp, Greg Welch, Jan-Michael Frahm, and Marc Pollefeys, Structure from motion via a two-stage pipeline of extended kalman filters,” Proceedings of the British Machine Vision Conference (BMVC 2007), September 10–13 2007.
- [6] Hua Yang and Greg Welch. Illumination Insensitive Model-Based 3D Object Tracking and Texture Refinement. In Proceedings of the Third International Symposium on 3D Data Processing, Visualization and Transmission (3DPVT 2006), The University of North Carolina at Chapel Hill, Chapel Hill, NC USA, June 14-16, 2006.
- [5] Ruigang Yang, Liang Wang, Greg Welch, and Marc Pollefeys. Stereovision on GPU. Poster presentation at the 2006 Workshop on Edge Computing Using New Commodity Architectures (EDGE 2006), May 23–24 (Chapel Hill, NC, USA).
- [4] Greg Welch, Hua Yang, Andrei State, Vincent Noel, Adrian Ilie, Ruigang Yang, Marc Pollefeys, and Henry Fuchs. GPU-Based View Synthesis Using an Orbital Reconstruction Frustum. Poster presentation at the 2006 Workshop on Edge Computing Using New Commodity Architectures (EDGE 2006), May 23–24 (Chapel Hill, NC, USA).
- [3] Adrian Ilie and Greg Welch. Ensuring Color Consistency Across Multiple Cameras. International Conference on Computer Vision (ICCV), October, 2005 (Beijing, China).
- [2] Bruce A. Cairns, Greg Welch, Adrian Ilie, Ruigang Yang, Kok-Lim Low, Anselmo Lastra, Henry Fuchs, and Anthony Meyer. Three Dimensional (3D) Acquisition and Display of Reality: The Potential for a ‘Holodeck’ in Trauma Surgery. Presented at *The American Association for the Surgery of Trauma 2003 Annual Meeting*.
- [1] Kok-Lim Low, Greg Welch, Anselmo Lastra, and Henry Fuchs. Life-sized projector-based dioramas: Spatially real and visually virtual. In *ACM SIGGRAPH 2001 Sketches and Applications*, August 2001.

TECHNICAL REPORTS

- [7] Ramesh Raskar, Kok-Lim Low and Greg Welch. Shader Lamps: Animating Real Objects with Image-Based Illumination. Technical Report TR00-027, University of North Carolina at Chapel Hill, Department of Computer Science, 2000.
- [6] Ruigang Yang and Greg Welch. Automatic Display Surface Estimation using Everyday Imagery. Technical Report TR00-015, University of North Carolina at Chapel Hill, Department of Computer Science, 2000.
- [5] Ramesh Raskar, Henry Fuchs, Greg Welch, Adam Lake, and Matt Cutts. 3D Talking Heads: Image Based Modeling at Interactive Rates Using Structured Light Projection. Technical Report TR98-017, University of North Carolina at Chapel Hill, Department of Computer Science, 1998.
- [4] Greg Welch. SCAAT: Incremental Tracking with Incomplete Information. Technical Report TR96-051, University of North Carolina at Chapel Hill, Department of Computer Science, 1996.
- [3] Greg Welch and Gary Bishop. One-Step-at-a-Time Tracking. Technical Report TR96-021, University of North Carolina at Chapel Hill, Department of Computer Science, 1996.
- [2] Greg Welch. Hybrid Self-tracker: An Inertial/Optical Hybrid Three-Dimensional Tracking System. Technical Report TR95-048, University of North Carolina at Chapel Hill, Department of Computer Science, 1995.
- [1] Greg Welch and Gary Bishop. An Introduction to the Kalman Filter. Technical Report TR95-041, University of North Carolina at Chapel Hill, Department of Computer Science, 1995.

PATENTS

- U.S. #7,068,274, “System and Method for Animating Real Objects With Projected Images,” with Kok-Lim Low and Ramesh Raskar.
- U.S. #6,930,681, “System and Method for Registering Multiple Images with Three-Dimensional Objects,” with Ramesh Raskar and Kok-Lim Low.
- U.S. #6,677,956, “Method for Cross-Fading Intensities of Multiple Images of a Scene for Seamless Reconstruction,” with Ramesh Raskar and Kok-Lim Low.
- U.S. #5,870,136, “Dynamic Generation of Imperceptible Structured Light for Tracking and Acquisition of Three Dimensional Scene Geometry and Surface Characteristics in Interactive Three Dimensional Computer Graphics Applications,” with Gary Bishop, Henry Fuchs, and Mark Livingston.

