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

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

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

**Collaborators for Lily Elefteriadou; University of Florida; co-PI**

1. Michael Hunter; Georgia Tech
2. Nagui Rouphail; North Carolina State University
3. Billy Williams; North Carolina State University
4. Mohammed Hadi; Florida International University
5. Virginia Sisiopiku; University of Alabama, Birmingham
6. Vassili Alexiadis; Cambridge Systematics
7. Rich Margiotta; Cambridge Systematics
8. Alexander Skabardonis; University of California, Berkeley
9. Ruth Steiner; University of Florida
10. Kevin Heaslip; Virginia Tech
11. Scott Washburn; University of Florida
12. Siva Srinivasan; University of Florida
13. Carl Crane; University of Florida
14. Sanjay Ranka; University of Florida

Pursuant to the National Science Foundation's Proposal Guide (PAPPG), each PI, co-PI, and Senior Personnel on a proposal must list affiliations and collaborators, to help identify potential conflicts in reviewer selection. (v.1/19/17)

Fill in this spreadsheet (e.g. in Excel, Google Sheets, LibreOffice...), save as .xlsx or .xls, and upload directly as a Fastlane Collab & Other Affil single copy doc. Do not upload .pdf -- Fastlane will convert to .pdf, but preserve searchable text.

There are four tables: A: Your Name & Affiliation(s); B: PhD Thesis Advisors/Advisees (all), C: Collaborators; D: Co-Editors.

List names as FamilyName, GivenName MiddleInitials; give email or department to disambiguate common names.
Fixed column widths keep this sheet one page wide; if you paste, set font size at most 10pt; abbreviate to make data fit.
To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows to sort.
"Last active" dates are optional, but help NSF staff see which information remains relevant for reviewer selection.

Table A: List your name and institutional affiliations (including considered affiliation) in the last 12 months.

| A | **Your Name:** | **Your Institutional affiliation(s), last 12 mo** | **last active** |
|---|---|---|---|
| | Rangarajan, Anand | University of Florida | |

Table B: List names (FamilyName, GivenName Middle/OtherInitials), and affiliations, if known, for:
G: Your Graduate PhD Advisor(s); and
T: All your PhD Thesis Advisees (supervised Masters and Postdoctoral students can be listed in table C).

| **B** | **Advisor/Advisee Name:** | **Institutional affiliation** | **optional (email, dept)** |
|---|---|---|---|
| G: | Chellappa, Rama | University of Maryland, College Park | |
| T: | Gold, Steven A. | deceased | |
| T: | Chui, Haili | | |
| T: | Zhang, Jie | | |
| T: | Guo, Hongyu | University of Houston-Victoria | |
| T: | Peter, Adrian M. | Florida Institute of Technology | |
| T: | Smith, Anthony O. | Florida Institute of Technology | |
| T: | Rajwade, Ajit V. | Indian Institute of Technology, Bombay | |
| T: | Gurumoorthy, Karthik S. | | |
| T: | Smock, Brandon | | |
| T: | Deng, Qi | | |
| T: | Sethi, Manu | | |
| T: | Chen, Ting | | |
| T: | Deng, Yan | | |

Table C: List the names (FamilyName, GivenName Middle/OtherInitials), and organizational affiliations, if known, for
A: Co-authors on any book, article, report, abstract or paper (with collaboration in last 48 mos; publ. date may be later);
C: Collaborators on projects, such as funded grants, graduate research or others (in last 48 months);
P: Postgraduate scholars sponsored (last 60 months); and
R: Additional names for whom a personal, family, or business relationship might preclude selection as a reviewer.

| **C** | **Name:** | **Institutional affiliation** | *to disambiguate common names* **optional (email, dept)** | **last active** |
|---|---|---|---|---|
| A: | Ranka, Sanjay | University of Florida | | |
| A: | Sahni, Sartaj | University of Florida | | |
| A: | Schmalz, Mark | University of Florida | | |
| A: | Gader, Paul D. | University of Florida | | |
| A: | Judge, Jasmeet | University of Florida | | |
| A: | Vemuri, Baba C. | University of Florida | | |
| A: | Banerjee, Arunava | University of Florida | | |
| A: | Zare, Alina | University of Florida | | |
| A: | Machiraju, Raghu | The Ohio State University | | |
| A: | Shen, Han-Wei | The Ohio State University | | |
| A: | Tari, Sibel | METU, Turkey | | |
| A: | Vese, Luminita | UCLA | | |

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|---|---|
| A: Heylen, Rob | KU Leuven |
| A: Scheunders, Paul | KU Leuven |
| A: Medioni, Gerard | USC, Los Angeles |
| A: Dickinson, Sven | University of Toronto |
| A: Belongie, Serge | UCSD |
| A: Yuille, Alan L. | Johns Hopkins University |
| A: Walters, Keith | Mississippi State University |
| A: Thompson, David S. | Mississippi State University |
| C: Corring, John | University of Florida |
| C: Yang, Chengliang | University of Florida |
| C: Yan, Yupeng | University of Florida |
| C: Chakrabarti, Subit | University of Florida |
| C: Huang, Xiaohui | University of Florida |
| C: Biswas, Ayan | The Ohio State University |
| C: Massoudifar, Pegah | |
| C: Zhou, Yuan | University of Florida |
| C: Guan, Birmingham Hang | University of Florida |
| C: Bongiovanni, Tara | |
| C: Principe, Jose | University of Florida |
| C: Kampa, Kittipat | |
| C: Eisenschenk, Stephan J. | University of Florida |
| C: Haber, Rana | Florida Institute of Technology |
| C: Moyou, Mark | Florida Institute of Technology |
| C: Vatsavai, Ranga Raju | NCSU |
| C: Arora, Kushal | |
| P: | |
| R: | |

Table D: List editorial board, editor-in-chief and co-editors with whom you interact. An editor-in-chief will list the whole board.
B: Editorial board: Name(s) of editor-in-chief and journal (in past 24 months); and
E: Other Co-Editors of journals or collections with whom you directly interacted (in past 24 months).

| **D Name:** | **Institutional affiliation** | **journal/collection** | **last active** |
|---|---|---|---|

Pursuant to the National Science Foundation's Proposal Guide (PAPPG), each PI, co-PI, and Senior Personnel on a proposal must list affiliations and collaborators, to help identify potential conflicts in reviewer selection. (v.1/19/17)

Fill in this spreadsheet (e.g. in Excel, Google Sheets, LibreOffice...), save as .xlsx or .xls, and upload directly as a Fastlane Collab & Other Affil single copy doc. Do not upload .pdf -- Fastlane will convert to .pdf, but preserve searchable text.

There are four tables: A: Your Name & Affiliation(s); B: PhD Thesis Advisors/Advisees (all), C: Collaborators; D: Co-Editors.

List names as FamilyName, GivenName MiddleInitials; give email or department to disambiguate common names.
Fixed column widths keep this sheet one page wide; if you paste, set font size at most 10pt; abbreviate to make data fit.
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You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows to sort.
"Last active" dates are optional, but help NSF staff see which information remains relevant for reviewer selection.

Table A: List your name and institutional affiliations (including considered affiliation) in the last 12 months.

| A | **Your Name:** | **Your Institutional affiliation(s), last 12 mo** | **last active** |
|---|---|---|---|
| | Ranka, Sanjay | University of Florida | |

Table B: List names (FamilyName, GivenName Middle/OtherInitials), and affiliations, if known, for:
G: Your Graduate PhD Advisor(s); and
T: All your PhD Thesis Advisees (supervised Masters and Postdoctoral students can be listed in table C).

| **B** | **Advisor/Advisee Name:** | **Institutional affiliation** | **optional (email, dept)** |
|---|---|---|---|
| G: | Sahni,Sartaj | University of Florida | |
| T: | Al-furaih,Ibraheem | National Labs Saudi Arabia | |
| T: | Alsabti,Khaled | University Saudi Arabia | |
| T: | Bae,Seungio | ETRI Korea | |
| T: | Bv,Phanisekhar | University of Florida | |
| T: | Chapman,William | University of Florida | |
| T: | Chitnis,Laukik | Google | |
| T: | Chung,Yeh-Chin | National Taiwan University | |
| T: | Heywood,Todd | IBM | |
| T: | In,Jang-uk | Microsoft Corporation | |
| T: | Kahveci,Tamer | University of Florida | |
| T: | Koester,David | MITRE | |
| T: | Lee,Jang | ETRI | |
| T: | Li,Junjie | University of Florida | |
| T: | Liu,Jun | Google | |
| T: | Maini,Harpal | Startup | |
| T: | Munir,Arslan | University of Nevada | |
| T: | Ou,Chao-Wei | Startup | |
| T: | Rangachari,Anand | IBM | |
| T: | Shankar,Ravi | Lucent | |
| T: | Somaiya,Manas | Facebook | |
| T: | Tan,Hengxing | University of Florida | |
| T: | Wang,Jhy-Chn | IBM | |
| T: | Wang,Weixun | University of Florida | |
| T: | Wang,Zhe | Facebook | |
| T: | Winterstein,Scott | Private Consultant | |
| T: | Yoon,Hankil | Oracle | |

Table C: List the names (FamilyName, GivenName Middle/OtherInitials), and organizational affiliations, if known, for
A: Co-authors on any book, article, report, abstract or paper (with collaboration in last 48 mos; publ. date may be later);
C: Collaborators on projects, such as funded grants, graduate research or others (in last 48 months);
P: Postgraduate scholars sponsored (last 60 months); and

R: Additional names for whom a personal, family, or business relationship might preclude selection as a reviewer.

| C | Name: | Institutional affiliation | *to disambiguate common names* optional (email, dept) | last active |
|---|---|---|---|---|
| A: | Aluru,Srinivas | Georgia Tech | | |
| A: | Burleigh,Gordon | University of Florida | | |
| A: | Dobra,Alin | University of Florida | | |
| A: | Dongarra,Jack | University of Tennessee | | |
| A: | Elefteriadou,Lily | Univesity of Florida | | |
| A: | Fox,Geoffrey | Indiana University | | |
| A: | Gordon-Ross,Ann | University of Florida | | |
| A: | Grama,Ananth | Purdue University | | |
| A: | Mishra,Prabhat | University of Florida | | |
| A: | Schmalz,Mark | University of Florida | | |
| A: | Weismann,Jon | University of Minnesota | | |
| A: | Rangarajan,Anand | University of Florida | | |
| A: | Kaddoura,Maher | Architecture Technology Corporation | | |
| A: | Jermaine,Chris | Rice University | | |
| A: | Judge,Jasmeet | University of Florida | | |
| A: | Crane,Carl | University of Florida | | |
| A: | Sheikh,Hafiz | University of Texas-Austin | | |
| A: | Su,Stanley | University of Florida | | |
| C: | Corring, John | University of Florida | | |
| C: | Yang, Chengliang | University of Florida | | |
| C: | Yan, Yupeng | University of Florida | | |
| C: | Chakrabarti, Subit | University of Florida | | |
| C: | Huang, Xiaohui | University of Florida | | |
| C: | Guan, Birmingham Hang | University of Florida | | |
| C: | Bongiovanni, Tara | | | |
| C: | Principe, Jose | University of Florida | | |
| C: | Vatsavai, Ranga Raju | NCSU | | |
| C: | Arora, Kushal | | | |

Table D: List editorial board, editor-in-chief and co-editors with whom you interact. An editor-in-chief will list the whole board.
B: Editorial board: Name(s) of editor-in-chief and journal (in past 24 months); and
E: Other Co-Editors of journals or collections with whom you directly interacted (in past 24 months).

| D | Name: | Institutional affiliation | journal/collection | last active |
|---|---|---|---|---|

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Table A: List your name and institutional affiliations (including considered affiliation) in the last 12 months.

| A | **Your Name:** | **Your Institutional affiliation(s), last 12 mo** | **last active** |
|---|---|---|---|
| | Srinivasan, Sivaramakrishnan | University of Florida | |

Table B: List names (FamilyName, GivenName Middle/OtherInitials), and affiliations, if known, for:
G: Your Graduate PhD Advisor(s); and
T: All your PhD Thesis Advisees (supervised Masters and Postdoctoral students can be listed in table C).

| **B** | **Advisor/Advisee Name:** | **Institutional affiliation** | **optional (email, dept)** |
|---|---|---|---|
| G: | Bhat, Chandra | UT Austin | |
| T: | Ma, Lu | | |
| T: | Zhu, Xiaoyu | | |
| T: | Dhakar, Nagendra | | |
| T: | Lim, Kwang-Kyun | | |
| T: | Nowrouzian, Roosbeh | | |
| T: | Haas, Phillip | | |
| T: | Lugo, Miguel | | |
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|---|---|---|---|---|
| C: | Ranka, Sanjay | University of Florida | | |
| C: | Rangarajan, Anand | University of Florida | | |
| C: | Elefteriadou, Lily | University of Florida | | |
| C: | Steiner, Ruth | University of Florida | | |
| C: | Bejleri, Ilir | University of Florida | | |
| C: | Yin, Yafeng | University of Michigan | | |
| C: | hadi, Md | FIU | | |
| C: | Jin, Xia | FIU | | |
| C: | Alluri, Priyanka | FIU | | |
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| C: | Carrick, Grady | Enforcement Engg | | |
| C: | Hunter, Michael | Georgia Tech | | |
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| A | **Your Name:** | **Your Institutional affiliation(s), last 12 mo** | **last active** |
|---|---|---|---|
| | Posadas, Emmanuel | City of Gainesville | |

Table B: List names (FamilyName, GivenName Middle/OtherInitials), and affiliations, if known, for:
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T: All your PhD Thesis Advisees (supervised Masters and Postdoctoral students can be listed in table C).

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|---|---|---|---|
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P: Postgraduate scholars sponsored (last 60 months); and
R: Additional names for whom a personal, family, or business relationship might preclude selection as a reviewer.

| **C** | **Name:** | **Institutional affiliation** | *to disambiguate common names* **optional (email, dept)** | **last active** |
|---|---|---|---|---|
| A: | Stevanovic, Alexander | Florida Atlantic University | | |
| A: | Awwad, Rasem | City of Boca Raton | | |
| A: | So, Jaehyun | Universitat Munchen | | |
| C: | Lin, Pei-Sung | University of South Florida | | |
| C: | Grippo, Daniel | City of Boca Raton | | |
| C: | Loewenherz, Franz | City of Bellevue | | |
| C: | Ananthanarayanan, Ganesh | Microsoft | | |
| C: | Wiesman, Mathew | MSW LLC | | |
| C: | Ginsburg, Matthew | Connected Signals, Inc | | |
| C: | Lasell, Robert | Connected Signals, Inc | | |
| C: | Ova, Keil | Traffic Technology Services, Inc | | |
| C: | Milster, Kris | Traffic Technology Services, Inc | | |

| | | | |
|---|---|---|---|
| C: | Mitrovic, Alexander | TraffOp.com | |

Table D: List editorial board, editor-in-chief and co-editors with whom you interact. An editor-in-chief will list the whole board.

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| **D** | **Name:** | **Institutional affiliation** | **journal/collection** | **last active** |
|---|---|---|---|---|

# COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

| PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE | ☐ Special Exception to Deadline Date Policy | FOR NSF USE ONLY |
|---|---|---|
| NSF 18-520 02/28/18 | | NSF PROPOSAL NUMBER |
| FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) IIS - S&CC: Smart & Connected Commun | | |

| DATE RECEIVED | NUMBER OF COPIES | DIVISION ASSIGNED | FUND CODE | DUNS# (Data Universal Numbering System) | FILE LOCATION |
|---|---|---|---|---|---|
| | | | | 010522159 | |

| EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN) | SHOW PREVIOUS AWARD NO. IF THIS IS ☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL | IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S) |
|---|---|---|
| 596000325 | | |

| NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE | ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE |
|---|---|
| City of Gainesville, FL | 200 E. University Avenue<br>Gainesville, FL 32601-3400 |
| AWARDEE ORGANIZATION CODE (IF KNOWN)<br>6250039612 | |
| NAME OF PRIMARY PLACE OF PERF<br>City of Gainesville, FL | ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE<br>City of Gainesville, FL<br>405 NW 39th Ave<br>Gainesville ,FL ,326091738 ,US. |

IS AWARDEE ORGANIZATION (Check All That Apply) ☐ SMALL BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS ☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **SCC: Video based Machine Learning for Smart Traffic Analysis and Management**

| REQUESTED AMOUNT | PROPOSED DURATION (1-60 MONTHS) | REQUESTED STARTING DATE | SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE |
|---|---|---|---|
| $ 2,299,279 | 48 months | 10/01/18 | |

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date ________
PHS Animal Welfare Assurance Number ________
☒ TYPE OF PROPOSAL Research

☐ HUMAN SUBJECTS Human Subjects Assurance Number ________
Exemption Subsection ______ or IRB App. Date ________
☒ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED
KS
☒ COLLABORATIVE STATUS
A collaborative proposal from multiple organizations (PAPPG II.D.3.b)

| PI/PD DEPARTMENT | PI/PD POSTAL ADDRESS |
|---|---|
| City Manager's Office | 200 E. University Avenue<br><br>Gainesville, FL 326013400<br>United States |
| PI/PD FAX NUMBER | |

| NAMES (TYPED) | High Degree | Yr of Degree | Telephone Number | Email Address |
|---|---|---|---|---|
| PI/PD NAME<br>Daniel Hoffman | MS | 2006 | 352-334-5010 | hoffmandc@cityofgainesville.org |
| CO-PI/PD<br>Lily-Ageliki Elefteriadou | PhD | 1994 | 352-392-9537 | elefter@ce.ufl.edu |
| CO-PI/PD<br>Anand Rangarajan | PhD | 1991 | 352-392-1507 | anand@cise.ufl.edu |
| CO-PI/PD<br>Sanjay Ranka | PhD | 1988 | 352-514-4213 | ranka@cise.ufl.edu |
| CO-PI/PD<br>Sivaramakrishna Srinivasan | PhD | 2004 | 352-392-9537 | siva@ce.ufl.edu |

# CERTIFICATION PAGE

### Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) 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 conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide (PAPPG). 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).

### Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of PAPPG Chapter IX.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

### Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Proposal & Award Policies & Procedures 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 Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Proposal & Award Policies & Procedures Guide.

### Certification Regarding Lobbying

This 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 Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Proposal & Award Policies & Procedures 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 Certification Pages, the Authorized Organizational Representative (or equivalent) 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 Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Chapter IX.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 AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

# CERTIFICATION PAGE - CONTINUED

## Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

## Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations.
By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

## Certification Regarding Unpaid Federal Tax Liability

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

## Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

## Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

| AUTHORIZED ORGANIZATIONAL REPRESENTATIVE | SIGNATURE | DATE |
|---|---|---|
| NAME | | |

| TELEPHONE NUMBER | EMAIL ADDRESS | FAX NUMBER |
|---|---|---|
| | | |

# PROJECT SUMMARY


## Overview:

This smart city proposal by the City of Gainesville (CoG) and UF seeks to use edge-based video-stream processing (using multicore and GPU processors) at intersections and in public vehicles (city buses, fire trucks, ambulances, school buses) to convert video data into space-time trajectories of individual vehicles/pedestrians that are transmitted to a cloud-based system. Key information will then be synthesized at the cloud from them to create a real-time city-wide traffic palette. Real-time or offline processing both at the edge and the cloud will then be leveraged to optimize intersection operations, manage network traffic, identify near-collisions between various units of traffic, provide street parking information and a host of other applications. Additional information such as weather and environment will also be leveraged. The usage of edge-based real-time machine learning (ML) techniques and video-stream processing has several significant advantages:

1. Since there is no need for storing copious amounts of video (few minutes typically suffice for edge-based processing), it automatically addresses concerns of public agencies and civil libertarians who do not want person identifiable information to be stored for reasons of citizen privacy and legality.

2. The processing of the video-stream at the edge will allow for the use of low bandwidth communication using wireline and wireless networks to a central system such as a cloud resulting in a compressed and holistic picture of the entire city. This can then be used for efficient processing.

3. The real-time nature of processing enables a wide variety of novel transportation applications at the intersections, streets and system levels that were not possible hitherto, significantly impacting safety and mobility.

## Intellectual Merit:

There are several areas of intellectual merit that arise from our core goal of designing a smart city, when addressing the technical challenges at the intersection, street and system levels.

1. Development of new algorithms for multi-target tracking: The problems of occlusion, temporal assignment of features to objects and target motion will be jointly formulated. Data association and track-to-track association - the core problems underlying most single-sensor and multi-sensor multi-target tracking systems ? will be solved using a novel Sinkhorn-Knopp relaxation of multi-dimensional assignment.

