**02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS**

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.C.a. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. *DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.*

**PI/PD Name:**    Mubarak   Shah

**Gender:**    ☒ Male        ☐ Female

**Ethnicity:** (Choose one response)    ☐ Hispanic or Latino    ☒ Not Hispanic or Latino

**Race:**
(Select one or more)
☐ American Indian or Alaska Native
☒ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☐ White

**Disability Status:**
(Select one or more)
☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☐ None

**Citizenship:**    (Choose one)    ☒ U.S. Citizen        ☐ Permanent Resident        ☐ Other non-U.S. Citizen

**Check here if you do not wish to provide any or all of the above information (excluding PI/PD name):**    ☒

**REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project    ☒**

**Ethnicity Definition:**
**Hispanic or Latino.** A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
**Race Definitions:**
**American Indian or Alaska Native.** A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
**Asian.** A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
**Black or African American.** A person having origins in any of the black racial groups of Africa.
**Native Hawaiian or Other Pacific Islander.** A person  having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
**White.** A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

**WHY THIS INFORMATION IS BEING REQUESTED:**

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement  of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

**02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS**

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**PI/PD Name:**  Niels D da Vitoria Lobo

**Gender:** ☒ Male ☐ Female

**Ethnicity:** (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

**Race:**
(Select one or more)
☐ American Indian or Alaska Native
☒ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☐ White

**Disability Status:**
(Select one or more)
☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☒ None

**Citizenship:** (Choose one) ☐ U.S. Citizen ☒ Permanent Resident ☐ Other non-U.S. Citizen

**Check here if you do not wish to provide any or all of the above information (excluding PI/PD name):** ☒

**REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project** ☒

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Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

# List of Suggested Reviewers or Reviewers Not To Include (optional)

**SUGGESTED REVIEWERS:**
**Not Listed**

**REVIEWERS NOT TO INCLUDE:**
**Not Listed**

# COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

| PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 11-1 | FOR NSF USE ONLY |
|---|---|
| NSF 09-598          08/24/11 | **NSF PROPOSAL NUMBER** |

**FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S)**   (Indicate the most specific unit known, i.e. program, division, etc.)

**CNS  - CISE - Research Experiences for Undergraduates Sites (Computer Sci. & Eng**

# 1156990

| DATE RECEIVED | NUMBER OF COPIES | DIVISION ASSIGNED | FUND CODE | DUNS# (Data Universal Numbering System) | FILE LOCATION |
|---|---|---|---|---|---|
| 08/24/2011 | 2 | 05050000 CNS | 1139 | 150805653 | 03/02/2013 8:35am  S |

| EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN) | SHOW PREVIOUS AWARD NO. IF THIS IS<br>☒ A RENEWAL<br>☐ AN ACCOMPLISHMENT-BASED RENEWAL | IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY?    YES ☐   NO ☒  IF YES, LIST ACRONYM(S) |
|---|---|---|
| 592924021 | 0851841 | |

| NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE | ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE |
|---|---|
| University of Central Florida | **University of Central Florida**<br>**Orlando, FL. 328263252** |

AWARDEE ORGANIZATION CODE (IF KNOWN)

**0039545000**

| NAME OF PRIMARY PLACE OF PERF | ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE |
|---|---|
| **University of Central Florida** | **University of Central Florida**<br><br>**FL ,328168005 ,US.** |

| IS AWARDEE ORGANIZATION (Check All That Apply)<br>(See GPG II.C For Definitions) | ☐ SMALL BUSINESS<br>☐ FOR-PROFIT ORGANIZATION | ☐ MINORITY BUSINESS<br>☐ WOMAN-OWNED BUSINESS | ☐ IF THIS IS A PRELIMINARY PROPOSAL<br>THEN CHECK HERE |
|---|---|---|---|

TITLE OF PROPOSED PROJECT   **REU Site: Research Experience for Undergraduates in Computer Vision**

| REQUESTED AMOUNT | PROPOSED DURATION (1-60 MONTHS) | REQUESTED STARTING DATE | SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE |
|---|---|---|---|
| $      375,197 | 36  months | 05/01/12 | |

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ EAGER* (GPG II.D.2)      ☐ RAPID** (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____
   PHS Animal Welfare Assurance Number _____

☐ HUMAN SUBJECTS (GPG II.D.7)  Human Subjects Assurance Number _____
   Exemption Subsection _____  or IRB App. Date _____
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED
   (GPG II.C.2.j)
_____
☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR
   REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

| PI/PD DEPARTMENT<br>**Joint appt w/Mathematics & Comp. Science** | PI/PD POSTAL ADDRESS<br>**Box 162362** |
|---|---|
| PI/PD FAX NUMBER<br>**407-823-5419** | **Orlando, FL 328162362**<br>**United States** |

| NAMES (TYPED) | High Degree | Yr of Degree | Telephone Number | Electronic Mail Address |
|---|---|---|---|---|
| PI/PD NAME<br>**Mubarak Shah** | **PhD** | **1986** | **407-823-5077** | **shah@cs.ucf.edu** |
| CO-PI/PD<br>**Niels D da Vitoria Lobo** | **Ph.D.** | **1992** | **407-823-2873** | **niels@cs.ucf.edu** |
| CO-PI/PD | | | | |
| CO-PI/PD | | | | |
| CO-PI/PD | | | | |

# CERTIFICATION PAGE

**Certification for Authorized Organizational Representative or Individual Applicant:**

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, lobbying activities (see below), responsible conduct of research, nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 11-1). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

**Conflict of Interest Certification**

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

**Drug Free Work Place Certification**

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

**Debarment and Suspension Certification**     (If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency?                                                    Yes ☐                    No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

**Certification Regarding Lobbying**

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

**Certification for Contracts, Grants, Loans and Cooperative Agreements**

The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

**Certification Regarding Nondiscrimination**

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

**Certification Regarding Flood Hazard Insurance**

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1)    community in which that area is located participates in the national flood insurance program; and
(2)    building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1)    for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2)    for other NSF Grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

**Certification Regarding Responsible Conduct of Research (RCR)**
**(This certification is not applicable to proposals for conferences, symposia, and workshops.)**

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research. The undersigned shall require that the language of this certification be included in any award documents for all subawards at all tiers.

| AUTHORIZED ORGANIZATIONAL REPRESENTATIVE | SIGNATURE | DATE |
|---|---|---|
| NAME<br>**Matthew A Cronan** | **Electronic Signature** | **Aug 24 2011  4:49PM** |

| TELEPHONE NUMBER | ELECTRONIC MAIL ADDRESS | FAX NUMBER |
|---|---|---|
| **407-823-3031** | **matthew.cronan@ucf.edu** | **407-823-3299** |

\* EAGER - EArly-concept Grants for Exploratory Research
\*\* RAPID - Grants for Rapid Response Research

**REU Site: Research Experience for Undergraduates in Computer Vision**
Mubarak A. Shah, Niels da Vitoria Lobo and Rahul Sukthankar

## PROJECT ELEMENTS

- Previously funded (NSF Award No. ID 0851841)
- Project Title: REU Site: Research Experience for Undergraduates in Computer Vision
- Principal Investigator: Mubarak A. Shah
- Submitted by: University of Central Florida
- Other organizations involved in the project's operation: None

- Location at which the proposed undergraduate research will occur: University of Central Florida
- Main field and sub-field: Computer Science, Computer Vision
- No. of undergraduate participants per year: 10
- REU site type: Summer
- No. of weeks per year: 12
- Project includes: Ethics Component (No Cost to NSF)
- Contact info for students: Mubarak Shah, phone: 407-823-5077, e-mail: shah@eecs.ucf.edu).
- The site web-address is `http://www.cs.ucf.edu/~vision/reu-web/REU.html`.

## PROJECT SUMMARY

This project represents a continuation of a Research Experience for Undergraduates site in Computer Vision which has operated successfully at the University of Central Florida for the past **twenty-four** years. Approximately **two hundred and forty** undergraduate students from forty-five institutions all over the country have participated in this program over the years. The research focus area is Computer Vision. The current proposal is to have 10 participants per year, for three years. Each year, students will participate in a 12-week duration full-time Summer program. From lessons learned in prior years, the proposed model includes round-the-clock mentoring by a team that includes a professor, and a post-doctoral fellow or a graduate student; a streamlined short course that lets participants start their research projects sooner; daily meetings with mentors to plan activities throughout the day; training in MatLab for quick turnaround of research ideas. Participants take the short course, match themselves to a project topic that they most desire, and spend sufficient time in focused research. They then can opt for follow-through over the year by working with the professors to write a technical report on their project, to prepare for the GREs and to apply to graduate programs. In past years, a substantial fraction of our REU participants have been able to prepare a paper for submission to a refereed conference, have the paper accepted and then attend the conference to present the paper.

**Intellectual Merit:** Development of new algorithms for solving scientific problems in learning scene models, geolocation using vision, object detection, tracking, activity and event recognition. We believe in both theory and practice; we are interested in mathematical modeling and analysis of difficult vision problems and developing algorithms, while at the same time building real systems for demonstrating those solutions in real life situations.

**Broader Impacts:** We will contribute to preparing a work force of young scientists in order to maintain America's previously-held strategic position of command in Science and Engineering. Participants will be trained in Computer Vision; in particular, they will learn fundamentals of image science and vision, which plays an important role in security/surveillance, gaming, entertainment, healthcare, defense, and manufacturing. Through this project we will able to provide opportunities to a diverse group of undergraduates, many from predominantly undergraduate institutions, to spend a summer with a highly successful research group. Our model for REU will be disseminated among other Schools.

# TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.B.2.

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| Cover Sheet for Proposal to the National Science Foundation | | |
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| Table of Contents | 1 | |
| Project Description (Including Results from Prior NSF Support) (not to exceed 15 pages) **(Exceed only if allowed by a specific program announcement/solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)** | 15 | |
| References Cited | 2 | |
| Biographical Sketches  (Not to exceed 2 pages each) | 6 | |
| Budget<br>(Plus up to 3 pages of budget justification) | 7 | |
| Current and Pending Support | 8 | |
| Facilities, Equipment and Other Resources | 1 | |
| Special Information/Supplementary Documents (Data Management Plan, Mentoring Plan and Other Supplementary Documents) | 3 | |
| Appendix (List below. )<br>**(Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)** | | |

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

# 1 Overview

Our society's future will be shaped by the young and talented minds going through our colleges and universities today. To maintain America's previously-held strategic position of command in Science and Engineering, American students need greater encouragement to pursue advanced studies in STEM disciplines. The goal of this REU site is to encourage more American undergraduates in Computer Science to pursue graduate studies, and to help them realize their full potential related to research. We believe that the best way to achieve this goal is to immerse capable undergraduates within **a successful, active research group**. This exposes them to the intellectual excitement that is involved in research activity, encourages them to think creatively and independently, and helps them to develop the skills necessary to work on research projects.

This proposed project represents renewal of the NSF-funded REU site in Computer Vision which has operated successfully at UCF for the past **twenty-four** years. Approximately **two hundred and forty** undergraduate students from **forty-five** institutions from all over the U.S. have participated in this program over the years. We propose to have 10 undergraduate researchers (henceforth termed **UGR**s) per year, for three years. Each year, UGRs will participate in a 12-week duration full-time Summer program, with optional follow-on part-time participation during the subsequent Fall and Spring. The key elements of our approach are (1) to have a full Summer experience planned for the UGRs, so that they have time to follow a substantial project through to completion, (2) to present each UGR with several possible project topics, so that they can feel they have chosen a project which is most interesting to them, (3) to immerse the UGRs in the general research environment essentially as if they were graduate students, by having them meet with their faculty advisor daily to discuss their project, participate in the weekly research group meetings, attend research presentations and meet with visiting researchers, and (4) to offer UGRs an optional follow-through over the year by working with the UGRs to write a technical report on their project, to prepare them for the GREs and help them apply to graduate programs. In past years, a substantial fraction of our UGRs have been able to prepare a paper for submission to a refereed conference, have the paper accepted and then attend the conference to present the paper. Several past UGRs have even accomplished enough research to additionally result in refereed journal publications.

Our previous experience has shown that interaction among UGRs from different institutions greatly increases the diversity of ideas and the quality of the experience. Hence, each year, our REU site will involve five undergraduates from UCF, and five from other institutions, mostly outside Florida.

# 2 Faculty Expertise and Research Environment

**2.1 Dr. Mubarak Shah** is Agere Chair professor of Computer Science, and the founding director of UCF's Computer Vision Laboratory. He is a fellow of IEEE, IAPR, AAAS and SPIE. In 2006, he was awarded a Pegasus Professor award, the highest award at UCF, given to a faculty member who has made a significant impact on the university, has made an extraordinary contribution to the university community, and has demonstrated excellence in teaching, research and service. In 2011, he received Scholarship of Teaching and Learning (SoTL) award. He is a Distinguished ACM Speaker. He was an IEEE Distinguished Speaker for 1997-2000 and received the IEEE Outstanding Engineering Educator Award in 1997. He received the Harris Corporation's Engineering Achievement Award in 1999, the TOKTEN awards from UNDP in 1995, 1997, and 2000; Teaching Incentive Program award in 1995 and 2003, Research Incentive Award in 2003, Millionaires' Club awards in 2005, 2006, 2009, 2010 and 2011; University Distinguished Researcher award in 2007; SANA award in 2007, an honorable mention for the ICCV 2005 Where Am I? Challenge Problem, and was nominated for the best paper award in ACM Multimedia Conference in 2005 and 2010.

Dr. Shah has co-authored three books, has published twelve book chapters, more than eighty journal and over 200 research papers in prestigious journals and conferences. He has supervised 24 Ph.D.

and 13 M.S. and 12 BS theses to completion, and is currently supervising more than 20 Ph.D. students. He has presented several short courses and more than one hundred and fifty keynote and invited talks all over the world. His pedagogical contributions are covered in several text books by popular authors: *Computer and Robot Vision* (Haralick and Shapiro), *Introductory Techniques for 3D Computer Vision* (Veri and Trucco), *Computer Vision* (Shapiro and Stockman), *Computer Vision: Algorithms and Applications* (Richard Szeliski) and taught in introductory classes in the US and all over the world. The implementation of Williams-Shah Active Contour algorithm is a regular exercise at many Universities; it is being used in other fields like medical imaging and entertainment; it is part of the Intel Open CV library, and numerous implementations are available on the internet; it has made one of the most fundamental contributions to the field (with more than 1,000 citations), and has popularized *snakes* in the vision community and beyond.

Dr. Shah has worked with a large number of undergraduates throughout his career (and been P.I. for the REU site for 24 years). These undergraduates have co-authored 79 research papers (in reputed journals, such as, PAMI, PR, CVGIP, and conferences, such as, ICCV, CVPR, ICPR). (See [5], for more detail). Approximately half of the participants in his REU site have gone to graduate schools, fifteen students have written Honors in the Major Theses, several participants are now faculty members at Universities, and five have started their own companies. Dr. Shah has published two papers in IEEE Transactions on Education, on education and training [1, 2]. Recently he co-authored two conference papers on mentoring math undergraduates in numerical methods [25, 26]. He co-organized the IEEE Course and Curriculum Development Workshop in 2001. He has organized two CISE NSF REU PI meetings (in 2002 in Orlando and in 2004 in Monterey). Dr. Shah introduced a new undergraduate honors course "Computer Vision Guided Tour of Mathematics", which he co-taught with a Math Professor; the main objective of this course is to re-invigorate interest in mathematics among students to deal with the declining enrollment in math related courses.

In addition to undergraduates, he has directed High School students, who have won prizes in Science Fair competitions. Several highly-successful cases are reported in the two-page biography section.

**2.2 Dr. Niels Da Vitoria Lobo** is an Associate Professor of Computer Science. He received the B.Sc. (Honors) from Dalhousie University, Canada, and the M.Sc. and Ph.D. from U. of Toronto. He joined UCF in 1993, and since then has supervised over 20 Ph.D., M.S., and B.S. theses to completion.

Dr. Lobo's research interests are in computer vision. In his graduate work, he introduced a collinear point algorithm for solving for 3-D motion in difficult structure-from-motion problems, in which independent motion occurs. Following that, he conducted research leading to the first real-time physics-based (Navier-Stokes) fluid model for animation. He has been innovative in processing facial images, offering the first algorithms for age classification and matching police sketches to mugshot images. He introduced the use of the Lekner and Dorf physical model for computing whether a visible surface appears wet or dry. He introduced the analysis of defocused motion, in which a scene defocuses due to relative camera motion. He co-authored a book ("Visual Event Detection", Kluwer, 2001), which offers a framework for handcrafting event recognizers. In addition, he has worked in the areas of object recognition and tracking. He has published over 60 refereed papers in journals and conferences, and has received funding from NSF, DoD, Harris Corporation, Boeing Corporation, Lockheed Martin Corporation, and several smaller organizations. He has been active in UCF's Computer Vision REU site since 1993, very active in its management since 1998, and has published 22 refereed papers with undergraduates. In 1996 and 2009, he received the Florida Teaching Incentive Program (TIP) Award. He has five patents, with his students as co-inventors. He was the faculty advisor for UCF's highly visible ACM undergraduate chapter from 1995 to 2006. He has been PI on an NSF-ITEST in which he worked with high schools in the local school district.

**2.3 Dr. Rahul Sukthankar** recently joined Google Research but continues to be actively affiliated

in academic research as Adjunct Research Professor at Carnegie Mellon (since 1997) and Courtesy Faculty in EECS at UCF (since 2007). Dr. Sukthankar received his B.S.E. (Highest Honors) in Computer Science from Princeton and his Ph.D. in Robotics from Carnegie Mellon. Previously, he was a Senior Principal Research Scientist at Intel Labs (2003-2011), where he led the company's efforts on Computational Perception, a Senior Researcher with HP Labs/Compaq Research (2000-2003), and a Research Scientist at Just Research (1997-2000). His current research focuses on computer vision and machine learning, particularly with applications to object recognition, action recognition and multimedia retrieval. Dr. Sukthankar has published over 100 refereed top-tier conference and journal papers, organized several conferences and workshops and edited special issues in leading academic journals. He currently serves as Associate Editor of MVA and IEEE Pervasive Computing.

Dr. Sukthankar currently co-supervises Ph.D. students at UCF and CMU and has served as an external member on thesis committees at several institutions. His former students have gone on to both faculty positions (e.g., UIUC) and industrial research (e.g., Microsoft). Dr. Sukthankar has participated in UCF's REU program since 2008. Some successes from the program include Kevin Tang, who published a CVPR paper on his REU project and is now a Ph.D. student at Stanford and Joel Jurik, a UCF undergraduate who continued his REU project at NVIDIA and is now a Ph.D. student at USC.

## 2.4 Research Environment

UCF currently enrolls over 57,000 students and has the second largest undergraduate student population in the country. UCF is strategically situated in one of the nation's most dynamic metropolitan areas. In addition to being the nation's center for entertainment and entertainment technology, the Orlando area is one of the most advanced high-tech areas in the South-East, and hosts stalwarts such as Lockheed-Martin, Siemens, the Naval Training Systems Center, NASA Kennedy Space Center, Harris Corporation, Boeing, Oracle, AMD (ATI), Electronic Arts Corporation, and all the industries in the Central Florida Research Park. Orlando is at the center of Florida's High Tech Corridor, home to numerous new and emerging high-tech companies.

