

## CURRICULUM VITAE

**William A. Hoff**

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### RESEARCH INTERESTS

Computer vision and pattern recognition, including object recognition, activity recognition, human-computer interfaces, 3D reconstruction, and motion estimation. Applications in augmented reality and robotics. I am particularly interested in integrated man-machine systems, such as a human assisting or being assisted by computer vision in performing a task.

### RESEARCH AND PROFESSIONAL EXPERIENCE

Principal Engineer, DAQRI – Vienna Austria *June 2017 - present*  
Research in computer vision and task modeling for augmented reality.

Associate Professor, Colorado School of Mines *August 2001 - present*  
Research in augmented reality, activity recognition, and vision-based navigation. Taught undergraduate courses in digital electronics and microcontrollers, and graduate courses on computer vision and image processing. Served as assistant director of the Engineering Division 2006-2011.

Visiting Scientist, Lockheed-Martin Missiles and Fire Control *2010*  
While on sabbatical, performed research in vision-based autonomous vehicle navigation. Developed a new sensor-based pose estimation approach to support lateral stability for extended convoy operations.

Assistant Professor, Colorado School of Mines *August 1994 – August 2001*  
Founded a research lab focusing on 3-D computer vision, specializing in the area of augmented reality and interactive computer vision systems. Developed a funded research program in augmented reality, focusing on registration using computer vision techniques and inertial sensors. Developed a funded research program in medical imaging, focusing on algorithms to analyze the kinematics of joints from x-ray fluoroscopy image sequences. Started a collaboration with a local medical research center, which developed into a NSF I/UCRC program in biomedical devices. Developed undergraduate courses in digital electronics and microcontrollers, focusing on data acquisition and control systems. Developed graduate courses on computer vision, image processing, and stochastic processes.

Visiting Scientist, Rocky Mountain Musculoskeletal Research Lab *2002 –2003*  
While on sabbatical, performed research in medical imaging, including fluoroscopy, ultrasound, and computed tomography.

Staff Engineer, Martin Marietta Astronautics Group *September 1988 - August 1994*  
Lead of target recognition algorithm development and integration team for DARPA's unmanned ground vehicle program, and successfully conducted two annual demonstrations. Developed the navigation and inspection systems of a robotic vehicle system for the Department of Energy that demonstrated autonomous monitoring and inspection of hazardous waste storage facilities. As principal investigator of an

independent research and development project on Computer Vision, directed the development and integration of vision technology into several robot testbeds, including a multi-arm supervisory controlled system and a free-flying vehicle simulator.

Staff Engineer, Martin Marietta Aero & Naval Systems      *January 1987 - September 1988*  
Performed research in computer vision for robotics and autonomous underwater vehicles. Served as a research associate at the National Institute of Standards and Technology (NIST), and implemented some of the first algorithms on the prototype PIPE image processing computer, including a real-time stereo vision algorithm and a moving edge detection algorithm.

Research Assistant, University of Illinois      *January 1983 - December 1986*  
Performed research in the area of computer vision. Ph.D thesis was on a new vision algorithm to compute the surface map of a scene from a stereo pair of images, that integrated feature matching, surface fitting, and contour detection. Developed tools and software for the vision research group, including display, graphics, and analysis tools.

## **EDUCATION**

Ph.D. Computer Science, University of Illinois (Urbana).  
*Thesis title: "Surfaces from Stereo: An Integrated Approach"*  
M.S. Physics, University of Illinois (Urbana).  
B.S. Physics, Illinois Institute of Technology.

## **COURSES DEVELOPED AND TAUGHT**

Digital Logic (EENG 384)  
Microcontroller Architecture and Interfacing (EENG 383)  
Stochastic Processes (EENG 598)  
Multidimensional Signal and Image Processing (EENG/CSCI 510)  
Computer Vision (EENG 507)  
Mobile Application Development (focusing on Android) (CSCI 448)  
iOS Application Development (CSCI 498)  
Advanced Topics in Computer Vision (CSCI/EENG 508)

## **EDUCATION RESOURCES ACQUIRED**

CSM Technology Fee Committee, 8 computers for Electronics Lab (\$19K), 1998.  
Alumni donation of new logic analyzer (\$2000), 1999.  
Altera Corp., PLD prototyping boards (\$1K), 1999.  
CSM Technology Fee Committee, 4 digital oscilloscopes (\$16K), 2000.  
Agilent Corp, 4 digital oscilloscopes (\$16K), 2000.  
Altera Corp., PLD prototyping boards (\$1K), 2003.  
CSM Technology Fee Committee, PLD programmer (\$1000), Spring 2004.  
CSM Technology Fee Committee, electronics lab equipment (\$6868), Fall 2004.  
CSM Technology Fee Committee, microcontroller equipment (\$864), Spring 2005.  
CSM Technology Fee Committee, LCD Tablet for Lecture Presentations (\$2000), Spring 2007  
CSM Technology Fee Committee, FPGA Boards for Digital Logic Lab (\$4035), Spring 2009  
CSM Technology Fee Committee, Oscilloscopes for Electronics Lab (\$4675), Spring 2013

- CSM Technology Fee Committee, Equipment for student projects in embedded systems and image processing (\$2974), Spring 2014
- CSM Technology Fee Committee, Laptop for Controlling a 3D Sensor for Computer Vision course (\$1540), Spring 2015
- CSM Technology Fee Committee, Equipment for Student Projects in Mobile Application Development (\$4149), Fall 2015