2. Integrated optimization and simulation for signal control:? We formulate the problem of estimating signal control parameters (offsets, phasing etc.) in a network as one of global optimization wherein we determine good suboptimal solutions to signal parameters in a high dimensional search space. To overcome the curse of dimensionality, we determine intelligent sub-problem decompositions (local arterials and corridors) to make the search more efficient

3. Real-time reinforcement learning is a natural choice when online ML meets real world feedback. Since a lot of processing will be performed on the edge, we propose to learn signal policy changes in an Our ability to obtain and analyze continuous-time data at the network level will provide insights on how conflict points and patterns can change through the network. They can also determine changes over time even at the same intersection. This will allow us to identify dynamic safety improvement response strategies which were not possible using crash-based analytics. Finally, data on human-driven vehicle trajectories can provide baseline information to optimize trajectories of connected vehicles.

## Broader Impacts:

The proposed work will leverage the confluence of economical video sensors, significantly lower computing hardware costs and cloud computing with open source analytics solutions to enable novel transportation applications. Hence, it will result in profound improvements in traffic management, smart city planning and safety. The methods proposed will have a direct impact on video analysis for transportation problems and related disciplines, and open novel problem definitions and avenues for research. We will disseminate our work to a wide audience of researchers and students using videos and screencasts on YouTube, and other free distribution channels. A major priority during student recruiting will be to ensure excellent participation by women and under-represented minorities.

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



*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.

## 1.0 Integrative Research, Community Engagement, Intellectual Merit and Broad Impact

Mitigating traffic congestion and improving safety are the important cornerstones of transportation for smart cities. Despite significant advances in vehicle technology, traffic engineering practices, and analytics based on crash data, the number of traffic crashes and fatalities are still too many. Many drivers are frustrated due to long (but potentially preventable) delays at intersections. Traffic signal control timing does not change in real-time based on accidents or changes in traffic patterns and behavior. For example, the University of Florida (UF) has seen an exponential growth of use of scooters by its students. Addressing all these challenges requires a thorough understanding of traffic patterns not only at the intersections but on streets as well as the overall network. Unfortunately, existing monitoring systems and decision making for this purpose have several limitations:

1. Current sensors have limited capability: Vehicle loop detectors have traditionally been deployed at intersections to detect the passage of vehicles are error-prone; have high deployment and maintenance costs; can only measure the absence or presence of vehicles passing above them; and are not always useful for observing the movements of pedestrians and scooters. When the sensors are not accurate, or timely, an adaptive strategy will not be effective. Video detection has great potential to improve accuracy and timeliness in the detection of vehicles, pedestrians, bicyclists, etc.
2. Current software systems for traffic monitoring are fragmented and not suitable for real-time decision making: Transportation professionals are presented with a plethora of fragmented data in various systems. Existing intersection control systems do not provide reports on a real-time basis (based on the vendor), and these are given at coarse levels of granularity (for example, traffic movement counts by the hour) limiting their use and ability to make real-time changes to adapt to dynamically changing conditions.

The advent of nominal cost video-based systems, open source tools for video processing and deep learning, and the availability of low cost GPU processors has opened the door for their use in real-time transportation decision systems. While video-based systems for intersection traffic measurement have recently been introduced by commercial vendors such as Iteris, Miovision etc., they are severely limited in their use: they are mainly deployed at intersections and merely perform simplistic counting of several objects. Additionally, the data collected are only used for offline processing. Consequently, this limits their use to a few intersections which are instrumented for this purpose; the data is either collected using a high bandwidth network or using specialized storage systems followed by *manual* collection. Overall, the lack of *real-time* processing fundamentally limits their use.

**Integrative Research**: This smart city proposal by the City of Gainesville (CoG) and UF seeks to use *edge-based* video-stream processing (using multicore and GPU processors) at intersections and in public vehicles (city buses, fire trucks, ambulances, school buses) to convert video data into space-time trajectories of individual vehicles/pedestrians that are transmitted to a cloud-based system. Key information will then be synthesized at the cloud from them to create a real-time city-wide traffic palette. Real-time or offline processing both at the edge and the cloud will then be leveraged to optimize intersection operations, manage network traffic, identify near-misses between various units of traffic, provide street parking information and a host of other applications. Additional information such as weather and environment will also be leveraged. The usage of edge-based real-time machine learning (ML) techniques and video-stream processing has several significant advantages:

1. Since there is no need for storing copious amounts of video (few minutes typically suffice for edge-based processing), it automatically addresses concerns of public agencies and civil libertarians who do not want person identifiable information to be stored for reasons of citizen privacy and legality.
2. The processing of the video-stream at the edge will allow for the use of low bandwidth communication using wireline and wireless networks to a central system such as a cloud resulting in a compressed and holistic picture of the entire city. This can then be used for efficient processing.
3. The real-time nature of processing enables a wide variety of novel transportation applications at the intersections, streets and system levels that were not possible hitherto, significantly impacting the safety and mobility of our community.

In addition, the use of cloud computing for processing aggregated data from multiple video and other sensors will provide information unification and the necessary on-demand computing horsepower for the large-scale simulations for system level optimizations and analytics. It will also allow for leveraging offline processing of historical data to be used in conjunction with real-time information (Details of the architecture is described in Section 4). This will also allow real-time optimization on the cloud.

| |
|---|
| **Smart Intersections** Smart intersections will be equipped with cameras to collect video data, which can be integrated with other real-time information about the site to improve the safety and efficiency of the site. As it is not efficient/desirable to record and/or transmit the entire raw video feeds to the cloud for processing, edge-computing techniques will be employed to reduce the video data into space-time trajectories of individual vehicles/pedestrians. This requires real-time detection, classification (vehicle by type, pedestrian, bicyclist, scooter etc.), and tracking. The space-time trajectories of the various vehicles and pedestrians navigating the intersection is saved on the cloud. These data can be processed in real-time or off-line to understand and improve the safety and efficiency of the intersection. Examining the conflict points of the vehicle/pedestrian trajectories can help identify potential collisions, or "near-misses," and how they are related to the state of the signal cycle (transition from green to yellow, from yellow to red, timing on the pedestrian count-down signal, etc.) and the presence of other vehicles and pedestrians on site. The availability of continuous streams of data will facilitate examining how these conflict points vary during the day and across the week. Appropriate countermeasures (related to intersection design or signalization) can be implemented to address the identified safety problem. The trajectories can also be aggregated into demand profiles (turning movement counts by vehicle type and pedestrian counts) which can be effectively used to determine how the signal should be retimed for different parts of the day or days of the week. Further, examining the trajectory of the vehicles in relation to the signal state can also help quantify more accurately the start-up lost time (time between the signal turning green and the vehicle stream starting to move). With the availability of communication capabilities at intersections, the impact of providing SPaT data to on-board units on vehicles to reduce start-up lost time can also be examined. Real-time information about the intersection (e.g. presence of pedestrians, signal timing information) can be broadcast to drivers. |
| **Smart Streets** Collecting video feeds covering entire links (defined broadly as a segment of roadway between two intersections) can be challenging. We propose to equip the City of Gainesville's transit buses with forward facing cameras to continuously collect video data from streets (and intersections). Given the dense coverage of Gainesville's transit system especially near the UF campus and the large number of routes and buses, we expect this approach to provide a very good coverage of the key roads of the city for most of the time. The video streams will have to be processed on the camera and reduced to objects and trajectories which can be relayed to the cloud for storage and analysis. The nature of the edge computing performed can be varied to meet different analysis requirements. For example, detection of pedestrians crossing the street can provide insights into jaywalking/ "mid-block crossing" behaviors which can be prevalent in university campuses. Such data can also provide insights into how passengers approach/leave the transit buses at stops. All these can be used to understand pedestrian safety both during day and night times. In contrast, tracking vehicles in terms of trajectories and state of brake lights and indicator lights, ahead of the bus can help understand lane-changing maneuvers undertaken before implementing a turn. The space-time trajectories of vehicles along adjacent lanes can be used to infer gap-acceptance behavior, which in turn, leads to lane changes. Again, differences can be examined across different weather conditions. |
| **Smart System** A group of smart intersections and smart streets suitably integrated by common underlying data constitutes a smart transportation system. The availability of video and other data from several intersections and streets from Gainesville makes it possible to analyze the city's transportation system holistically to determine network-level safety and operations enhancements. For example, video data from locations upstream of a crash location can be used to determine the possibility of traffic backups and secondary crashes. The availability of turning movements by vehicle type in real time for several intersections simultaneously will allow for the possibility of re-timing signal progression dynamically and for different corridors by time of day and day of the week to reflect the changes in network demand. System-wide data helps us ensure that localized treatments to address problems specific to an intersection or a street do not adversely affect other parts of the system. |

**Table 1: Key Social Dimensions at the intersection, Street and System levels**

We broadly describe the social dimensions consisting of community safety and mobility understanding and improvements at three levels: smart intersections, smart streets and smart system (Table 1). These assume that there exist video-based systems that can observe traffic at intersections or from publicly owned vehicles. The data collected from the above sources afford real-time measurements and decisions which will then be used as part of an iterative approach to observe traffic and pedestrian mobility, allowing for the introduction of new design concepts (such as leading pedestrian intervals), new technologies (like reaction to autonomous and emergency vehicles) and impacts of environmental improvements (lighting, landscaping, and geometric design changes) at intersections. Thus, this proposal will lead to major improvements in the current state of practice: the underlying technology, the associated data and the resulting policies and procedures are interlocked through a cross disciplinary approach utilizing advances in computer science (video analytics, machine learning, sensor fusion) and traffic engineering. We believe that our approach can have a tangible impact on the USDOT goal of the Vision Zero plan to minimize, and eventually eliminate motor vehicle related crashes and accidents.

**Community Engagemen**t: This is a collaborative effort between teams of researchers from city government (Posadas, Hoffman) and academia (Ranka, Rangarajan, Elefteriadou Srinivasan). As discussed earlier, the goal is to significantly improve our understanding of normal and special situation traffic patterns and use it for improving community safety and mobility. This requires a multidisciplinary team with a range of disciplines essential to the success of this project: traffic operations (Elefteriadou, Posadas, Srinivasan), policy (Hoffman), machine learning and video analytics (Rangarajan and Ranka), traffic optimization and safety analysis (Elefteriadou, Srinivasan), and GPU and cloud computing (Ranka). The investigators have extensive research experience in their respective fields and have already made significant contributions to the state-of-the-art and state-of-the-practice. The development of this proposal and target applications is based on monthly meetings between the participants over the last year as part of the I-STREET Testbed (http://www.transporation.institute.ufl.edu/research-2/istreet-about-us/ and please see evaluation plan for its proposed use). The Gainesville city government and UF will be collaboratively participating in overall planning and decision making regarding important issues such as key project details and final evaluation (with the management plan containing more details). The city will also provide access to historical and current data and will enable edge processing capabilities that will be instrumental to the success of this project. Effectively, a portion of the Gainesville network will serve as a living lab where technological advances will be staged (please see evaluation plan for more details).

**Intellectual Merit** There are several areas of intellectual merit that arise from our core goal of designing a smart city, when addressing the technical challenges at the intersection, street and system levels.

*Multi-target tracking* is now heavily used in advanced driver assistance systems and traffic surveillance. Typically, data from multiple sensors can be fused to get highly accurate tracks within an increased field-of-view. The problems of occlusion, temporal assignment of features to objects and target motion will be jointly formulated. Data association and track-to-track association - the core problems underlying most single-sensor and multi-sensor multi-target tracking systems – will be solved using a novel Sinkhorn-Knopp relaxation of multi-dimensional assignment.

*Integrated optimization and simulation for signal control:* There is a paucity of previous work on network level signal control optimization. We formulate the problem of estimating signal control parameters (offsets, phasing etc.) in a network as one of global optimization wherein we determine good suboptimal solutions to signal parameters in a high dimensional search space. To overcome the curse of dimensionality, we determine intelligent sub-problem decompositions (local arterials and corridors) to make the search more efficient. A second constraint is the need to limit the number of calls to a traffic simulator (since every change in signal offsets, for example, results in a call to the traffic simulator to re-calculate the system performances for that timing plan) while obtaining good solutions. The result is a novel approach integrating global optimization and simulation for network signal control.

*Real-time reinforcement learning* is a natural choice when online ML meets real world feedback. Since a lot of processing will be performed on the edge, we propose to learn signal policy changes in an online setting with direct impact on traffic (tested in a simulator). The result is a real-time feedback between policy and change (in traffic patterns) which will be scored by a critic (considering net flow and other measures). To achieve this, we formulate the problem as real-time reinforcement learning and propose to investigate novel, recently developed Sinkhorn policy updates (which integrate deep learning-based actors and critics within reinforcement learning) as natural gradients.

*Real-time Edge Processing*: The proposed work relies on real-time GPU processing at edge servers (usually placed at intersections) with minimal transmission (video summarization, signal offset timings) sent to the cloud. This architectural design is a good fit for the smart city, leveraging the availability of hardware for video processing and reducing bandwidth requirements for communication with the cloud.

*Transportation Safety:* The study focuses on emerging proactive measures for assessing and enhancing transportation safety and mobility. Regarding safety, unlike conventional methods which rely on crashes and as such represent a reactive approach to addressing safety problems, the use of space-time trajectories of vehicles and pedestrians to identify near-misses could help identify problems before actual crashes occur. While, there has been significant recent interest in developing such trajectories, our ability to obtain and analyze continuous-time data at the network level will provide insights on how conflict points and patterns can change through the network. They can also determine changes over time even at the same intersection. This will allow us to identify dynamic safety improvement response strategies which were not possible using crash-based analytics. The availability of continuous time turning movements by vehicle type (including pedestrians) will also allow us to develop dynamic traffic operation strategies (signal timing plans) which can maximize system throughput while maintaining minimum desired performance levels at critical intersections. Finally, data on human-driven vehicle trajectories can provide baseline information to optimize trajectories of connected and autonomous vehicles in the future.

**Broader Impact:** The proposed work will leverage the confluence of economical video sensors, significantly lower computing hardware costs and cloud computing with open source analytics solutions to enable novel transportation applications. Hence, it will result in profound improvements in traffic management, smart city planning and safety.

*Save Lives:* The ability to detect and understand un-safe driving/walking conditions (measured as “near misses” rather than “crashes”) and react to them in real time would be critical in further moving the needle towards the goal of vision zero. Further, with the anticipated increase in connected and automated vehicles, a technology that most road users are not familiar with, there is an increased need to manage the system to ensure safety under mixed traffic (conventional and automated vehicles). This study aims to improve the road safety for both motorists and pedestrians thereby directly impacting the Vision Zero goals of DOT. The reduction of traffic incidents will also lead to reductions in time wasted in traffic delays.

Urban traffic control is one of the most important and challenging issues facing cities and requires practically effective and efficient solutions. The increasing volume of traffic in cities has a significant effect on road traffic congestion and consequently travel time of road users. Congestion wastes time, hampers social and economic activities, and harms the environment, which all deteriorate the quality of our lives.

*Research and Education Infrastructure:* The methods proposed will have a direct impact on video analysis for transportation problems and related disciplines, and open novel problem definitions and avenues for research. The proposed research will produce novel techniques and prototype software for machine learning/data mining of video-based transportation applications. We plan to publish both in transportation engineering and applied ML conferences/journals. We will actively disseminate our software and facilitate its adoption by governments, academia and industry. Details of the software dissemination are provided in the data management plan. We will continue to have a broad impact on the education of students who can further this field with their independent contributions. Our goal is to create courses/modules to teach students how to develop algorithms and software for traffic applications.

*Widening Community Outreach and Dissemination:* This group of PIs has a strong and well-established record of community outreach, having given numerous tutorials at various international conferences. For that reason, and to reach a dramatically wider audience of researchers and students, we will take the lead in creating a set of screencasts (via Camtasia Studio, Adobe Premier) to introduce and expand upon the use of machine learning methods. We will make these screencasts available by way of YouTube, and other free distribution channels; this will not only make them available globally, but also allow us to gather statistics that will assist us in evaluating the success of the proposed work (see the Management Plan).

*Recruiting:* A major priority during student recruiting will be to ensure excellent participation by women and under-represented minorities, as they will be vital role models. UF has established track records of attracting students from diverse backgrounds. UF hosts the McNair Graduate Assistantship Program, which focuses on getting underrepresented minorities into graduate school through undergraduate research. We will actively interact with interested McNair Scholars, thereby expanding our access to well qualified minority undergraduates. the co-PIs at UF will closely interact with the NSF-funded SEAGEP program at UF, which provides strong peer support for minority students as they work towards their degrees.

**2.0 Prior Research**

In the following, we briefly describe our experiences in developing real-time and automated-decision making in cyber-physical systems for transportation, machine learning, video processing and GPU computing that are necessary requirements for successful implementation of the proposed work.

**Sensor Fusion and Intersection Management:** Through support from NSF and the Florida Dept. of Transportation (FDOT), we have developed and deployed an intelligent controller for signalized intersections (Figure 1) at the FDOT Transportation Engineering Research Laboratory (TERL). The main components of the controller are an optimization algorithm for joint vehicle trajectory and signal control, a multi-sensor fusion system for obtaining real-time information from the surrounding traffic, and a signal controller for adapting the traffic signals based on the optimization results. The optimization algorithm considers both automated and conventional vehicles and produces signal timings that are field-implementable. Based on the real-time information from the sensor fusion component, it optimizes trajectories for automated vehicles; the trajectories are transmitted to the vehicles with Dedicated Short-Range Communication (DSRC). The recommended trajectory is an ordered list of points and speeds that the vehicle can interpret to use its lane most efficiently. Our simulation results (following work in Rosero, 2017 and Na, 2015) show that significant improvements can be achieved. For the tests at the isolated traffic intersection at TERL, we designed and implemented a multi-sensor fusion system based on DSRC and Doppler radar. We obtained the latitude, longitude and speed information from vehicles equipped with DSRC. Using the radar, we were also able to get this information for conventional vehicles. These measurements were processed separately and converted intro real-time tracks with a bank of Kalman filters, and subsequently fused to produce accurate estimates of the state of each vehicle within range of the intersection. Our system (following Chavez-Garcia, 2016) was able to correctly classify all vehicles as automated, connected, or conventional correctly during our tests, as well as estimate their position and speed with a high degree of confidence. We ran experiments with a vehicle equipped with a Cohda Wireless Mk5 On-board Unit, and a high precision GPS sensor to generate ground-truth data. We compared the tracking performance of different approaches configured with various vehicle kinematics models. Recently, we have started to experiment with vision-based multi-target tracking for traffic surveillance, with aims of developing a complete multi-sensor fusion system that combines video, radar, and DSRC.

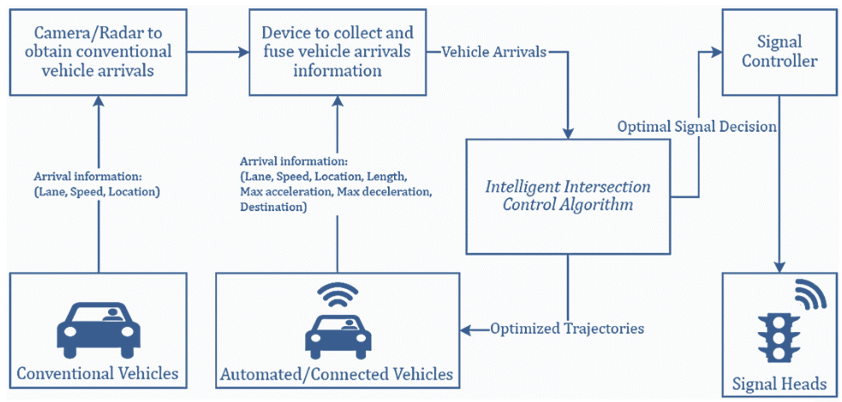
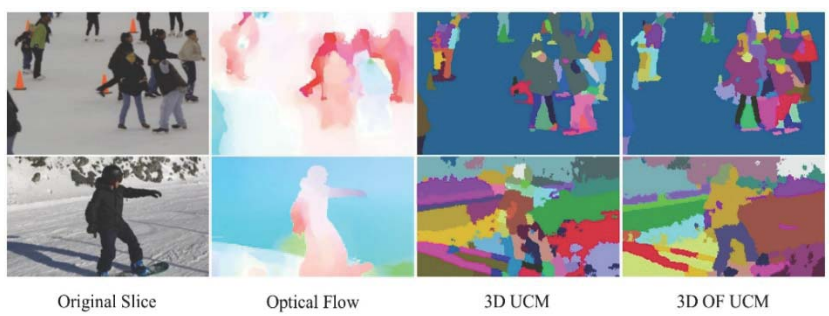



Figure 1: The Intelligent Intersection Control System

**GPU Computing:** We (via UF co-PI Ranka) have significant experience with development of multicore and GPU algorithms and implementations for a variety of applications achieving 100+ GFlops in many cases:




1. Combustible Multiphase Turbulence (data parallel workflow): This application consists of a number of operations on each of the three data structures (cubes, faces, and particles) and interactions between them. We have developed high performance implementations on multicore CPUs and GPUs (Gadou, 2016).
2. Sparse Matrix Factorization (hierarchical workflow): The use of sparse direct methods in applications in computational science can be used to find solutions to many numerical algebra applications, vision and scientific applications. We have developed codes for QR and Cholesky Factorization (Tang,2017, Yeralan, 2017).
3. Synthetic Aperture Radar Reconstruction (task parallel workflow): SAR image formation utilizes tensor-product based transformation of radar return pulses to yield a spatial representation containing possible target objects. We have developed GPU and multicore algorithms (Wijayasiri, 2016, Wijayasiri, 2017).