UCF's Department of Electrical Engineering and Computer Science moved in 2006 to a new 75,000 square-feet building, with state of the art laboratories and an attractive environment for faculty-student interaction. UCF has identified Computer Science as a key area for future growth and academic excellence, and has allocated substantial enhancement funds to accomplish this goal.

The UCF Computer Vision Lab [4] is one of the leading vision labs in the world (according to Google, the Lab's website is the most popular). The Computer Vision group currently consists of over twenty Ph.D. students, five undergraduates, two post docs, a lab manager, and three visitors. Eight new Ph.D. students have joined the lab in Fall 2011. The research is funded by NSF, DARPA, IARPA, ARO, DHS, Army Night Vision Lab, and industry. Funded projects include: DARPA VIRAT (Video Image Retrieval and Analysis Tool); DARPA PerSEAS (Persistent Stare Exploitation and Analysis System); IARPA ALADDIN (Automated Low-Level Analysis and Description of Diverse Intelligence Video); DHS ISIS Video Data for the Wide Area Surveillance; Visual Crowd Analysis by ARO, etc.

The lab is very active in publishing in high quality journals and conferences. The UCF Computer Vision Lab has consistently published some of the largest number of papers in the three most prestigious conferences (CVPR, ICCV and ECCV) with acceptance rate as low as 4%. Former PhD graduates of the lab have gone to high-ranked institutions like CMU, Oxford, Ohio State and companies like IBM, SRI, SAIC, and ObjectVideo.

The lab currently houses over fifty desktop and laptop computers, numerous cameras (EO, IR), projectors, TV monitors, printers and recording devices. Each graduate student is given a laptop. The UGRs typically prefer to use their own laptops, but we will have three spare laptops to supplement their needs.

The UGRs will be integrated with the graduate students, and this environment has previously been

very successful in stimulating UGRs and leading them to publish (see list at [5]).

The new UCF Provost, Dr. Waldrop, has made undergraduate research the highest University Priority and has sponsored the creation of an undergraduate research office [8]. In addition to the proposed continued Computer Vision REU site, UCF currently has NSF REU sites in Laser Optics, and Advanced Materials. Other funding sources augment the undergraduate research programs at UCF, so that overall undergraduate research activity is quite high. NSF funding is critical to continued success of the quality environment UCF is striving to maintain in undergraduate research. Continuation of this site will also extend opportunities to undergraduates across the nation, including from primarily four-year colleges, to participate in a high-quality, motivating, and door-opening, summer experience. UCF also has a strong ACM programming team consisting of CS undergrads, which for the last twenty-eight years has won the Southeast Regional Contest (typically 80-90 teams) twelve times, placed 2nd nine times, and placed 3rd the remaining seven times.

# 3   Results From Prior NSF REU Site Grants

We have received NSF REU Site grants for the past 24 years. Approximately **two hundred and forty** undergraduate students from eight institutions in Florida and thirty-seven institutions from other states, have participated in UCF's program. These UGRs have co-authored 79 research papers (see [5]), approximately **half** of all our UGRs have gone to graduate schools, fifteen have written Honors in the Major Theses, five past UGRs are now faculty members at different Universities, and five past UGRs have started their own companies. Please visit [5] for examples of success over the 24 years; it also provides the names and home institutions of the UGRs over the years.

During the past five years from Summer 2007 to (including) Summer 2011, 49 undergraduates have participated: twenty-two from UCF, twenty-seven from outside. We are short one student this past summer (of 2011), because a female student from South Carolina quit during the first week. Of the 49 participants, eight are female; of the 41 males, four are Hispanic, one is African-American; out of the 36 males who are neither Hispanic nor African-American, fourteen are first-generation-in-college. Thus, over half of our participants satisfy at least one of the descriptions: female, Hispanic, African-American, or first-generation-in-college. Of the 49, six got high-quality ([15, 14, 13, 12, 10, 9], for all these the acceptance rate is lower than 25%) refereed publications (an additional two have a journal submission under review [11]), and thirty-nine others turned in final reports; nineteen have already proceeded to graduate school, and the majority from the recent summers (2010 and 2011) are indicating an interest in pursuing graduate school, but are not finished their undergraduate degrees yet. Students who did not pursue graduate school include those who accepted attractive offers from companies like LinkedIn, Facebook, Apple and Google. All 49 students did weekly presentations throughout the summer and improved their skills at researching and communicating technical material. The 27 non-UCF UGRs came from the following schools: Elizabethtown College, Bemidji State U., Eastern Illinois U., Clemson U., Tufts, U. Winconsin-Madison, CMU, Cornell, Rice, U. Florida, U. Rochester, Indiana University-Purdue, U. Southern California, U. Nevada-Reno, U. Notre Dame, Amherst College, M.I.T., Clemson U., and U Maryland-College Park.

In addition to the 49 students, over the five years, we have embedded 10 High-School teachers (funded by RET-supplements to our REU site grant) within the REU. The teacher demographics are: three female, two African-American, one Hispanic. The teachers teach High School mathematics in heavily minority populated schools (where Hispanic and African-American combined populations exceed seventy percent).

Here are some highlights from the past five years:

- 2010-2011 UGR from UCF, Antonio Rodriguez, worked on statistical models of learning, and, in particular, Category Learning from One Example. He is currently pursuing the PhD in Operations Research at Georgia Tech.

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- 2009-2010 UGR from UCF, Joel Jurik, worked on using visual bits for category learning. His project concluded that visual bits outperform the bag of words model for object category recognition. He then worked at NVIDIA, and is now getting his PhD at USC in computer vision.
- 2009-2010 UGR from Cornell U., Kevin Tang, worked on the topic of visual learning from a single example. He published his paper at CVPR-2010, and is pursuing machine learning and computer vision in the PhD program at Stanford U.
- 2009-2010 UGR from U. Wisconsin, Lance Hartung, worked on detection of anomalous motion using unsupervised learning from dense optical flow. His paper was published at CVPR-2010. He is in the PhD program at U. Wisconsin-Madison.
- 2009-2010 UGR from Eastern Illinois U., Jonathan Harter, worked on developing navigation algorithms and gesture recognition using a four-camera device. His REU work is under review for a journal, and he is now a PhD student at UNC-Chapel Hill.
- 2009-2010 UGR from U. Notre Dame, Sean McMillan, worked on the NIST TRECVID competition project; he is currently pursuing the PhD at U. Michigan.
- 2009-2010 UGR from Amherst College, Benjamin Mears, worked on classification using motion and the weighting of features. He assisted UCF's effort in the NIST TRECVID Classification Competition. He is pursuing the PhD at UMass-Amherst in computer vision.
- 2008-2009 UGR from IUPUI, Karthik Prabhakar, worked on Action Recognition for the UCF Sports Data Set. He employed Linear and Log Polar 3D binning, and got very promising baseline results on the dataset. He won an NSF Graduate Fellowship and is pursuing the PhD at Georgia Tech, working on computer vision with James Rehg.
- 2008-2009 UGR from U. Nevada-Reno, Alexis Oyama, worked on detection abnormal crowd behaviors, using a force model. He got a paper in CVPR-2009. He is now a graduate student at Carnegie Mellon University's Entertainment Technology Center.
- 2008-2009 UGR from UCF, Sarah Applegate worked on pedagogical research using imaging applications to introduce computing to High School students in their mathematics classes. She is now in the MS program at UCF.
- 2008-2009 UGR from UCF, Jason Hochreiter, worked on classification of events and concepts for the TRECVID Classification Competition. In Spring 2012, he intends to commence the PhD at UCF in computer vision.
- 2008-2009 UGR from U. Rochester, Lam Tran, worked on shape from shading computation using Markov Random Fields. He published his work in a conference that accompanied the prestigious ICCV. Lam won an NSF Graduate Fellowship, and is in the PhD program at UC San Diego, working in the area of Conditional Random Fields for computer vision.
- 2008-2009 UGR from U. Florida, Joshua Hartman, is currently working at LinkedIn, using vision and machine learning approaches he investigated in the UCF-REU.
- 2007-2008 UGR Andrew Miller published papers in ICME 2007, AAAI 2007, and ICRA 2008. In addition, Andrew was the only undergraduate member on the UCF team that entered a robotic car in the DARPA Urban Challenge, in which the UCF team reached the finals. Andrew also led the UCF team for CLEAR and ETISEO evaluation, and published two summary papers in Springer LNCS. His work received the Best Poster Award: Most Technically Challenging Project at the 2008 REU PI meeting. Currently he is in the PhD program at UCF.

- 2007-2008 UGR from a four-year college, Elizabethtown College, James Painter, worked on GPU-based acceleration of image denoising/deblurring algorithms. He submitted his work to ICASSP, was rejected, but unfortunately was unable to continue work on the research for resubmission. He did the MS in Image Systems at Stanford University, then interned in Intel's vision group for two years, and spent Summer 2011 interning at Sharp Labs working on Advanced Video and Display. He is now in the computer vision PhD at Temple University.

- 2007-2008 UGR Taylor Goodhart from Rice University worked on computing visual motion using SPREFS, and got a paper accepted at International Conference on Acoustics, Speech and Signal Processing (ICASSP-2008). Taylor has been working at Applied Signal Technology (Raytheon) for the past two years, and intends to continue to graduate school within two years.