**PROFESSIONAL ACTIVITIES**

- (1992 – 2014) Editorial board member for the journal, *Pattern Recognition*, and member of Pattern Recognition Society
- (2011 – 2013) Associate editor for the journal *ISRN Machine Vision*
- (2009) Program committee, for IFAC Workshop on Networked Robotics, Oct 6-8, 2009, Golden, Colorado
- (2003 – 2006) Director of campus research center – Center for Automation, Robotics and Distributed Intelligence (CARDI)
- (2000) NSF Proposal Panel
- (2000, 2001, 2002) Program Committee, IEEE/ACM International Symposium on Augmented Reality
- (1999) Demos and exhibits chair at IEEE Computer Vision and Pattern Recognition Conference
- (1997) Session chair at IEEE International Conference on Robotics and Automation
- (1996 – 2000) Member of Operating Board and also Executive Board for the Colorado Advanced Software Institute
- (1995) Gave short course on Computer Vision to the Idaho National Engineering Lab
- (1995) Session co-chair at SPIE conference on Mobile Robots
- (1983 – present) Member of IEEE (Computer Society; Robotics & Automation),
- (1984 to present) Reviewer for many conferences and journals, including:
  - IEEE Transactions on Pattern Analysis and Machine Intelligence
  - IEEE Transactions on Medical Imaging
  - National Science Foundation proposals
  - IEEE International Conference on Computer Vision
  - IEEE Computer Vision and Pattern Recognition Conference
  - IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR)
  - ASME Journal of Biomechanics
  - EURASIP Journal on Advances in Signal Processing
  - Image and Vision Computing Journal

**CSM COMMITTEES AND OTHER SERVICE**

CSM “Active Learning” committee	2016
EECS department undergraduate committee	2015-present
EECS department planning committee	2014-2015
EECS department graduate committee (chair from 2012-2013)	2011-2014
CSM Graduate Council	2012
CSM Faculty Compensation Committee	2009
Engineering Division website development Committee	2008

Engineering Division assistant director	2006-2011
CSM Student Scholastic Awards Committee	2005-2007
CSM ad-hoc committee on future of bioscience and bioengineering	2006
CSM Faculty Oversight Committee on Sports and Athletics	2003-2005
CSM Curriculum Committee	2001-2002
Advisor for IEEE Student Chapter	1999-2005
Engineering Division admissions committee	2000-2002
CSM Readmissions Committee	1996-2000
Engineering Division ABET preparation committee	1999-2000

#### **DEPARTMENTAL SEARCH COMMITTEES**

Member of EECS faculty search committee (CS)	2017
Chair of EECS faculty search committee (2 EE teaching faculty positions)	2016
Chair of EECS faculty search committee (EE)	2015
Member of EECS search committee (2 CS positions)	2014
Member of EECS search committee (4 EE and CS positions)	2013
Chair of EECS department head search committee	2012
Chair of EECS faculty search committee (machine learning)	2012
Chair of Engineering Division faculty search committee (EE power)	2011
Chair of Engineering Division lecturer search committee (EE)	2009
Engineering Division faculty search committee (comp eng)	2009
Engineering Division faculty search committee (signals)	2008
Engineering Division faculty search committee (power)	2007
Engineering Division faculty search committee (division director)	2006
Engineering Division faculty search committee (Dobelman chair)	2005
Chair of Engineering Division faculty search committee (Dobelman chair)	2004
Engineering Division faculty search committee (telecommunications)	2003
Chair of Engineering Division faculty search committee (Paden chair)	2002
Chair of Engineering Division faculty search committee (bioengineering)	2000
Engineering Division faculty search committee (Paden chair)	1999
Engineering Division faculty search committee (signal processing)	1998
Engineering Division faculty search committee (controls)	1997
Engineering Division faculty search committee (power)	1996

#### **PAST AND CURRENT RESEARCH PROJECTS**

William Hoff, Hao Zhang, “Registration and Tracking of a Handheld Device”, Metcalf Archaeological Consultants, Inc, \$ 126,392, 2017.

William Hoff, Hao Zhang, “Automated Maintenance Guide”, DAQRI, Inc, \$30,000, 2016.

William Hoff, “3D Reconstruction from 2D Images Using Shape Priors”, Rocky Mountain Scientific Laboratory, \$129,876, 2014-2015.

William Hoff, “Detection and Object Tracking Support”, Northrop-Grumman, \$6,000, 2014.

William Hoff, Ravel Ammerman, Catherine Skokan, “Evaluation of Hybrid Instruction in EGGN 381”, Trefny Foundation for educational research, \$5,000, 2011.

William Hoff, Andrzej Szymczak, “Framework for Activity Recognition and Prediction using Semi-supervised Learning”, Northrop-Grumman Information Systems, \$24,962, Aug 2009 – Feb 2011.

William Hoff (co-PI), “Activity Recognition and Prediction” – this is one of five subtasks on “Cyber-Enabled Efficient Energy Management of Structures”, NSF, \$1.4M, Sep 2009 – Aug 2012.

William Hoff, Michael Colagrosso, “Activity Mathematics”, Lockheed Martin, \$120,000, January 2008 – December 2008.

Kevin Moore, William Hoff, “Fast Rope Video Analysis”, Kuchera Defense Systems, \$11,626 , May 2007 – July 2007

William Hoff, Tyrone Vincent, “Tracking support for Loadmaster Training System”, Pathfinder Systems, Inc, \$54,138, Feb 2007 – Aug 2007

William Hoff, “Biplanar Registration Algorithm”, University of Tennessee, \$48,000, August 2005 – December 2007.

William Hoff, Jae Young Lee, “Activity Mathematics”, Lockheed Martin, \$99,994, January 2007 – December 2007.

William Hoff, Jae Young Lee, “Activity Notation Transformations”, Lockheed Martin, \$29,482, August 2006 – December 2006.

William Hoff, Tyrone Vincent, “Video Aided Navigation, SBIR Phase 2” PercepTek Inc., \$130,000, June 2006 – April 2008.

William Hoff, “Moving Target Reconstruction,” PercepTek Inc., \$34,978, July 2005 – April 2006.

William Hoff, “Video Aided Navigation,” PercepTek Inc., \$32,994, July 2005 – March 2006.

William Hoff, Tyrone Vincent, “Dismounted Augmented Reality Training System”, Pathfinder Systems Inc., \$15,939, July 2005 – September 2005.