**Video Processing** UF co-PI Rangarajan has over twenty-five years of experience in machine learning and computer vision. This includes research experience in multi-frame correspondence, robust estimation of optical flow, 3D segmentation and recognition. Recent work (Yang, 2016) on video processing is focused on joint estimation of optical flow and 3D supervoxel-based segmentation. Examples of this effort, integrating the 3D ultrametric contour map (UCM) with optical flow (published Yang, 2016 and submitted to a journal) are shown in Figure 2.

**3.0 Proposed Research**

Below, we describe the proposed research focused on machine learning and optimization in service of the overall smart cities project. As mentioned above, we first restrict focus to a single intersection, followed by an examination of a network corridor of roads and traffic. Subsequently, this is expanded to a holistic investigation of the city-wide network while integrating information from buses and emergency vehicles.

- *Intersection Level:* We propose to fuse information from video and roadside sensors resulting in integrated image and vehicle count information. We expect the video sensors at each intersection to range from the more uncommon fisheye lenses to the more mundane "set of cameras." Subsequently, this is fused with information obtained from sensors beneath the road to obtain a coherent map. Estimating the position and speed of all objects within the surveillance regions will be handled by a novel real-time multi-target tracking system.
- *Segment Level:* Existing literature on the optimization of signal timing patterns are often arbitrarily restricted to a single intersection. We propose to leverage machine learning and optimization to estimate traffic signal parameters (offsets etc.) across a segment of a network using the integrated video processing data available from the earlier stages. To test a segment model, we propose to use the SUMO simulation software for the developing, testing, and evaluation of the resulting approach.
- *Network Level:* Activity recognition in the presence of moving cameras has recently become important in the computer vision community. We leverage the best of breed methods for activity recognition from video (obtained from cameras on city buses and emergency responder vehicles). This is used in service of detecting major traffic activities (arterial patterns, pedestrian clusters etc.). Once this information is integrated, compressed and sent to the cloud, we can perform city-wide network traffic signal improvements. Finally, we expect to present a summarization of all relevant activity to city planners so that they can change policies to further improve the city.

This represents an exciting opportunity – ***an integration of computer vision and traffic control management in service of the smart city***. With the interdisciplinary team (spanning city and university personnel) at our disposal, we expect to be able to balance hardware, security and traffic planning constraints while working toward a fully integrated solution

**Smart Intersections:** Using standard and fisheye cameras mounted at intersections (and integrating weight sensors placed beneath streets), we propose to leverage the state of the art in computer vision and machine learning to perform vehicle tracking (localization, tracking, turn estimation) and pedestrian monitoring at intersections. Traffic surveillance of dynamic objects, particularly vehicles on the road, has been an active research topic in past decades, in the fields of computer vision and intelligent transportation systems. In the interests of real-time feedback, security and citizen anonymity, we elect to mainly focus on real-time (and near real-time) video processing at intersections. (The description of edge computer hardware that can handle the processing requirements is later spelled out.) Our goal at this juncture is to take the best of breed computer vision-and machine learning-based video processing and tracking approaches and leverage them into efficient real-time (and near real-time) representations. Subsequently, these compressed representations will drive applications such as the identification of near misses, summary of pedestrian movements and the extraction of vehicle trajectories at intersections. Since video information will be clocked and integrated with weight sensors, we anticipate real-time feedback to signal controllers resulting ultimately in improvements to intersection level signal planning (offsets, phase switches etc.). *The uplink of compressed information to the cloud is a side benefit resulting in much lower communication costs.*

*Multi-target tracking:* As mentioned above, we envision an intelligent transportation system developed for a smart city that will use data extracted in real time from traffic – essentially a network of urban traffic intersections, all equipped with sensors that are capable of tracking, classifying, and analyzing pedestrians, bicyclists, and vehicles. However, there are many technical challenges that must be addressed before such a system can be built and deployed. One area of interest is multi-target tracking, a vital component of traffic surveillance technology. Given one or more (potentially heterogeneous) sensors, the objective of multi-target tracking is to use sensor data streams to accurately estimate the position and speed of each object present in the visible surveillance region. Unfortunately, traffic scenes are complex environments; unpredictable behavior, heavy occlusion, and variations in lighting and weather can all have a detrimental effect on tracking performance. Deep learning has revolutionized representation learning in computer vision and natural language processing, as well as in many other fields. This fact, along with advances in compute capabilities and the availability of massive datasets, has made possible the development of systems that are almost entirely built end-to-end with deep learning methods. One of the main strengths of this approach is that the system can autonomously extract complex patterns and features from the data; the nature of deep learning is such that these patterns tend to be compositional and hierarchical. Also, these techniques have empirically been shown to outperform the previous state-of-the-art in tasks such as machine translation, object detection, and image captioning. Researchers have developed large-scale deep learning models with millions of parameters on thousands of CPU cores and GPUs with the latter architecture being much faster for training. In our recent survey paper, we discuss work where deep learning has begun to be applied to multi-target tracking (Emami, 2018). (Details of the deep learning stack are available in the software and computing section).

*Data association and track-to-track association*: Two fundamental problems in single-sensor and multi-sensor multi-target tracking, are instances of the multidimensional assignment problem (MDAP) situated within optical flow (when applied to camera data). Over the last few years, data-driven approaches to tackling MDAPs in tracking have become increasingly popular. We propose to take an end-to-end approach to multi-target tracking. Our method will involve specifying a probabilistic model parameterized by weights that can be used to directly infer optimal (or good suboptimal) assignments. Unlike previous approaches, we represent our model entirely as a deep neural network; therefore, our model is differentiable end-to-end, and can be trained to directly predict full tracks with IDs from annotated training data. To do this, our model needs to have the ability to predict track initiation events, deletion events, and track maintenance between time steps. We note that between adjacent frames, this information can be represented as a permutation matrix that matches existing detections or tracks to new detections. However, permutation matrices are discrete, combinatorial structures that are non-differentiable. We can leverage the differentiable approximation to the Sinkhorn-Knopp algorithm (proposed in Adams, 2011) to include it as a layer in a deep neural network, which we call a Sinkhorn layer. [UF co-PI Rangarajan has extensive experience with the use of Sinkhorn projections in combinatorial optimization (Rangarajan, 1996, Gold, 1996), graph matching, non-rigid shape matching (Chui, 2003) and unsupervised learning.]

*Causal Reasoning:* Traffic scenes are incredibly complex and involve many different actors, all which have different physical properties and can exhibit a variety of behaviors (Yang, 2017). Typically, multi-target trackers rely blindly on the object detector to indicate whether an object exists in the surveillance region and must use a fixed-length sliding window to attempt to handle long-term occlusion. In scenarios where objects are interacting in intricate ways (e.g., pedestrians crossing paths at a busy traffic intersection), current trackers tend to perform poorly. An indicator of this is large numbers of fragmented tracks and ID switches. We suggest augmenting these trackers with mechanisms for symbolic and causal reasoning (Carmi, 2013, Huang, 1994 and Lebeda, 2015) that make use of learned models of the appearance and physics of the objects and how they interact with each other. For example, consider a scenario where a sedan slows to a stop behind a bus at a red light and is unable to be tracked. The sedan and bus may have to wait at the light for 1-2 minutes before finally moving, at which point a current multi-target tracker will assign the sedan a new track ID. We would like the tracker to reason the following: “If a sedan stops behind a bus, I expect the same sedan to still be behind the bus when the bus departs”. To accomplish this type of reasoning, we will develop novel probabilistic models that encode relationships between objects and their interactions with each other and with the environment. We can model interactions between traffic participants as a graph, where vertices are representations of the object classes and edges are interaction probabilities. Concretely, the simplest interaction we are interested in is the pairwise interaction “X occludes Y.” A spatio-temporal probabilistic model conditional on the object class can be learned from the data that can then rollout future object trajectories from a specific point in time. Based on these trajectory rollouts and our estimates of the uncertainty about them, we can then predict the probability of pairwise occlusions. This approach can be extended by adding other interactions as well, e.g., “X may collide with Y”, in which case an extra step of predicting the type of interaction must be performed. Once the graph edges are annotated with interaction likelihoods, we will have a model for the joint distribution over interactions for all surveilled objects. These inferences can be used by multi-target trackers to reduce track fragmentation, false alarms and erroneous ID switches (Sadeghian, 2017).

*Domain Adaptation:* To deploy a multi-target tracking system successfully in multiple locations, it must be able to maintain a high level of performance regardless of the environment. Domain adaptation (Csurka, 2017) is a branch of transfer learning that deals specifically with the setting where labels are available in a source domain but are unavailable in the target domain. In multi-target tracking, this problem is encountered both when re-purposing generic object detectors trained on large-scale datasets (Fang, 2017), and when testing a tracker on a sequence of videos that non-trivially differ from the training sequences. The approach in (Gaidon, 2015) suggests to jointly train target-specific detectors online with a multi-task loss to share parameters and reduce drift. In our research, we will adapt ideas from few-shot learning (Fu, 2017) (and meta and adversarial learning) to efficiently update our tracker online to handle changes in target appearance and reduce missed detections under domain shift.

Consider, for example computation of performance measures that help detect the performance of a signalized intersection. The work in (Day, 2009) lists these measures that, in general, are dependent on how robust the detector layout is at that intersection (e.g. phase events, vehicle counting, capacity, time to service, queues, green/red occupancy ratios, percentage on green, Purdue coordination diagrams, platoon ratios, red light running). The Purdue Coordination Diagram has been widely used as a powerful visualization tool to quantitatively analyze signal operations (Figure 2) but has challenges that it requires human participation. Video analysis will provide significantly more details about the vehicle counts by types, their precise arrival times, size, velocity, trajectories move through an intersection. Our goal is not only to generate reports from this information but use ML techniques to automatically score the intersection activities at different times of the day so that a traffic engineer is only alerted for intersections that are showing problematic behavior consistently – this is necessary requirement for their use in practice when managing hundreds of intersections as this will allow the personnel to focus on low scoring intersections.

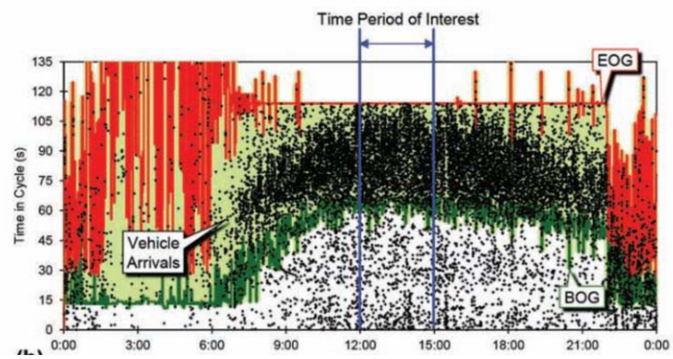



Figure 3: Purdue Coordination Diagram (PCD). The horizontal axis represents the time of day, while the vertical axis is the time in cycle. Each dot on this graph represents the arrival time of a vehicle as detected by a setback detector (with this figure derived from Day, 2009).

As another example, we will develop edge video processing to allow real-time generation of SPaT data that can then be broadcast to on-board units of vehicles to reduce start-up lost time.

Challenges for Pedestrian/Human Recognition:

Traditional detectors alone cannot detect pedestrian movement, and it is here that video analysis really shines. While the detection of human motion from video is an important feature, traditional detectors are focused more on obtaining turn movement counts of vehicles rather than monitor pedestrian motion.

*Expected outcomes:* We now detail the expected outcomes of intersection level processing using machine learning and computer vision. Real-time (and near real time) video processing integrated with other sensors will give us information on vehicular and pedestrian movements which can be used to aid in signal planning (offsets, phase adjustments etc.). Security and privacy requirements are met via real-time processing: only traffic attributes and anonymous features – a compression of the overall activity at each intersection – will be sent to the cloud to aid in urban policy planning in addition to the more mundane requirements of signal planning. Real-time processing at the edge imposes a set of constraints. We will ensure that these constraints are met by only communicating dominant features, attributes, objects and tracks to the cloud. This incurs significantly less bandwidth costs, while improving latency.

**Smart Streets:** We now describe processing segments of the entire traffic network. Instead of focusing on signal timing adjustments, we shift perspective to include onboard video information (on city buses, emergency vehicles and police cars). Once again, we plan to leverage best of breed computer vision algorithms to perform tracking of vehicles, assessment of near collisions, jaywalking, tailgating – essentially the entire gamut of live traffic centered activities. Since the city buses (for example) are moving, tracking will have to be performed taking camera motion into account; the same applies for integration and cloud communication. Egomotion issues, for example, are not a problem since accurate GPS information can be used to determine camera coordinates extrinsically. Multiple cameras on the buses allow for better integration and more accurate estimation of vehicular tracks. Bluetooth communication from the bus to roadside sensors can also be integrated into the system if available.

Such data can also provide insights into how passengers approach/leave the transit buses at stops. All these can be used to understand pedestrian safety both during day and night times. In contrast, tracking vehicles in terms of trajectories and state of brake lights and indicator lights, ahead of the bus can help understand lane-changing maneuvers undertaken before implementing a turn. The space-time trajectories of vehicles along adjacent lanes can be used to infer gap-acceptance behavior, which in turn, leads to lane changes. Again, differences can be examined across different weather conditions. Additionally, the video collected can be used to determine free parking spots along the bus routes that can be communicated in real-time to the cloud followed by to the citizens. Furthermore, the integration of motion tracking, traffic pattern identification etc. from video (and other sensors) using city buses etc. is fundamentally novel to the traffic engineering field. While summarization information from the segments will still be sent to the cloud, the edge-based processing will directly result in changes to signal parameters with these effects first tested in SUMO (and/or VISSIM).

*Expected outcomes:* The expected outcomes from segment level processing are as follows: (i) the inclusion of real-time (and near real-time) video processing conducted on city buses (and other authorized vehicles) gives us additional information for planning signal timing patterns; (ii) further, a coherent set of important activities can be summarized from onboard video; (iii) finally, video summarization not focused on signal planning can be sent to the cloud to aid further smart city planning.

**Smart System:** We envisage a comprehensive effort at the network level aimed at nothing less than a complete characterization and activity recognition (Zhuang, 2017) of important traffic patterns, the clustering of vehicles and pedestrians, responses to emergency vehicles, adjustments made during school closings etc. ***We propose to use all summarized information (traffic and pedestrian activity patterns, dominant arterials, corridors and sub-networks) sent to the cloud to perform network level traffic signal planning using pre-timed signal optimization and dynamic reinforcement learning while undertaking comprehensive policy testing in traffic simulation software such as SUMO and VISSIM.***

*Machine learning on historical data:* Once all relevant traffic data has been sent to the cloud, we can begin analysis of historical data to perform a space-time decomposition of the network. Essentially, we seek to utilize the video and other sensor summarization information to carve up the network spatially into different arterials, corridors and sub-networks and for relevant time periods. While the simplest approach we envisage is space-time clustering, this may be insufficient to extract long arterials. A more novel machine learning approach is to cluster segments (represented as graph edges) while enforcing graph connectivity and temporal compactness (e.g., a long section of Newberry road in Gainesville from 4-6PM weekdays – a typical example of a high-volume corridor at peak rush hour). From an ML perspective, this is an unsupervised (or semi-supervised if annotations from Gainesville traffic professionals are available) learning problem in a spatio-temporal graph which we seek to decompose into relevant fragments while ensuring spatial connectivity (artery or corridor) and temporal compactness (a reasonable block of time). This is novel from a transportation engineering perspective and is an excellent application of best of breed ML. Once this step has been accomplished, we propose to first perform pre-timed signal optimization and subsequently reinforcement learning for real-time and unforeseen events.

The decomposition of the network into important fragments (arterials etc.) has a huge payoff in larger networks: the decomposition facilitates network-level optimization of signal timing. The difficulty of the optimization problem stems from the high dimensionality of the signal timing parameters and decomposition allows us to carve up the problem into reasonably sized fragments.

*Proposed Work on signal timing optimization:* The primary distinction between the network and segment levels is the scale of the network which can be quite large. The network comprises the entire graph of intersections and segments. Assuming the previous ML step on historical data has been accomplished, we will possess a database of traffic information for important arterials (at different time intervals). The broad goal is to adjust the timing plans for a set of critical intersections simultaneously in order to improve the performance of the entire network while recognizing that the set of “critical intersections” will change by time of day and seasonally.

Different measures of effectiveness (MoEs) that are used for measuring network performance include mean delay time, mean queue length, network utility, total traffic flow throughput etc. The goal is to respond to the demands of motor vehicles, bicycles, and pedestrians in a safe manner. Effective signal optimization also leads to minimizing stops and delays, fuel consumption and air pollution emissions. Traffic signal control methods try to establish the relationship between observed MOEs with traffic signal parameters such as offset, phase sequence, cycle length, and green split. Many mathematical models and approaches have been proposed for optimizing one or more of the traffic parameters at a corridor or grid network using reasonable assumptions about network and traffic behavior. Depending on the complexity level of the model, strict mathematical optimization techniques or heuristics are used to find optimal or sub-optimal solutions. Offset settings are critical to the performance of traffic signal systems operated in a coordinated mode (TRRL (Transport and Road Research Laboratory), HCM (Highway Capacity Manual) as well as adaptive traffic control software like SCATS (Sydney Coordinated Adaptive Traffic System) and SCOOT (Split Cycle Offset Optimizing Technique)). The optimum offset vector has been obtained as a solution to a quadratically-constrained quadratic program (QCQP) by relaxing the original non-convex problem to a Semi-Definite Program (SDP) (Coogan, 2017). The Burer-Monteiro (BM) method has also been used for solving large SDPs: it avoids conic constraints and solves a lower dimensional non-convex problem. Genetic Algorithms (GA) have also been used to obtain candidate offset solutions (Park, 2003). GAs are also convenient when the network is decomposed into *minimally overlapping sub-networks*. Here, it is reasonable to divide the area into smaller subsystems and employ coordination mechanisms along main arterials which constitute the major demands. This decomposition is an important aspect of our optimization plans.

The SUMO *open source* software platform has advantages over many of its counterparts (closed source VISSIM etc.). The network-level optimization problem above will involve numerous SUMO simulator calls (in order to assess the effectiveness of the signal plan under consideration). Open source SUMO will allow us to simultaneously execute many instances in parallel (in memory) without encountering licensing issues. This is a huge advantage since we have to solve a large-scale optimization problem at the network level. Different decompositions of the network will result in different levels of effectiveness of the genetic algorithms (or other fitness landscape-based efforts). At the same time, different decompositions will also result in more/less SUMO simulator calls. While the open source nature of SUMO is a huge advantage, we will explore “price/performance” tradeoffs. Full-blown global optimization is not an option at the network level with clever “divide and conquer” approaches being absolutely necessary to obtain good local minima.

*Proposed work on reinforcement learning:* However, the above pre-timed optimization approaches are unable to respond to unforeseen conditions and fluctuating demands. Recently, through advancement in technology, adaptive systems have become popular and many algorithms have been proposed to improve the performance of these systems. In the next step, we propose to use machine learning techniques to develop algorithms for real-time traffic response systems. These algorithms are self-learning and have the potential to address unpredictable traffic condition issues. Reinforcement learning (RL) is a popular unsupervised machine learning technique in which an agent tries to reach a goal through interaction with an environment. For each action taken by agent, the environment provides a feedback to the agent which shows how much action is beneficial to the system for reaching its goal. The twin goals of RL are to be model free and achieve self-learning. The basic idea is to improve online performance without an explicit representation of the operating environment. The system performance itself is used without requiring a detailed specification of a model and/or its features (Kok-Lim, 2017). Even though RL does not depend on having access to ground truth data, it still requires a reward function to be specified *a priori*. To address this, we will examine the use of intrinsic objectives, i.e., objectives and related feedback that stem from internal goals and desires, as opposed to an external “teacher.” *Deep reinforcement learning* is now starting to gain traction and we expect to be able to cull a best of breed approach while incorporating our ongoing work on Sinkhorn policy updates (Emami, 2018).