  **Some earlier examples of successful students are:**
- In 2005-2006, Vladimir Reilly's REU project was on human detection. He completed his BS Honors thesis in 2006 and was admitted to Ph.D. at UCF with a fellowship. He published his first paper at CVPR 2007, and has since then published many more. He is close to finishing his PhD in computer science at UCF.
- Jan Prokaj, participated in 2005-06, published his REU work as a paper in Springer-LNCS and is now a PhD student at University of Southern California.
- Chris Schwarz, participated in 2004-05, published two papers from his REU project, and is now a PhD student at UC-Davis in medical imaging.

Our model for REU has generated praise and interest among colleagues. In 1990 NSF selected three top REU groups in the nation: Cornell, Arizona and **UCF**. Dr. Shah was invited to visit Washington with an undergraduate student and give a talk about REU. We have received requests for copies of our winning proposal from several schools, in particular, predominantly undergraduate institutions. We have made our proposal available on the web [6]. In June 1997, we also presented our REU model and our experience in mentoring undergraduates in the *IEEE Workshop on Undergraduate Education & Image Computation*, with a large number of participants from undergraduate institutions in attendance, who were supported by NSF travel grants. The final version of our REU model was published in IEEE Transactions on Education [1]. In August 2007, we celebrated 20 Years of NSF REU at UCF, and had previous UGRs visit and share their successes with current UGRs [3].

In addition to the REU site, Dr. Shah is P.I. for a recent NSF-CSUMS project, and a recent NSF-SSTEP project. and Dr. Lobo has been P.I. on an NSF-ITEST project.

# 4  Lessons Learned from Prior Years

In recent years, we have experimented with several new practices in our REU model. In Summers of 2010 and 2011, we also experimented with professional assessment. We used feedback received in the middle of both summers to make adjustments to improve the quality of the UGR experience. Here are some lessons learned, and the corrective actions we propose to implement in the new REU. Additionally, the new site includes the assessment process as a regular component (see Section 9).

- On each UGR's team include a Grad Student or a Post-Doc, and a Professor. Since each UGR is given a desk (with a laptop/desktop) in the Computer Vision Lab, which is also populated by graduate students and post docs, this is a great opportunity for UGRs to constantly interact with more experienced researchers, and experience their working style and get inspired. Several REU projects are extensions of current and past graduate students' projects, this arrangement provides UGRs an opportunity to bounce ideas and seek help in programming and some math related concepts. By providing each UGR with his/her own mentoring team, the UGR is able to get round-the-clock mentoring and assistance.
- Fine-Tune the Contents of the Short Course. This is intended to help the UGRs dive into their research as quickly as possible. To accomplish this, we have identified several key topics that form the basis of most modern computer vision research. Helping the UGRs master these topics quickly will enable them to better understand current research and push their projects farther and more quickly. These topics include:
  - Numerical Optimization – We introduce UGRs to the concept of numerically optimizing functions. They are also taught the steepest-descent algorithm for optimizing functions.

- Pattern Recognition – UGRs are introduced to basic models of classification, including boosting and logistic regression.
- Image Processing - UGRs are introduced to linear filtering and basic non-linear filtering, such as median filtering.
- Computer Vision concepts of Edge Detection, Optical Flow, and Pyramids

To help the UGRs progress quickly, we introduce them to the MATLAB programming environment. MATLAB has become popular in the computer vision research community because it supports rapid development and experimentation. We introduce the UGRs to MATLAB and the above topics simultaneously by giving them implementations of key algorithms, with select portions removed. The UGRs are trained to implement algorithms in MATLAB and also see how mathematical models can be translated into code.

- Choose a Research Topic as early as possible, by end of second (or third) week; as, after this, UGRs need at least nine weeks of focused attention on the topic to make sufficient progress.
- Advertise and maintain a daily schedule of mentoring and monitoring student activity. Meeting with the UGR at start and end of day keeps the whole team focused and staying on task.
- Have balanced distribution of students amongst advisors. We are including a third team member, an adjunct faculty member Rahul Suktankar, an accomplished researcher who graduated from CMU and is now at Google, who is able to mentor several undergraduates. So a balanced distribution of UGRs will be easy to achieve. It appears that roughly three to four UGRs per advisor is optimal for providing each student the attention needed. In addition, each UGR will have at least one advanced Ph.D. student on his/her team.

# 5 Proposed Activities: Sample Research Projects

This section briefly outlines some example research projects for the UGRs. When the time arrives for UGRs to select individual projects, the P.I.s present the UGRs with a greater number of possible topics than there are participants, so that each UGR will be able, within these limits, to **choose** a project topic rather than have one **assigned**. We feel that this is important in terms of having the UGR feel that the project is "theirs." Also, we are careful to structure projects so that they have several possible levels of completion. This ensures that each UGR will be able to complete some (possibly simplified) version of their project and experience the resulting feeling of accomplishment. It also allows the more talented or ambitious UGR who works hard enough to achieve a substantial research publication.

## 5.1 Sample Project: Action/Activity Recognition

Action recognition is a very interesting and challenging problem in computer vision. In recent years, there has been a growing interest in visual surveillance and security. Different approaches have been proposed over years which have many limitations and can hardly handle real world videos [27, 31, 28]. One reason for this limitation in the area of research, is the lack of publically available datasets with realistic videos taken in unconstrained environments. The Computer Vision Lab at UCF has generated an action recognition dataset called UCF50. This new dataset has the highest number of action categories than any other available action recognition dataset. This dataset is generated by downloading user uploaded videos from YouTube which depict everyday human activities commonly performed, and therefore these videos are considered unconstrained videos. Here are some of the challenges embedded in the UCF50 dataset: 50 action categories, random camera motion, poor video quality and lighting conditions, significant clutter, and changes in scale, appearance and viewpoints.

In this project we need to develop a new method to perform human action recognition on the UCF50 dataset, achieving high performance. Thus far, our lab has conducted early work to show that scene information along with motion information when properly fused helps to improve the performance over the baseline (which is the Bag of Video Words approach, [27]). The current performance we have achieved on UCF50 using scene context information in conjunction with motion descriptors is

68.20% compared to 53.06% using Bag of Video Words approach. The goal is to improve these results. Various ideas can be pursued: a) Use multiple features from motion, appearance and scene and properly fusing them [29]. b) Use particle trajectories and Robust-PCA on UCF50 [30]. c) Improving Bag of Video Words representation using GMST (Genearlized Minimum Spanning Tree). Since GMST is computationally expensive an alternative to GMST would also be a valuable contribution. d) Dividing the actions into atomic actions, for example, that the pole vault action can be considered to have the following atomic actions: running, jumping and falling down in sequence. One can explore the idea of detecting atomic actions and use HMMs to capture the order of these atomic actions to make a decision on the action class. Research in this direction would help UCF's team's participation in the TRECVID challenge, an international competition for algorithms for recognizing actions in video data [24].

## 5.2 Sample Project: Detection of complex road structures from surveillance and UAV videos using spatio-temporal dependencies of motion patterns

The objective of the project is to be able to detect complex road networks and structures such as intersections, flyovers, circular roads, bus stops, etc., using combinations of motion patterns. This will be done by defining the spatio-temporal relationships of motion patterns that are obtained from such networks and recognizing them in query videos. A group of patterns that constitutes a road network may be represented using graphs, with the nodes in the graph representing patterns and the edges representing transformations that exist between patterns in the group. This work is based on our previous work on motion patterns, co-authored by a 2009-10 UGR [10], which should be good inspiration to a new UGR.

A UGR would begin by reading the following papers [10, 19, 20]. One of the objectives will also be to improve the existing methods for obtaining patterns and transformations between patterns. Some of the steps to be undertaken by the UGR are: a) Identify additional examples of road networks that may identifiable using the proposed approach. There may also be other applications of this method not necessarily restricted to roads, such as pedestrian walkways or entry and exit points. b) Collect instances of relevant events from these datasets data sets such as CLIF and NGSIM. 3) Work on improving methods for obtaining motion patterns and their inter-dependencies. 4) Obtain motion patterns from these events and use them to perform graph matching.

## 5.3 Sample Project: The Where Am I? Project

The Where Am I? Project is about finding exact geolocation of images. The input to the systems developed in this project is an image, and the output is the exact location where the image has been photographed. In [16], we presented an algorithm that uses SIFT features of the query image to match SIFT features of the reference images employing nearest-neighbor search in a tree. Each of the retrieved nearest-neighbors then vote for the reference image it originated from. Smoothing and pruning, followed by a measurement of Localization Confidence, yield good estimates of where the query image was photographed.

### 5.3.1 Subproject A: Use Reverse Geocoding and Yellow pages in order to retrieve the name of the businesses shown in the query image:

The output of [16] is the location of the camera at the instance of taking the query image. The goal of this subproject is finding the location of the objects shown in the query image and retrieving further information such as the reviews for the businesses shown in the image.

To work on this subproject, a UGR would first understand the SIFT feature finder method in reasonable depth. An easy-to-understand, practical tutorial page for SIFT by VLFeat can be found at [22]. The reference paper for SIFT and its basic implementation are at [21]. The next step would be for the UGR to read and understand our paper [16]. Several presentations and documents are available for understanding [16]. Another step requires reverse Geocoding. Reverse Geocoding is the process of finding the physical address of given GPS coordinates (Longitude and Latitude). There are several

easy-to-understand APIs available on the web for reverse geocoding. The UGR would work with these APIs, and learn how to call them from a MATLAB or C++ environment. An additional step requires retrieving some information about a business having its physical address. There are several resources and APIs for this purpose. Yellow pages, Yelp and Google are good examples. The UGR would learn how to work with them and call them from a MATLAB or C++ environment. There are also parts of this project that require the use of recognition of text and icons in the marquees storefronts of campanies.

### 5.3.2 Subproject B: Generating Reference Dataset using User-uploaded images:
In [16], we used a reference dataset based on Google Street view. It is useful to extend this approach to the locations where there is no street view.