William Hoff, Jae Young Lee, “Universal Activity Theory”, Lockheed Martin, \$60,000. December 2004 – December 2005.

William Hoff, Alan Norton, “Activity Identification and Visualization”, Lockheed Martin, \$120,000. December 2003 – December 2004.

Chris Debrunner, William Hoff, “Tomographic Imaging from Fluoroscopic Video”, Colorado Alliance for Bioengineering, \$57,700. January 2002 – June 2002.

Chris Debrunner, William Hoff, “Markerless Human Motion Tracking”, Colorado Advanced Software Institute, \$40,000. July 2001 – August 2002.

William A. Hoff, “Real-Time 3D Modeling Development”, \$29,500, Sandia National Laboratory, December 1999 – May 2002.

William Hoff, Tracy Camp, Xindong Wu, “Mentored Internships,” Colorado Advanced Software Institute, \$12,500. February 2001 - June 2001.

William A. Hoff, "Registration of Range Data", \$8,245, Sandia National Laboratory, November 1998 – May 1999.

William A. Hoff, "Tactical Mobile Robots Support", \$107,238, SAIC Corporation, July 1998 - April 2000.

William A. Hoff, "Measurement of Normal Knee Kinematics from X-ray Images," \$39,900, Colorado Advanced Software Institute, July 1998 - August 1999.

William A. Hoff, "InImEx Interactive SAR Object Recognition," \$58,859, Lockheed-Martin Astronautics, February 1998 - June 2001.

Rahmat Shoureshi, William Hoff, Richard Komistek, "NSF Industry/University Cooperative Research Center for Intelligent Biomedical Devices and Musculoskeletal Systems," \$550,000, January 1998 - August 2002

William A. Hoff, "Measurement of Implant Component Position and Orientation from X-ray Images," \$40,651, Colorado Advanced Software Institute, July 1997 - August 1998.

William A. Hoff, "Vision-based tracking system for an augmented reality-based surgical aid," \$24,996, Johnson & Johnson Professional Inc., July 1996 - August 1997.

Richard Komistek, William Hoff, "Planning Meeting for an Industry/University Cooperative Research Center for Musculoskeletal System Analysis", NSF Grant EEC-9616415, \$10,000, July 1996 - July 1997.

William A. Hoff, "Measurement of Joint Kinematics from Fluoroscopy Images", \$1700, NSF Coalition to Increase Minority Degrees, Grant KMD-2414-3-7/SUB, June 1996 - August 1996.

William A. Hoff, Robert King, "Evaluation of Interactive Techniques for the Creation and Updating of Site Models for Remote Operations and Inspection", \$160,546, Lockheed Martin INEL - Department of Energy, Contract PO CC-S-596129, June 1995 - Sept 1996.

## **CONSULTING ACTIVITY**

Rocky Mountain Musculoskeletal Research Laboratory, August 2002 – May 2003. Bioimaging research.

Peak Performance, Inc., August 2004 – June 2005. Project: "Objective Radiographic Oropharyngeal Swallowing Analysis", SBIR from NIH.

Lockheed-Martin Missiles and Fire Control, January 2010 – December 2010. Research in vision-based autonomous vehicle navigation.

## **PAST GRADUATE STUDENTS**

Torsten Lyon (M.S. 1995). Thesis title: "Three-dimensional Pose Estimation from Noisy Two-Dimensional Image Observations Using Multiple Cameras"

Fred Hood (M.S. 1997). Thesis title: "Evaluation of an Interactive Site Modeling System"

Khoi Nguyen (M.S. 1998). Thesis title: "Inertial Data Fusion Using Kalman Filter Methods for Augmented Reality"

Mark Sarojak (M.S. 1998). Thesis title: "Interactive pose estimation of total joint arthroplasty via x-ray fluoroscopy"

Jason Luck (M.S. 1999). Thesis title: "Registration of Range Images Through the Use of a Hybrid Simulated Annealing and Iterative Closest Point Algorithm"

Lin Chai (M.S. 2000). Thesis title: "3-D Motion and Structure Estimation Using Inertial Sensors and Computer Vision for Augmented Reality"

Josh Lisle (MS 2002). Thesis title: "Design and Evaluation of a Virtual Reality Interface for Mobile Robot Control Using a Small Display"

Mohamed Mahfouz (PhD 2002). Thesis title: "A New Registration Method for Implanted and Non Implanted Knee Joints Using Single Plane X-ray Fluoroscopy"

Jason Luck (PhD 2003). Thesis title: "Real-time markerless human motion tracking using linked kinematic chains"

Josh King (MS 2007). Thesis title: "Bi-Planar Image Registration and Modeling of Bones"

Marc Wennogle (MS 2007). Thesis title: "Three Dimensional Segmentation of Intravascular Ultrasound Data"

Stuart Guarnieri (MS 2008). Thesis title: "3D Object Segmentation Using Correspondence Space Grouping and Propagation"

John Steinbis, (MS 2008). Thesis title: "A New Vision and Inertial Pose Estimation System for Handheld Augmented Reality"

Matt Kupilik, (MS 2008). Thesis title: "Scale Factor Estimation and Propagation in Monocular Vision Based Navigation"

Chris Baker, (PhD 2013). Thesis title: "DIRSAC: A Directed Sample and Consensus Algorithm for Localization with Quasi-Degenerate Data"

Jim Howard, (PhD 2015). Thesis title: "A Method For Using Activity Recognition To Improve Ensemble Forecasting For Traffic Systems"

Hisham Sager, (PhD 2015). Thesis title: "Pedestrian Detection In Low-Resolution Videos"

Abdelsalam Masoud, (PhD 2015). Thesis title: "Segmentation and Tracking Of Non-Planar Templates To Improve VSLAM"

Chris Card, (MS 2015). Thesis title: "Qualitative Image Based Localization in a Large Building"

Brian Reily, (MS 2016). Co-advised with Hao Zhang. Thesis title: "Human Activity Recognition and Gymnastics Analysis Through Depth Imagery"

## **HONORS AND AWARDS**

Best paper runner up at BigMine 2013 conference, 2013

Engineering Division Outstanding Service Award, 2009

Third place at National Security Innovation Competition, 2009

Outstanding faculty member award (from CSM graduate student ballots), 2006

Winner of the "Exemplary Project" award from CASI, for the project "Measurement of Implant Component Position and Orientation from X-ray Images", October 1999

Best paper of session award at the Rocky Mountain Bioengineering Symposium, April 1999

Winner of the "Clinical Biomechanics" award, European Society of Biomechanics, August 1996.

