Environment and Natural Resources Trust Fund

2024 Request for Proposal

General Information

Proposal ID: 2024-203

Proposal Title: Robotic Detection and Cleanup of Harmful Algal Blooms

Project Manager Information

Name: Junaed Sattar

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: This project will prototype a distributed robotic system that relies on observations from two autonomous aerial and surface vehicles to properly detect and clean harmful algal blooms from Minnesota's lakes.

Funds Requested: $1,213,000

Proposed Project Completion: June 30, 2027

LCCMR Funding Category: Water Resources (B)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

With increasing summer temperatures and agricultural runoffs, blooms of blue-green algae are becoming increasingly common in Minnesota lakes. Certain species of these algal blooms can become harmful to the ecosystem by producing toxins that are linked to illness in humans and animals. Swallowing, coming into contact with, or even breathing airborne water droplets can create adverse health conditions and symptoms such as vomiting, diarrhea, rash, eye irritation, cough, sore throat, and headache. To ensure healthy recreational and drinking water, it is critical to develop cost-effective and sustainable technologies and methods to clean up these harmful algal blooms (HABs), preferably at their early stage of development to prevent widespread growth. The oldest and most widely used approach to controlling HABs involves the application of certain types of clay during blooms. When sprinkled on surface waters during an algal bloom, the tiny but dense clay particles will "flocculate" the HAB cells. However, for large-scale blooms adding too much clay might significantly damage the benthic ecosystem at the bottom of the lake. We need technologies that can routinely monitor the lakes, detect the onset of HABs, and collect or flocculate them with minimal damage to the ecosystem.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

The investigators will design and build an intelligent robotic boat to detect and clean up harmful algal blooms. The system will consist of small unmanned aerial vehicles (UAVs), equipped with visual, inertial, and location sensors, to capture imagery of lakes with algal blooms, map their specific locations through modern remote sensing, and communicate this information with autonomous surface vehicle (or ASV -- which is essentially an intelligent robotic boat). The ASV will use its onboard sensors to navigate to the areas covered with HABs, remove them from the water with a specifically-designed algal filtration system, and bring them to a safe disposal site to be discarded. The disposal site will be equipped with robotic arms to transfer the algal load from the ASV into a safe containment. To make the proposed robotic system (ASV) operate sustainably, we will install solar batteries for long-term use and use a floating docking station to receive additional power for cloudy days or nighttime operations. The research team is requesting funding to (1) create the autonomous surface platform with a filtration mechanism, (2) develop methods for the robots to detect, localize, and map HABs early initiation and spread , (3) enable multi-robot coordination for effective and efficient

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

The outcome of this project is the creation of a solar-powered multi-robotic system that will automatically and efficiently detect, flocculate and remove HABs. Traditional methods have proven very difficult to eliminate or reduce the amount of nutrients that aid in the growth of such algal blooms, which become an inherent part of the overall algal community. This project will create a multi-robotic and easily deployable algal removal system, to enhance and subsequently protect and conserve the water quality of Minnesota lakes, which will in turn improve the health and well-being of Minnesota's residents.

Activities and Milestones

Activity 1: Design of ASV-mounted filtration and AUV-ASV coordination system

Activity Budget: $819,500

Activity Description:
This activity will design the components of the ASV-carried surface algae filtration system, including the multi-robot coordination between the ASV and the AUV, and develop capabilities of the autonomous system to operate in an end-to-end manner. Dr. Sattar's group will create the physical design of the ASV and create prototype systems, develop the algorithms for autonomous navigation and localization for the ASV so that it can safely locate regions of algal growths, and establish protocols for ASV-AUV coordination. Dr. Ebtehaj will develop modern sensing technologies on both aerial and surface vehicles to map the spatiotemporal distribution of HABs and guide the clean-up effort. Dr. Yang will design a filtration system to collect algal cells, and test and compare three filtration mechanisms: membrane-based filtration, flocculation-based method, and a new method based on magnetic particles and magnetic attraction for the ASV. Dr. Desingh's group will work on designing the autonomous disposal system equipped with a robot arm, which will detect the docked ASV, followed by the robot arm grasping and detaching the collection bin on ASV, emptying the bin by transferring the algal load into the containment station and reattaching the empty bin back into the ASV.