*Expected outcomes:* (i) Cloud processing using all available information will result in a comprehensive network level optimization of intersection signal parameters; (ii) Deep reinforcement learning (using the SUMO simulator platform) will result in an online adaptive system which responds to unforeseen and unpredictable changes in traffic while employing a self-learning approach.

## 4.0 Evaluation Plan

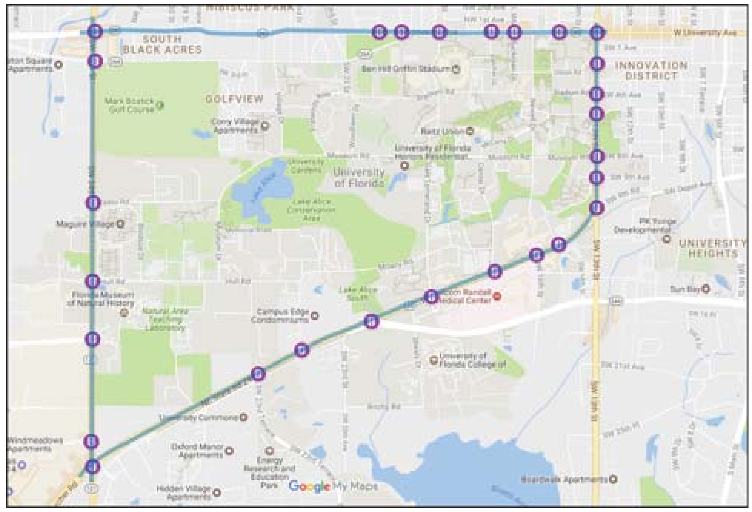



Figure 4: UF/CoG Trapezium as part of I-Street Testbed

The University of Florida Transportation Institute (UFTI), with support from FDOT and CoG is developing a smart testbed on the UF campus and adjoining city streets. The testbed, called I-STREET[1] was established to deploy and evaluate numerous advanced technologies for conventional, connected and autonomous vehicles. This includes the use of smart devices, and sensors to develop novel applications. The overall testbed includes heavy pedestrian flow, extensive bicycle facilities, scooters and mopeds on campus, and a variety of highway facilities ranging from four lane arterials to two-lane low speed roadways. Gainesville is home to one of the most heavily used transit systems in Florida (RTS - http://go-rts.com/ ), which also serves the UF campus. Additionally, the forthcoming Gainesville SPaT Trapezium will deploy and test connected vehicle technologies and applications along four roads forming a trapezium surrounding the University of Florida main campus as shown in Figure 4. The goal of the project is to improve travel time reliability, safety, throughput, and traveler information. Approximately 45 Roadside Units will be installed in this project. The roadways and intersections along and within this “Trapezium” and bus routes serving this area will constitute the fundamental real-world test bed for this study. Most of the signalized intersections of interest to this study have live CCTV RTSP feeds streamed at 30 frames per second HD quality (720p or 1080p), and Pan Tilt and Zoom capabilities and Video Detection for stop bar/presence and traffic counting. On select intersections, Multi Modal Video Detection for Pedestrians, Bicycles and Vehicles (using Iteris Vantage Live, Smart cycle and PedTrax) and Fish Eye video detection with motion tracking and vehicle classification capabilities are planned for installation. ATC controllers can provide signal-timing history at deci-second resolutions (upgrades to the latter are planned for year 2018). Thus, a variety of video feeds and signal-timings are available that will be used for ratification of the methods developed in this proposal (Please note that our methods are real-time as compared to the current methods are offline). These video cameras will be addressable via a local network at every intersection and the proposed research calls for processing these video feeds before they leave this network. Hence, processing elements will be installed on the “edge” of this local network. SPaT (Signal Phasing and Timing) Data streams are also planned for 2018 through Localized DSRC Radios within the trapezium and Cloud based SPaT data stream through data services providers (Connected Signals, Inc. and Traffic Technology Services Inc.). Eight or Twelve port copper Ethernet (fast and Gigabit) connectivity capable of VLAN segmentation are available at each intersection, with a single mode fiber backhaul to the Traffic Management Center. These will facilitate the transfer of data from the intersections to the cloud. We are also developing a cloud-based architecture to archive data to be received from various sensors in within the Trapezium (for details, see Computing and Software Architecture). About 5 intersections will be chosen to pilot test the smart-intersections efforts. Edge processors will be added to the video cameras present at these intersections (with the CoG and UF jointly designing and testing them to ensure effective real-time processing).

These will be chosen to reflect a variety of roadway geometries, traffic types and volumes, and the availability of additional data sources from those locations. To validate the edge-computing algorithms, which will generate the spatio-temporal profiles from the videos, we will store the real videos from these

[1] http://www.transportation.institute.ufl.edu/research-2/istreet-about-us/

intersections for limited durations during both day and night times and during special events like football games. After the pilot testing, the effort will be scaled to more intersections in the test bed. The generated space-time profiles will be stored on the cloud. Machine learning algorithms will be developed to analyze these to identify near misses, incidents, and to convert these into continuous-time demand profiles (turning movement counts).

| Milestone | Evaluation Criteria / Methodology |
|---|---|
| Technology Deployment | Localized testing of individual cameras, ensuring that the data feeds are collected on the cloud |
| Edge computing algorithms to reduce videos to space-time trajectories | Comparisons of derived trajectories against raw video feeds recorded for selected times |
| Conflict (near miss) detection (social goal: improving safety) | Comparisons of detected near-misses against video data; surveys of users of the intersections about their perceived safety issues on site |
| Generation of continuous-time demand profiles (social goal: throughput enhancement) | Comparisons of generated demand-profiles against turning movement counts obtained manually for selected periods. Use of traffic simulators to use the generated demands to modify signal timing plans for each intersection independently |
| Translation to traffic engineering practice | Stakeholder (city of Gainesville, Florida Department of Transportation, RTS) meetings, discussion of policy, design, and operational changes, deployment extensions |

**Smart Streets** There are a variety of bus routes that serve the Trapezium area (see figure). As in the case of intersections, we will choose 2-3 bus routes and instrument a subset of buses serving those routes with front-facing cameras. Once the edge computing algorithms are validated (against stored video feeds), we will explore scaling this to more buses and routes. Initially, data will be downloaded every night at the bus terminus for algorithm development, followed by real-time transmission using 4G/5G connectivity. As already discussed, use cases based on these video feeds include detection of pedestrians' mid-block crossing behaviors and lane changing maneuvers of vehicles.

| Milestone | Evaluation Criteria / Methodology |
|---|---|
| Technology Deployment | Localized testing of individual cameras, followed by transmission to the cloud |
| Edge computing algorithms to reduce videos to space-time trajectories | Comparisons of derived trajectories against raw video feeds recorded for selected times |
| Detection of mid-block crossings (social goal: safety enhancement) | Comparisons of detected crossings against video data; surveys of pedestrians and motorists about pedestrians' mid block crossing behaviors and perceived safety issues |
| Generation of lane changing profiles at approaches to intersections (social goal: improving throughput) | Comparisons of generated lane change profiles against turning movement counts obtained manually for selected periods |
| Translation to traffic engineering practice | Stakeholder (city of Gainesville, Florida Department of Transportation, RTS) meetings, discussion of policy, design, and operational changes, deployment extensions |

**Smart Systems** Unlike the smart-intersections and smart-streets efforts, which directly begin with real-world testing, smart systems efforts, will begin with simulated testing. The appropriate parts of the Gainesville network will be coded into a traffic simulation software and calibrated to aggregate demand profiles for different parts of the day (AM Peak, mid-day, PM Peak, night) and days of the week (weekday and weekend). Assuming the availability of continuous-time demand profiles (as they would be from smart-intersections) we will develop machine learning algorithms to optimize signal phasing and offsets (coordination) at a finer time resolution. This would require a "traffic-simulator in the loop" optimization approach in which the traffic conditions are repeatedly simulated for tens of thousands of combinations of signal timing parameters of the various intersections. The (Pareto) optimal signal timing parameters that those that help satisfy one or more system performance measures such as delays, system travel time and queue lengths at critical approaches. The algorithms will be developed using hypothetical demand profiles of the space-time profiles of vehicles at intersections which are obtained by processing video data.

| **Milestone** | **Evaluation Criteria / Methodology** |
|---|---|
| Develop a traffic-simulation model of the Trapezium | Code the network and intersection controls into a traffic simulator, calibrate to existing conditions |
| Development and testing of optimization algorithms | Use simulated continuous-time demand profiles to develop best signal timing plans for different times of the day and days of the week for the entire Trapezium network |
| Apply algorithms to real world data (social goal: improve throughput) | Once the continuous-time turn movements are available form smart-intersections initiatives, apply the algorithm on these to retime signals |
| Detection of the possibility of secondary crashes (social goal: safety enhancement) | Examine video data from transit buses and intersections upstream of a location with a crash to determine whether there is a possibility of secondary crashes |
| Translation to traffic engineering practice | Stakeholder (city of Gainesville, Florida Department of Transportation, RTS) meetings, discussion of policy, design, and operational changes, deployment extensions |

### 5.0 Computing and Software Architecture

This proposal seeks to use edge-based video-stream processing (using multicore and GPU processors) at intersections and in public vehicles to convert video data into space-time trajectories of individual vehicles/pedestrians that are transmitted and synthesized on a cloud-based system. Improving image processing techniques for traffic surveillance is an ongoing area of research in the computer vision and intelligent transportation systems (ITS) communities. For these reasons, Edge computing is centered around the concept of adding a layer of compute resources between the “IoT” devices and servers on the “cloud”. The goal of the in-between layer is to improve performance (by reducing network latency) and reduce the volume of data being transported (in an open and interoperable way). The value of this approach is also in enabling seamless interoperability between the heterogeneous datasets and providing the computing power necessary for bulk data processing and providing real-time applications that only need data collected locally. Lastly, data form vehicle detectors may be noisy and fine grained. Hence, it may need cleaning and aggregation before being sent to the cloud. We expect to use the Linux Foundation’s EdgeX framework to ensure openness and interoperability in the edge architecture.

*Edge Processing*: Below we describe key computing and software challenges for edge video processing:

- Video Characteristics: At 20-30 frames-per-second, high-definition video from a single camera can generate over 2 Gigabytes per hour. This will require GPU processing for real-time usage. Some of the main challenges faced by traffic video are the sensitivity to variations in lighting and weather, and the occlusion of vehicles. To obtain information about the speed/position of the vehicle from image data, the traffic camera must be calibrated to allow transforming detections from pixel coordinates to world-frame coordinates. Up to about 200-300 feet away, a traffic camera can reasonably localize vehicles within their lane and estimate their speed within 2-3 meters/sec (Roy, 2011).
- Deep Neural Network Software: Deep neural networks (DNNs) are currently widely used for many artificial intelligence (AI) applications, by gathering knowledge from experience with a hierarchy of concepts. While DNNs can deliver state-of-the-art performance, it comes at a cost of high computational complexity. Practitioners have found that significant maintenance burdens and leaky abstractions can be avoided, by having a single system that can integrate large-scale training and small-scale deployment. Tensor Flow provides us an excellent interface for expressing and executing machine learning algorithms. TensorFlow expresses the computation using a dataflow-like model and maps them onto a wide variety of different hardware platforms (Abadi, 2016). It has been widely used for conducting research and for deploying machine learning systems into production. TensorFlow also allows for processing available on a variety of computational devices.

GPU processing: Most image processing and deep learning frameworks can effectively leverage Nvidia’s cuDNN and other libraries. for rapid execution. This acceleration is transparent to the user of the framework library. Similar processing capabilities are also available on cloud platforms on Amazon and Google. For the image processing and matrix computation, we expect to use Halide, a new programming language, with a front end embedded in C++ which is expected to perform well on modern computer vision applications. x86/SSE, ARM v7/NEON, CUDA, and OpenCL will receive compiler support. MinPy, provides a pure NumPy interface above the popular MXNet backend, supporting a quick prototype of advanced and complex algorithms. *Cloud Computing*: Cloud computing platforms are available from a variety of vendors such as Google, Amazon, IBM, and Microsoft. We expect to use AWS from Amazon because of our experience along with the fact that it provides a relatively more mature platform for IOT applications (Amazon IoT) as compared to other vendors (though most of the approach described in this proposal is relatively independent of this choice). Devices can connect to and communicate with applications running on the cloud over many different protocols. Device specific SDKs are available for different languages. It offers support for reliable bi-directional messaging using the concept of device shadows to enable communication when the device network connectivity is not reliable. The cloud services that we expect to exploit include 1) declarative, SQL like rules engine to perform basic transformations IoT data then reroute it to endpoints such as a storage container (S3 bucket), 2) support for triggers in the AWS event-based programming platform called Lambda, 3) redirect data streams into the Kinesis streams service to support real time analytics, and 4) an archival storage service (Glacier).

*Connecting Edge and Cloud:* A comprehensive device integration management strategy will be needed to enable easy maintenance of the many devices in the field and their related firmware/software. While it may not be possible to integrate the device management software into sensors and cameras already deployed in the field, it is critical that such software be integrated into any new hardware that is deployed. Such a mechanism to remotely monitor the sensors serves dual benefits of easier maintenance of the sensors and performing an early quality check on the collected data. We will also use applications such as *Elixir* for this purpose. Elixir *is a* "*dynamic functional language*" which is built with scalability and maintainability of applications in mind. It leverages the Erlang VM, the Erlang OTP and implements Carl Hewitt's Actor model to build distributed, fault tolerant and scalable systems. Communication between actors in Elixir is enabled by a highly efficient pub-sub implementation. It is easy to address individual actors (processing elements) or group of functionally identical actors.

Security Issues: While security is not a primaryfocus, we will use state of the art security mechanisms at the edge and the cloud. AWS will be responsible for providing basic cloud security (physical, filtering and hypervisor security) while CoG will be responsible for network firewalling, access control, encryption etc.

**7.0 Results from Related Prior NSF Research (only for PIs and Co-PIs that have prior support)**

**Sanjay Ranka** NSF CNS-1514116: *SparseKaffe: High-performance, auto-tuned, energy-aware algorithms for sparse direct methods on modern heterogeneous architectures*, $395,454. Intellectual Merit: The grant led to the development of innovative scheduling algorithms for non-uniform hierarchical workflow on a GPU resulting in high performance GPU implementations of QR and Cholesky Factorization (Tang 2017, Yeralan 2016). Broader Impact: Development of a sparse matrix library should accelerate a large number of numerical algebra-based applications, including sparse linear systems, linear least squares, and eigenvalue problems. This currently supports two graduate students (Meng Tang and Mohamed Gadou).

**Anand Rangarajan** has been supported by NSF IIS-1065081: *Large data visualization using an interactive machine learning framework* (2011-2015), $303,444. Intellectual Merit: In particular, we highlight boosting for vortex detection (Zhang, 2014), labeling of remote sensing datasets (Sethi, 2015), functional neighborhood gerrymandering (Haber, 2015), superpixel estimation (Massoudifar, 2014), stochastic block dual averaging for optimization (Deng, 2013, 2015) and label propagation using graph Laplacians (Chen, 2011) as relevant to the themes of this proposal. Broader Impacts: Detection of vortices in fluid flow datasets. Training: Neil Smith, an African American Ph.D. student is now Asst. Prof., Dept. of ECE, Florida Inst. of Tech. (FIT)

**Lily Elefteriadou and Sanjay Ranka** NSF #1446813 *CPS: TTP Option: Synergy: Traffic Signal Control with Connected and Autonomous Vehicles in the Traffic Stream* 2015-2019, $1,296,428.00. Intellectual Merit: We have developed and implemented optimization strategies consisting of multiple sensor data stream fusion, as well as a mixed vehicle stream (autonomous, connected, and conventional vehicles) under real-world conditions of uncertain and missing data. Resultant publications include (Omidvar, 2018, Zhuofei, 2018, Emami, 2017, Pourmehrab, 2017, Letter, 2017, and Li, 2014) and show significant improvements over current approaches. Broad Impact: Algorithms were tested on FDOT Terl testbed for real-time cyber physical systems. Three graduate students are currently supported by this ongoing grant.

## 6.0 Management Plan and Timelines

Management Plan: This project will be led by a two-person Management Team, constituted by the institutional lead PIs: Hoffman and Ranka, that will work in conjunction with other co-PIs, graduate students and senior personnel. The graduate students will conduct algorithmic research and develop software. They city personnel will lead the evaluation. The city and university have established working relationships over the past two years that will form the managerial foundation for this effort. The two PIs have established records for managing distributed, high-impact projects of comparable scope to the work proposed here. The research and development activities of the project encompass two types of activities.

1. The algorithm and software development activity will draw upon our research and implementation experiences to develop novel methods for video processing, machine learning and high-performance computing. It will include developing an edge and cloud-based computing platform
2. The evaluation activity will involve the performance evaluation and benchmarking for the software for real applications on real testbeds and simulated testbeds (wherever necessary).

As principles emerge from the above the participants will review and feed the best ideas back into the research program. This kind of close coordination and rapid feedback is needed to achieve its overall goal. We will have frequent videoconferencing (once a week) and in-person (once a month) meetings.

*Metrics for Success:* We will also measure our success by the level of adoption of our results by other cities industry, federal labs, and academia, which we expect to be high, based on the broad range of applications that depend the type of techniques described in this proposal.

*Roles and Expertise of the team:* A multidisciplinary team with a range of disciplines essential to the success of this project: traffic operations (Elefteriadou, Posadas, Srinivasan), policy (Hoffman), machine learning and video analytics (Rangarajan and Ranka), traffic optimization and safety analysis (Elefteriadou, Srinivasan), and GPU and cloud computing (Ranka). The investigators have extensive experience in their respective fields and have already made significant contributions to their disciplines.

Deliverables and Timelines: Activities such as writing papers, course development, dissemination, workshops, industrial collaboration, etc. will be conducted during the entire duration of the project.

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<tr><td></td><td colspan="2">Year 1</td><td colspan="2">Year 2</td><td colspan="2">Year 3</td><td colspan="2">Year 4</td></tr>
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<tr><td rowspan="2">Intersection Algorithms and Software</td><td colspan="2">Multi-target tracking</td><td colspan="2">Causal Reasoning Parallelization</td><td></td><td colspan="2" rowspan="2">Algorithm refinements</td><td></td></tr>
<tr><td></td><td colspan="2">Track Association</td><td colspan="2">Domain Adaption</td><td></td></tr>
<tr><td rowspan="2">Intersection Evaluation</td><td colspan="2">Technology Deployment</td><td colspan="3">Edge Computing Evaluation</td><td rowspan="2">Solution Deployment</td><td colspan="2" rowspan="2">Solution Refinement</td></tr>
<tr><td></td><td></td><td colspan="3">Conflict Evaluation<br>Turn Movement Counts</td></tr>
<tr><td rowspan="2">Street Algorithms and Software</td><td></td><td></td><td>Deriving Trajectories</td><td colspan="2">Lane Changing Profile</td><td colspan="2" rowspan="2">Algorithm Refinements</td><td></td></tr>
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<tr><td rowspan="2">Street Evaluation</td><td></td><td></td><td>Technology Deployment</td><td colspan="2">Derived Trajecs.</td><td rowspan="2">Lane Changing Profile Evaluation</td><td rowspan="2">Solution Deployment</td><td rowspan="2">Solution Dissemination</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Mid Block Crossings</td></tr>
<tr><td rowspan="2">System Algorithms and Software</td><td colspan="3">Historical Data Analysis</td><td colspan="4">Algorithm Refinements</td><td></td></tr>
<tr><td colspan="2">Subnetwork/Corridor Optimization</td><td colspan="2">Overall Network Optimization</td><td colspan="2">Reinforcement Learning</td><td></td><td></td></tr>
<tr><td rowspan="2">System Implementation</td><td colspan="2">Trapezium Simulation Model</td><td colspan="2">Corridor Optimization</td><td></td><td colspan="3">Real-time Adaption to Changing Traffic/Crash</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="3">Network Level Deployment</td><td></td></tr>
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35. A. Wijayasiri, T. Banerjee, S. Ranka, S. Sahni, M. Schmalz, Dynamic Data Driven Image Reconstruction Using Multiple GPUs, Proceedings of International Symposium on Signal Processing and Information Technology (ISSPIT), December 12-16, 2016, pp. 241 – 246.
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41. Zhuofei L., M. Pourmehrab, L. Elefteriadou, S. Ranka, "Intersection Control Optimization for Automated Vehicles Using Genetic Algorithm", Under review, ASCE Journal of Transportation Engineering, January 2018.