## JOURNAL PUBLICATIONS

(note - student names are underlined)

1. Hoff, W. and Ahuja, N., "Surfaces from Stereo: Integrating Feature Matching, Disparity Estimation, and Contour Detection," *IEEE Trans. Pattern Analysis and Machine Intelligence*, Vol. 11, No. 2, pp. 121-136, 1989.
2. Magee, M., Hoff, W., Gatrell, L., Sklair, C., and Wolfe, W., "Employing Sensor Repositioning to Refine Spatial Reasoning in an Industrial Robotic Environment," *International Journal of Applied Intelligence*, Vol. 1, No. 1, pp. 69-85, 1991.
3. Hoff, W., Gatrell, L., and Spofford, J., "Machine Vision Based Teleoperation Aid," *Telematics and Informatics*, Vol. 8, No. 4, pp. 403-423, 1991.
4. Byler, E., Chun, W., Hoff, W., and Layne, D., "Autonomous hazardous waste inspection vehicle," *IEEE Robotics and Automation Magazine*, Vol. 2, No. 1, pp. 6-17, 1995.
5. Dennis, D. A., Komistek, R. D., Hoff, W. A., and Gabriel, S. M., "In-Vivo Knee Kinematics Derived Using an Inverse Perspective Technique," *Clinical Orthopaedics and Related Research*, Vol. 331, pp. 107-117, 1996.
6. Stiehl, J. B., Komistek, R. D., Dennis, D. A., Paxson, R. D., and Hoff, W. A., "Fluoroscopic analysis of kinematics after posterior-cruciate retaining knee arthroplasty," *Journal of Bone and Joint Surgery-British*, Vol. 77-B, No. 6, pp. 884-889, 1996.
7. Stiehl, J. B., Komistek, R. D., Dennis, D. A., Paxson, R. D., and Hoff, W. A., "Comparison of Biomechanical Aspects of Posterior Cruciate Retaining vs. Posterior Cruciate Sparing Total Knee Arthroplasty," *Journal of Contemporary Orthopaedics*, 1996.
8. Walker, S. A., Hoff, W. A., Komistek, R. D., and Dennis, D. A., "In Vivo Pose Estimation of Artificial Knee Implants Using Computer Vision," *Biomed Sciences Instrumentation*, Vol. 32, No. 1996.
9. Hoff, W. A., R. D. Komistek, D. A. Dennis, S. M. Gabriel, and S. A. Walker, "Three-dimensional determination of femoral-tibial contact positions under "in-vivo" conditions using fluoroscopy," *Clinical Biomechanics*, Vol. 13, No. 7, pp. 455-472, 1998. (*Clinical Biomechanics Award 1996*)
10. Hoff, W. A. and T. Vincent, "Analysis of Head Pose Accuracy in Augmented Reality," *IEEE Trans. Visualization and Computer Graphics*, Vol 6., No. 4, pp. 319-334, 2000.
11. Bertin, K., Komistek, R., Dennis, D., Hoff, W., Anderson, D., Langer, T., "In vivo determination of posterior femoral rollback for subjects having a NexGen posterior cruciate retaining total knee arthroplasty," *J Arthroplasty*, vol. 17, no. 8, pp. 1040-1048, 2002.
12. Chai, L., W. A. Hoff, and T. Vincent, "Three-dimensional motion and structure estimation using inertial sensors and computer vision for augmented reality," *Presence: Teleoperators and Virtual Environments*, vol. 11, no. 5, pp. 474-492, 2002.
13. Mahfouz, M., W. Hoff, R. Komistek, and D. Dennis, "A Robust Method for Registration of Three-Dimensional Knee Implant Models to Two-Dimensional Fluoroscopy Images," *IEEE Trans. Medical Imaging*, vol. 22, no. 12, pp. 1561-74, 2003.



14. Mahfouz, M., R. Komistek, D. Dennis, and W. Hoff, "In vivo assessment of the kinematics in normal and anterior cruciate ligament-deficient knees," *J Bone Joint Surg Am.*, vol. 86, pp. 56-61, 2004.
15. Dennis, D., M. Mahfouz, R. Komistek, and W. Hoff, "In vivo determination of normal and anterior cruciate ligament-deficient knee kinematics," *J Biomech.*, vol. 38, no. 2, pp. 241-53, 2005.
16. Mahfouz, M., W. Hoff, R. Komistek, and D. Dennis, "Effect of segmentation errors on 3D-to-2D registration of implant models in X-ray images," *J Biomech.*, vol. 38, no. 2, pp. 229-39, 2005.
17. Masoud, A. and W. Hoff, "Segmentation and tracking of nonplanar templates to improve VSLAM," *Journal of Robotics and Autonomous Systems*, vol. 86, pp. 29-56, 2016.
18. Reily, B., H. Zhang, and W. Hoff. "Real-time Gymnast Detection and Performance Analysis with a Portable 3D Camera." *Computer Vision and Image Understanding*, vol. 159, pp. 154-163, 2017.
19. Han, F., B. Reily, W. Hoff, and H. Zhang. "Space-time representation of people based on 3d skeletal data: a review." *Computer Vision and Image Understanding*, vol. 158, pp. 85-105, 2017.
20. Baker, C. and W. Hoff. "DIRSAC: A directed sample and consensus algorithm for localization with quasi-degenerate data." *Journal of Robotics and Autonomous Systems*, vol. 97, pp. 92-107, 2017.