Activity Milestones:

Description	Approximate Completion Date
Design and prototype building of ASV and the autonomous docking system at the disposal site	August 31, 2025
Create navigation and localization system for ASV	October 31, 2025
Develop a filtration system for effectively removing cells for mounting on the ASV	December 31, 2025
Design and prototype the robot gripper and the collection bin on the filtration system	December 31, 2025
Develop methods to detect the docked ASV and its onboard collection bin for the robot	April 30, 2026

Activity 2: Field validation, approach refinement component integration, and system deployment

Activity Budget: $393,500

Activity Description:
This activity will focus on integrating the various components of the project into a unified system, and validate and test the system as a whole. Specifically, Dr. Sattar will lead efforts to validate the ASV system outdoors, on two or three lakes, along with validating the coordination between the AUV-ASV robots. Dr. Desingh will support the efforts to validate the robotic arm-equipped autonomous docking and disposal system at the collection site. Results from the initial validation tests will be used to refine the algorithms and the robot design, and hardware performance metrics will assist in the refinement of the ASV platform, including the suite of sensors that will finally be used.
We will test the efficiency of the robots in detecting and removing harmful algal blooms (HABs) in two to three HABs-contaminated ponds in Minnesota. We will collect water samples and measure the cell and toxin concentrations after using the robots to clean up the lake and determine the removal of the percentage of cells and toxins in the water.

Activity Milestones:

Description	Approximate Completion Date
Initial field deployment and validation of ASV system	July 31, 2026
Initial field validation of ASV-AUV coordination system	August 31, 2026
Initial field validation of the autonomous docking and disposal system at the collection site	August 31, 2026

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Karthik Desingh	University of Minnesota Twin Cities	Assistant Professor, project collaborator, specializing in robotic manipulation and perception, and vision-based robotics. Concerned with robotic removal of algae.	Yes
Ardeshir Ebtihaj	University of Minnesota Twin Cities	Associate Professor of Civil, Environmental, and Geo-Engineering, specializes in remote sensing technology development from visible to short-wave infrared imaging, usable for detecting blooms and for mapping their concentration density and toxicity over lakes	Yes
Judy Yang	University of Minnesota Twin Cities	Assistant Professor of Civil, Environmental, and Geo-Engineering, specializes in water filter system to filter algae, including membrane-, particle-, and magnetic-based methods to collect algae.	Yes

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?

The findings from the proposed work will provide an easily deployable, and cost-effective tool for cleaning HABs from Minnesota lakes. The results of this project will be implemented using AUV, ASV, and robotic arms at disposal sites. The project team will document the designs of the robotic tools, algorithms, datasets, and operating instructions in detail, so that the system can easily be replicated. By the end of the project, we expect to have several patents related to the design of the robot system and the filtration system. Our project may also lead to future commercializable lake cleaning products.

Project Manager and Organization Qualifications

Project Manager Name: Junaed Sattar

Job Title: Associate Professor, Department of Computer Science, University of Minnesota Twin Cities

Provide description of the project manager's qualifications to manage the proposed project.

Junaed Sattar is an Associate Professor, Department of Computer Science, University of Minnesota Twin Cities, and the founding director of the Minnesota Interactive Robotics and Vision Laboratory, at the Minnesota Robotics Institute. Dr. Sattar manages a team of 9 graduate and 6 undergraduate students, conducting research in Field and Marine Robotics. He creates novel systems and methods to enable robust autonomous behavior for outdoor robots, particularly those that operate in the aquatic domain, towards environmental preservation and human well-being. He and his group have extensive experience designing, building, and operating robotic platforms for outdoor use, and these systems have seen significant applications in the lakes and rivers of Minnesota, and also in the Caribbean Sea for marine life inspection tasks. Dr. Sattar possesses expertise in robot localization, visual perception and object detection, and multi-robot coordination and collaboration, all in the context of field and outdoors robotics, in environments that are often fraught with significant challenges for robots to reliably exhibit such capabilities. These are important and relevant experiences and skills required for the successful completion of the proposed project for a number of reasons. Firstly, the proposed research will involve the construction of sensor-driven autonomous surface vehicles (ASVs) capable of detecting and removing algal blooms. These blooms need to be detected unambiguously before they are successfully removed, so robust detection and localization methods are necessary. Secondly, the multi-robot coordination and communication of visual data of algal blooms must be successfully conducted so that an autonomous surface robot can locate and remove these harmful algae from the water surface. Dr. Sattar's expertise in addressing these issues in robot construction, robot vision systems, and his experience in deploying robust vision algorithms in pragmatic systems make him uniquely suitable to lead this project.