The students who are interested in this subproject should read the IM2GPS paper [23]. In this paper, user uploaded images are used as the reference dataset for the purpose of extracting geographical information. Some information about their crawler is available at their webpage.

The UGR would start from collecting images from photo sharing websites such as Flickr, Panoramio and Picasa using a crawler. Several crawlers for these websites are available on the web. The UGR would run the crawlers and monitor their progress. The downloaded images would be filtered based on the quality of their location-tag as we are not interested in images which have very inaccurate tags. Some cameras have built-in GPS chips. The images taken by these cameras are ideal examples of images for this project. The project would start with Pittsburgh, PA. We can later extend this to Manhattan and Orlando. If the project can successfully complete these cities, a subsequent target would be cities for which there is no street view, such as Beijing.

Based on the quality and the number of useful images the next step will be determined. If the number of images is large enough in a way that we have a dense sampling of the city, we might be able to immediately apply the method in [16] and localize new query images. However, if the sampling is not dense enough, we might have to have additional steps, such as the ones in Subproject A, in order to make the dataset more useful.

## 5.4 Other Sample Project Topics
Additional topics are available in: on-line algorithms for tracking object motion; underwater vision; unmanned aerial vehicle perception; analysis of brain activity from FMRI signals; medical image segmentation and diagnosis; all of these are areas in which our lab has recent high-quality publications and advanced PhD students pursuing active investigations.

# 6 Proposed Activities: Logistics

## 6.1 Project Schedule
*May 17 – May 31*

The first major activity for the students is the short course in Computer Vision. Drs. Shah and Lobo will present four-hour lectures (with breaks) on Mondays, Wednesdays, and Fridays. During the remainder of each week, the UGRs will be assigned some readings in the area covered by the lecture material and be given one or two short programming projects which support the material. Early on, additional instruction in Matlab programming and image manipulation routines will be given. The short course will last for 2 weeks. The content and schedule of the short course have been arrived at by substantial experimentation over the past five years of UCF's REU.

*May 21 – June 1*

During May 21 – June 1, the advisors, post-docs and (many) graduate students will present daily half-hour lectures (for a total of about 1.5 hours per day); at least twenty-five possible projects and research topics will be presented. Each UGR will then be asked to make a short-list of topics of interest, iterating until a topic is finalized. UGRs will also be asked if they prefer a topic outside of those covered in detail, in which case several meetings will be spent on assisting him/her to refine

| Activity | Frequency | Dates |
|---|---|---|
| Computer Vision Short Course | Every Mon–Wed–Fri | May 17–May 31 |
| Research Presentations/Topic Selection | Eight days | May 21–June 1 |
| Ethics and Computing | Four lectures | July 15–July 22 |
| **Research Project** | | |
| Initial project selection | - | May 21–June 1 |
| Focused research activity | - | June 1–Aug 5 |
| Poster Presentation | 1 event | Aug 9 |
| Write Report/Paper | - | Aug 1–Aug 11 |
| Optional Follow-up; Write Report/Paper | telecon every two weeks | August – April |
| **Student-Faculty Interaction** | | |
| Individual Meetings | Start and end of each day | Summer |
| UCF Vision Research Group Meetings | Weekly | Summer |
| REU Group Meetings | Weekly | Summer |
| Distinguished Speaker Series | 2 | Summer |
| Participation in Professional Meetings | One | Variable |
| Career Mentoring (Summer) | every three weeks | Summer |
| Career Mentoring (Fall/Spring) | as needed | year-round to apply to grad schools |
| **Professional Mentoring Events** | | |
| BBQ Cookout | 1 | Late May |
| Buffet lunch | 2 | Late-June & Late-July |
| REU Banquet | 1 | August 10 |
| Dinner with Distinguished Speaker | 1 | Summer |
| Dinner for graduating Ph.D. student | at least 1 | Summer |
| **Field Trips** | | |
| Kennedy Space Center & UCF LaunchPad | 1 | Summer |
| Hi-Tech Company, e.g., Lockheed-Martin | 2 | Summer |

Figure 1: REU Activities Through the Year.

the topic and providing him/her with the necessary background so that s/he can further clarify the issues in his/her chosen topic. UGRs will be given background reading material and program fragments for their chosen project. The program fragments will come from current/prior projects in our lab and shared computer vision programs from the Internet. This will enable each UGR to get off to a productive and quick start on their project. There will be the occasional UGR who will arrive on the first day with a topic in mind, and our structure will also accommodate this participant easily.

*June 1 – August 5*

Through the next nine weeks, UGRs will be engaged in focused research activity. The group will meet once a week (Fridays) for ninety minutes to give progress reports. The UGRs will be divided into those who report on odd-numbered weeks, and those who report on even-numbered weeks. Each UGR will present a powerpoint presentation of their progress during the past two weeks. The presentation will be about fifteen minutes and will sketch out progress made, delays encountered, dead-ends run into, help needed, and plans for the next week. At the end of his/her presentation, each UGR should expect to get feedback comments and assistance from the professors, post-docs, the graduate students assisting them, and most importantly from their peers. We have found that this meeting/reporting structure

facilitates code-sharing, group bonding, and quick solutions to problems related to infrastructure such as compiler problems, compression formats, hardware issues, insufficient disk space, laptop crashes, etc. Additionally, the UGRs with more insight can offer helpful suggestions to those who are struggling. Also, the peer support factor and the public reporting keep the UGRs motivated to ensure that they have something to report every two weeks.

By August 5, UGRs should be prepared to write a detailed report of their research project. Some will also possibly have conducted initial experiments and will have initial results. Some might even be as advanced as being in a position to write up a first rough draft of a paper to eventually be sent to reviewed submission.

## 6.2 Poster Presentation

Around August 9, each UGR will prepare a conference-style poster from their most recent power-point presentation, and will participate in the University-wide REU Symposium, to which dignitaries, local industry leaders, and the REUs in the other areas at UCF will be invited.

## 6.3 Mentoring to Encourage Success

One of the important goals of this experience is sparking the UGR's interest in scientific research as early as possible through student-faculty and student-student interaction. At the same time, we feel that each UGR must have sufficient time to mull over problems and somewhat independently achieve a reasonable level of solution of a problem of their own choosing. UGRs will generally be able to accomplish a lot of learning and research in their projects during the summer, as they will pursue this work full-time. If they get a sufficient amount of work completed during the summer, they can opt to spend time during the subsequent two regular academic semesters, conducting additional experiments, and polishing up their work for submission to publication.

### 6.3.1 Student-Faculty Interaction

The appropriate level of student-faculty interaction and supervision of the UGRs will be achieved by the following means:

**Daily Individual Meetings** Each advisor will meet with each of the three or four assigned UGRs for about five minutes at the beginning of each day and at the end of each day. The morning meeting will overview the plan for the day, and the evening meeting will review progress and results, and discuss options to consider the next day.

**Office Hours** Each advisor will set aside 3-5 hours per week of office hours strictly for REU UGRs. The UGRs will have a chance to ask questions and discuss projects during this time in addition to other regular meetings.

**Post-Doc and GTA Office Hours** The two graduate student tutors will hold 10 hours weekly office hours for the UGRs. UGRs can get help with matters related to equipment, computer systems, implementation details, and programming. The post-docs will meet with the UGRs on an as-needed basis. The additional one or two advanced Ph.D. students on the UGR's research team will also be available for support every day for about half an hour.

**Weekly UCF Computer Vision Research Group Meetings** The advisors hold a weekly seminar-style meeting with their graduate research group, in which current research papers are discussed, up-coming presentations by group members are rehearsed and discussed, papers by group members (PhD students) are "pre-reviewed," participants give presentations on the status of their project, etc. This meeting is held in the evening and starts with an informal dinner for the whole group and takes roughly two hours. The UGRs will attend these meetings as observers, and will be encouraged to make comments, participate in discussions, ask questions, etc.

**REU Group Meetings** The whole REU group (advisors, post-docs, grad students and UGRs) will meet weekly on Fridays for the UGRs' report presentations.

## 6.4 Fall and Spring Follow-up

During the Fall and Spring semesters, UGRs who choose to, will continue working on their individual projects. Financial support for some of these UGRs will be available from other grant and scholarship opportunities. The in-state UGRs will continue to make presentations of their project progress. The out-of-state UGRs will be kept in touch via video-conferences with the professors.

UGRs will be encouraged to take computer vision classes (if available at their universities/colleges), independent study courses, senior design project or senior thesis, to get credit for the work they are accomplishing in the REU. We will help them as they apply for graduate school admission during the academic year. We will encourage them to take the GREs early enough that they can take them again if they do not do well initially. (It has been our experience that students taking the exam a second time often improve their score by over a hundred points.) We will advise UGRs about which schools have good programs in what subareas. We will also direct qualified students to apply for graduate fellowships awarded by NSF, NASA, ONR, AFOSR, the Goldwater program, the Hertz Foundation, the McKnight program, and their own States. We will facilitate interaction with outside researchers visiting campus during the academic year, so that UGRs develop the contacts necessary for admission to the best schools. We will also contact company representatives and have them arrange interviews and site visits for students interested in industry. Further, the UGRs will be taken to at least one conference/workshop at which Computer Vision is a major topic. At the end of the year, each UGR will be asked to write a comprehensive report describing the project. UGRs with publishable results will be encouraged to write conference and/or journal papers.