## BOOK CHAPTERS

(note - student names are underlined)

1. Magee, M., Hoff, W., Gatrell, L., and Wolfe, W., "Intelligent Control of a Vision-Based Spatial Reasoning System Integrated with a Robot Manipulator," in *Progress in Robotics and Intelligent Systems*, Vol. 3, G. Zobrist and C. Y. Ho, Ed., Norwood, New Jersey, Ablex Publishing Corp., pp. 261-286, 1995.
2. E. Berg, M. Mahfouz, C. Debrunner, B. Merkl, and W. Hoff., "Fourier descriptor-based deformable models for segmentation of the distal femur in CT," chapter in *Advanced Computer Information Systems*, K. Saeed and J. Pejas, Ed.: Springer Verlag, 2005.

## REFEREED CONFERENCE PROCEEDINGS

(note - student names are underlined)

1. Ahuja, N. and Hoff, W., "Augmented Medial Axis Transform," *Proc. of IEEE Workshop on Computer Vision: Representation and Control*, April, pp. 251-256, 1984.
2. Ahuja, N. and Hoff, W., "Depth from Stereo," *Proc. of 4th Scandinavian Conference on Image Analysis*, Trondheim, Norway, June, pp. 761-768, 1985.
3. Hoff, W. and Ahuja, N., "Extracting Surfaces from Stereo Images: An Integrated Approach," *Proc. of First Int'l Conf. on Computer Vision*, IEEE, London, June, pp. 284-294, 1987.
4. Hoff, W. and Sklair, C., "Planetary Terminal Descent Hazard Avoidance Using Optical Flow," *Proc. of IEEE Conf. Robotics and Automation*, pp. 238-243, 1990.

5. Magee, M., Hoff, W., Gatrell, L., and Wolfe, W., "Adaptive Camera Calibration in an Industrial Robotic Environment," *Proc. of 3rd Int'l Conf. on Industrial and Engineering Applications of AI*, ACM, July, 1990.
6. Magee, M., Hoff, W., Gatrell, L., and Wolfe, W., "Integrated Planning of Robotic and Computer Vision Based Spatial Reasoning," *Proc. of 3rd Int'l Conf. on Industrial and Engineering Applications of AI*, ACM, July, 1990.
7. Cuseo, J., Fleming, P., Hoff, W., Sklair, C., Eshera, M., and Whitten, G., "Machine Vision Techniques for Planetary Terminal Descent Hazard Avoidance and Landmark Tracking," *Proc. of American Control Conference*, June, 1991.
8. Hoff, W., Komistek, R., Dennis, D., Walker, S., Northcut, E., and Spargo, K., "Pose Estimation of Artificial Knee Implants in Fluoroscopy Images Using a Template Matching Technique," *Proc. of 3rd Workshop on Applications of Computer Vision*, IEEE, Sarasota, FL, Dec. 2-4, pp. 181-186, 1996.
9. Hoff, W. A., Hood, F. W., and King, R. H., "An Interactive System for Creating Object Models from Range Data Based on Simulated Annealing," *Proc. of Int'l Conference on Robotics and Automation*, IEEE, Albuquerque, NM, April 21-27, 1997.
10. W. A. Hoff, "Fusion of Data from Head-Mounted and Fixed Sensors," *Proc. of First International Workshop on Augmented Reality*, IEEE, San Francisco, California, November 1, 1998.
11. M. E. Sarojak, W. A. Hoff, R. D. Komistek, and D. A. Dennis, "Utilization of an automated model fitting process to determine kinematics of TKA," *Proc. of Orthopaedic Research Society*, Anaheim, California, February 1-5, 1999.
12. L. Chai, K. Nguyen, W. Hoff, and T. Vincent, "An adaptive estimator for registration in augmented reality," *Proc. of 2nd IEEE/ACM Int'l Workshop on Augmented Reality*, San Francisco, Oct. 20-21, 1999.
13. J. Luck, C. Little, and W. Hoff, "Registration of range data using a hybrid simulated annealing and iterative closest point algorithm," *Proc. of IEEE International Conference on Robotics and Automation*, San Francisco, April 24-28, 2000.
14. D. A. Dennis, R. Komistek, M. Mahfouz, W. Hoff, J. Stiehl, "In vivo determination of three dimensional normal knee motion during five weight-bearing activities," *Proc. of Annual Meeting of the American Academy of Orthopaedic Surgeons*, San Francisco, CA, 2001, San Francisco, CA, Feb. 28 - Mar. 4.
15. M. Mahfouz, W. A. Hoff, R. Komistek, and D. A. Dennis, "Post-Operative Analysis Of Non-Implanted Knee Joint Kinematics Using Fluoroscopy," *Proc. of Fifth Annual North American Program on Computer Assisted Orthopaedic Surgery*, Pittsburgh, Pennsylvania, 2001, Pittsburgh, Pennsylvania, July 6-8.
16. M. Mahfouz, W. Hoff, D. Anderson, E. Northcut, R. Komistek, "Verification Of Three-Dimensional Joint Kinematics Determined Using Fluoroscopy: An Error Analysis," *Proc. of 48th Annual Meeting Orthopaedic Research Society - Poster*, Dallas, TX, 2002, Dallas, TX, February.
17. J. P. Luck, C. Debrunner, W. Hoff, Q. He, D. Small, "Development and Analysis of a Real-Time Human Motion Tracking System," *Proc. of Workshop on Applications of Computer Vision*, Orlando, FL, 2002, Orlando, FL, Dec 3-4, pp. 196-202.