Organization: U of MN - College of Science and Engineering

Organization Description:
The Minnesota Robotics Institute (MnRI) is made up of researchers who are pushing the frontiers of robotic locomotion and perception in the land, air, and water across a vast array of domains including Precision Agriculture, Environmental Monitoring, Underwater Communication & Collaboration, Swarm Robotics, Social Robots, and Robot Perception. The Interactive Robotics Laboratory (http://irvlab.cs.umn.edu), as part of the MnRI, conducts research in underwater robotics motivated by the needs of environmental assessment, conservation biology, water quality assessment, and coral reef mapping and monitoring. The IRVLab specializes in cutting-edge perceptual computing for robotics applications in degraded visual conditions, and rugged robotic device construction, among others. Robotic field trials are a core part of the IRVLab's mission to invent robotics-driven solutions to a number of real-world problems. Students are exposed to the latest innovations in autonomous outdoor systems, and often are creating such innovations themselves. becoming well-equipped to face the challenges in the 21st-century economy in Minnesota and beyond.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Principal Investigator- Junaed Sattar		Responsible for developing and leading the research			36.8%	0.24		$63,087
Co-Investigator - Judy Yang		Share advising duties with the PI of the graduate researchers for the project			36.8%	0.06		$12,092
Co-Investigator- Ardeshir Ebtehaj		Share advising duties with PI of the graduate students on the research project			36.8%	0.06		$13,110
Co-Investigator - Karthik Desingh		Share advising duties with PI of the graduate students on the research project			36.8%	0.24		$57,104
SAFL Engineers		These Engineers will help to build the systems for the project			36.8%	0.48		$65,330
SAFL Staff		Help support the project by aiding with equipment distribution and guide			32%	0.18		$20,315
Two Research Assistant from CS&E		The GRA will work under the direct supervision of Senior Personnel.			24%	3		$327,353
Two Research Assistant from SAFL		The GRA will work under the direct supervision of Senior Personnel			24%	3		$324,971
Two Undergraduates Students		The students will work under the supervision of the GRA and senior personnel			0%	1.11		$48,220
							Sub Total	**$931,582**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Equipment	Autonomous surface vehicle platform	Capture imagery of lakes with algal blooms, map their specific locations through modern remote sensing, and					$100,000

			communicate this information with autonomous surface vehicle					
	Equipment	Aerial platform (drone)	Capture imagery of lakes with algal blooms, map their specific locations					$20,000
	Equipment	Sensors/computing	Sensors to navigate to the areas covered with HABs, remove them from the water with a specifically-designed algal filtration system, and bring them to a safe disposal site to be discarded.					$10,000
	Tools and Supplies	Marine robot maintenance and expansion material	Maintenance of the robot for optimal function					$30,000
	Tools and Supplies	Multiple cameras (Zed stereos and FLIR thermal cameras)	Capture imagery of lakes with algal blooms					$5,000
	Tools and Supplies	3D Printing Materials	Materials to build parts of the platform for the system					$4,676
	Tools and Supplies	Laptop or computing on the robot	To be able to run the system accurately					$3,500
	Tools and Supplies	(1) the filter system, (2) algae cultivation costsand (3) materials to test and count algae	HABs, remove them from the water with a specifically-designed algal filtration system, and bring them to a safe disposal site to be discarded.					$45,000
	Equipment	Robot Manipulator - UR5e	Will be used to build the platform of the robot					$28,000
	Equipment	Robot Gripper (Robotiq 2F-85)	Will be added to the manipulator on the platform of the robot					$5,000
							Sub Total	**$251,176**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Other	Trips to lake sites in Minnesota with the team	This is for trips to lake sites in Minnesota with the team members, robot gears, etc. to test, evaluate,					$10,000

			demonstrate our robotic solution to clean algae.					
							Sub Total	**$10,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publications of research papers to journals, abstracts, etc.	To share the findings with the public and scholars					$4,000
							Sub Total	**$4,000**
Other Expenses								
		Computer Service-Network	Networking and computer charges are expenses charged to sponsored and non-sponsored accounts to support the portion of networking and computer infrastructure used by sponsored and non-sponsored research projects.					$16,242
							Sub Total	**$16,242**
							Grand Total	**$1,213,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Attachments

Required Attachments

Visual Component

File: 21151d51-2c3.pdf

Alternate Text for Visual Component

Shows a solar-powered robotic system that can map the lake boundaries, detect and safely maneuver floating objects (i.e., boats), distinguish harmful algal blooms (HABs) from other debris and algal species, and filter out the blooms from the Minnesota lakes on a regular basis....

Optional Attachments

Support Letter, Photos, Media, Other

Title	File
Budget and Justification	2dbcd876-4da.pdf
UMN SPA Approval Letter	42e9c03d-8a1.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Does your project include the design, construction, or renovation of a building, trail, campground, or other capital asset costing $10,000 or more?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services, as defined in Minnesota Statutes section 299C.61 Subd.7?

No