ACTIVE FUNDING

- DOE grant for “Advanced Kalman Filter for Real-Time Responsiveness in Complex Systems,” with Zhenyu (Henry) Huang, Pacific Northwest National Laboratory. \$320,502 total for September 2009–August 2012.
- ONR grant for “3D Display and Capture of Humans for Live-Virtual Training,” with Henry Fuchs at UNC and Amela Sadagic at the Naval Postgraduate School. Roy Stripling, Ph.D., Program Manager. \$2.3M total for May 2009–April 2012.
- ONR SBIR Phase II contract for “Deployable Intelligent Projection Systems for Training,” PI with Henry Fuchs, sub-contract from Renaissance Sciences Corporation (RSC), Jeff Clark, CEO, \$374,920 for March 2009–February 2011.
- ONR contract for “Behavior Analysis and Synthesis for Intelligent Training (BASE-IT),” PI with Henry Fuchs at UNC, Amela Sadagic at the Naval Postgraduate School, and Rakesh Kumar and Hui Cheng at Sarnoff. Roy Stripling, Ph.D., Program Manager. \$2.2M total for February 2008–September 2011.
- NSF CRI:IAD grant for “Integrated Projector-Camera Modules for the Capture and Creation of Wide-Area Immersive Experiences,” with Co-PI with Henry Fuchs (PI), Leonard McMillan (Co-PI), Mary Whitton (Co-PI), and Svetlana Lazebnik (Co-PI). \$310K total for April 2008–March 2011.

PAST FUNDING

- IARPA A-SpaceX contract for “Mockup Future Analyst Workspace (A-Desk),” PI with Henry Fuchs. Jeff Morrison, Ph.D., Program Manager. \$260K for April 2008–December 2008.
- ONR SBIR contract for “Deployable Intelligent Projection Systems for Training,” PI with Karl Matias of Renaissance Sciences Corporation, sub-contract to UNC-Chapel Hill (Henry Fuchs, PI), \$80K for Phase 1, June 2007–September 2008.
- IARPA VACE contract for “3D Content Extraction from Video Streams,” Co-PI with Marc Pollefeys (PI) and Jan-Michael Frahm. Dan Aldridge, Program Manager; Dennis Moellman and Paul Matthews, Senior Technical Advisors. \$660K October 2006–September 2008.
- Cisco Systems grant for “Telepresence Wall: Research Exhibit,” with Henry Fuchs. \$439K total for August 2007–July 2008.
- ONR STTR contract for “Deployable Intelligent Projection Systems for Training: Enhanced Integrated Pose Estimation Technologies,” PI with Karl Matias of Renaissance Sciences Corporation, sub-contract to UNC-Chapel Hill (Henry Fuchs, PI), \$70K for Phase 1, August 2007–February 2008.
- Cisco Systems grant for “Prototype for Two-station, Four-Person, Proper Eye-Gaze Telepresence System,” with Henry Fuchs. \$376K total for August 2006–July 2007.
- National Library of Medicine contract for “3D Telepresence for Medical Consultation” Co-PI with Prof. Henry Fuchs (PI, UNC Computer Science), Prof. Bruce Cairns, M.D. (Co-PI, UNC), Prof. Ketan Mayer-Patel (Co-PI, UNC), and Prof. Diane Sonnenwald (Co-PI, Göteborg University and the University College of Borås). \$2.5M total for October 2003–December 2007.
- ONR VIRTE contract for “Front-Projective Display For Virtual Environments: Phase 2,” with Henry Fuchs and Herman Towles. Dylan Schmorow, Ph.D. CDR MSC USN, Program Manager. \$560K total for October 2004–December 2007.
- Office of Naval Research DURIP 2006 grant for “Computing for Real World Acquisition, Display and Immersive Training,” with Henry Fuchs and Marc Pollefeys. \$136K total.

