



THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

Undergraduate Research Opportunities Consortium



UROC

Abstract Review

August 2015

UROC: Undergraduate Research Opportunities Consortium 2015



Electrical and Computer Engineering Cognitive and Autonomous Test Vehicle

Program Co-Director: Jonathan Sprinkle, PhD Program Coordinator: Nancy Emptage

This research experience for undergraduates (REU) is engaged in the myriad of applications that are related to autonomous ground vehicles. Each summer, NSF-funded undergraduate students participate in an immersive research experience, sitting side-by-side with graduate researchers and working on one of the most compelling, and complex, applications of today: autonomous systems.

FRANK LYKES CLAYTOR

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



WOFFORD COLLEGE

SPARTANBURG, SOUTH CAROLINA

MENTOR: DR. JONATHAN SPRINKLE

TITLE: INTERSECTION MANAGEMENT VIA THE OPPORTUNISTIC ORGANIZATION OF PLATOONS BY ROUTE (Partner: Alberto Javier Heras w/ Summer Research Institute)

ABSTRACT: Traffic congestion is major source of energy, monetary, and time loss (Fajardo, Au, Waller, Stone, & Yang, 2012). Previous research has, through the use of autonomous vehicles, devised formations called platoons to increase traffic efficiency on highways, as well as signalized and un-signalized intersection management systems so that wait time at intersections is minimized (Amoozadeh, Deng, Chuah, Zhang, & Ghosal, 2015; Dresner & Stone, 2008). The intersection management methodology that is proposed in this paper, in order to reduce delay experienced at intersections will combine both platooning of autonomous vehicles and the un-signalized intersection by organizing platoons based on their expected paths through an intersection. To simulate this method of intersection management, the simulators SUMO and OMNET++, in conjunction with another program called PLEXE, will be used (Segata, Joerer, Bloessl, Sommer, Dressler, & Cigno, 2014; Krajzewicz, Erdmann, Behrisch, & Bieker, 2012). The results of this research show the delay of an intersection in relation to the platoon depth. Another foreseen benefit is the reduction of the computational cost of previous methods (Dresner & Stone, 2008) while also increasing the efficiency of traffic flow in comparison to conventional methods.

JUAN D. GUERRA

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



**UNIVERSITY OF CALIFORNIA,
MERCED**

MERCED, CALIFORNIA

MENTOR: DR. JONATHAN SPRINKLE

POWER EFFICIENT VEHICULAR AD-HOC NETWORKS (Partners: Nikolas Sterling Holbom and Audrey Elizabeth Knowlton)

ABSTRACT: Inter-vehicular communication is a growing platform for improving roadway safety. The highly mobile nature of Vehicle to Vehicle communications causes rapid changes in network topologies and propagation conditions. Since the advent of Vehicular Ad-Hoc Networks (VANETs) over fifty routing protocols with attendant topologies have been proposed. Despite these protocols' merits, many of them are not optimized for power management and frequency reuse. Our approach utilizes the one dimensional dynamic of roadways to simplify the routing problem and reduce energy consumption. Since each car is aware of only two types of connections, up road and down-road, we can form low power, line of sight links between adjacent vehicles. We also utilize a fuzzy logic algorithm that predicts the location of up-road cars to reduce interference from request for link signals. Once these links have been established, up-road vehicles send data down-road for a length of time based on the relative speed of the two vehicles. After this time period has expired the down-road vehicle must request additional information, restarting the timer. Data sent through the network will include information on up-road vehicles, and when required, messages such as accident notifications, alerts, and traffic warnings. Through simulation, we show an approach to VANETs that reduces power consumption by simplifying the network topology and predicting node locations during the linking process.

NICKOLAS STERLING HOLCOMB

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES

GEOORGIA SOUTHERN
UNIVERSITY

STATESBORO, GEORGIA

MENTOR: DR. JONATHAN SPRINKLE

TITLE: POWER EFFICIENT VEHICULAR AD HOC NETWORKS (Partners: Juan D. Guerra and Audrey Elizabeth Knowlton)



ABSTRACT: Inter-vehicular communication is a growing platform for improving roadway safety. The highly mobile nature of Vehicle to Vehicle communications causes rapid changes in network topologies and propagation conditions. Since the advent of Vehicular Ad-Hoc Networks (VANETs) over fifty routing protocols with attendant topologies have been proposed. Despite these protocols' merits, many of them are not optimized for power management and frequency reuse. Our approach utilizes the one dimensional dynamic of roadways to simplify the routing problem and reduce energy consumption. Since each car is aware of only two types of connections, up road and down-road, we can form low power, line of sight links between adjacent vehicles. We also utilize a fuzzy logic algorithm that predicts the location of up-road cars to reduce interference from request for link signals.. Once these links have been established, up-road vehicles send data down-road for a length of time based on the relative speed of the two vehicles. After this time period has expired the down-road vehicle must request additional information, restarting the timer. Data sent through the network will include information on up-road vehicles, and when required, messages such as accident notifications, alerts, and traffic warnings. Through simulation, we show an approach to VANETs that reduces power consumption by simplifying the network topology and predicting node locations during the linking process.