Daniel Hoffman
Assistant City Manager, City of Gainesville, Florida
200 East University Ave.
Gainesville, FL 32601
Tel: (352)393-8603, E-mail: hoffmandc@citygainesville.org

**(a) Professional Preparation**

a. Johns Hopkins University, Organization Development and Strategic Human Resources, Masters of Science, 2006
b. George Washington University, Political Science, Bachelors, 1999
c. George Washington University, Business Analysis, Graduate Certificate,
d. Project Management Institute, Project Management Professional certification (PMP), 2007

**(b) Appointments**

Montgomery County, Maryland – Chief Innovation Officer, October 2012 to July 2017
University of Maryland – Adjunct Professor, August 2016 to May 2017
U.S. Nuclear Regulatory Commission (NRC) – Term Appointee – Project Manager, June 2010 to October 2012
PricewaterhouseCoopers LLP – Washington Federal Practice – Senior Associate, June 2007 to June 2010
Program Manager – Government of the District of Columbia, Child and Family Services Agency Project Manager/Analyst, March 2006 to June 2007
Bread for the City – Communications and Marketing Director, August 2004 to March 2006
Clear Channel Communications – Associate Producer, January 2002 to August 2004

**(c) Products**

Hoffman, D., Benson, K., Nickel, E., (2015), "Research Roadmap for Smart Firefighting", National Institutes of Standards and Technology, Special Publication 1191

**(d) Synergistic Activities**

As Chief Innovation Officer for Montgomery County, Maryland Mr. Hoffman ran the Innovation Program and operated a variety of initiatives including:

- The Thingstitute, a living laboratory for the public sector exploration of IoT technologies. The Thingstitute operates test beds that provide opportunities for entrepreneurs and other organizations to test smart city solutions in real world settings.
- The SCALE (Safe Community Alert Network) Project, an internationally recognized effort that brings together stakeholders from the private, public and academic sectors to advance the deployment of IoT devices to vulnerable populations.
- The Smart Transit Spotlight Project, exploring the impact of connected and autonomous transportation and public transit.
- Cooperative agreements with the National Institutes of Standards and Technology to advance replicable smart city technologies.
- Smart firefighting programs including co-authored content for a research roadmap for the National Fire Protection Research Foundation.

# Lily (Ageliki) Elefteriadou, Ph.D.

**Barbara Goldsby Professor of Civil Endineering, University of Florida**
TEL: (352) 294 7802, E-mail: elefter@ce.ufl.edu

**(a) Professional Preparation**

Graduate Diploma, Surveying and Environmental Engineering, (five year program) Aristotle University of Thessaloniki, Greece, June 1987
M.S., Civil Engineering, Auburn University, Auburn, Alabama, June 1990
Ph.D., Transportation Planning and Engineering, New York University, New York, June 1994

**(b) Appointments**

Interim Chair, Department of Industrial and Systems Engineering, University of Florida (August 2016 - present)
Director, University of Florida Transportation Institute (UFTI) and Professor, Civil and Coastal Engineering, University of Florida, (June 2013-present)
Director, Transportation Research Center (TRC), and Professor, Civil and Coastal Engineering, University of Florida, (June 2008-June 2013)
Director, Transportation Research Center (TRC), and Associate Professor, Civil and Coastal Engineering, University of Florida, (July 2004-May 2008)
Interim Director, Pennsylvania Transportation Institute (PTI), Penn State University (August 2003-June 2004)
Associate Director, PTI, Penn State University (July 2002 – August 2003)
Associate Professor (July 2000-June 2004), and Assistant Professor (Aug. 1994-June 2000), Department of Civil and Environmental Engineering, PSU
Transportation Engineer, Garmen Associates, Montville, New Jersey (Sept. 1993 - Aug. 1994)
Senior Teaching Fellow, Polytechnic University, Brooklyn, New York (Sept. 1990-Aug. 1993)
Graduate Research Assistant, Auburn University, Auburn, Alabama (Sept. 1988-June 1990)

**(c) Products**

**(i) Five Products Related to the Proposed Research**

1. M. Pourmehrab, L. Elefteriadou, and S. Ranka, Smart Intersection Control Algorithms for Automated Vehicles, Tenth International Conference on Contemporary Computing (IC3 2017), 2017, November 2017.
2. Letter, C., L. Elefteriadou "Efficient Control of Fully Automated Connected Vehicles at Freeway Merge Segments", accepted for publication, Transportation Research Part C, April 2017.
3. Li, Z., L. Elefteriadou, S. Ranka, "Signal Control Optimization for Automated Vehicles at Isolated Signalized Intersections", Transportation Research Part C, Volume 49, pages 1-18, December 2014.
4. Fang, C. and L. Elefteriadou, "Capability-Enhanced Microscopic Simulation with Real-Time Traffic Signal Control," IEEE Transactions on Intelligent Transportation Systems, Volume 9, Number 4, December 2008.
5. Fang, C. and L. Elefteriadou, "Development of an Optimization Methodology for Adaptive Traffic Signal Control at Diamond Interchanges," ASCE Journal of Transportation Engineering, Vol. 132, No. 8, August 2006, pp. 629-637.

**(ii) Five other Products**

1. Zheng, Y., L. Elefteriadou, "A Model of Pedestrian Delay at Unsignalized Intersections in Urban Networks, Transportation Research: Part B 100 (2017) pp. 138-155.

2. Zheng, Y., Chase, R.T., Elefteriadou, L., Schroeder, B., Sisiopiku, V.P., "Modeling Pedestrian-Vehicle Interactions Outside of Crosswalks", Simulation Modelling Practice and Theory, Volume 59, December 2015, Pages 89–101.
3. Kondyli, A., L. Elefteriadou, W. Brilon, F. Hall, B. Persaud, and S. Washburn "Enhancing Ramp Metering Algorithms with the Use of Probability of Breakdown Models", ASCE Journal of Transportation Engineering, Volume 140, Number 4, 9 pages, April 2014.
4. Sun, D., L. Elefteriadou, "Research and Implementation of Lane Changing Model Based on Driver Behavior" Transportation Research Record: Journal of the Transportation Research Board, No 2161, Transportation Research Board of the National Academies, Washington DC 2010, pp. 1-10 (Received the 2010 Best Model Development Paper Award by the Joint Subcommittee on Traffic Simulation).
5. McFadden, J., L. Elefteriadou, "Development of a New Procedure for Evaluating the Horizontal Alignment Design Consistency of Two-Lane Rural Highways," Transportation Research Record: Journal of the Transportation Research Board, No 1737, National Academy Press, 2000, pp. 9-17 (Won the Transportation Research Board's Fred Burggraf Award - 2000).

**(d) Synergistic Activities**

i. Director of the USDOT Regional University Transportation Center (UTC) for the Southeast (Southeast Transportation Research, Innovation, Development, and Education– STRIDE) - Current – ($14 Million). The center, led by UF, involves a total of ten universities and focuses on reducing congestion.
ii. Past Chair of TRB's Highway Capacity and Quality of Service Committee – AHB40, which produces the Highway Capacity Manual (HCM), a document used around the world for traffic operational analysis (2010 – 2016). The HCM is TRB's most widely distributed publication.
iii. Collaborated with the Florida Department of Transportation and the City of Gainesville to develop I-STREET (http://www.transportation.institute.ufl.edu/research-2/istreet-about-us/) a real-world testbed for advanced transportation technologies in Gainesville, Florida
iv. Led the effort to create a Women in Transportation Seminar (WTS) student chapter, the first one of its kind, in collaboration with the Orlando, Florida WTS professional chapter.

**Anand Rangarajan**

## PROFESSIONAL PREPARATION

- B.Tech, Electrical Engineering, June 1984, Indian Institute of Technology, Madras, India.
- Ph.D., Electrical Engineering, May 1991, University of Southern California, Los Angeles, U.S.A., Thesis title: *Representation and recovery of discontinuities in some early vision problems.*

## PROFESSIONAL APPOINTMENTS

- Associate Professor, August 2000 until present, Department of Computer and Information Science & Engineering, University of Florida, Gainesville, FL (tenured).
- Assistant Professor, January 1996 to August 2000, Departments of Diagnostic Radiology and Electrical Engineering, Yale University, New Haven, CT.
- Associate Research Scientist, December 1992 to December 1995, Departments of Computer Science and Diagnostic Radiology, Yale University, New Haven, CT.
- Postdoctoral Associate, December 1990 to December 1992, Departments of Computer Science and Diagnostic Radiology, Yale University, New Haven, CT.
- Graduate Research Assistant, September 1984 to December 1990, University of Southern California, Los Angeles, CA.

## PUBLICATIONS RELATED TO THE PROJECT

- Yupeng Yan, Manu Sethi, Anand Rangarajan, Ranga Raju Vatsavai and Sanjay Ranka, Graph-based semi-supervised classification on very high resolution remote sensing images, *International Journal of Big Data Intelligence (IJBDI)*, 4(2):108-122, 2017.
- Chengliang Yang, Manu Sethi, Anand Rangarajan and Sanjay Ranka, Supervoxel-based segmentation of 3D volumetric images, *Asian Conference on Computer Vision (ACCV),* (1) 2016: 37-53
- Rana Haber, Anand Rangarajan and Adrian M. Peter*,* Discriminative interpolation for classification of functional data*, ECML/PKDD,* (1):20-36, 2015.
- Anand Rangarajan, Steven Gold and Eric Mjolsness, A novel optimizing network architecture with applications, Neural Computation, 8(5):1041-1060, 1996.
- Alan L. Yuille and Anand Rangarajan: The concave-convex procedure. Neural Computation 15(4): 915-936 (2003).

## OTHER SIGNIFICANT PUBLICATIONS

- Manu Sethi, Yupeng Yan, Anand Rangarajan, Ranga Raju Vatsavai and Sanjay Ranka, Scalable machine learning approaches for neighborhood classification using very high resolution remote sensing imagery, *Knowledge Discovery and Data Mining (KDD)*, 2069-2078, 2015.
- Karthik S. Gurumoorthy and Anand Rangarajan, Distance transform gradient density estimation using the stationary phase approximation, *SIAM J. Math. Analysis,* 44(6): 4250-4273 (2012).
- L. Zhang, Q. Deng. R. Machiraju, A. Rangarajan, D. Thompson, D.K. Walters and H.-W. Shen, Boosting techniques for physics-based vortex detection, *Computer Graphics Forum*, 33(1):282-293, 2014.
- Ajit Rajwade, Anand Rangarajan and Arunava Banerjee, Image denoising using the higher order singular value decomposition, *IEEE Trans. Pattern Anal. Mach. Intell.,* 35(4): 849-862 (2013).
- Adrian Peter and Anand Rangarajan, Information geometry for landmark shape analysis: Unifying shape representation and deformation, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 31(2):337-350, February, 2009.

## SYNERGISTIC ACTIVITIES

Unless otherwise indicated, the open source programs mentioned here are available on my website.

- Developed face and shape databases—RaceSpace and GatorBait 100 respectively-–available as open source.
- 2D wavelet density estimation available under GPL, ©A. Peter and A. Rangarajan
- Robust point matching for non-rigid registration (TPS-RPM) available under GPL, ©Haili Chui and Anand Rangarajan.
- Associate Editor, IEEE Transactions on Pattern Analysis and Machine Intelligence (2003-2007) and Computer Vision and Image Understanding (CVIU), 2007-2011.
- Co-organized Frontiers in Computer Vision (FiCV) in conjunction with IEEE CVPR 2012, ITinCVPR with F. Escolano in conjunction with IEEE ICCV 2011 (Barcelona, Spain), General Chair, EMMCVPR 2005 (St. Augustine, FL), and EMMCVPR 2003 (Lisbon, Portugal).

**Sanjay Ranka**

**Professor of Computer Information Science and Engineering**
**University of Florida, Gainesville**
Email: ranka@cise.ufl.edu Telephone: 352-514-4213

**(a) Professional Preparation**

| | | | |
|---|---|---|---|
| 1988 | Ph.D. | Computer and Information Science | University of Minnesota, Minneapolis |
| 1987 | M.S. | Computer and Information Science | University of Minnesota, Minneapolis |
| 1985 | B.Tech. | Computer Science and Engineering | Indian Institute of Technology, Kanpur |

**(b) Appointments**

| | |
|---|---|
| 2002-- | Professor, Computer Science, University of Florida, Gainesville, FL |
| 1999-2002 | Chief Scientist and CTO, Paramark Inc., Sunnyvale, CA |
| 1995-99 | Associate Professor, Computer Science, University of Florida, Gainesville, FL |
| 1993-95 | Associate Professor, Computer Science, Syracuse University, Syracuse, NY |
| 1988-93 | Assistant Professor, Computer Science, Syracuse University, Syracuse, NY |

**(c) Products**

**(i) Five Products Related to the Proposed Research**

1. S. N. Yeralan, T. A. Davis, W. M. Sid-Lakhdar, and S. Ranka, Algorithm 9xx: Sparse QR Factorization on the GPU, in ACM Transactions on Mathematical Software, July 2017, Vol 44(2): 17:1-17:29.
2. Y. Yan, M. Sethi, A. Rangarajan, R. Vatsavai, and S. Ranka, Graph-Based Semi-Supervised Classification on High Resolution Remote Sensing Images, in International Journal of Big Data Intelligence, 2017, Vol. 4, No. 2, pp. 108-122.
3. A. Wijayasiri, T. Banerjee, S. Ranka, S. Sahni, M. Schmalz, Multiobjective Optimization of SAR Reconstruction on Hybrid Multicore Systems, Proceedings of HiPC 2017, to appear.
4. M. Tang, M. Gadou and S. Ranka, A Multithreaded Algorithm for Sparse Cholesky Factorization on Hybrid Multicore Architectures. Proceedings of International Conference on Computational Sciences (ICCS), June 12-14, 2017, pp. 616-625
5. J. Li, S. Ranka and S. Sahni, Optimal Alignment of Three Sequences on A GPU. Proceedings of 6th International Conference on Bioinformatics and Computational Biology (BICoB), March 24-26, 2014, pp. 177-182. (Best Paper Award).

**(ii) Five other Products**

1. M. Sethi, Y. Yan, A. Rangarajan, R. R. Vatsavai and S. Ranka, Scalable Machine Learning Approaches for Neighborhood Classification Using Very High Resolution Remote Sensing Imagery. Proceedings of Knowledge Discovery and Data Mining (KDD) August 10-13, 2015, pp. 2069-2078.
2. I. Al-furaih, S. Aluru and S. Ranka: Parallel Construction of Multidimensional Binary Search Trees, IEEE Transactions on Parallel and Distributed Systems, February 2000, pp. 136-148.
3. C. W. Ou and S. Ranka, Parallel Incremental Graph Partitioning, IEEE Transactions on Parallel and Distributed Systems, August 1997, pp. 884-896.
4. Mingxi Wu, Chris Jermaine, and Sanjay Ranka, A LRT Framework for Fast Spatial Anomaly Detection, KDD 2009 (Best Paper Runner up Award).

5. Manas Somaiya, Chris Jermaine and Sanjay Ranka, Learning Correlations Using the Mixture-Of-Subsets Model. *ACM Transactions on Knowledge Discovery from Data,* Volume 1, Number 4, 2008, pp 1-42.

**(d) Synergistic Activities**

1. I was a co-developer of the Fortran90D compiler, one of the first compilers that allowed the programmer to view distributed memory as a single global shared space and automatically generate the message passing code required for data movement on distributed memory machines. This compiler demonstrated that the data decomposition directives and the explicit data parallel constructs in Fortran90D can be used to generate codes that are comparable to hand optimized code and led to the development of High Performance Fortran (HPF), a language supported by many vendors in the late 1990s. The Fortran90D compiler technology co-developed was transferred to PortlandGroup and led to commercial grade compilers for clusters and supercomputers. Key features in Fortran90D to support data parallelism and data distribution are present in more recent vendor-supported HPC languages (Chapel, Fortress, X10) and the NVIDIA CUDA environment. As part of the compiler effort, I led the development of scalable and highly tuned runtime libraries, that were architecture-independent, had significant algorithm novelty and supported a multitude of user-defined array distribution directives (e.g. block and cyclic) and parallel constructs (e.g. assignment statement, forall statement/construct, redistribution statement).
2. As the CTO and co-founder of Paramark, I conceptualized, designed and developed a real-time, parallel and fault-tolerant optimization service called PILOT in 1999. PILOT served more than 10 million optimized decisions a day in 2001 with a 99.99% uptime. Because of PILOT based products, Paramark was recognized by VentureWire/Technologic Partners as a top 100 Internet technology company in 2001 and 2002 and was acquired in 2002. Real-time optimization pioneered by Paramark is present today in marketing/CRM solutions provided by companies such as Adobe-Omniture and SAP. PILOT used active learning along with data mining techniques to in real-time update the best advertisement based on changing conditions and/or consumer profiles. This resulted in 20-100% improvement in revenue generated for advertisement campaigns for Capitol One, American Express, Chase Bank, and Next-Card.
3. Energy consumption has become a critical issue in large scale grids and data centers as their energy requirements for powering and cooling are becoming comparable to the costs of acquisition. My research has resulted in several important contributions in managing energy for multicore, manycore and GPU machines. Several of these contributions appear in co-authored monographs “Dynamic Reconfiguration in Real-Time Systems: Energy, Performance, and Thermal Perspectives” (Springer Verlag, 2012) and “Parallel and Distributed Embedded Systems” (John Wiley, 2016).

**Sivaramakrishnan (Siva) Srinivasan**

## Professional Preparation

Indian Institute of Technology, Madras
    B. Tech. (Civil Engg.), May 1999
The University of Texas at Austin
    M.S.E. (Civil Engg.), December 2000
    Ph.D. (Civil Engg.), December 2004
    Postdoctoral Research (Civil Engg.), Jan 05 – July 05

## Appointments

| | |
|---|---|
| August, 2011 – Present | Associate Professor, Department of Civil and Coastal Engineering, University of Florida. |
| August, 2011 – Present | Associate Professor, (affiliate appointment), Department of Urban and Regional Planning, University of Florida. |
| August, 2005 – July 2011 | Assistant Professor, Department of Civil and Coastal Engineering, University of Florida. |
| July, 2009 – July 2011 | Assistant Professor (affiliate appointment), Department of Urban and Regional Planning, University of Florida. |

## Related Publications

- **Srinivasan, S.,** Smith, S, and Milakis, D (2016) "Implications of Vehicle Automation for Planning" in Road Vehicle Automation 3 (Chapter 23), pp 287-295, edited by Meyer, G. and Beiker, S.
- **Srinivasan, S.,** Lugo, M., Spana, S., Maldonando, P., Steiner, R., Elefteriadou, L., Yin, Y., and Crane, C (2016) Surveying Florida MPO Readiness to Incorporate Innovative Technologies into Long Range Transportation Plans, Final Report FDOT #BDV32-977-06, 63 pages
- **Srinivasan, S.,** Carrick, G., Zhu, X, Heaslip, K., and Washburn, S (2008) "Analysis of Crashes in Freeway Work Zone Queues: A Case Study, Final Report Research Project #: 07-UF-R-S3, Grant #: DTRS99-G-0004 (24 pages)
- **Srinivasan, S.,** Haas, P, Dhakar, N.S, Hormel, R., Torbic, D., and Harwood, D (2011) Development and Calibration of Highway Safety Manual Equations for Florida Conditions, Final Report, FDOT Project BDK77 977-06, 76 pages
- Yin, Y, **Srinivasan, S.,** Carrick, G., Jermprapai, K., Sun, X., Shirmohammadi, N., Shahabi, M. (2016) Warrants, Design, and Safety of Road Ranger Service Patrols, Final Report, FDOT Project BDV31-977-52, 143 pages

## Other Significant Publications

- Alivand, M.(**G),** Hochmair, H., and **Srinivasan, S.** (2015) "Analyzing how travelers choose scenic routes using route choice models", *Computers, Environment and Urban System,* Volume 50, pp. 41-52
- Dhakar, N. and **Srinivasan, S** (2014) "Route-Choice Modeling Using GPS-Based Travel Surveys", *Transportation Research Record*, Vol 2413, pp. 65-73.
- Villegas,J., Matyas, C., **Srinivasan, S**., Cahyanto, I, Thapa, B., Pennington-Gray, L. (2013) "Cognitive and affective responses of Florida tourists after exposure to hurricane warning messages" *Natural Hazards*, Volume 66, Issue 1, pp 97-116.
- Zhu, X. and **Srinivasan, S.** (2011) "A Comprehensive Analysis of Factors Affecting the Injury-Severity of Large-Truck Crashes", *Accident Analysis and Prevention*, Vol. 43, Issue 1, pp. 49-57.
- Carrick, G., **Srinivasan, S.**, and Washburn, S. (2010) "Descriptive Analysis and Characterization of Law Enforcement Vehicle Crashes in Florida" *Transportation Research Record*, Vol. 2182, pp. 40-47.