18. J. Argenson, R. Komistek, D. Dennis, W. Hoff, T. Langer, "In Vivo Determination Of Knee Kinematics During Gait For Subjects Implanted with A Unicompartmental Arthroplasty," *Proc. of AAOS 2003 Annual Meeting*, New Orleans, Louisiana, 2003, New Orleans, Louisiana.
19. J. Goffin, R. Komistek, M. Mahfouz, D. Wong, D. Macht, W. Hoff, "In vivo kinematics of normal, degenerative, fused and disk-replaced cervical spines," *Proc. of AAOS 2003 Annual Meeting*, New Orleans, Louisiana, 2003, New Orleans, Louisiana.
20. W. Hoff and J. Lisle, "Mobile Robot Control Using a Small Display," *Proc. of International Conference on Intelligent Robots and Systems (IROS)*, Las Vegas, Nevada, 2003, Las Vegas, Nevada, October 27-31. Acceptance rate = 60%.
21. E. Berg, M. Mahfouz, C. Debrunner, and W. Hoff, "A 2D Fourier Approach To Deformable Model Segmentation Of 3D Medical Images," *Proc. of International Symposium on Biomedical Imaging*, Arlington, VA, 2004, Arlington, VA, 15-18 April.
22. C. Baker, Debrunner, C., Mahfouz, M., Hoff, W., Bowen, J., "CT from an Unmodified Standard Fluoroscopy Machine using a Non-Reproducible Path," *Proc. of Computer Vision Approaches to Medical Image Analysis (CVAMIA)*, Prague, 2004, May 15, 11-23.
23. C. Debrunner, Baker C., Hoff, W., Bowen, J., Mahfouz, M., "Tomographic Reconstruction From an Uncontrolled Sensor Trajectory," *Proceedings of the 2004 IEEE International Symposium on Biomedical Imaging: From Nano to Macro*, 2004, Arlington, VA, USA, 15-18 April, 1416-1419.
24. E. Berg, M. Mahfouz, C. Debrunner, and W. Hoff, "A 2D Fourier Approach to Deformable Model Segmentation of 3D Medical Images," *Proc. of Computer Vision and Mathematical Methods in Medical and Biomedical Image Analysis*, Prague, Czech Republic, 2004, May 15, pp. 181-192.
25. E. Berg, C. Debrunner, W. Hoff, and M. Mahfouz, "Automatic Segmentation of 3D Medical Images Using Fourier Descriptor-Based Deformable Models," *Proc. of Advanced Computer Systems-Computer Information Systems and Industrial Management Applications (ACS-CISIM)*, Elk, Poland, 2004, June 14-16.
26. R. Parker, W. Hoff, A. Norton, J. Lee, and M. Colagrosso, "Activity Identification and Visualization," *Proc. of Pattern Recognition in Information Systems – PRIS 2005*, Miami, FL, 2005, May 24-25, pp. 124 – 133. (acceptance rate 50%)
27. C. Baker, C. Debrunner, S. Gooding, W. Hoff, and W. Severson, "Autonomous Vehicle Video Aided Navigation - Coupling INS and Video Approaches," *Proc. of 2nd International Symposium on Visual Computing*, Lake Tahoe, NV, 2006, Nov. 6-8, pp. 534-543. (acceptance rate 44%)
28. J. Lee, W. Hoff, "Activity Identification Utilizing Data Mining Techniques," *Proc. of IEEE Workshop on Motion and Video Computing*, Austin, TX, 2007, Feb. 23-24.
29. R. Rimey, W. Hoff, J. Lee, "Recognizing wide-area and process-type activities," *Proc. of 10th International Conference on Information Fusion*, Quebec City, QC, Canada, 2007, Jul. 9-12, pp. 1-8.
30. J. Steinbis, W. Hoff, T. Vincent, "3D Fiducials for Scalable AR Visual Tracking," *Proc. of 7th IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, Cambridge, UK, 2008, Sept 15-18, pp. 183-184. (acceptance rate 20%)

31. J. Steinbis, T. Vincent, W. Hoff, "New Extensions of the 3-Simplex for Exterior Orientation," *Proc. of 19<sup>th</sup> Int'l Conf. on Pattern Recognition (ICPR)*, Tampa, FL, 2008, Dec 8-11.
32. M. Wennogle, W. Hoff, "Three Dimensional Segmentation of Intravascular Ultrasound Data," *Proc. of Int'l Conf. on Image Analysis and Recognition (ICIAR 2009)*, Halifax, Canada, 2009, July 6-8, pp. 772-781.
33. W. Hoff, J. Howard, "Activity Recognition in A Dense Sensor Network," *Proc. of First International Conference on Sensor Networks and Applications (SNA2009)*, Nov 4-6, 2009, pp. 67-72, San Francisco, California USA.
34. C. Baker and W. Hoff, "DIRSAC: A Directed Sampling And Consensus Approach to Quasi-Degenerate Data Fitting," *Workshop on Applications of Computer Vision (WACV)*, 2013, pp. 154-159, Clearwater, FL.
35. C. Skokan, R. Ammerman, and W. Hoff, "Evaluation of Hybrid Instruction of an Introductory Electronics Course," *ASEE Annual Conference*, 2013, Atlanta, GA.
36. J. Howard, W. Hoff, "Forecasting Building Occupancy Using Sensor Network Data," *Proc. of 2nd International Workshop on Big Data, Streams and Heterogeneous Source Mining (BigMine 13)*, pp. 87-94, August 2013, Chicago, Illinois. (best paper runner-up)
37. A. Masoud and W. Hoff, "Segmentation and Tracking of Partial Planar Templates," *Proc. of Winter Conference on Applications of Computer Vision*, pp. 1128-1133, March 2014, Steamboat Springs, Colorado. (acceptance rate 40%)
38. H. Sager and W. Hoff, "Pedestrian Detection in Low Resolution Videos," *Proc. of Winter Conference on Applications of Computer Vision*, pp. 668-673, March 2014, Steamboat Springs, Colorado. (acceptance rate 40%)
39. A. Masoud and W. Hoff, "Estimation and Tracking of Partial Planar Templates to Improve VSLAM," *Proc. of 7th Iberian Conference on Pattern Recognition and Image Analysis (IbPRIA)*, pp. 83-92, June 2015, Santiago de Compostela, Spain.
40. C. Card and W. Hoff, "Qualitative Image-Based Localization in a Large Building," *Proc. of 19th International Conference on Image Processing, Computer Vision, & Pattern Recognition (IPCV)*, July 2015, Las Vegas, Nevada.
41. W. Hoff and H. Zhang, "Learning Object and State Models for AR Task Guidance," *Proc of International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 272-273, September 2016, Merida, Mexico.
42. F. Han, J. Liu, W. Hoff and H. Zhang, "[POSTER] Planning-based Workflow Modeling for AR-enabled Automated Task Guidance," *Proc of International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 58-62, October 2017, Nantes, France.
43. Y. Xie, G. Tang, and W. Hoff, "Geometry-Based Populated Chessboard Recognition." *International Conference on Machine Vision (ICMV)*, November 2017, Vienna, Austria.
44. Y. Xie, G. Tang, and W. Hoff, "Chess Piece Recognition Using Oriented Chamfer Matching with a Comparison to CNN," *Proc. of Winter Conference on Applications of Computer Vision (WACV)*, March 2018, Lake Tahoe, Nevada.