## 6.5 Distinguished Speaker Series

UCF conducts a Distinguished Speaker Series in Computer Vision, as part of its commitment to excellence in computer vision. As part of this series, eight to ten world-class researchers (typically Fellows in IEEE and/or ACM and/or SPIE) speak at UCF each year, and spend two days on campus. At least two of these are scheduled during the summer semester. All ten UGRs will hear these two speakers during the summer, and will be invited to meet with the speakers in an informal discussion session where the UGRs will be free to ask questions related to any topic in computer vision. In the past, the UGRs have also made brief presentations on their project directions and received invaluable advice and comments from the speakers. The UCF UGRs will also be able to benefit from the Distinguished Speaker visits during the Fall and Spring following the summer. The 2007-2011 speakers have included: Larry Davis (U Maryland), Takeo Kanade (CMU), Dmitri Terzopoulos (UCLA), David Fleet (Toronto), Jitendra Malik (Berkeley), Jan-Olof Eklund (KTH-Sweden).

## 6.6 Participation in Professional Meetings

Attendance at professional meetings gives the UGRs exposure to well-known researchers in the field, provides an opportunity to see polished and less-polished research presentations, and provides an opportunity to assimilate the latest research results. We propose to take as many of the UGRs as possible to at least one professional meeting related to computer vision. We are fortunate in that our geographic location in Orlando will make this possible at a reasonable cost. The annual SPIE AeroSense meeting held in Orlando each summer has at least one conference devoted to robotics and computer vision. This will be our default option. In many years, a more focused meeting is held close by.

## 6.7 Professional Mentoring Events

Our lab's motto is: *if you work hard, then you must play even harder.* To ensure that this message is not lost in the midst of all the scholarly activity, we will schedule six Professional Mentoring events: 1) a BBQ-cookout for all the University-wide REUs; 2) and 3) two "Orlando special" buffet lunches with the professors; 4) a dinner event at a professor's house, where a Distinguished Speaker of international fame in computer vision will attend, 5) a dinner event for any graduating Ph.D. student from our lab, and 6) a dockers/dress-shirt "graduation" banquet at a restaurant that is comparable to the banquets at

the major conferences/workshops (this, held the day after poster presentations, is intended to give the UGRs the full experience of the professional research life). All these Professional events provide the professors with venues to continue mentoring in non-scholarly aspects of the profession.

## 6.8 Field Trips

To give our REU participants exposure to hi-tech industrial opportunities, we will arrange field trips to 1) a behind-the-scenes tour of NASA Kennedy Space Center, including a visit to the launchpad operated by UCF's Space Institute; 2) Lockheed Martin's Missiles Division; and 3) Harris Corporation's Satellite Communication Labs. These serve as samples of industries that employ graduates of M.S. and Ph.D. programs. We already have working relationships with these companies since they have been supporting our research over the years.

## 6.9 Ethics component is presented in Appendix A in Supplementary Documentation.

The Ethics Component is presented under Supplementary Documentation, and will not require the NSF to disburse additional funds for its inclusion in the project.

## 6.10 Duration: Twelve Weeks

Our experience in previous years has shown us that 12 weeks is the right duration to encourage UGRs to complete their projects, allowing sufficient time for the short course, topic selection, actual investigation, and initial write-up. A shorter duration would not provide UGRs the chance to achieve the feeling that they have made a significant original contribution. Since this feeling of accomplishment is the primary motivation of most researchers, we believe that our REU experience must be structured so that each UGR has the maximum opportunity to successfully complete his/her chosen project. Additionally, the twelve week duration permits the completion of all the activities, including the Professional Mentoring events, Field trips, Research Group meetings, Ethics component, Distinguished Speaker events, and the Poster presentation. We also provide follow-on support for those wishing to continue during the following Fall and Spring. This approach is described in [1].

## 6.11 Housing Arrangements and Campus Life

The out-of-town UGRs will be housed at Pegasus Landing, UCF-affiliated housing, which offers first-rate private-room private-bath arrangements and full cooking and recreational facilities. This is across the street from UCF and several hundred yards from a large shopping center, making it an ideal summer residence for independent living. The leases at Pegasus Landing run from May 15 till August 15. In addition, the UGRs will have privileged access to all UCF campus athletic (and other) facilities. The city has an excellent public transportation system, enabling the UGRs to be quite mobile for occasional weekend recreational activities. On the first day, UGRs will be given an orientation regarding feeding and care, grocery shopping, local transportation, recreation and research facilities, and support personnel. Out-of-state UGRs will be picked up from and dropped of at the airport. We will assist all UGRs in making travel arrangements and send detailed instructions about what to pack, etc.

# 7 Project Management

Dr. Shah will oversee management of this project, with day-to-day management conducted by co-PI Dr. Lobo. Dr. Shah and Dr. Lobo will present the short course, will provide research topics, and will mentor the students in their research. The two PhD students supported (one by NSF, one by UCF) on this project will assist the P.I.s in management, and tutoring the UGRs. They will also assist in running the summer operations, to keep things moving smoothly. These tasks include Pickup/Drop-off at the airport, giving the out-of-town UGRs a tour of grocery shopping, interacting with the management/staff of the UGRs' summer residence, providing short rides when the UGRs need to run errands, assisting the UGRs in learning Matlab, tutorials on using software such as LibSVM, assisting the UGRs with their system capabilities, debugging, getting their peripherals to work, helping them print their posters, assisting to organize the Professional Mentoring events, assisting the evaluator in organizing the evaluation sessions, and the like. Sometimes, these 2 PhD students might also directly be

able to assist with the research topics of the UGRs. Dr. Shah and Dr. Lobo will oversee the activities of these 2 PhD students, to ensure smooth running of the scheduled events listed in the Proposed Activities. The post-docs and other advanced PhD students will help to provide detailed research advice on the project topics. The P.I.s will screen and select all UGRs, and will each supervise three or four UGRs. Dr. Sukthankar will also supervise several students.

# 8    Student Recruitment and Selection

We will primarily look for students who will be juniors or seniors in the Fall semester of each year, who have a GPA of at least 3.25, and who have a strong background in Mathematics and basic Computer Science. Each candidate will be asked to complete an application form that lists academic skills and demographic information. After an initial screening, the P.I.s will video-conference interview the potential participants individually and decide who should receive offers. In the telephone interview, we enquire whether the student is first-generation-in-college. It is planned that each year at least *five* of the ten UGRs will be women, minorities, or first-generation-in-college. Our past experience indicates that this is an achievable goal. We have already contacted the Minority Programs offices at UCF and will have their help in recruitment when it is needed. In addition, we have had past participants from institutions with large minority populations, such as, FAMU, Winston Salem State University, and University of Texas (Pan American), and we have good connections to these Universities. In addition, as the P.I. is in the ACM Distinguished Speakers Program [32], he visits different Universities all over the U.S. to give lectures about his research in Computer Vision, giving him a great opportunity to advertize and recruit for this REU site.

Five UGRs each year will be from institutions in other states in the Union. We will select at least half of these from schools where research programs are limited. These UGRs will be primarily recruited through aggressive advertizing to ACM/IEEE chapters, the common-application form at the NSF web-page, and by word-of-mouth of previous participants. Our UGRs in previous years have come from a mix of schools, including, U. South Dakota, Amherst College, Fairfield U. (Connecticut), Humboldt State U (California), U.Nevada-Reno, U.Cent.Arkansas, Swarthmore, City College (New York), Transylvania U. (Kentucky), William and Mary, California State (Hayward), U.Saint Thomas (Houston), Illinois.Inst.Tech., Winston Salem State (North Carolina), U Texas-Pan American, Trinity College (Connecticut), SUNY-Brockport, Elizabethtown U, and Kennesaw State U. We will have no difficulties recruiting two or three UGRs per year from these schools and four-year colleges. The remainder of the out-of-state positions will be selected with an emphasis on incoming skill set. This manner of selection ensures a diverse demographical distribution, and offers a high quality summer experience for all UGRs.

At UCF and other Florida universities, while we have found that "word of mouth" from current and past UGRs is the most effective recruiting tool, the following efforts will also be made:

1. advertisement of the opportunity in the campus newspapers and webpage,

2. notices posted at various places on the campuses around Central Florida,

3. announcements made in the junior level classes,

4. announcements distributed in Tau Beta Pi (Engineering honor society), UPE (Computer Science honor society), IEEE and ACM student chapters,

5. juniors majoring with a GPA of 3.25 or above will be sent a letter inviting them to apply,

6. students in the *Honors* programs will be contacted, and encouraged to apply,

7. current REU participants will be asked to give a talk about their experience at SWE (Society of Women Engineers) and SME (Society of Minority Engineers) meetings in the spring semester, Faculty/Student Seminars, and

8. the PIs will personally contact women, minority and especially-talented students and encourage them to apply.

Our recruitment efforts in the past three years have resulted in over 100 applicants per year (increasing by about 15 each year).

# 9 Project Evaluation

Bonnie Swan, an independent evaluator at UCF (see Budget Justification for detailed information on Dr. Swan's expertise), will coordinate the evaluation process and will manage IRB related paperwork required by UCF. The short-term success of the project in achieving its goals, will be measured both qualitatively and quantitatively using pre and post project measures aimed at determining the degree of student learning that has been achieved. It will also measure the overall quality of the recruitment and selection process and criteria. REU participants will complete pre and post assessments and will be asked to participate in a focus group at the middle and at the end of the summer. These instruments have been designed and administered by PEER for the expiring REU project-using items from the CISE REU PI Community A La Cart Survey and from other proven instruments-to collect confidential feedback about how effective REU experiences are. Relevant data from the surveys will be provided to Audrey Rorrer at the University of North Carolina at Charlotte, who is conducting CISE REU cross-institutional comparisons. Follow-up research is planned by the project team to track the participating students beyond graduation, with the aim of gauging the degree to which the REU experience has been a lasting influence in the students' career paths. Focus group and pre and post assessment questions focus on several topics. Some include: an overall rating of the REU experience and for different aspects of it; their research experiences; attitudes toward the REU experience, perceptions about possible long-term influence on their academic or career path(s); and recommendations for change. Methods will seek to measure the degree to which REU participants: acquire research and computing knowledge and communications and presentation skills; interact with other students and faculty; face challenges; acquire knowledge about computing careers; plan to remain in/or change majors; and developed intent to go to graduate school. Also, what they feel is most rewarding about the program, how effective the REU mentoring components are, and recommendations for change. The mid-summer recommendations for change will lead to short term course-corrections, and the end-of-summer recommendations will assist the P.I.s to plan for the next year.