## Synergistic Activities

- Chair, Transportation Research Board Committee on Impacts of Information and Communication Technologies on Travel Choices
- Member, Transportation Research Board Committee on Traveler Behavior and Values
- Member of the Florid Department of Transportation Automated Vehicles Working Group (policy)
- Member of the Model Advancement Committee of the Florida Statewide Model Task Force, Florida Department of Transportation (FDOT)
- Member of the Editorial Advisory Board, Transportation Research Part B

Emmanuel Posadas
Traffic Operations Manager
405 NW 39th Avenue, Gainesville Fl.
Tel: 352-393-8429 E-mail:posadasep@cityofgainesville.org

**(a) Professional Preparation**

2006 M of Urban and Regional Planning, Boca Raton FL
1999 BS Civil Engineering, De La Salle University, Manila, Philippines
State of Florida Licensed Professional Engineer. PE License # 62512
Institute of Transportation Engineers – Certified Professional Traffic Operations Engineer
Microsoft Certified Professional – Network, Workstations, Servers (2000 Edition)
Informatics Ltd, Singapore – Visual Basic Professional
Stanford University Online – Machine Learning Certificate

**(b) Appointments**

| | |
|---|---|
| 2015-current | Traffic Operations Manager, Public Works Department, City of Gainesville |
| 2014-16 | Transportation Intelligence llc, Principal & Managing Partner, Coconut Creek, FL |
| 2005-15 | Traffic Operations Engineer, Municipal Services Department, City of Boca Raton |
| 2001-05 | Engineer I/II, Traffic Engineering Division, Broward County, Ft Lauderdale, FL |
| 2000-01 | Inspector I/Inspector II, Florida Department of Transportation, D4, Ft Lauderdale |
| 1999-2000 | The Answer Group Inc, Tec Support Engineer, North Lauderdale, FL, |

**(c) Products**

1. So J., Stevanovic A., Posadas E., Awwad R., "Field Evaluation of Synchro Green Adaptive Signal Systems", American Society of Civil Engineers, TD&I Congress, June 2014, Orlando, FL
2. Posadas, E., "Incorporating Common Technology Advances in ITS Deployments with Minimal Costs". Institute of Transportation Engineers Annual Meeting, August 2008, Anaheim, CA
3. Prosperi, D.C., Posadas, E. and Guise, L., "Searching for E-Government: Data Mining the Broward County Web-server" 23rd Urban Data Management Society, Prague, Czech Republic, October 2002.

**(d) Selected Synergistic Activities**

1. Agency (City of Gainesville) Collaborator/Participant for UF I-STREET and I-75 FRAME . 2017 – Current.
2. Agency (City of Gainesville) Participant for "Development of Statewide Guidelines for Implementing Leading Pedestrian Intervals in Florida" (FDOT Research BDV25-977-22 led by Pei-Sung Lin, Ph.D) 2015 - 2017
3. Agency Collaborator/Participant for "Demand Based Signal Retiming" (FDOT Research ID BDV27-2-977-01, led by Florida Atlantic University, Alexander Stevanovic, PhD). 2013 - 2015
4. Protected Routes for Secret Service for Obama/Romney Debate in Lynn University, Boca Raton, using virtual signal pre-emption/priority. 2012.
5. Agency (City of Boca Raton) Participant for "Impact of Communication/Detection Degradation on Advanced Traffic Management Systems Operations", 2007 - 2009 (FDOT Research BDH 29, led by Pei-Sung Lin, Ph.D)
6. Co Project Manager for wide scale pre-emption system (29 Municipalities, 15 Fire Departments, over 300 arterial signals, in a 1,000 traffic signal network, 1.2M Population – Broward County), 2003-2005
7. UTCS/Urban Traffic Control System Modernization, Modernized/lifespan extension of a 1970s based system to pass formatted data streams using VB and ESRI's ArcView 3.1. Broward County Commercial Blvd Signal Alpha Test – First Area wide, packetize TCP/IP (10Mbps) interconnected signal corridor in Florida. 2001

# SUMMARY PROPOSAL BUDGET

YEAR 1

| | | | | | |
|---|---|---|---|---|---|
| ORGANIZATION: **City of Gainesville, FL** | FOR NSF USE ONLY | PROPOSAL NO. | DURATION (months) Proposed | Granted | |
| PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Daniel Hoffman** | | AWARD NO. | | | |

| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) |
|---|---|---|---|---|---|
| 1. **Daniel Hoffman - PI** | 1.00 | 0.00 | 0.00 | **12,917** | |
| 2. **Emmanuel Posadas - Senior Personnel** | 2.00 | 0.00 | 0.00 | **18,919** | |
| 3. | | | | | |
| 4. | | | | | |
| 5. | | | | | |
| 6. ( **0** ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | **0** | |
| 7. ( **2** ) TOTAL SENIOR PERSONNEL (1 - 6) | 3.00 | 0.00 | 0.00 | **31,836** | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | |
| 1. ( **0** ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | **0** | |
| 2. ( **1** ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 2.00 | 0.00 | 0.00 | **13,622** | |
| 3. ( **0** ) GRADUATE STUDENTS | | | | **0** | |
| 4. ( **0** ) UNDERGRADUATE STUDENTS | | | | **0** | |
| 5. ( **0** ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | **0** | |
| 6. ( **1** ) OTHER | | | | **35,000** | |
| TOTAL SALARIES AND WAGES (A + B) | | | | **80,458** | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | **22,909** | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | **103,367** | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) | | | | | |
| **Field Hardened Edge Devices (8 Each)** | $ **32,000** | | | | |
| **Streaming on Board Video for buses** | **15,000** | | | | |
| TOTAL EQUIPMENT | | | | **47,000** | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | **0** | |
| 2. INTERNATIONAL | | | | **0** | |
| F. PARTICIPANT SUPPORT COSTS | | | | | |
| 1. STIPENDS $ **0** | | | | | |
| 2. TRAVEL **0** | | | | | |
| 3. SUBSISTENCE **0** | | | | | |
| 4. OTHER **0** | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( **0** ) TOTAL PARTICIPANT COSTS | | | | **0** | |
| G. OTHER DIRECT COSTS | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | **11,840** | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | **0** | |
| 3. CONSULTANT SERVICES | | | | **20,000** | |
| 4. COMPUTER SERVICES | | | | **0** | |
| 5. SUBAWARDS | | | | **411,992** | |
| 6. OTHER | | | | **8,953** | |
| TOTAL OTHER DIRECT COSTS | | | | **452,785** | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | **603,152** | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **none (Rate: 0.0000, Base: 0)** | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | **0** | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | **603,152** | |
| K. SMALL BUSINESS FEE | | | | **0** | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | **603,152** | |
| M. COST SHARING PROPOSED LEVEL $ **0** | AGREED LEVEL IF DIFFERENT $ | | | | |

| | | | |
|---|---|---|---|
| PI/PD NAME: **Daniel Hoffman** | FOR NSF USE ONLY | | |
| | INDIRECT COST RATE VERIFICATION | | |
| ORG. REP. NAME* | Date Checked | Date Of Rate Sheet | Initials - ORG |

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

# SUMMARY PROPOSAL BUDGET

YEAR 2

| | | | | | |
|---|---|---|---|---|---|
| **FOR NSF USE ONLY** | | | | | |
| ORGANIZATION: **City of Gainesville, FL** | PROPOSAL NO. | DURATION (months) Proposed | Granted | | |
| PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Daniel Hoffman** | AWARD NO. | | | | |

| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) |
|---|---|---|---|---|---|
| 1. **Daniel Hoffman - PI** | 1.00 | 0.00 | 0.00 | **13,175** | |
| 2. **Emmanuel Posadas - Senior Personnel** | 2.00 | 0.00 | 0.00 | **19,928** | |
| 3. | | | | | |
| 4. | | | | | |
| 5. | | | | | |
| 6. ( **0** ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | **0** | |
| 7. ( **2** ) TOTAL SENIOR PERSONNEL (1 - 6) | 3.00 | 0.00 | 0.00 | **33,103** | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | |
| 1. ( **0** ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | **0** | |
| 2. ( **0** ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 2.00 | 0.00 | 0.00 | **13,935** | |
| 3. ( **0** ) GRADUATE STUDENTS | | | | **0** | |
| 4. ( **0** ) UNDERGRADUATE STUDENTS | | | | **0** | |
| 5. ( **0** ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | **0** | |
| 6. ( **0** ) OTHER | | | | **35,700** | |
| TOTAL SALARIES AND WAGES (A + B) | | | | **82,738** | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | **23,368** | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | **106,106** | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) | | | | | |
| TOTAL EQUIPMENT | | | | **0** | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | **0** | |
| 2. INTERNATIONAL | | | | **0** | |
| F. PARTICIPANT SUPPORT COSTS<br>1. STIPENDS $ **0**<br>2. TRAVEL **0**<br>3. SUBSISTENCE **0**<br>4. OTHER **0** | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( **0** ) TOTAL PARTICIPANT COSTS | | | | **0** | |
| G. OTHER DIRECT COSTS | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | **11,840** | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | **0** | |
| 3. CONSULTANT SERVICES | | | | **0** | |
| 4. COMPUTER SERVICES | | | | **0** | |
| 5. SUBAWARDS | | | | **424,236** | |
| 6. OTHER | | | | **8,283** | |
| TOTAL OTHER DIRECT COSTS | | | | **444,359** | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | **550,465** | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **(Rate: , Base: )** | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | **0** | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | **550,465** | |
| K. SMALL BUSINESS FEE | | | | **0** | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | **550,465** | |
| M. COST SHARING PROPOSED LEVEL $ **0** | AGREED LEVEL IF DIFFERENT $ | | | | |

| | | | |
|---|---|---|---|
| PI/PD NAME: **Daniel Hoffman** | **FOR NSF USE ONLY** — INDIRECT COST RATE VERIFICATION | | |
| ORG. REP. NAME* | Date Checked | Date Of Rate Sheet | Initials - ORG |

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

# SUMMARY PROPOSAL BUDGET

YEAR 3

| | | | | | | |
|---|---|---|---|---|---|---|
| ORGANIZATION<br>City of Gainesville, FL | | | | FOR NSF USE ONLY<br>PROPOSAL NO. | DURATION (months)<br>Proposed | Granted |
| PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR<br>Daniel Hoffman | | | | AWARD NO. | | |
| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) | |
| 1. Daniel Hoffman - PI | 1.00 | 0.00 | 0.00 | 13,439 | | |
| 2. Emmanuel Posadas - Senior Personnel | 2.00 | 0.00 | 0.00 | 19,684 | | |
| 3. | | | | | | |
| 4. | | | | | | |
| 5. | | | | | | |
| 6. ( 0 ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | 0 | | |
| 7. ( 2 ) TOTAL SENIOR PERSONNEL (1 - 6) | 3.00 | 0.00 | 0.00 | 33,123 | | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | | |
| 1. ( 0 ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | 0 | | |
| 2. ( 1 ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 2.00 | 0.00 | 0.00 | 14,214 | | |
| 3. ( 0 ) GRADUATE STUDENTS | | | | 0 | | |
| 4. ( 0 ) UNDERGRADUATE STUDENTS | | | | 0 | | |
| 5. ( 0 ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | 0 | | |
| 6. ( 1 ) OTHER | | | | 36,414 | | |
| TOTAL SALARIES AND WAGES (A + B) | | | | 83,751 | | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | 23,835 | | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | 107,586 | | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) | | | | | | |
| TOTAL EQUIPMENT | | | | 0 | | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | 0 | | |
| 2. INTERNATIONAL | | | | 0 | | |
| F. PARTICIPANT SUPPORT COSTS<br>1. STIPENDS $ 0<br>2. TRAVEL 0<br>3. SUBSISTENCE 0<br>4. OTHER 0 | | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( 0 ) TOTAL PARTICIPANT COSTS | | | | 0 | | |
| G. OTHER DIRECT COSTS | | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | 11,840 | | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | 0 | | |
| 3. CONSULTANT SERVICES | | | | 0 | | |
| 4. COMPUTER SERVICES | | | | 0 | | |
| 5. SUBAWARDS | | | | 436,885 | | |
| 6. OTHER | | | | 8,914 | | |
| TOTAL OTHER DIRECT COSTS | | | | 457,639 | | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | 565,225 | | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)<br>(Rate: , Base: ) | | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | 0 | | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | 565,225 | | |
| K. SMALL BUSINESS FEE | | | | 0 | | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | 565,225 | | |
| M. COST SHARING PROPOSED LEVEL $ 0 | AGREED LEVEL IF DIFFERENT $ | | | | | |
| PI/PD NAME<br>Daniel Hoffman | | | | FOR NSF USE ONLY<br>INDIRECT COST RATE VERIFICATION | | |
| ORG. REP. NAME* | | | | Date Checked | Date Of Rate Sheet | Initials - ORG |

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

# SUMMARY PROPOSAL BUDGET

YEAR 4

| | | | | | | |
|---|---|---|---|---|---|---|
| ORGANIZATION: City of Gainesville, FL | | | | FOR NSF USE ONLY — PROPOSAL NO. | DURATION (months) Proposed | Granted |
| PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Daniel Hoffman | | | | AWARD NO. | | |
| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) | |
| 1. Daniel Hoffman - PI | 1.00 | 0.00 | 0.00 | 13,707 | | |
| 2. Emmanuel Posadas - Senior Personnel | 2.00 | 0.00 | 0.00 | 20,077 | | |
| 3. | | | | | | |
| 4. | | | | | | |
| 5. | | | | | | |
| 6. ( 0 ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | 0 | | |
| 7. ( 2 ) TOTAL SENIOR PERSONNEL (1 - 6) | 3.00 | 0.00 | 0.00 | 33,784 | | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | | |
| 1. ( 0 ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | 0 | | |
| 2. ( 1 ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 2.00 | 0.00 | 0.00 | 14,498 | | |
| 3. ( 0 ) GRADUATE STUDENTS | | | | 0 | | |
| 4. ( 0 ) UNDERGRADUATE STUDENTS | | | | 0 | | |
| 5. ( 0 ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | 0 | | |
| 6. ( 1 ) OTHER | | | | 37,142 | | |
| TOTAL SALARIES AND WAGES (A + B) | | | | 85,424 | | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | 24,312 | | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | 109,736 | | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) | | | | | | |
| TOTAL EQUIPMENT | | | | 0 | | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | 0 | | |
| 2. INTERNATIONAL | | | | 0 | | |
| F. PARTICIPANT SUPPORT COSTS | | | | | | |
| 1. STIPENDS $ 0 | | | | | | |
| 2. TRAVEL 0 | | | | | | |
| 3. SUBSISTENCE 0 | | | | | | |
| 4. OTHER 0 | | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( 0 ) TOTAL PARTICIPANT COSTS | | | | 0 | | |
| G. OTHER DIRECT COSTS | | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | 11,840 | | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | 0 | | |
| 3. CONSULTANT SERVICES | | | | 0 | | |
| 4. COMPUTER SERVICES | | | | 0 | | |
| 5. SUBAWARDS | | | | 449,947 | | |
| 6. OTHER | | | | 8,914 | | |
| TOTAL OTHER DIRECT COSTS | | | | 470,701 | | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | 580,437 | | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) (Rate: , Base: ) | | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | 0 | | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | 580,437 | | |
| K. SMALL BUSINESS FEE | | | | 0 | | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | 580,437 | | |
| M. COST SHARING PROPOSED LEVEL $ 0 | AGREED LEVEL IF DIFFERENT $ | | | | | |
| PI/PD NAME: Daniel Hoffman | | | | FOR NSF USE ONLY — INDIRECT COST RATE VERIFICATION | | |
| ORG. REP. NAME* | | | | Date Checked | Date Of Rate Sheet | Initials - ORG |

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

# SUMMARY PROPOSAL BUDGET

Cumulative

| | | | | | |
|---|---|---|---|---|---|
| ORGANIZATION<br>City of Gainesville, FL | | | | FOR NSF USE ONLY<br>PROPOSAL NO. | DURATION (months)<br>Proposed / Granted |
| PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR<br>Daniel Hoffman | | | | AWARD NO. | |

| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) |
|---|---|---|---|---|---|
| 1. Daniel Hoffman - PI | 4.00 | 0.00 | 0.00 | 53,238 | |
| 2. Emmanuel Posadas - Senior Personnel | 8.00 | 0.00 | 0.00 | 78,608 | |
| 3. | | | | | |
| 4. | | | | | |
| 5. | | | | | |
| 6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | 0 | |
| 7. ( 2 ) TOTAL SENIOR PERSONNEL (1 - 6) | 12.00 | 0.00 | 0.00 | 131,846 | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | |
| 1. ( 0 ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | 0 | |
| 2. ( 3 ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 8.00 | 0.00 | 0.00 | 56,269 | |
| 3. ( 0 ) GRADUATE STUDENTS | | | | 0 | |
| 4. ( 0 ) UNDERGRADUATE STUDENTS | | | | 0 | |
| 5. ( 0 ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | 0 | |
| 6. ( 3 ) OTHER | | | | 144,256 | |
| TOTAL SALARIES AND WAGES (A + B) | | | | 332,371 | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | 94,424 | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | 426,795 | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)<br>$ 47,000 | | | | | |
| TOTAL EQUIPMENT | | | | 47,000 | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | 0 | |
| 2. INTERNATIONAL | | | | 0 | |
| F. PARTICIPANT SUPPORT COSTS<br>1. STIPENDS $ 0<br>2. TRAVEL 0<br>3. SUBSISTENCE 0<br>4. OTHER 0 | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( 0 ) TOTAL PARTICIPANT COSTS | | | | 0 | |
| G. OTHER DIRECT COSTS | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | 47,360 | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | 0 | |
| 3. CONSULTANT SERVICES | | | | 20,000 | |
| 4. COMPUTER SERVICES | | | | 0 | |
| 5. SUBAWARDS | | | | 1,723,060 | |
| 6. OTHER | | | | 35,064 | |
| TOTAL OTHER DIRECT COSTS | | | | 1,825,484 | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | 2,299,279 | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | 0 | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | 2,299,279 | |
| K. SMALL BUSINESS FEE | | | | 0 | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | 2,299,279 | |
| M. COST SHARING PROPOSED LEVEL $ 0 | AGREED LEVEL IF DIFFERENT $ | | | | |

| | | | |
|---|---|---|---|
| PI/PD NAME<br>Daniel Hoffman | FOR NSF USE ONLY<br>INDIRECT COST RATE VERIFICATION | | |
| ORG. REP. NAME* | Date Checked | Date Of Rate Sheet | Initials - ORG |

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

# BUDGET JUSTIFICATION – CITY of GAINESVILLE

## A. PERSONNEL:

**Senior Personnel**

Dan Hoffman**-** Principal Investigator (PI): Funds are requested to support project over years 1, 2, 3 and 4 respectively. PI will oversee City portion and field implementation of the project.

Emmanuel Posadas – Senior Personnel (Co-P.I.): Funds are requested to support project over years 1, 2, 3 and 4 respectively. Senior Personnel will administer procurement, configuration and installation of signalized intersection video sharing, on-board bus video sharing

**Other Personnel**

Engineer: Field Engineer to assist in deployment, configuration, installation and integration of field hardware devices.

Sr. Technical Systems Analyst to assist in network routing, security, streaming video and management of City owned field edge computers and VMWare based cluster. Field engineer will also be “on-call” to support this project, in the event of any system or traffic signal malfunction.

**B. FRINGE:** A variable fringe benefits are calculated as 28.46% for all City Personnel that is paid out of the City’s General Fund Balance. This variable fringe benefits include FICA, General Pension Contribution, Retirement Health Savings, Workers Compensation.

**C. MATERIALS, SUPPLIES, SERVICE COST:** Material, Supplies and Services Cost are based on estimated recurring services for data connectivity of onboard bus video, and estimated at 10% of initial capital cost on year 1. Additional City Fixed cost are taken as $9,724 annually. This is estimated for four year duration of this project, based on bargained group health insurance and group life insurance.

**D. EQUIPMENT:** Funds are included to purchase On Board Bus Video streaming services, secured network connectivity for LTE streaming video for 10 buses. Also, 8 intersection field hardened computers with localized processing, high powered GPU, with adequate memory and storage will be procured.

**E. SUBAWARD:** Subaward to the University of Florida. UF will carryout the machine learning and computer vision tasks as detailed in the scope of work.