## INVITED TALKS AND PRESENTATIONS

1. "Multi-Resolution Techniques in Stereo Vision," *Workshop in Computational Vision on Multi-Resolution Representation of Images*. Copenhagen, Denmark, Invited presentation, 1987.
2. "Research in Augmented Reality," invited presentation to Center for LifeLong Learning and Design (L3D) group at University of Colorado – Boulder, March 1997.
3. "The Use of Optimization in Solving Registration Problems in Biomedical Imaging and Robot Vision," invited presentation to the Optimization and Bio-Mathematics/Statistics research groups at CU-Denver, 9/22/98.
4. "Automation and Robotics Research and Education at the Colorado School of Mines," invited presentation to Sigma Xi chapter at Mesa State College, 4/24/00.
5. "Projection on Convex Sets", presentation to U. Tennessee Biomedical Engineering Dept, August 2007.
6. "Activity Recognition in a Dense Sensor Network," National Homeland Defense Symposium VII, sponsored by National Homeland Defense Foundation, Colorado Springs, Colorado, Nov 9-11, 2009.
7. "Real-time gymnast detection and performance analysis with a portable 3D camera", invited presentation at International Conference and Expo on Computer Graphics & Animation, Berlin, Germany, September 25-26, 2017.

## NON-REFEREED CONFERENCES, PRESENTATIONS, AND TECH REPORTS

(note - student names are underlined>

1. Hoff, W. and Mathis, D., "Connectionist Model-Based Stereo Vision for Telerobotics," *Proc. of Visual Information Processing for Television and Telerobotics*, Vol. NASA CP-3053, Williamsburg, Virginia, May, pp. 261-270, 1989.
2. Magee, M., Hoff, W., Gatrell, L., and Wolfe, W., "Task Panel Sensing with a Movable Camera," *Proc. of Advances in Intelligent Robotics Systems*, Vol. 1193, SPIE, Philadelphia, Pennsylvania, November, 1989.
3. Sklair, C., Gatrell, L., and Hoff, W., "Optical Target Location Using Machine Vision in Space Robotics Tasks," *Proc. of Advances in Intelligent Systems*, Vol. 1387, SPIE, November, pp. 380-391, 1990.
4. Hoff, W. and Sklair, C., "Terrain Shape Estimation from Optical Flow Using Kalman Filtering," *Proc. of Symposium on Electronic Imaging Science and Technology*, Vol. 1260, SPIE, Santa Clara, California, February, pp. 86-97, 1990.
5. Gatrell, L., Hoff, W., and Sklair, C., "Robust Image Features: Concentric Contrasting Circles and Their Image Extraction," *Proc. of Cooperative Intelligent Robotics in Space*, Vol. 1612, SPIE, W. Stoney (ed.), 1991.
6. Sklair, C., Hoff, W., and Gatrell, L., "Accuracy of Locating Circular Features Using Machine Vision," *Proc. of Proc. of Cooperative Intelligent Robotics in Space*, Vol. 1612, SPIE, W. Stoney (ed.), Nov. 10-15, 1991.

