Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 036-A**

Realtime Monitoring of Statewide Pollen in Minnesota

Category: A. Foundational Natural Resource Data and Information

Sub-Category:

Total Project Budget: $ 319,133

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

This project aims to develop a low-cost phone attachment and mobile app that can be used by the public, enabling real-time monitoring of statewide pollen condition in Minnesota.

Name: Jiarong Hong

Sponsoring Organization: U of MN

Job Title: Prof.

Department: Mechanical Engineering

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Minneapolis MN 55414

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Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Figure 1 demonstrates the proposed system to image and analyze pollen; Figure 2 shows the 4G coverage map in Minnesota and ten tentative sample sites for field data collection.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Real-time monitoring of statewide pollen in Minnesota

I. PROJECT STATEMENT

This project aims to develop a low-cost and compact module that can transform a smartphone into a sensor for real-time monitoring of pollen conditions in Minnesota. The module includes a miniature phone attachment that allows *in situ* recording images of pollen in the air, based on digital inline holography (DIH), and a user-friendly and self-guided mobile app, which uses machine-learning based algorithm to identify and quantify different types of allergenic pollens, automatically.

Pollen is one of the main triggers of allergies which affects more than 50 million Americans each year. Studies have shown that as many as 2/3 of people who have asthma, also suffer from allergies. In Minnesota, asthma affects one in 16 children (6.4%) and one in 13 adults (7.4%). The pollen season in Minnesota typically starts in early April and ends when a hard frost occurs in the fall, which could also be lengthened by climate change (e.g. ragweed pollen season is now 18 to 21 days longer than in the mid-1990s). As winters are warming, some non-native, allergenic plants might also expand their range into Minnesota. Therefore, it becomes increasingly important to monitor statewide pollen levels as part of the daily air quality control. The pollen data could allow allergy and asthma patients to better manage their allergies by taking medication and minimize exposure to allergenic pollen through the year, such as avoiding locations where pollen is likely to be high.

Currently, websites or smartphone applications (apps) provide a forecast of the pollen count (low, medium or high) from models, based upon historical and climatological data. The National Allergy Bureau is the most trusted resource for accurate pollen counts collected at over 70 stations nationwide with the Clinical Research Institute, Inc. (CRI) being the only site in Minnesota. Despite its accuracy, the process is labor-intense. It requires collecting samples at a specific location for a 24-hour period, then manually counting the grains of each pollen type by a certified counter, under a microscope. These data overall are not sufficient to accurately forecast the types of prevalent pollen, their concentration levels, or their change over time at a given location.

With the phone attachment and app developed in this project, pollen counts will be collected in an extended geographic scale of Minnesota and be monitored in real time, by engaging citizen scientists. A spatial database of pollen levels can be created from the shared pollen counts and locations from smartphone users. Long-term tracking of individual pollen types will also be generated. This database will be made public via an interactive web interface to citizens, government agencies, health professionals and researchers.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Perform lab measurements of common pollen in Minnesota using DIH

Description: This activity will involve the development of basic methodology for how to image and categorize different types of pollen grains using DIH, which has been broadly used for 3D imaging and live tracking particles yet thoroughly tested in analyzing pollen. The activity will take place at PI Hong's lab using the existing DIH setup, which consists of a laser source and a digital camera. This setup captures distinct marks made by the pollen grains floating in the air within the laser beam path on the camera sensor, called holograms (example shown in Figure 1). The holograms are then processed using a computer program developed in Hong's lab to reconstruct the in-focused images of individual pollen grains and their 3D spatial distribution in the air column, and successively derive the size and morphology of each grain. A machine-learning algorithm will be implemented to automatically categorize different types of pollen and measure the pollen counts.

ENRTF BUDGET: $99,239

Outcome	Completion Date
1. Perform 3D imaging and analysis of pollen grains using DIH	June 2021
2. Derive general relationship between pollen holograms and physical parameters	June 2021
3. Develop a machine-learning algorithm to automatically categorize and count pollen	June 2021

Activity 2: Develop the phone attachment and a mobile app

Description: This activity will involve the development of a hardware attachment to the smartphone, which will consist of a low power laser as the illumination light source and a miniature lens piece attached to phone camera that converts it into a digital microscope (Figure 1). A mobile app will be developed which incorporates the hologram analysis codes and machine-learning algorithms developed in Activity 1. We will select three sites around the Twin-Cities area to collect field data through the year. The results will be compared to the pollen counts from the CRI and forecasts from websites for cross-validation on a daily basis. The hardware design and app will be optimized according to the outcomes of field tests to be compatible with the smartphone computing power, while maintaining accuracy and speed.