CHARLES RICHARDS

JAWNY

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES

NOVA SOUTHEASTERN
UNIVERSITY

FORT LAUDERDALE, FLORIDA

MENTOR: DR. JONATHAN SPRINKLE

HYBRID MODEL PREDICTIVE CONTROL FOR AUTONOMOUS VEHICLE PATH PLANNING AND OBSTACLE AVOIDANCE (Partner: Yesenia Velasco)



ABSTRACT: The field of autonomous vehicles is still a young one, with much garnered interest from researchers and car manufacturing industries alike. To ensure an improved driving performance of such vehicles, model predictive control (MPC) has gained some attention due to its ability to optimize solutions in real time while in view of constraints and future events, i.e. obstacles or the environment. This is done by repetitively calculating the optimal path represented as a finite set of predicted states, based upon a variety of variables and constraints until a target state is reached. Commonly, MPC is used with a single predictive model which has shown promising results for vehicle maneuvering under certain driving scenarios. The kinematic predictive model, for instance, performs well when driving under low steering angles, but due to its simplified nature, inaccuracy in the model quickly increases. The dynamic predictive model has shown to be more complex and precise than the kinematic and as a result, requires a longer computational time. If the dynamic model fails to return a solution within a reasonable amount of time, the fast, yet simplified kinematic model is preferred. Thus in order to account for a wider range of driving scenarios, multiple predictive models are needed. In this paper a hybrid MPC is used to alternate between several predictive models of an autonomous vehicle with uncontrollable divergence as our switching logic. Uncontrollable divergence is defined as the difference of the actual vehicle state from when the MPC was called to when it returns since the vehicle state is continually shifting while waiting for the MPC to return. The use of uncontrollable divergence as the switching logic leads to the predictive model with the best balance of fast optimization time and low model mismatch to be chosen given the current driving situation. The effectiveness of our solution is demonstrated in both a simulated and physical autonomous vehicle maneuvering successfully through an obstacle course. This method had shown to enhance path planning for autonomous vehicles all while avoiding obstacles.

ADAM MICHAEL JOHNSON

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



VIRGINIA COMMONWEALTH UNIVERSITY

RICHMOND, VIRGINIA

MENTOR: DR. JONATHAN SPRINKLE

FUZZY LOGIC CONTROLLER TO AUTONOMOUSLY DRIVE A CAR WITH A CELLPHONE CAMERA (Partner: Elizabeth Ann Olson)

ABSTRACT: Current localization techniques are either too expensive for the commercial availability of autonomous vehicles, or too complicated to be easily embedded into new technologies.

Our research generated code that explored the capabilities of a camera phone and GPS as the low-cost sensory for a cognitive autonomous testing vehicle under urban traffic conditions. The perception system efficiently makes use of the road's current vision-based cues through processing images from a cellphone camera to analyze its surroundings. This less-complex approach will also provide a module for future software development of mobile devices to be used as the sensors of autonomous vehicles, making the technology more accessible.

The software implements an intelligent, image-based, robust control system to accurately and safely operate the autonomous vehicle on urban trajectories, despite only having a low-cost and low-resolution cellphone camera as the sensory. The control system was based on fuzzy logic and state of the art techniques used for road perception and obstacle detection. The cellphone's camera resolution and system's processor specifications required were determined through numerical simulations. The control system software determines the vehicles location and decides its needed course and driving sequence for the desired trajectory. We tested this system on the CAT vehicle by having it identify and follow a chosen vehicle on a simple trajectory.