7. Hoff, W., Gatrell, L., and Spofford, J., "Machine Vision Based Teleoperation Aid," *Proc. of Goddard Conf on Space Applications of Artificial Intelligence*, Vol. NASA Conference Publication 3110, May, pp. 199-213, 1991.
8. Hoff, W., Gatrell, L., Layne, D., Bruno, G., and Sklair, C., "Compensating for Centroid Errors Due to Surface Tilt and Lens Distortion," *Proc. of Conference on Mathematical Aspects of Computer Vision*, University of Colorado at Colorado Springs, 1992.
9. Hoff, W., Sklair, C., Xu, W., and Su, R., "Comparative Study of Pose Estimation Algorithms," *Proc. of Int'l Conf on Intelligent Information Processing of Systems*, Natural Science Foundation of China, Beijing, China, October 30-Nov 1, 1992, 1992.
10. Dennis, D. A., Komistek, R. D., Hoff, W. A., and Gabriel, S. M., "In-vivo knee kinematics derived using an inverse perspective technique," *Proc. of Knee Society Closed Meeting*, Boston, September, 1995.
11. Dennis, D. A., Komistek, R. D., Hoff, W. A., and Kettler, P., "Passive versus weight-bearing range of motion study determined using fluoroscopy," *Proc. of Knee Society Closed Meeting*, Boston, September, 1995.
12. Komistek, R. D., Dennis, D. A., and Hoff, W. A., "A Kinematic Comparison of Prosthetically Implanted and Nonimplanted Knees Using Dynamic Fluoroscopy," *Proc. of 19th Annual Meeting of the American Society of Biomechanics*, Stanford, California, August, 1995.
13. Murphy, R. R., Hoff, W. A., Blich, J., Hawkins, D., Hoffman, J. C., Krosley, R., Lyon, T., Mali, A., MacMillan, J., and Warshawsky, S., "CSM Behavioral Approach to the 1995 UGV Competition," *Proc. of Mobile Robots*, Vol. 2591, SPIE, Philadelphia, PA, 1995.
14. Hoff, W. A., Lyon, T., and Nguyen, K., "Computer Vision-Based Registration Techniques for Augmented Reality," *Proc. of Intelligent Robots and Computer Vision XV*, Vol. 2904, in *Intelligent Systems & Advanced Manufacturing*, SPIE, Boston, Massachusetts, Nov. 19-21, pp. 538-548, 1996.
15. Dennis, D. A., Komistek, R. D., Stiehl, J. B., Hoff, W. A., and Cheal, E., "An "in vivo" determination of condylar lift-off using an inverse perspective technique that utilizes fluoroscopy," *Proc. of American Society of Orthopedic Surgeons Scientific Exhibit*, Atlanta, Georgia, February, 1996.
16. Walker, S. A., Hoff, W. A., Dennis, D. A., and Komistek, R. D., "'In Vivo" Pose Estimation of Artificial Knee Implants Using Computer Vision," *Proc. of Annual Rocky Mountain Bioengineering Symposium*, ISA, United States Air Force Academy, Colorado Springs, April, pp. 143-150, 1996. (*won best student paper*)
17. Dennis, D. A., Komistek, R. D., Stiehl, J. B., Hoff, W. A., and Cheal, E., "An In Vivo Determination of Condylar Lift-Off Using an Inverse Perspective Technique that Utilizes Fluoroscopy," *Orthopaedic Transactions*, 1996.
18. Hoff, W. A., Hood, F., and Nguyen, K., "Evaluation of Interactive Techniques for the Creation and Updating of Site Models for Remote Operations and Inspection", presentation at INEL Summer Workshop, July 1996.
19. Hood, F. W., Hoff, W. A., and King, R. H., "Evaluation of An Interactive System for Creating Object Models from Range Data," *Proc. of ANS 7th Topical Meeting on Robotics and Remote Systems*, Augusta, GA, April 27-May 1, 1997.

20. Hoff, W. A., and M. Sarojak, “Measurement of Implant Component Position and Orientation from X-ray Images”, Poster at Colorado Advanced Software Institute Annual Research Symposium, October 1997.
21. W. A. Hoff, M. Sarojak, “Measurement of Implant Component Position and Orientation from X-ray Images”, final report and presentation at Colorado Advanced Software Institute Annual Research Symposium, October 1998.
22. W. A. Hoff, M. Sarojak, “Measurement of Normal Knee Kinematics from X-ray Images”, poster at Colorado Advanced Software Institute Annual Research Symposium, October 1998.
23. W.A. Hoff, “Augmented Reality-Based Surgical Aid”, final report for Johnson & Johnson project, August 1998.
24. M. Sarojak, W. Hoff, R. D. Komistek, and D. A. Dennis, “An interactive system for kinematic analysis of artificial joint implants,” *Proc. of 36th Rocky Mountain Bioengineering Symposium*, April 16-18, 1999, Copper Mountain, Colorado.
25. W. A. Hoff, M. Sarojak, M. Mahfouz, “Measurement of Normal Knee Kinematics from X-ray Images”, final report and presentation at Colorado Advanced Software Institute Annual Research Symposium, October 1999.
26. W. Hoff, “Final Report for INIMEX Interactive SAR Object Recognition,” June 2001, Lockheed-Martin Corporation
27. W. Hoff, “Final Report for CASI Mentored Internship Program on Clinical Research Database”, September, 2001
28. M. Mahfouz, W. A. Hoff, R. G. Underwood, R. Komistek, D. A. Dennis, “Global Optimization For Recovering the Position And Orientation of Free-Form Objects in Medical Imaging Registration Using A New Smoothing Approach,” *Fifth International Symposium On Computer Methods In Biomechanics and Biomedical Engineering*, 31st October - 3rd November 2001, Rome, Italy.
29. M. Mahfouz, W. A. Hoff, D. Anderson, E. Northcut, R. Komistek, D. A. Dennis, “Estimation of normal knee kinematics from single plane fluoroscopy images, using a direct image-to-image matching technique,” *Fifth International Symposium On Computer Methods In Biomechanics and Biomedical Engineering*, 31st October - 3rd November 2001, Rome, Italy.
30. W. Hoff, “Final Report for 3D Human Motion Tracking”, June 2002, Sandia National Labs.
31. C. Debrunner and W. Hoff, “Final Report for Markerless Human Motion Tracking”, November 2002, Colorado Advanced Software Institute.
32. C. Debrunner and W. Hoff, “Final Report for Tomographic Imaging from Fluoroscopic Video”, October 2002, Colorado Alliance for Bioengineering.
33. W. Hoff, “Tomographic Imaging from Fluoroscopic Video”, November 2002, presentation to Colorado Alliance for Bioengineering. Also a poster at their December meeting.
34. W. Hoff, A. Norton, R. Parker, “Final Report for Activity Identification and Visualization Project”, December 2004, to Lockheed-Martin.
35. W. Hoff, M. Colagrosso, “Activity Mathematics”, December 2008, to Lockheed-Martin.

36. J. Howard, W. Hoff, “Activity Recognition in a Dense Sensor Network,” poster at *National Security Innovation Competition*, sponsored by National Homeland Defense Foundation, Colorado Springs, Colorado, May 1, 2009.
37. W. Hoff, “Activity Recognition and Anomaly Detection in a Dense Sensor Network”, presentation at *IFAC Workshop on Networked Robotics*, Oct 6-8, 2009, Golden, Colorado USA.
38. A. Szymczak, W. Hoff and M. Mahfouz, “3D Shape from Silhouette Points in Registered 2D Images Using Conjugate Gradient Method,” *Medical Imaging 2010: Image Processing. Proceedings of the SPIE*, Volume 7623, pp. 762316-762316-8, 2010.