ENRTF BUDGET: $110,201

Outcome	Completion Date
1. Develop a phone attachment and mobile app for pollen monitoring	March 2022
2. Identify locations of test sites and collect field data	January 2022
3. Analyze field data and improve hardware and app design according to the outcomes	December 2022

Activity 3: Engage citizen-scientists and build a spatial database for long-term pollen monitoring

Description: We will use the finalized hardware design in Activity 2 to assemble 20 mobile phone attachments to distribute to volunteers from 10 sites statewide within the 4G network coverage area (tentative sites shown in Figure 2). A remote server will be set up at St. Anthony Falls laboratory (SAFL) to continuously receive and store the pollen data and locations from each mobile phone. A user-friendly website will be created and managed by SAFL, where a spatial map of pollen counts of each monitored type will be reported daily and open to the public. The long-term spatial database will be accessible through a web server hosted by one virtual machine through the Office of Information Technology (OIT) at the University of Minnesota and be open to the public.

ENRTF BUDGET: $109,693

Outcome	Completion Date
1. Engage citizen-scientists by distributing phone attachments and mobile app	February 2023
2. Create a spatial map of pollen counts daily and build the long-term spatial database	June 2023
3. Finish a website to report pollen counts and to provide open access to the database	June 2023

III. LONG-TERM IMPLEMENTATION AND FUNDING:

The long-term implementation of the developed technology from this proposal will be conducted through close collaboration with Minnesota Department of Health, Department of Natural Resources and Minnesota Pollution Control Agency to better meet their missions. We will construct an official website hosted in collaboration with state agencies to post daily pollen report which could provide a guideline for allergy and asthma patients to take proactive approaches to better manage their symptoms. Results from this research will also be disseminated in peer-reviewed journals, presented at conferences, and shared with local media outlets. The openly accessible long-term spatial database could be used by any researcher in relevant fields, for instance, to build better models for predicting onset and duration of allergenic pollen season, or to investigate the effect of climate change on pollen allergies and local forestry. The tools developed in this research, including the phone attachment and mobile app, could be leveraged in educational efforts, including the SAFL outreach program towards middle school students.

Built upon this project, we will apply funding opportunities from the Environmental Protection Agency or the National Institute of Allergy and Infectious Diseases to expand pollen monitoring nationwide and to extend the functionality of the mobile app by monitoring other air particles for indoor and outdoor air quality control.

V. SEE ADDITIONAL PROPOSAL COMPONENTS:

Proposal Budget Spreadsheet, Visual Component, Project Manager Qualifications and Organization Description

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Jiarong Hong
Project Title: Realtime monitoring of statewide pollen in Minnesota
Organization: Regents of the University of Minnesota
Project Budget: $319,133
Project Length and Completion Date: 3 Years, complete on June 30th, 2023
Today's Date: 4/10/2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 293,133	$ -	$ 293,133
PI Hong at 5% FTE for 3 years; 1 postdoctoral fellow at 100% FTE for 3 years; 1 graduate student at 50% FTE for 3 years.			
Professional/Technical/Service Contracts			
Equipment/Tools/Supplies	$ 22,000	$ -	$ 22,000
Equipments for air sample collection and measurement in laboratory ($2,000)			
Supplies for developing phone attachment ($5,000)			
Supplies for develop mobile app ($5,000)			
Supplies for the manufacture of 20 phone attachement, $250 each ($5,000)			
Remote server setup and maintenance ($5,000)			
Capital Expenditures Over $5,000			
	$ -	$ -	$ -
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
	$ -	$ -	$ -
Travel expenses in Minnesota			
Field trips to collect pollen samples daily	$ 4,000	$ -	$ 4,000
Other			
	$ -	$ -	$ -
COLUMN TOTAL	$ 319,133	$ -	$ 319,133

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Unrecoverd F&A calculated at 54% MTDC	secured	$ 158,987	$ -	$ 158,987