# SUMMARY PROPOSAL BUDGET

YEAR 1

| FOR NSF USE ONLY | | |
|---|---|---|
| PROPOSAL NO. | DURATION (months) | |
| | Proposed | Granted |
| AWARD NO. | | |

ORGANIZATION
**University of Florida**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
**Daniel Hoffman**

| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) |
|---|---|---|---|---|---|
| 1. **Lily-Ageliki Elefteriadou - Co-PI** | 1.00 | 0.00 | 0.00 | 21,650 | |
| 2. **Anand Rangarajan - Co-PI** | 2.00 | 0.00 | 0.00 | 27,260 | |
| 3. **Sanjay Ranka - PI** | 2.00 | 0.00 | 0.00 | 47,467 | |
| 4. **Sivaramakrishna Srinivasan - Co-PI** | 1.00 | 0.00 | 0.00 | 10,798 | |
| 5. | | | | | |
| 6. ( 0 ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | 0 | |
| 7. ( 4 ) TOTAL SENIOR PERSONNEL (1 - 6) | 6.00 | 0.00 | 0.00 | 107,175 | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | |
| 1. ( 0 ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | 0 | |
| 2. ( 0 ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 0.00 | 0.00 | 0.00 | 0 | |
| 3. ( 3 ) GRADUATE STUDENTS | | | | 87,000 | |
| 4. ( 0 ) UNDERGRADUATE STUDENTS | | | | 0 | |
| 5. ( 0 ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | 0 | |
| 6. ( 0 ) OTHER | | | | 0 | |
| TOTAL SALARIES AND WAGES (A + B) | | | | 194,175 | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | 38,240 | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | 232,415 | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) | | | | | |
| TOTAL EQUIPMENT | | | | 0 | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | 6,000 | |
| 2. INTERNATIONAL | | | | 4,000 | |
| F. PARTICIPANT SUPPORT COSTS<br>1. STIPENDS $ 0<br>2. TRAVEL 0<br>3. SUBSISTENCE 0<br>4. OTHER 0 | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( 0 ) TOTAL PARTICIPANT COSTS | | | | 0 | |
| G. OTHER DIRECT COSTS | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | 0 | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | 0 | |
| 3. CONSULTANT SERVICES | | | | 0 | |
| 4. COMPUTER SERVICES | | | | 0 | |
| 5. SUBAWARDS | | | | 0 | |
| 6. OTHER | | | | 38,867 | |
| TOTAL OTHER DIRECT COSTS | | | | 38,867 | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | 281,282 | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)<br>**MTDC (Rate: 52.5000, Base: 248972)** | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | 130,710 | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | 411,992 | |
| K. SMALL BUSINESS FEE | | | | 0 | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | 411,992 | |

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
**Daniel Hoffman**

ORG. REP. NAME*

| FOR NSF USE ONLY | | |
|---|---|---|
| INDIRECT COST RATE VERIFICATION | | |
| Date Checked | Date Of Rate Sheet | Initials - ORG |
| | | |

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

# SUMMARY PROPOSAL BUDGET

YEAR 2

| | | | | | | |
|---|---|---|---|---|---|---|
| ORGANIZATION<br>**University of Florida** | | | | FOR NSF USE ONLY<br>PROPOSAL NO. | DURATION (months)<br>Proposed | Granted |
| PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR<br>**Daniel Hoffman** | | | | AWARD NO. | | |

| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) |
|---|---|---|---|---|---|
| 1. **Lily-Ageliki Elefteriadou - CO-PI** | 1.00 | 0.00 | 0.00 | **22,299** | |
| 2. **Anand Rangarajan - Co-PI** | 2.00 | 0.00 | 0.00 | **28,078** | |
| 3. **Sanjay Ranka - PI** | 2.00 | 0.00 | 0.00 | **48,890** | |
| 4. **Sivaramakrishna Srinivasan - Co-PI** | 1.00 | 0.00 | 0.00 | **11,122** | |
| 5. | | | | | |
| 6. ( **0** ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | **0** | |
| 7. ( **4** ) TOTAL SENIOR PERSONNEL (1 - 6) | 6.00 | 0.00 | 0.00 | **110,389** | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | |
| 1. ( **0** ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | **0** | |
| 2. ( **0** ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 0.00 | 0.00 | 0.00 | **0** | |
| 3. ( **3** ) GRADUATE STUDENTS | | | | **89,610** | |
| 4. ( **0** ) UNDERGRADUATE STUDENTS | | | | **0** | |
| 5. ( **0** ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | **0** | |
| 6. ( **0** ) OTHER | | | | **0** | |
| TOTAL SALARIES AND WAGES (A + B) | | | | **199,999** | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | **39,386** | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | **239,385** | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) | | | | | |
| TOTAL EQUIPMENT | | | | **0** | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | **6,000** | |
| 2. INTERNATIONAL | | | | **4,000** | |
| F. PARTICIPANT SUPPORT COSTS<br>1. STIPENDS $ **0**<br>2. TRAVEL **0**<br>3. SUBSISTENCE **0**<br>4. OTHER **0** | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( **0** ) TOTAL PARTICIPANT COSTS | | | | **0** | |
| G. OTHER DIRECT COSTS | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | **0** | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | **0** | |
| 3. CONSULTANT SERVICES | | | | **0** | |
| 4. COMPUTER SERVICES | | | | **0** | |
| 5. SUBAWARDS | | | | **0** | |
| 6. OTHER | | | | **40,481** | |
| TOTAL OTHER DIRECT COSTS | | | | **40,481** | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | **289,866** | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)<br>**MTDC (Rate: 52.5000, Base: 255942)** | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | **134,370** | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | **424,236** | |
| K. SMALL BUSINESS FEE | | | | **0** | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | **424,236** | |

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

| | | | |
|---|---|---|---|
| PI/PD NAME<br>**Daniel Hoffman** | FOR NSF USE ONLY<br>INDIRECT COST RATE VERIFICATION | | |
| ORG. REP. NAME* | Date Checked | Date Of Rate Sheet | Initials - ORG |

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

# SUMMARY PROPOSAL BUDGET

YEAR 3

| FOR NSF USE ONLY | | |
|---|---|---|
| PROPOSAL NO. | DURATION (months) | |
| | Proposed | Granted |
| AWARD NO. | | |

ORGANIZATION
**University of Florida**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
**Daniel Hoffman**

| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) |
|---|---|---|---|---|---|
| 1. Lily-Ageliki Elefteriadou - Co-PI | 1.00 | 0.00 | 0.00 | 22,968 | |
| 2. Anand Rangarajan - Co-PI | 2.00 | 0.00 | 0.00 | 28,920 | |
| 3. Sanjay Ranka - PI | 2.00 | 0.00 | 0.00 | 50,357 | |
| 4. Sivaramakrishna Srinivasan - Co-PI | 1.00 | 0.00 | 0.00 | 11,456 | |
| 5. | | | | | |
| 6. ( 0 ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | 0 | |
| 7. ( 4 ) TOTAL SENIOR PERSONNEL (1 - 6) | 6.00 | 0.00 | 0.00 | 113,701 | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | |
| 1. ( 0 ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | 0 | |
| 2. ( 0 ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 0.00 | 0.00 | 0.00 | 0 | |
| 3. ( 3 ) GRADUATE STUDENTS | | | | 92,298 | |
| 4. ( 0 ) UNDERGRADUATE STUDENTS | | | | 0 | |
| 5. ( 0 ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | 0 | |
| 6. ( 0 ) OTHER | | | | 0 | |
| TOTAL SALARIES AND WAGES (A + B) | | | | 205,999 | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | 40,568 | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | 246,567 | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) | | | | | |
| TOTAL EQUIPMENT | | | | 0 | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | 6,000 | |
| 2. INTERNATIONAL | | | | 4,000 | |
| F. PARTICIPANT SUPPORT COSTS | | | | | |
| 1. STIPENDS $ 0 | | | | | |
| 2. TRAVEL 0 | | | | | |
| 3. SUBSISTENCE 0 | | | | | |
| 4. OTHER 0 | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( 0 ) TOTAL PARTICIPANT COSTS | | | | 0 | |
| G. OTHER DIRECT COSTS | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | 0 | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | 0 | |
| 3. CONSULTANT SERVICES | | | | 0 | |
| 4. COMPUTER SERVICES | | | | 0 | |
| 5. SUBAWARDS | | | | 0 | |
| 6. OTHER | | | | 42,178 | |
| TOTAL OTHER DIRECT COSTS | | | | 42,178 | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | 298,745 | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 52.5000, Base: 263124) | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | 138,140 | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | 436,885 | |
| K. SMALL BUSINESS FEE | | | | 0 | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | 436,885 | |

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
**Daniel Hoffman**

ORG. REP. NAME*

| FOR NSF USE ONLY | | |
|---|---|---|
| INDIRECT COST RATE VERIFICATION | | |
| Date Checked | Date Of Rate Sheet | Initials - ORG |
| | | |

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

# SUMMARY PROPOSAL BUDGET

YEAR 4

| FOR NSF USE ONLY | | |
|---|---|---|
| PROPOSAL NO. | DURATION (months) | |
| | Proposed | Granted |
| AWARD NO. | | |

ORGANIZATION
**University of Florida**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
**Daniel Hoffman**

| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) |
|---|---|---|---|---|---|
| 1. **Lily-Ageliki Elefteriadou - Co-PI** | 1.00 | 0.00 | 0.00 | **23,657** | |
| 2. **Anand Rangarajan - Co-PI** | 2.00 | 0.00 | 0.00 | **29,787** | |
| 3. **Sanjay Ranka - PI** | 2.00 | 0.00 | 0.00 | **51,868** | |
| 4. **Sivaramakrishna Srinivasan - Co-PI** | 1.00 | 0.00 | 0.00 | **11,800** | |
| 5. | | | | | |
| 6. ( **0** ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | **0** | |
| 7. ( **4** ) TOTAL SENIOR PERSONNEL (1 - 6) | 6.00 | 0.00 | 0.00 | **117,112** | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | |
| 1. ( **0** ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | **0** | |
| 2. ( **0** ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 0.00 | 0.00 | 0.00 | **0** | |
| 3. ( **3** ) GRADUATE STUDENTS | | | | **95,067** | |
| 4. ( **0** ) UNDERGRADUATE STUDENTS | | | | **0** | |
| 5. ( **0** ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | **0** | |
| 6. ( **0** ) OTHER | | | | **0** | |
| TOTAL SALARIES AND WAGES (A + B) | | | | **212,179** | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | **41,786** | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | **253,965** | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) | | | | | |
| TOTAL EQUIPMENT | | | | **0** | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | **6,000** | |
| 2. INTERNATIONAL | | | | **4,000** | |
| F. PARTICIPANT SUPPORT COSTS<br>1. STIPENDS $ **0**<br>2. TRAVEL **0**<br>3. SUBSISTENCE **0**<br>4. OTHER **0** | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( **0** ) TOTAL PARTICIPANT COSTS | | | | **0** | |
| G. OTHER DIRECT COSTS | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | **0** | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | **0** | |
| 3. CONSULTANT SERVICES | | | | **0** | |
| 4. COMPUTER SERVICES | | | | **0** | |
| 5. SUBAWARDS | | | | **0** | |
| 6. OTHER | | | | **43,957** | |
| TOTAL OTHER DIRECT COSTS | | | | **43,957** | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | **307,922** | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)<br>**mtdc (Rate: 52.5000, Base: 270522)** | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | **142,024** | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | **449,946** | |
| K. SMALL BUSINESS FEE | | | | **0** | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | **449,946** | |

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
**Daniel Hoffman**

ORG. REP. NAME*

| FOR NSF USE ONLY | | |
|---|---|---|
| INDIRECT COST RATE VERIFICATION | | |
| Date Checked | Date Of Rate Sheet | Initials - ORG |
| | | |

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

# SUMMARY PROPOSAL BUDGET

Cumulative

| | | | | | |
|---|---|---|---|---|---|
| ORGANIZATION: University of Florida | | | | FOR NSF USE ONLY | |
| PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Daniel Hoffman | | | | PROPOSAL NO. / AWARD NO. | DURATION (months): Proposed / Granted |

| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | NSF Funded Person-months CAL | ACAD | SUMR | Funds Requested By proposer | Funds granted by NSF (if different) |
|---|---|---|---|---|---|
| 1. Lily-Ageliki Elefteriadou - CO-PI | 4.00 | 0.00 | 0.00 | 90,574 | |
| 2. Anand Rangarajan - Co-PI | 8.00 | 0.00 | 0.00 | 114,045 | |
| 3. Sanjay Ranka - PI | 8.00 | 0.00 | 0.00 | 198,582 | |
| 4. Sivaramakrishna Srinivasan - Co-PI | 4.00 | 0.00 | 0.00 | 45,176 | |
| 5. | | | | | |
| 6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 0.00 | 0.00 | 0.00 | 0 | |
| 7. ( 4 ) TOTAL SENIOR PERSONNEL (1 - 6) | 24.00 | 0.00 | 0.00 | 448,377 | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | |
| 1. ( 0 ) POST DOCTORAL SCHOLARS | 0.00 | 0.00 | 0.00 | 0 | |
| 2. ( 0 ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 0.00 | 0.00 | 0.00 | 0 | |
| 3. ( 12 ) GRADUATE STUDENTS | | | | 363,975 | |
| 4. ( 0 ) UNDERGRADUATE STUDENTS | | | | 0 | |
| 5. ( 0 ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | 0 | |
| 6. ( 0 ) OTHER | | | | 0 | |
| TOTAL SALARIES AND WAGES (A + B) | | | | 812,352 | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | 159,980 | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | 972,332 | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) | | | | | |
| TOTAL EQUIPMENT | | | | 0 | |
| E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS) | | | | 24,000 | |
| 2. INTERNATIONAL | | | | 16,000 | |
| F. PARTICIPANT SUPPORT COSTS | | | | | |
| 1. STIPENDS $ 0 | | | | | |
| 2. TRAVEL 0 | | | | | |
| 3. SUBSISTENCE 0 | | | | | |
| 4. OTHER 0 | | | | | |
| TOTAL NUMBER OF PARTICIPANTS ( 0 ) TOTAL PARTICIPANT COSTS | | | | 0 | |
| G. OTHER DIRECT COSTS | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | 0 | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | 0 | |
| 3. CONSULTANT SERVICES | | | | 0 | |
| 4. COMPUTER SERVICES | | | | 0 | |
| 5. SUBAWARDS | | | | 0 | |
| 6. OTHER | | | | 165,483 | |
| TOTAL OTHER DIRECT COSTS | | | | 165,483 | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | 1,177,815 | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | 545,244 | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | 1,723,059 | |
| K. SMALL BUSINESS FEE | | | | 0 | |
| L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K) | | | | 1,723,059 | |
| M. COST SHARING PROPOSED LEVEL $ 0 | AGREED LEVEL IF DIFFERENT $ | | | | |

| | | | |
|---|---|---|---|
| PI/PD NAME: Daniel Hoffman | FOR NSF USE ONLY | | |
| | INDIRECT COST RATE VERIFICATION | | |
| ORG. REP. NAME* | Date Checked | Date Of Rate Sheet | Initials - ORG |

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

# BUDGET JUSTIFICATION – UNIVERSITY OF FLORIDA

## A. PERSONNEL:

**Senior Personnel**
Prof. Sanjay Ranka**-** Principal Investigator (PI): Funds are requested to support 8 months of effort for Dr. Ranka over the life of the project. PI will oversee all aspects of the project.

Prof. Anand Rangarajan – Co-Principal Investigator (Co-P.I.): Funds are requested to support 8 months of effort for Dr. Rangarajan over the life of the project.

Prof. Lily Elefteriadou – Co-Principal Investigator (Co-P.I.): Funds are requested to support 4 months of effort for Dr. Elefteriadoug over the life of the project.

Prof. Siva Srinivasan – Co-Principal Investigator (Co-P.I.): Funds are requested to support 4 months of effort for Dr. Srinivasan over the life of the project.

The proposed salary for all the UF key persons, in combination with other current NSF support, exceeds the two-month limit for senior personnel. The proposed level of commitment for this proposal is appropriate for the scope of work and is required in order to fulfill the objectives of this project within the proposed timeframe

The PI and the co-PIs will be primarily involved in the development of algorithms and providing insight to the graduate students.

**Other Personnel**
Graduate Students: Funds are requested to support three 50% full-time equivalent graduate students for the duration of the project. The graduate students will spend most of their time implementing the proposed algorithms, conducting benchmark studies, and performing design space explorations.

Salaries for the PIs and graduate students include an annual 3% increase.

**B. FRINGE:** Fringe benefits are calculated as 27.4% for PI salary and 10.2% for graduate student salary. Fringe benefits include FICA, state unemployment, workers compensation, retirement, and life and health insurance. Fringe benefits are based on the rate settlement agreement approved by DHHS, effective July 1, 2017.

**C. TRAVEL:** Funds are requested to support domestic by the PI, Co-PIs and graduate students to disseminate research data at annual conferences and meetings. Projected international travel includes the International Conference on Computer Vision (slated to be held in South Korea in 2019). We will also attend and present the work in leading transporation conferences in the country. Cost estimates are based on historical UF travel expenses in accordance with UF travel directives (http://www.fa.ufl.edu/directives-and-procedures/travel/) and include airfare, lodging, registration, meals and local transportation expenses.

D. **Expense:** Funds are included to purchase cloud services on Amazon. This amount is as follows:

   This amount will support data ingestion, data processing and GPU processing on the cloud.

E. **OTHER:** Funds are requested for the cost of tuition for the graduate students for the duration of the project. Beginning in year two, tuition costs include an increase of 5% as mandated by university policy.

F. **INDIRECT COST:** Negotiated and determined by the Department of Health and Human Services. The University currently has a provisional IDC rate of 52.5% of Modified Total Direct Costs for on-campus organized research – effective beginning 7/1/2016.

   http://research.ufl.edu/research/pdf/FA_Rate_Agreement_062292015.pdf

# Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Dan Hoffman

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Video based Machine Learning for Smart Traffic Analysis and Management (this proposal)

Source of Support: NSF

Total Award Amount: $2,299,279 Total Award Period Covered: 7/1/2018-6/30/2022

Location of Project: Gainesville, Florida

Person-Months Per Year Committed to the Project. 1.0 Cal: 1.0 Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

# Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Ageliki (Lily) Elefteriadou

Other agencies (including NSF) to which this proposal has been/will be submit-

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Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Video Based Machine Learning for Smart Traffic Analysis and Management

Source of Support: National Science Foundation

Total Award Amount: $1,723,061 Total Award Period Covered: 07/01/2018-06/30/2022

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. Cal: 1.0 Acad: Sumr:

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Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Highway Capacity Manual Methodologies for Corridors Involving Freeways and Surface Streets

Source of Support: National Academy of Sciences

Total Award Amount: $799,999 Total Award Period Covered: 08/08/2016-02/17/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. Cal: 1.8 Acad: Sumr:

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Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ Transfer of Support

Project/Proposal Title:

Dynamic Intersection Learning Machine Optimization Real-time Engine

Source of Support: Florida Department of Transportation

Total Award Amount: $211,974 Total Award Period Covered 06/08/2017-12/31/2018

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. Cal: 0.13 Acad: Sumr:

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Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

CPS: TTP Option: Synergy: Traffic Signal Control with Connected and Autonomous Vehicles in the Traffic Stream

Source of Support: National Science Foundation

Total Award Amount $1,296,428 Total Award Period Covered: 09/01/2015-08/30/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. Cal: 0.6 Acad: Sumr:

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Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Before and After Implementation Studies of Advanced Signal Control Technologies in Florida

Source of Support: Florida Department of Transportation Research Center

Total Award Amount: $$840,133 Total Award Period Covered: 05/07/2014-07/31/2018

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. Cal: 1.06 Acad: Sumr:

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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

# Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Ageliki (Lily) Elefteriadou

Other agencies (including NSF) to which this proposal has been/will be submitted.