- DARPA DSO contract for “Wide Area Visuals for a Simulator in a Box,” with Henry Fuchs and Herman Towles. Ralph Chatham, DARWARS Program Manager. \$1.2M total for 2003–2006.
- NSF ITR grant “Electronic Books for the Tele-Immersion Age: A New Paradigm for Teaching Surgical Procedures,” Co-PI with Andy van Dam (UNC/Brown grant), \$609K (UNC) for Sep 2001–Aug 2005.
- DOE contract “Front-Projection Display Wall, Group Tele-Immersion, and Tracking,” with Henry Fuchs and Herman Towles, \$1.8M for September 2001–August 2004.
- “3D Tele-Immersion Over Next Generation Internet,” UNC/UPenn DARPA contract with Henry Fuchs, Herman Towles, Kostas Danillidis, and Ruzena Bajcsy, \$550K (UNC) for June 2001–December 2002.
- Argonne National Laboratories contract “Compensating for Color Variations Across Multi-Projector Displays,” \$61K for September 2001–August 2002.
- NSF grant “High-Fidelity Tele-Immersion for Advanced Surgical Training,” UNC/UPenn/Brown, with Henry Fuchs, Kostas Danillidis, and Andy van Dam, \$750K (UNC) for January 2001–December 2001.
- Naval Research Lab contract “Technology for Full-Body Tracking,” with Gary Bishop. Larry Rosenblum, NRL program manager. \$100,271 over October 2000–September 2001.
- NSF Research Infrastructure grant for the NSF Graphics and Visualization Science and Technology Center. The entire Center participated in the proposal process, Greg Welch played a significant role in the proposal content and realization. This grant is in support of equipment for the Center-wide televideo network, and several related research projects. Support under this grant totaled \$1.3M for the Center over three years (October 1998–September 2001). The UNC portion was \$304K.
- “The National Tele-Immersion Initiative,” with Henry Fuchs. Gift from Advanced Network and Services, Inc., Al Weiss, Terry Rogers, and Jaron Lanier. \$750K per year over January 1998–December 2000.
- NSF Graphics and Visualization Science and Technology Center, 5-year Renewal. The entire Center participated in the renewal proposal process, including a major site visit at the University of Utah, summer 1997. In addition to contributing to the written proposal, Greg Welch played a significant role in the Utah site visit. Total Center support under this renewal totals approximately \$13.7M for the entire Center for the final four years (February 1998–January 2002). The UNC portion totaled approximately \$2.7M over those four years.
- DARPA contract “Geospatially Registered Information for Dismounted Infantry” (GRIDS), with Gary Bishop and Vernon Chi. Joint effort with Raytheon Defense Systems, Hughes Research Labs, the University of North Carolina, and the University of Southern California. Total support over two years (May 1997–April 1999) was approximately \$3.1M, UNC portion was approximately \$1.2M.

PROFESSIONAL EMPLOYMENT EXPERIENCE**Renaissance Sciences Corporation, Chandler, Arizona**

Principal Investigator II, June 2007–2008

- Part-time research and development efforts related to “intelligent projector units” for deployable training systems.
- Work with Jeff Clark and Karl Mathias at RSC to coordinate UNC-RSC joint efforts.

University of North Carolina at Chapel Hill, Chapel Hill, North Carolina

Research Associate Professor, Computer Science, September 2001–present

Adjunct Associate Professor, Applied & Materials Sciences, 2005–present

Adjunct Assistant Professor, Applied & Materials Sciences, 2000–2003

Research Assistant Professor, Computer Science, September 1996–August 2001

- Obtain funding, coordinate research, and advise students on projects such as the Office of the Future and Wide-Area Tracking.
- Act as academic advisor for graduate students (primary advisor or committee member).
- Periodically teach or assist with graduate seminars and primary courses.

UNC Site Coordinator, NSF Graphics and Visualization STC, September 1996–August 1998

- Coordinate and advise on research related to UNC portion of the NSF Graphics and Visualization Science and Technology Center (STC). STC members include Brown University, The California Institute of Technology, Cornell University, The University of Utah, and The University of North Carolina at Chapel Hill.

Northrop Defense Systems Division, Rolling Meadows, Illinois

Senior Software Engineer, Digital Systems, June 1990–June 1992 (Secret Clearance)

- Developed, integrated, and maintained embedded software for the AN/ALQ-135, the electronic (radar) countermeasures system currently deployed on the USAF F-15 Eagle.
- Responsible for the AN/ALQ-135 Receiver-Transmitter Compatibility Feature which ensures that radar countermeasures do not interfere with radar or threat acquisitions.

NASA Jet Propulsion Laboratory (Caltech), Pasadena, California

CCS/COMSIM Programmer and Analyst, Voyager Sequence Team, January 1987–May 1990

- Enhanced and maintained the software Command Simulator for the Voyager spacecraft. This simulator is (still) used to validate all instructions sent to the spacecraft.
- Programmed and maintained the Voyager spacecraft Computer Command Subsystem (CCS), the master processor on both Voyager spacecraft.
- Simulated and validated Voyager spacecraft command sequence activity. Responsible for the simulation and validation of all sequenced commanding during Voyager II closest approach to the planet Neptune.

Significant Projects (developed under own initiative)

- Developed MEMMAN, a ground-based software system that optimizes the allocation of the limited Voyager spacecraft memory. Savings during the Voyager II Neptune encounter (August, 1989) enabled additional planetary imaging.
- Developed specialized IBM PC/AT telecommunications software for the Voyager Flight Team. Software submitted to NASA for distribution under COSMIC. Still used today.

UNDERGRADUATE SENIOR PROJECT

Purdue University, West Lafayette, Indiana

Undergraduate, Electrical Engineering Technology, August 1982–May 1986

- Co-developed “The Easy Chair: A Microprocessor-Controlled Wheelchair for Children With Muscular Disorders.” The wheelchair included an ultrasonic “bumper” system, a custom infrared touch-pad, motor controllers, and a user-programmable 8085-based control unit.
- The Easy Chair project was awarded *Outstanding Senior Design Project* by the Purdue University Department of Electrical Engineering Technology, May 1986.