In addition, we will longitudinally track the students to

1. determine how many of them are admitted to graduate schools, how many of those are getting fellowships, how many of those admitted are completing M.S., and Ph.D. degrees. A positive response of respectively 50%, 20%, 70%, 50% or better will indicate success.

2. encourage UGRs to publish research papers related to their REU projects in leading conferences and journals. A positive response of 25% will indicate success.

3. solicit employer feedback to determine how well prepared our students are for research roles in high-tech industries. An 60% rate of positive responses or better will indicate success.

4. solicit long-term feedback from past REU participants through a survey and informally during contacts at academic and industry gatherings. An 60% rate of positive responses or better will indicate success.

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# 12  Biographical Sketch: Professor Mubarak Shah

– **Ph.D.**  Computer Engineering, Wayne State University Detroit, Michigan, 1986.
– **M.S.**  Wayne State University Detroit, Michigan, 1982 (Major: Computer Engineering)

**PROFESSIONAL EXPERIENCE**

| | |
|---|---|
| April 2005- | Agere Chair Professor, Computer Science, UCF. |
| August 1996- | Professor, School of Computer Science, UCF. |
| August 1991 to July 1996 | Associate Professor, School of Computer Science, UCF. |
| August 1986 to July 1991 | Assistant Professor, School of Computer Science, UCF. |

**Synergistic Activities**

- Dr. Shah has co-authored three books (**Motion-Based Recognition**, 1997; **Video Registration**, 2003), **Automated Multi-Camera Surveillance: Algorithms and Practice** all from Springer, and has published twelve book chapters and over 200 research papers in prestigious journals and conferences (with acceptance rate as low as 4%) on topics including visual motion, tracking, activity and gesture recognition, edge and contour detection, multi-sensor fusion, and shape from shading.

- Dr. Shah is a **Fellow** of the **IEEE**, **IAPR**, **AAAS** and **SPIE**. He was an IEEE Distinguished Visitor speaker for 1997-2000, and is often invited to present seminars, tutorials and invited talks all over the world. He received Pegasus award in 2006; Scholarship of Teaching and Learning award in 2011; Teaching Incentive Program award in 1995 and 2003; Research Incentive Award in 2003 and 2009; Millionaires' Club award in 2005, 2006, 2009, 2010 and 2011,the Harris Corporation Engineering Achievement Award in 1999; the TOKTEN awards from UNDP in 1995, 1997, and 2000; 2009 IEEE Outstanding Engineering Educator Award in 1997, an honorable mention for the ICCV 2005 Where Am I? Challenge Problem, and nomination for the best paper award in ACM Multimedia Conference 2005 and 2010.

- He is an editor of the international book series on "Video Computing"; editor in chief of Machine Vision and Applications journal, and an associate editor of the journals, ACM Computing Surveys, and Pattern Recognition. He was an associate editor of the IEEE PAMI, and a guest editor of the special issue of International Journal of Computer Vision.

- Dr. Shah has supervised twelve undergraduate Honors in The Major Theses. He has conducted nine short courses and presented over 150 invited and plenary talks. In addition to leading one of the largest Computer Vision group in the world (currently consisting of more than 20 Ph.D.), Dr. Shah has contributed to education and research at the undergraduate and High School level.

- Dr. Shah has served as a mentor for a number of local High School students.

  - In 2006, Chris R. Bethel and Elizabeth A. Ennis from Lake Brantley High School, in Altamonte Springs, FL worked on software for automated detection of abandoned luggage in surveillance videos. The two students participated in the County Science Fair where they won first place. From there, they advanced to the Florida State Science & Engineering Fair where they were awarded 3rd place in the senior team category. The pair then made it to the 2006 Intel International Science and Engineering Fair (ISEF) presented by Agilent Technologies in Indianapolis in May of 2006.

  - Another student from Lake Brantley High School, Joey Wilson, worked on "Detecting Logos in TV Commercials" project. Joey, who had the highest GPA in his School, and graduated as valedictorian won a first prize in Computer Science in the 47th Annual Florida State Science and Engineering Fair 2002, he also received Intel Excellence in Computing award, and was invited to 2003 Taiwan International Science Fair, where he won the second prize. Joey got admitted to all Schools he applied including UC Berkeley, and accepted Lombardi Scholar offer from U. of Florida. In 2007, he graduated summa cum laude with my B.S. in Electrical Engineering. He was also selected as the UF College of Engineering's Four Year Male Scholar – a distinction given to only one male, graduating engineering student based on academics and commitment to service. For his graduate schools he was accepted,

Berkeley, Stanford, UC-San Diego, Rice, and Cornell. He ultimately chose Berkeley for his PhD in Bioengineering. However, he is deferring his enrollment at Berkeley for two years (with "enthusiastic support" from the Berkeley admissions committee) to participate the Teach For America Program (http://www.teachforamerica.com).

## Five Publications With Undergraduates (in bold *)

1. Imran Saleemi, **Lance Hartung**, and Mubarak Shah, "Scene Understanding by Statistical Modeling of Motion Patterns", IEEE Conference on Computer Vision and Pattern Recognition 2010, San Francisco, CA. *Lance is in the PhD program at U. Wisconsin-Madison.*

2. Ramin Mehran, **Alexis Oyama**, and Mubarak Shah, "Abnormal Crowd Behavior Detection suing Social Force Model", CVPR 2009, June 2009. *Alexis is a graduate student at CMU.*

3. **\*Andrew Miller**, Mubarak Shah, and Don Harper, "Landing a UAV on a Runway Using Image Registration, International Conference on Robotics & Automation, 2008.
*Andrew was 2007-08 Participant. In addition, he published papers in ICME 2007, and AAAI 2007. Also, Andrew was the only undergraduate member of the UCF team that entered a robotic car in the DARPA Urban Challenge, in which the UCF team reached the finals. Andrew also led UCF team for CLEAR and ETISEO evaluation, and published two summary papers in Springer LNCS. Currently he is working on his Ph.D. at UCF.*

4. **\*Ankur Datta**, Mubarak Shah and Niels Da Vitoria Lobo, "Person-on-Person Violence Detection in Video Data", International Conference on Pattern Recognition, 2002.
*(Ankur Dutta was 2000-01 REU participant from UCF. He completed his Honors in the Majors Thesis on his REU project in 2004, and received the NSF graduate fellowship. During the summer of 2003, he was selected for a summer program organized by JPL and Caltech. He obtained an honorable mention for the Barry Goldwater scholarship in 2003, he was the CRA Outstanding Undergraduate Award Finalist in 2004. He completed his Ph.D. under Takeo Kanade at CMU and works at IBM TJ Watson.)*

5. **\*James Davis** and Mubarak Shah, "Visual Gesture Recognition", *Vision, Image and Signal Processing*, Vol 141, No. 2, April 1994. A short version of this also appeared in ECCV-94.
*(Jim participated in the REU program in the 1993/94. He completed his Ph.D. at MIT in 2000, and currently he is an associate professor at Ohio State University.)*

## Five Other Publications

1. Xin Li, Niels Lobo and Mubarak Shah, "GAUSS: An NSF CSUMS Project at UCF", The 2nd International Conference on Education Technology and Computer, June 22-24 2010, Shanghai, China.

2. Xin Li, and Mubarak Shah, "Using Computer Vision and Image Anal- ysis for Training Undergraduate Students in Numerical Methods", In- ternational Conference on Engineering and Meta-Engineering: ICEME, April 6th - 9th, 2010.

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4. G. Bebis. D. Egbert, and M. Shah, "Review of Computer Vision Education", IEEE Transactions on Education, vol. 46, no. 1, pp. 2-21, 2003.

5. Saad Ali and Mubarak Shah, "Human Action Recognition in Videos Using Kinematic Fea- tures and Multiple Instance Learning", IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI), Volume 32 , Issue 2, Pages: 288-303, February 2010.

## Names of graduate advisors
(1) Professor Ramesh Jain, (2) Professor Arun Sood, (3) Professor George Lee.

## Research Collaborators Other Than Cited in the Publication List
None.

# 13 Biographical Sketch: Professor Niels da Vitoria Lobo

## Education

– Ph.D., Computer Science Dept, University of Toronto, 1993.

– M.Sc., Computer Science Dept, University of Toronto, 1985.

– B.Sc. (Honors), Mathematics Dept, Dalhousie University, Canada, 1982.

## Professional Appointments

| | |
|---|---|
| August 1998–present | Associate Professor, School of Computer Science, University of Central Florida, Orlando. |
| August 1993 to July 1998 | Assistant Professor, School of Computer Science, University of Central Florida, Orlando. |

## Five Most Relevant Publications (Undergrad shown bold *)

1. **\*C. Schwarz**, N. Da Vitoria Lobo, "The Camera-driven Interactive Table," *Proc. IEEE Workshop on Applications of Computer Vision*, Austin, TX, Feb 2007.

2. **\*J. Prokaj**, N. Da Vitoria Lobo, "Scale Space Based Grammar for Hand Detection," in Procs. International Workshop on Intelligent Computing in Pattern Analysis/Synthesis, held with International Conference on Pattern Recognition, August 2006, China. Also appears as Springer Lecture Notes in Computer Science, Vol 4153/2006, pp. 17–26.