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Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:
Southeastern Transportation, Research, Innovation, Development, and Education Center (STRIDE)

Source of Support: US Department of Transportation
Total Award Amount: $5,175,800 Total Award Period Covered: 01/19/2017-09/30/2022
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 1.8 Acad: Sumr:

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Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:
Freight Mobility Research Institute

Source of Support: Florida Atlantic University
Total Award Amount: $175,000 Total Award Period Covered: 11/30/2016-11/29/2018
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 0.36 Acad: Sumr:

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Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ Transfer of Support

Project/Proposal Title:
Evaluation of Arterial Corridor Improvements and Traffic Management Plans in Florida

Source of Support: Florida Department of Transportation Research Center
Total Award Amount: $137,164 Total Award Period Covered: 06/11/2015-05/31/2018
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 0.4 Acad: Sumr:

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Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:
Total Award Amount Total Award Period Covered:
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

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Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:
Total Award Amount: Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

# Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Anand Rangarajan

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

A downscaling-assimilation framework for SMAP observations to obtain high-resolution crop yields in heterogeneous agricultural regions

Source of Support: NASA

Total Award Amount: $448,796 Total Award Period Covered: 10/01/2016-09/30/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 0.4 Cal: 0 Acad: 0.0 Sumr: 0.4

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

EAGER - Parallel Semi-supervised Machine Learning for Volumetric Datasets

Source of Support: NSF

Total Award Amount: $100,000 Total Award Period Covered: 06/01/2017 – 11/30/2018

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 0.0 Cal: 0.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Data Management and Analytics for UF Smart Testbed

Source of Support: FDOT

Total Award Amount: $543,450 Total Award Period Covered: 6/7/2017 – 3/31/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 0.8 Cal: 0.8 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Dynamic Intersection Learning Machine Optimization Real-time Engine.

Source of Support: FDOT

Total Award Amount: $211,974 Total Award Period Covered: 6/8/2017 – 6/30/2018

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 1 Cal: 1 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Truck Taxonomy & Classification using Video and Weigh-In Motion (WIM) Technology

Source of Support: FDOT

Total Award Amount: $200,000 Total Award Period Covered: 8/21/2017 – 1/21/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 1.0 Cal: 1.0 Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

# Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

| Investigator: Anand Rangarajan | Other agencies (including NSF) to which this proposal has been/will be submitted. |
|---|---|

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Infrasonic Cyber-Physical MASINT for Environmental Characterization and Classification

Source of Support: AFRL - FIT

Total Award Amount: $525,000 Total Award Period Covered: 2/1/2018 – 1/31/2020

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 1.15 Cal: 1.15 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Video based Machine Learning for Smart Traffic Analysis and Management

Source of Support: City of Gainesville / NSF

Total Award Amount: $1,723,061.00 Total Award Period Covered: 7/1/2018 – 6/30/2022

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 2 Cal: 2 Acad: Sumr:

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Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

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Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

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Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

## Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Other agencies (including NSF) to which this proposal has been/will be submitted.

Investigator: Sanjay Ranka

Support: [X] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title:

Center for Compressible Multiphase Turbulence (CCMT)

Source of Support: DOE

Total Award Amount: $5,944,400 Total Award Period Covered: 12/01/13-01/26/19

Location of Project: University of Florida, Gainesville FL

Person-Months Per Year Committed to the Project. 1.63 Cal: 0.63 Acad: Sumr: 1.0

Support: [X] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title:

Texas External Quality Review Organization Vendor and Quality Vendor

Source of Support: State of Texas Health Human Services Commission

Total Award Amount: $37,373,869 Total Award Period Covered: 04/01/2015-08/31/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 0.6 Cal: 0.6 Acad: Sumr:

Support: [X] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title:

Energy Aware Real Time Change Detection Using Synthetic Aperture Radar on High-Performance Heterogeneous Architectures: A DDDAS Approach

Source of Support: AFOSR

Total Award Amount: $700,020 Total Award Period Covered: 05/15/2015-05/14/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 0.7 Cal: Acad: Sumr: 0.7

Support: [X] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title:

CSR:Medium:Collaborative Research: SparseKaffe: high-performance, auto-tuned energy-aware algorithms for sparse direct methods on modern heterogeneous architectures

Source of Support: NSF

Total Award Amount: $395,454 Total Award Period Covered: 05/01/2015-04/30/2018

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 1 (varies) Cal: Acad: Sumr: 1

Support: [X] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title:

CPS: TTP Option: Synergy: Traffic Signal Control with Connected and Autonomous Vehicles in the Traffic Stream

Source of Support: NSF

Total Award Amount: $1,280,428 Total Award Period Covered: 09/01/2015-08/31/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 0.6 Cal: Acad: Sumr: 0.6

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.



## Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Sanjay Ranka

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Performance, Energy and Thermal Tradeoffs for Next Generation Intel Multicore Machines

Source of Support: Intel

Total Award Amount: $100,000 Total Award Period Covered: 01/01/2016-12/31/2016

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 1.0 Cal: 1.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Development and Testing of Optimized Autonomous and Connected Vehicle Trajectories at Signalized Intersections

Source of Support: FDOT

Total Award Amount: $392,604 Total Award Period Covered: 05/01/2015-12/31/2017

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 1.0 Cal: 1.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Big Data Management Pilot

Source of Support: FDOT

Total Award Amount: $629,353 Total Award Period Covered: 02/01/2016-05/31/2017

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 3.0 Cal: 3.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

PEAKS: Validation of Mobile Technologies for Clinical Assessment, Monitoring and Intervention

Source of Support: Everyfit Inc

Total Award Amount: $665,000 Total Award Period Covered: 09/15/2015-09/14/2017

Location of Project:

Person-Months Per Year Committed to the Project. 0.6 Cal: 0.6 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

A downscaling-assimilation framework for SMAP observations to obtain high-resolution crop yields in heterogeneous agricultural regions

Source of Support: NASA

Total Award Amount: $448,796 Total Award Period Covered: 10/01/2016-09/30/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 0.4 Cal: 0 Acad: 0.0 Sumr: 0.4

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.



## Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Other agencies (including NSF) to which this proposal has been/will be submitted.

Investigator: Sanjay Ranka

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Parallel Semi-supervised Machine Learning for Volumetric Datasets

Source of Support: NSF

Total Award Amount: $99,998.00 Total Award Period Covered: 06/01/2017 – 11/30/2018

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 0.0 Cal: 0.0 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Machine learning approaches for image coding, denoising, segmentation and classification.

Source of Support: Sony

Total Award Amount: $150,000 Total Award Period Covered: 05/16/2017-05/15/2018

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 1.0 Cal: 1.0 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

University of Florida Claude D. Pepper Older Americans Independence Center (OAIC)

Source of Support: NIH

Total Award Amount: $5,648,429 Total Award Period Covered: 04/01/2017-03/31/2022

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Dynamic Intersection Learning Machine

Source of Support: Florida Department of Transportation

Total Award Amount: $211,974.00 Total Award Period Covered: 7/1/2017 – 6/30/2018

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 2.0 Cal: 2.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:Data Management and Analytics for UF Smart Testbed

Source of Support: Florida Department of Transportation / US Department of Transportation

Total Award Amount: $543,450.00 Total Award Period Covered: 6/7/2017 – 3/31/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 3.71 Cal: 3.71 Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

# Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Sanjay Ranka

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Weill Med College of Cornell Univ NY

Source of Support: Cornell University Weill Medical College

Total Award Amount: $308,000.00 Total Award Period Covered: 9/1/2016 – 8/31/2017

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 1.2 Cal: 1.2 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: EAGER:Software-hardware co-design approaches for multi-level memories

Source of Support: NSF

Total Award Amount: $300,000 Total Award Period Covered: 8/1/2017 – 7/31/2019

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 1.4 Cal: 1.4 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title

Video based Machine Learning for Smart Traffic Analysis and Management
(This Proposal)

Source of Support: City of Gainesville / NSF

Total Award Amount: $ 1,723,061.00 Total Award Period Covered: 7/1/2018 – 6/30/2022

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. 2.0 Cal: 2.0 Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support

Total Award Amount: $ Total Award Period Covered:

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project: University of Florida

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

# Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Sivaramakrishnan Srinivasan

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Video Based Machine Learning for Smart Traffic Analysis and Management
Source of Support: National Science Foundation
Total Award Amount: $1,723,061 Total Award Period Covered: 07/01/2018-06/30/2022
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 1.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Data Management and Analytics for UF Smart Testbed

Source of Support: Florida Department of Transportation
Total Award Amount: $543,447 Total Award Period Covered: 06/07/2017-03/31/2019
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 0.78 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ Transfer of Support
Project/Proposal Title:
Strategies for Mitigating Congestion in Small Urban and Rural Areas (Project H)

Source of Support: US Department of Transportation
Total Award Amount: $32,634 Total Award Period Covered: 05/31/2017-11/30/2018
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 0.4 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Dynamic Intersection Learning Machine Optimization Real-time Engine

Source of Support: Florida Department of Transportation
Total Award Amount $211,974 Total Award Period Covered: 06/07/2017-12/31/2018
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 0.75 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Transportation Safety Center (TSC) 2018-2020

Source of Support: Florida Department of Transportation
Total Award Amount: $886,990 Total Award Period Covered: 03/01/2018-12/31/2019
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 1.2 Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

# Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Sivaramakrishnan Srinivasan

Other agencies (including NSF) to which this proposal has been/will be submitted.

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Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:
Human Factors Study on the Use of Colors for Express Lane Delineators

Source of Support: Florida Department of Transportation
Total Award Amount: $199,927 Total Award Period Covered: 10/31/2017-04/30/2019
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 0.97 Acad: Sumr:

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Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:
Dwight David Eisenhower Transportation Fellowship Program Graduate Fellowship

Source of Support: US Department of Transportation Federal Highway Administration
Total Award Amount: $11,500 Total Award Period Covered: 12/23/2017-08/31/2018
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 0.12 Acad: Sumr:

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Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ Transfer of Support

Project/Proposal Title:
Performance Measurement and Management Using Connected and Automated Vehicle Data (Project C)

Source of Support: US Department of Transportatin
Total Award Amount: $62,507 Total Award Period Covered: 05/01/2017-08/01/2018
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: 0.08 Acad: Sumr:

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Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:
Total Award Amount Total Award Period Covered:
Location of Project: University of Florida
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

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Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:
Total Award Amount: Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

## Current and Pending Support

**(See GPG Section II.D.8 for guidance on information to include on this form.)**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

| Investigator: Emmanuel Posadas | Other agencies (including NSF) to which this proposal has been/will be submitted. |
|---|---|

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Video based Machine Learning for Smart Traffic Analysis and Management

Source of Support: NSF

Total Award Amount: $2,299,279 Total Award Period Covered: 7/1/2018-6/30/2022

Location of Project: Gainesville, Florida

Person-Months Per Year Committed to the Project. 2.0 Cal: 2.0 Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

## Resources and Environment

Facilities and Resources to be provided by City of Gainesville is as follows:

**TMS (Traffic Management Center) Located Devices:**

- Video Wall, consisting of 18 – 50" monitor system driven by nine Windows 7 Pro units, using NVidia GForce GTX 470, 2GB, GDDDR3 video memory for graphics, and 3rd Gen Intel Core I7 chip, 8GB physical memory, 40 GB HDD.
- Physical Host via VMWare: Dell Poweredge R720s -Rack Server. Powered by 6 Intel Xeon Processors and 240GB of Physical Memory
- Storage: Dell EqualLogic PS6210, SANS with 72TB of Storage
- Network Connectivity via Juniper 8208 and EX4200 at the TMS; Connected to Florida Lamda Rail (FLR) at 2 fully dedicated x 1G Ethernet IP Transports (internal to any FLR Partners) and 100 MBps external/commercial internet.
- Second by Second Controller Status through ATMS (Advance Traffic Management System) central software

**Field (Signalized Intersection Level) Located Devices**

- Video Monitoring: All Signalized intersections will have Bosch Autodome HD Cameras (Either VG4 Autodome or Autodome VG5-ITS-7000) running at either 720p or 1080p at full frame rate. All cameras are 28x or 36x optical zoom capable, wider dynamic range (WDR), and day and night modes, and vertical/horizontal aperture correction. The camera has CPP4 (Bosch Common Product Platform) for efficient H.264 encoding and streaming. Video Monitoring Camera allows for two simultaneous streams that have configurable bit rates, frame rates and codecs.
- Connectivity: All signalized intersections will be connected via a field hardened Ethernet switch, either 8 ports or 12 ports (10/100/1000TX Copper Ports up to 56 GBPS Back-Plane). Field Edge switch also has some Layer 2/3 capabilities, such as Managed IGMP Video Switching, VLANs and complies with the following standards: IEEE Std. 802.3 10BASE-T; IEEE Std. 802.3u 100BASE-TX and 100BASE FX; IEEE Std. 802.3z 1000BASE-X; IEEE Std. 802.3ab 1000BASE-T; IEEE Std. 802.3x Flow; IEEE Std., 802.3ad Port trunk with LACP; IEEE Std. 802.1d Spanning Tree Protocol; IEEE Std., 802.1w Rapid spanning tree; IEEE Std. 802.1p Class of service; IEEE Std. 802.1q VLAN Tagging; IEEE Std. 802.1x user authentication; IEEE Std. 802.1s MSTP; IEEE Std., 802.1ab LLDP.

**Future Devices** (to be procured if awarded)

- On Board video streaming to be provided by Seon Bus Video and Surveillance.
- Field edge and field hardened computer with high-end GPU at signalized intersections within controller cabinets.

Facilities and Resources to be provided by University of Florida is as follows:

The CISE (Dept. of CISE, UF) data science cluster has twelve subsystems (8 AMD and 4 Intel based systems) connected with Infiniband (40Gbit/s) and Gigabit internet. Each AMD subsystem will have 64 2.3 GHz cores, 512 GB and 24 4 Terabyte hard drives. Each Intel based subsystem will have 16 2.1 GHz cores, 128 GB main memory and 10 2TB hard drives. The total capacity of the cluster will be 576 cores, 4.6TB main memory and 848 TB disk space with 30GB/s cross network bandwidth. The data science cluster also has a number of GPGPUs/Video Cards: 2 NVidia Tesla K20, 5GB RAM each 2 NVidia Tesla K40, 12GB RAM each; 1 ATI Saphire, 16GB RAM; 3 Intel Phi 3120a, 6GB RAM each; 1 Intel Phi 5120; 2 NVidia GTX 790, 3GB RAM each.

CISE also provides a compute cluster consisting of a head node with dual Opterons, 16GB of memory and 3.5TB of storage with 20 worker nodes with dual Opterons and 32GB of memory running Linux (Ubuntu Server 10.04). These will be used for prototype software development. All graduate students have access to a workstation that can be used to access this cluster. All faculty offices are equipped with a Windows or Linux workstation with standard software installations. Wireless access is available throughout the CSE Building and all of campus.

Additionally, we also have access to the resources at the HPC center at University of Florida. The HPC Center runs several clusters with about 23,000 cores in multi-core servers. Most of the servers are part of one of two distinct InfiniBand fabrics. The clusters share over 4 PetaBytes of distributed storage via the Lustre parallel file system. In the Spring of 2013 a new cluster HiPerGator was installed with 16,000 cores and 2.88 PB of raw storage to hold a fast, highly available, parallel Lustre file system for scratch data.

The use of cloud services will allow us to easily archive aggregated data from the variety of sensors deployed throughout the transportation network and enable easy dissemination of results.

**Description:** We have provisioned a M5 large server on AWS with 96 virtual cores and 384 GB of memory, a GPU server with 4 Nvidia Tesla V100's and 32 processing cores. Both machines support up to 10gigabits per second I/O. We also have 10 TB of archival storage (Glacier) and 5 TB of blob storage (S3) on the cloud. Moreover, we can transcode up to 600 minutes of HD video every day using the ASW transcoding service.

**Data Management Plan**
**Video based Machine Learning for Smart Traffic Analysis and Management**

**Types of Data:** The main data that will be produced from this project is novel software for machine learning for traffic management. All of our methods will be equipped with an easy-to-use API, mainly in C/C++ (but also in Python etc.) and, to enable wide usage by non-experts. We will disseminate our algorithms, methods, codes, and matrix collection as widely as possible thus enabling their use in commercial, government lab, and open-source applications. We will use simulation datasets and real-world intersection datasets for testing our machine learning algorithms. If any of the outputs are relevant for broad audience, we will archive them and provide them for public dissemination.

**Physical and Cyber Resources for Storing and Preserving Data:** We will maintain a central web site (http://www.cise.ufl.edu/research/traffic-management/ produced and maintained by the Co-PIs. The investigators have in-house resources with adequate capacity for this purpose.

For large data sets we will use the Hipergator Facility that is maintained by UF Research Computing Division at University of Florida. This facility supports researchers for large scale data storage and dissemination using the Lustre File System. Lustre is a high-performance parallel system dedicated to HPC applications. The main Lustre filesystem has a capacity of several petabytes and consists of thousands of spindles to provide the high performance throughput. This storage is directly mounted on every single of HiPerGator clusters compute nodes and all servers.

UF Research Computing has deployed Globus as one mechanism to facilitate data transfer to and from HiPerGator. This will be used for data transfer within the collaboration as well as external entities. Globus is a high-performance data transfer tool developed by the Computation Institute, the University of Chicago and Argonne National Laboratory. Each of the data transfer servers has 10G Ethernet directly connected to the core switches that are on the 200G campus network and 100G WAN. The Lustre filesystem is directly mounted on the data transfer servers via 50Gbps Infiniband.

**Formats and Dissemination Methods:** The developed software will be released as open source via the project web page that will be maintained beyond the duration of the proposed project. We will also deposit the software in publicly available Source-forge repository (http://sourceforge.net/). Sourceforge provides persistent web space for open source projects. Results from the proposed research will be published in leading journals and conferences in computer science, numerical analysis, and parallel computing.

**Policies for Data Sharing and Public Access:** All software will be published under Apache 2.0 open source licensing (and/or GPL version 2 depending on suitability) and source code will be open and freely available. The open source license will permit the dissemination and commercialization of enhanced or customized versions of the software, or incorporation of the software or pieces of it into other software packages. It will also allow software transfers so that another individual or team can continue development in the event that the original investigators are unwilling or unable to do so. Any modifications by other researchers can be shared for later modifications by other researchers.

**PI Ranka** has significant experience in development of production quality software development and dissemination (experience as part of a CTO for a Silicon valley startup). Our goal will be to develop a infrastructure that is modular so that others can modify or customize it for their applications. We will develop suitable repositories so that enhancements made by others can be published along with the base code thereby developing an ecosystem of users.

In addition to the normal academic venues (publication in journals and conferences, external talks, and software distribution), for our project we will host technical workshops at leading conferences on related topics. These workshops will bring potential users, collaborators, and other researchers to discuss problems and progress in the area. We will also initiate multiple industrial/academic/government lab collaborations to benefit from their experience, evaluations, and suggestions into our planning process.

**Rights and Obligations for Management and Retention of Research Data:** The PIs and the graduate students to be hired on the project, will be responsible for managing software development. We will maintain detailed documentation at each stage of the implementation, and use standard tools for software version control to maintain development history.

**List of Project Personnel and Partner Institutions**

City of Gainesville

Dan Hoffman, PI
Emmanuel Posadas, Investigator

University of Florida

Sanjay Ranka, Dept. of CISE, co-PI
Anand Rangarajan, Dept. of CISE, co-PI
Lily Elefteriadou, Civil and Coastal Engineering, co-PI
Siva Srinivasan, Civil and Coastal Engineering, co-PI

Gainesville.
Citizen centered
People empowered

**City of Gainesville**

**Regional Transit System**
PO Box 490, Station 58
Gainesville, Florida
32627
352 334 5070

Date: February 28, 2018

**LETTER OF SUPPORT**

National Science Foundation
Smart and Connected Communities (S&CC)
Program Solicitation NSF 18-520
2415 Eisenhower Ave, Alexandria,
VA 22314

Dear Program Directors and Program Officers:

I am writing this letter to express the support of City of Gainesville Regional Transit System for the proposal entitled "Video Based Machine Learning for Smart Traffic Analysis and Management" being submitted by The University of Florida and the City of Gainesville.

The City of Gainesville Regional Transit System is committed to improving the transportation safety and the mobility of its people and enabling the overall goal of a smart city. The 21st century has seen a huge uptick in the adoption of artificial intelligence-based technologies in the transportation sector. Therefore, we feel that the use of advanced sensing methods including video detection and associated analytics such as machine learning holds great promise in helping the state achieve its transportation goals. The City of Gainesville has an extensive track record of working with the University of Florida. As a part of the I-STREET initiative, UF, City of Gainesville and the Florida Department of Transportation has already developed a broader, long-term strategy for collaborative research on advanced transportation technology and has also committed significant resources to the City of Gainesville and to UF for these pursuits. The proposed research - in service of the holistic goal of a smart city - will further advance our fundamental understanding of how video detection technologies coupled with edge computing and machine learning can be made efficient and scalable for deployment system wide.

We at City of Gainesville Regional Transit System are very happy to support this proposal and we hope that this will be considered favorably for funding by the NSF. Please feel free to reach out if you have any further questions regarding this project.

Sincerely,

Jesus Gomez
gomezjm@cityofgainesville.org
RTS Director
Gainesville – Regional Transit System

*How can I empower you?*

CITYOFGAINESVILLE.ORG