AUDREY ELIZABETH KNOWLTON

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



NEW YORK INSTITUTE OF **T**ECHNOLOGY

NEW YORK CITY, NEW YORK

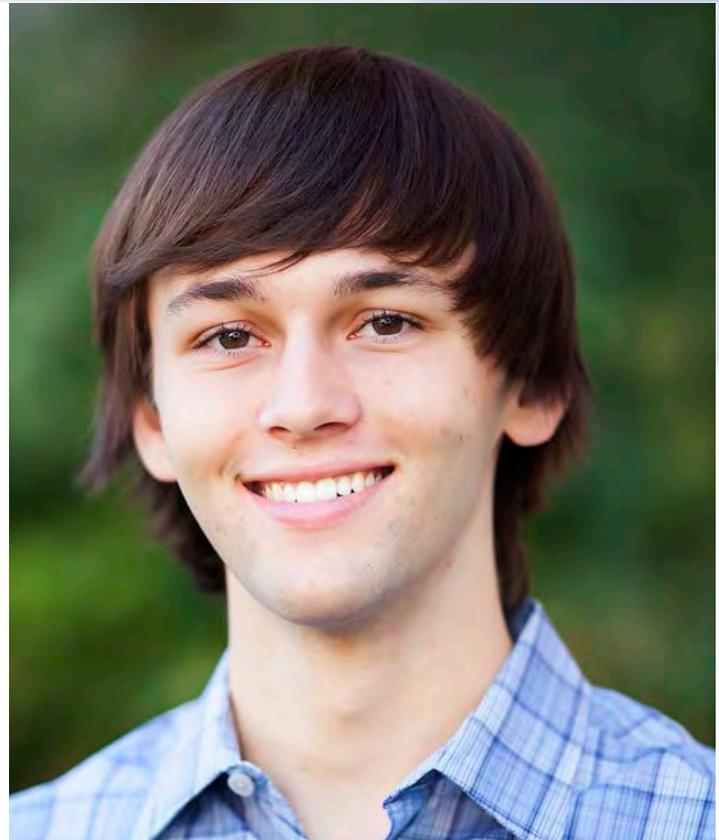
MENTOR: DR. JONATHAN SPRINKLE

POWER EFFICIENT VEHICULAR AD-HOC NETWORKS (Partner: Juan D. Guerra and Nikolas Sterling Holcomb)

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KENNON MCKEEVER

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



UNIVERSITY OF ARIZONA

TUCSON, ARIZONA

MENTOR: DR. JONATHAN SPRINKLE

CONTROL SYNTHESIS (Partner: Yegeta Zeleke)

ABSTRACT: Today, autonomous vehicles are typically programmed using a general-purpose programming language such as C++. Although this approach works, it is not efficient when programming primitive motions of autonomous vehicles. Aside from general-purpose programming languages, there are languages that are specifically designed to model autonomous vehicles, such as SHIFT but these languages are for simulation purposes only.

This article discusses the creation of a domain-specific language that allows for faster programming of autonomous vehicles. This language generates code for multiple controllers that will operate alternatively to allow for fast and effective programming of primitive motions. In addition to improving coding efficiency and reducing the number of programming errors, this adds a level of abstraction to programming autonomous vehicles, meaning the vehicle can be programmed easily by people with little knowledge of low-level details of the car's operation.

Furthermore, this language is meant to ensure safe operation of the vehicle by enforcing a set of constraints on the output path. The main set of constraints that are applied to every generated path have been chosen to enforce safe switching between controllers and prevent unsafe actions. Moreover, it allows to further add specific constraints for particular path; these constraints are checked for validity after the main constraint check is performed.

ELIZABETH ANN OLSON

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



UNIVERSITY OF OREGON

EUGENE, OREGON

MENTOR: DR. JONATHAN SPRINKLE

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RYAN KEITH SUMMIT

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



SOUTHEASTERN OKLAHOMA STATE UNIVERSITY

DURANT, OKLAHOMA

MENTOR: DR. JONATHAN SPRINKLE

INEXPENSIVE VEHICLE DETECTION AND ESTIMATION (Partner: Samuel E. Taylor)

ABSTRACT: Autonomous vehicles have been a leading research topic for many years, with one of the main goals being to create a fully functioning autonomous road vehicle. This paper focuses on the costs associated with autonomous functions, with the intention of creating affordable autonomous availability. At the moment, most autonomous vehicles contain an assortment of sensors, such as proximity sensors, GPS, and LIDAR(Light Detection and Ranging). Costs can be greatly reduced through utilization of inexpensive sensors, such as cameras. This research project will emulate cheap sensors through adding noise to expensive sensors. The noise filled, expensive sensor, will go through filtering, and then be used to control the speed of the vehicle so it can successfully follow another car in stop-and-go traffic. The noise filled sensor will imitate the data of a camera, with the goal being to use a camera and visual servoing to estimate the distance to the vehicle in front of the car. This distance will then be fed into a controller that will determine the speed the autonomous vehicle should be going to maintain its following distance, and thus reduce the cost of autonomous vehicles.