3. **\*D. Batz, \*M. Batz**, N. Da Vitoria Lobo, M. Shah, "Visual System for Monitoring Medication Intake," in Procs. Canadian Conference on Computer and Robot Vision, CRV2005, May 2005, Victoria.

4. **\*J. Garcia**, N. Da Vitoria Lobo, M. Shah, **\*J. Feinstein**, "Finding Heads in Single Images," in Procs. Canadian Conference on Computer and Robot Vision, CRV2005, May 2005, Victoria.

5. **\*M. Wells**, N. Da Vitoria Lobo, M. Shah, "Automatic Visual Tracking for Analysis of Lifting," in Procs. Irish Machine Vision and Image Processing Conference, IMVIP2004 , Sept. 2004, Dublin, pp. 104-109. Also appears as Society of Manufacturing Engineers SME Technical Paper TP05PUB80.

## Five Other Relevant Publications

1. **\*Datta A.**, da Vitoria Lobo N., Leeson J., "Novel Feature Vector for Image Authentication", IEEE International Conference on Multimedia and Expo, Maryland, July 2003.

2. **\*C. Schwarz**, N. Da Vitoria Lobo, "Hand Pose Detection using Segments," in Procs. Canadian Conference on Computer and Robot Vision, CRV2005, May 2005, Victoria.

3. **\*M. Wells**, N. Da Vitoria Lobo, M. Shah, "Automatic Visual Tracking for Analysis of Lifting," in Procs. Irish Machine Vision and Image Processing Conference, IMVIP2004, Sept. 2004, Dublin, pp. 104-109.

4. **\*Wallick M.**, da Vitoria Lobo N., and Shah M., "A System for Placing Videotaped and Digital Lectures On-line", *2001 International Symposium on Intelligent Multimedia, Video and Speech Processing,* Kowloon, Hong Kong, May 2001. Michael finished his PhD at U Wisconsin, and now works at NASA-JPL.

5. **\*Bhatt J.**, da Vitoria Lobo N., Shah M., Bebis G., "Automatic recognition of a baby gesture", Proceedings of 15th IEEE International Conference on Tools with Artificial Intelligence (ICTAI), Sacramento, California, November 2003.

## Synergistic Activities

1. Assisted in management of REU site at UCF, recruited many minorities and women to participate. Published many papers with undergrads.

2. Designed new undergraduate courses at UCF in Computer Vision and related areas. Introduced research into the classroom.

3. Faculty advisor (for 10 years) to the local ACM chapter, organized weekly talks on research topics by international speakers and local companies. Actively encourage the women and minority members to take leadership roles in the chapter.

4. Reviewer for major journals, and IEEE conferences. Program co-Chair for IEEE Workshop on Applications of Computer Vision, Orlando 2002.

5. Active in community affairs, such as, the organization of High School Science Fairs.

## Research Supervised

1. Paul Smith (as Ph.D. student), Topic: Recognizing Human Actions, Date: October 2005.

2. Zarina Myles (as Ph.D. student), Topic: Defocused Motion, Date: August 2004.

3. Niels Haering (as Ph.D. student), Topic: Computation of Visual Events, Date: July 1999.

4. Jim Chen (as Ph.D. student), Topic: Fluids modelling using Navier Stokes. Graduation Date: June 1995.

5. Zaffar Abbas (M.S. student), area: Deformable Affine Motion, December 2002.

6. Zerelina David (M.S. student), area: Models of Hair, August 1999.

7. Michael Jebb (M.S. student), area: Telerobotic Interface, May 1999.

8. Donna Kocak (M.S. student), area: Oceanographic Tracking of Bioluminescence, July 1998.

9. Sean Ramsey (M.S. student), area: Robot gripper stability, July 1995.

10. Robert Uhl (M.S. student), area: Recognizing Police Facial Sketches, Date: December 1994.

11. Young Kown (M.S. student), area: Age classification from face images, Graduation Date: December 1993.

12. **Chris Elwell** (B.S. student), area: Steganographic Edges, December 2003.

13. **Josh Wilson** (B.S. student), area: Tracking Dining Activities,
    August 2003.

14. **Ashish Myles** (B.S. student at U.F.), area: Tracking Wheelchair Motion, Graduation Date: May 2002.

15. **Michael Wallick** (B.S. student), area: Intelligent Classroom and Lecture Archiving, Graduation Date: May 2001.

16. **Warren Macchi** (B.S. student), area: Interreflections of rough surfaces, Date: May 1994.

## Research Collaborators Other Than Cited in the Publication List

None.

## Names of graduate advisors

Prof. John K. Tsotsos, York University, Toronto, Canada.

# 14    Biographical Sketch: Professor Rahul Sukthankar

## Education

**Ph.D.**    Robotics Institute, School of Computer Science,
Carnegie Mellon University, Pittsburgh PA, 1997.

**B.S.E. (Highest Honors),**    Computer Science Department,
Princeton University, Princeton, NJ, 1991.

## Professional Appointments

August 2007–present    Courtesy Professor, Dept of Elec. Engg. and Computer Science,
University of Central Florida, Orlando, FL.
August 1997–present    Adjunct Research Professor, Robotics Institute,
Carnegie Mellon University, Pittsburgh, PA.
2011–present    Google Research
2003–2011    Senior Principal Research Scientist, Intel Labs

## Five Most Relevant Publications

1. K. Tang, M. Tappen, R. Sukthankar, C. Lampert. "Optimizing One-Shot Recognition with Micro-Set Learning", Appeared in *The Proceedings of the 2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)*.

2. S. Bhattacharya, R. Sukthankar, M. Shah. "A Framework for Photo-Quality Assessment and Enhancement based on Visual Aesthetics.", Appeared in *The Proceedings of the 2010 ACM Multimedia Conference.*

3. L. Zhao, X. Wang, G. Sukthankar, R. Sukthankar. "Motif Discovery and Feature Selection for CRF-Based Activity Recognition" Appeared in *The Proceedings of the 2010 International Conference on Pattern Recognition (ICPR).*

4. S. Bhattacharya, R. Sukthankar, R. Jin, M. Shah "A Probabilistic Representation for Efficient Large Scale Visual Recognition Tasks", Appeared in *The Proceedings of the 2011 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR).*

5. H. Boyraz, M. Tappen, R. Sukthankar. "Localizing Actions through Sequential 2D Video Projections". In *The Proceedings of IEEE Workshop on Human Communicative Behavior Analysis* held at 2011 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR).

## Other Relevant Publications

1. P. Matikainen, R. Sukthankar, M. Hebert. "Feature Seeding for Action Recognition", Appeared in *The Proceedings of the 2011 IEEE International Conference on Computer Vision (ICCV).*

2. Y. Ke, R. Sukthankar, M. Hebert. "Volumetric Features for Video Event Detection", In *International Journal of Computer Vision*, Vol. 88, No. 3., 2010.

3. L. Yang, R. Jin, L. Mummert, R. Sukthankar, A. Goode, B. Zheng, S. Hoi, M. Satyanarayanan. "A Boosting Framework for Visuality-Preserving Distance Metric Learning and its Application to Medical Image Retrieval" , In *IEEE Transactions on PAMI*, Vol.32, No.1, 2010.

4. M. Leordeanu, M. Hebert, R. Sukthankar. "An Integer Projected Fixed Point Method for Graph Matching", In *Proceedings of NIPS*, 2009.

5. Y. Ke, R. Sukthankar. "PCA-SIFT: A More Distinctive Representation for Local Image Descriptors", Appeared in *The Proceedings of the 2004 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)* **over 1000 citations**.

## Synergistic Activities

1. Dr. Sukthankar currently co-supervises Ph.D. students at UCF and CMU and has served as an external member on thesis committees at several institutions. His former students have gone on to both faculty positions (e.g., UIUC) and industrial research (e.g., Microsoft).

2. Participated in UCF's REU program since 2008. Advised participants Kevin Tang (who published a paper in CVPR) and Joel Jurik (who is now a PhD student at USC).

3. Mentored undergraduate researchers through Intel's First-Year Research Experience (IFYRE) program.

4. Has over 100 publications. Serves as Associate Editor of MVA and IEEE Pervasive Computing.

## Research Collaborators Other Than Cited in the Publication List

O. Deniz, G. Bueno, E. Bermejo, P. Pillai, M. Satyanarayanan, A. Goode, N. Bila, J. Harkes, A. Wolbach, L. Huston, E. de Lara, S. Yang, M. Chen, S. Schlosser, X. Wang, B. Zheng, S. Hoi, K. Dhingra, W. Wu, C. Helfrich, R. Jin, J. Campbell, D. Batra, F. Jurie, R. Freeman, G. Gordon, K. Lynch, S. Srinivasa, J. Saltzman, D. Ross, S. Szymanski, A. Tarachandani, C. Pantofaru, D. Jukic, D. Parikh, J. Summet, M. Flagg, T.-J. Cham, J. Rehg, S. Funiak, C. Guestrin, M. Paskin, D. Hoiem, S. Nath, S. Seshan, P. Gibbons, G. Wallace, O. Anshus, P. Bi, D. Clark, P. Cook, A. Finkelstein, T. Funkhouser, A. Gupta, M. Hibbs, O. Troyanskaya, A. Nizhner, P. Steenkiste, I. Nourbakhsh, A. Pahwa, M. Ashdown, G. Abowd, R. Wickremesinghe, G. Ganger, E. Riedel, A. Ailamaki, B. Sanders, R. Nelson, M. Mullin, C. Thorpe, D. Pomerleau.

## Names of Graduate Advisors

Prof. Charles "Chuck" Thorpe, Carnegie Mellon University
Prof. Dean Pomerleau, Carnegie Mellon University