SAMUEL E. TAYLOR

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



UNIVERSITY OF ILLINOIS, **U**RBANA-CHAMPAIGN

CHAMPAIGN, ILLINOIS

MENTOR: DR. JONATHAN SPRINKLE

INEXPENSIVE VEHICLE DETECTION AND ESTIMATION (Partner: Ryan Summit)

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YESENIA VELASCO

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



NORTH CAROLINA CENTRAL UNIVERSITY

DURHAM, NORTH CAROLINA

MENTOR: DR. JONATHAN SPRINKLE

HYBRID MODEL PREDICTIVE CONTROL FOR AUTONOMOUS VEHICLE PATH PLANNING AND OBSTACLE AVOIDANCE (Partner: Yesenia Velasco)

ABSTRACT: The field of autonomous vehicles is still a young one, with much garnered interest from researchers and car manufacturing industries alike. To ensure an improved driving performance of such vehicles, model predictive control (MPC) has gained some attention due to its ability to optimize solutions in real time while in view of constraints and future events, i.e. obstacles or the environment. This is done by repetitively calculating the optimal path represented as a finite set of predicted states, based upon a variety of variables and constraints until a target state is reached. Commonly, MPC is used with a single predictive model which has shown promising results for vehicle maneuvering under certain driving scenarios. The kinematic predictive model, for instance, performs well when driving under low steering angles, but due to its simplified nature, inaccuracy in the model quickly increases. The dynamic predictive model has shown to be more complex and precise than the kinematic and as a result, requires a longer computational time. If the dynamic model fails to return a solution within a reasonable amount of time, the fast, yet simplified kinematic model is preferred. Thus in order to account for a wider range of driving scenarios, multiple predictive models are needed. In this paper a hybrid MPC is used to alternate between several predictive models of an autonomous vehicle with uncontrollable divergence as our switching logic. Uncontrollable divergence is defined as the difference of the actual vehicle state from when the MPC was called to when it returns since the vehicle state is continually shifting while waiting for the MPC to return. The use of uncontrollable divergence as the switching logic leads to the predictive model with the best balance of fast optimization time and low model mismatch to be chosen given the current driving situation. The effectiveness of our solution is demonstrated in both a simulated and physical autonomous vehicle maneuvering successfully through an obstacle course. This method had shown to enhance path planning for autonomous vehicles all while avoiding obstacles.

YEGETA ZELEKE

CAT VEHICLE - RESEARCH EXPERIENCE
FOR UNDERGRADUATES



**UNIVERSITY OF CALIFORNIA,
SANTA CRUZ**

SANTA CRUZ, CALIFORNIA

MENTOR: DR. JONATHAN SPRINKLE

CONTROL SYNTHESIS (Partner: Kennon McKeever)

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Coordinator: Donna Treloar, MA
Instructors: Andrew Huerta, PhD, Renee Reynolds, ABD,
Joanna Sanchez-Avila

Sponsors: University of Arizona; Graduate College; The Partnership for Native American Cancer Prevention (NACP) training program, a collaboration between Northern Arizona University and the University of Arizona Cancer Center, funded by the National Cancer Institute; College of Medicine – Office of Diversity and Inclusion, Health Resources and Services Administration (HRSA) Centers of Excellence; Western Alliance to Expand Student Opportunities (WAESO); Department of Physics.

MINORITY HEALTH DISPARITIES SUMMER RESEARCH PROGRAM (MHD)

Coordinator: Stephanie Adamson, Holly Lopez
Sponsors: University of Arizona; Graduate College; Western Alliance to Expand Student Opportunities (WAESO).

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PIs: Nasser Peyghambarian, PhD
Sponsors: University of Washington/National Science Foundation (NSF). Funding for this research was provided by NSF Grant No. CHE-1156598.

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Coordinator: Ameé J. Hennig, Daniel Lamoreaux
Sponsors: National Science Foundation (NSF) Engineering Research Center for Integrated Access Networks (ERC CIAN).

Funding for this research was provided by the NSF Engineering Research Center No. EEC-0812072.

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PI: Katerina Dontsova, PhD
Sponsors: National Science Foundation Research Experiences for Undergraduates Program.

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Instructors: Andrew Huerta, PhD, Renee Reynolds, MA, Joanna Sanchez-Avila
Sponsors: University of Arizona; Graduate College; Division of Student Affairs; Western Alliance to Expand Student Opportunities (WAESO).

UROC-PREP

Coordinator: Donna Treloar, MA
Instructor: Andrew Huerta, PhD
Sponsors: University of Arizona; Graduate College, Western Alliance to Expand Student Opportunities (WAESO).

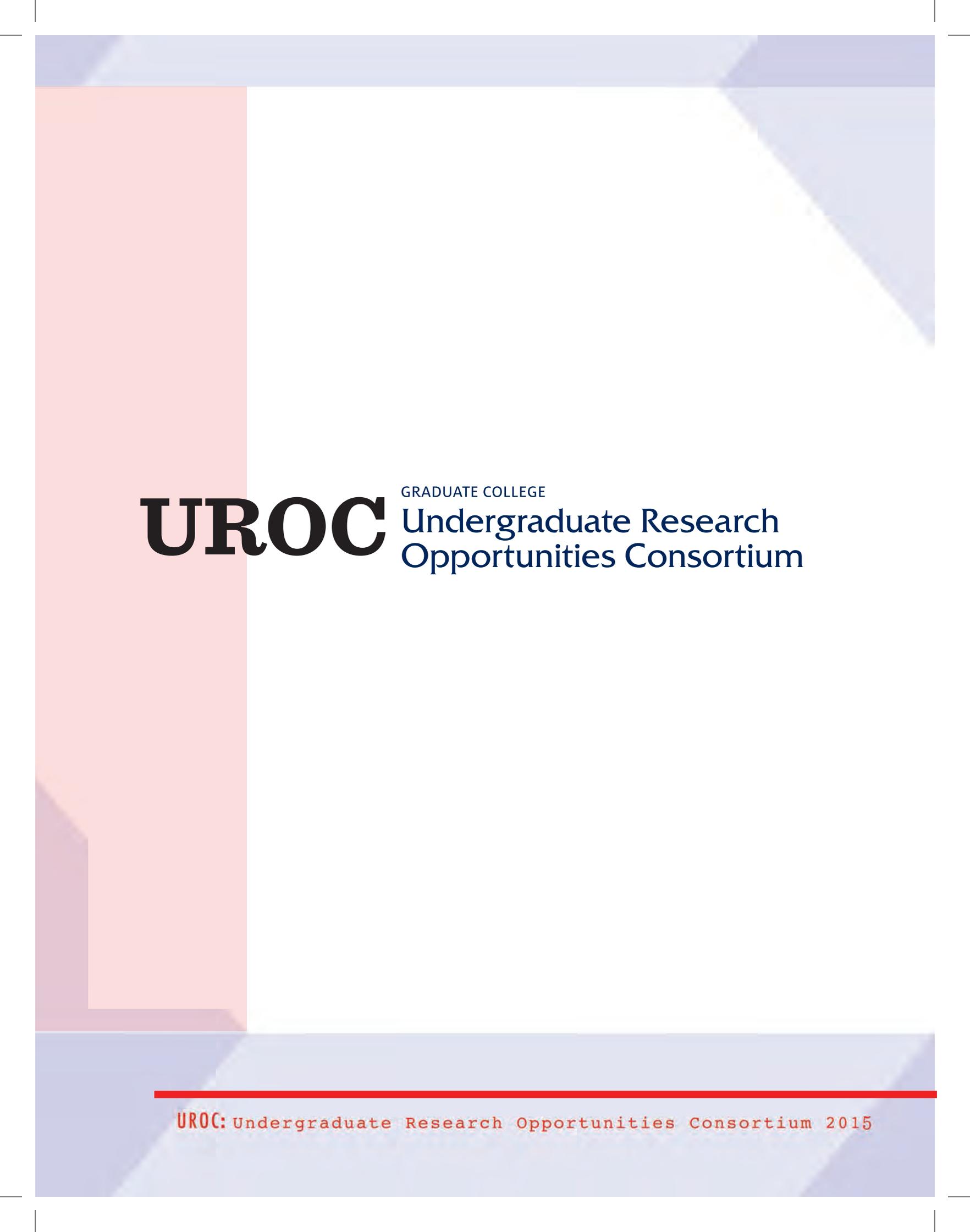
CAT VEHICLE PROGRAM/ ECE REU

PI: Jonathan Sprinkle, PhD
Coordinator: Nancy Emptage
Sponsor: National Science Foundation Research Experiences for Undergraduates Program

RESEARCH IN OPTICS (RIO)

PI: R. John Koshel, PhD
Coordinator: Melissa Sarmiento Ayala, MEd
Sponsor: National Science Foundation (NSF)
Award No. 1460723.





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