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		$ -	$ -	$ -

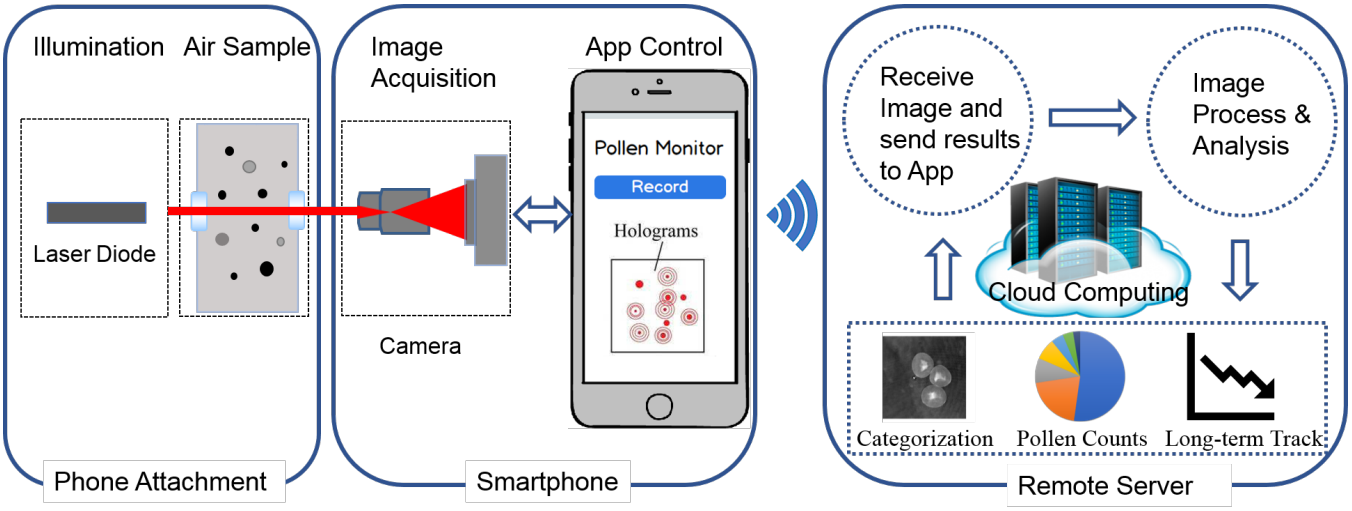

Figure 1. Schematic illustration of imaging and analyzing pollen grains using smartphones with a customized hardware attachment and app.

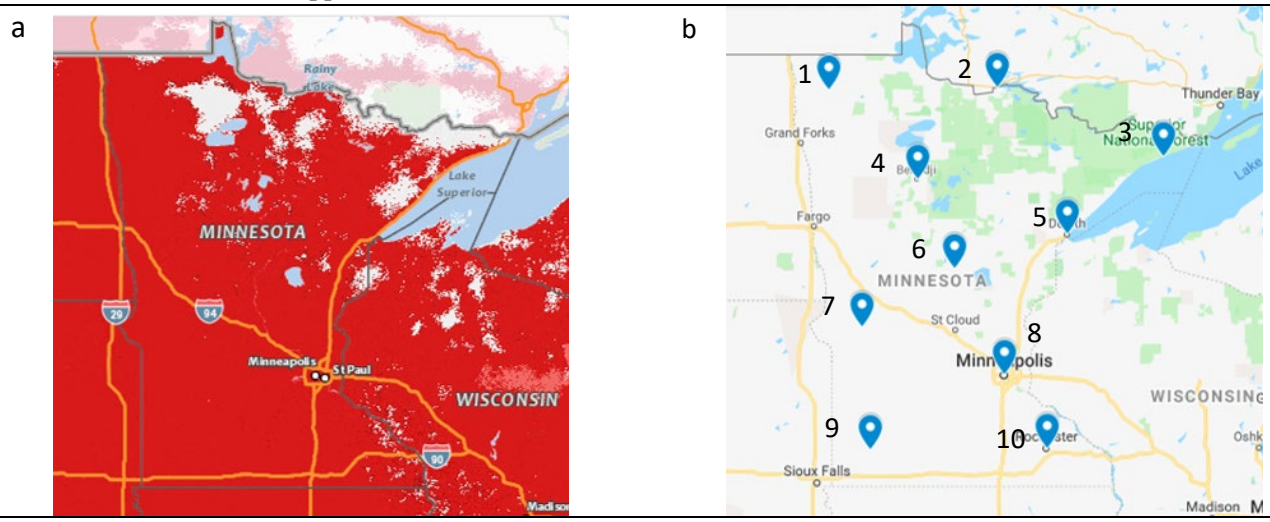

Figure 2. (a) 4G coverage map of Verizon in Minnesota (courtesy of Verizon Wireless) (b) The proposed ten sample sites within Minnesota (courtesy of Google Map): (from 1 to 10) Karlstad, International Falls, Grand Marais, Bemidji, Duluth, Brainerd, Morris, Minneapolis, Slayton, Rochester.

Project Manager Quantifications and Organization Description

Project manager: Jiarong Hong

Benjamin Mayhugh Associate Professor, McKnight Land-grant Professor in Saint Anthony Falls Laboratory (SAFL) and Department of Mechanical Engineering at University of Minnesota
B.S., Mechanical Engineering, University of Science and Technology from China, 2005
Ph.D., Mechanical Engineering, Johns Hopkins University, 2011

Research Focus: Hong's research focuses on the environmental fluid dynamics and the related technical development involving particle characterization, image and signal analysis and optical instrumentation. He has 14 years of experience in the digital inline holography technology and two patents related to this technology. His work has been widely reported by major international media including *Nature, National Geographic, and Yahoo News, etc.* In addition, PI Hong is the main investigator or co-investigator for a number of federal grants and industrial grants related to the proposed technology, including two major robotics grants from National Science Foundation, Young Investigator Award from Office of Naval Research, and one grant from Land O'Lakes. The proposed project will significantly leverage the resources from these grants.

Awards: Robert T. Knapp Award from the Fluids Engineering Division of American Society of Mechanical Engineers (2011), Corrsin-Kovasznay Outstanding Paper Award (2012), CAREER award from National Science Foundation (2015), McKnight Land-Grant Award (2016), and Office of Naval Research Young Investigator Awards (2016).

Organization Description:

Prof. Jiarong Hong will serve as the project manager and oversee all the development in the proposed project. PI Hong is affiliated with SAFL (http://www.safl.umn.edu), a world-renown research laboratory in environmental engineering and fluid mechanics. The lab has a large number of faculty and research engineers who have contributed to the projects related to environment research and management across the state. Instrumentation development is a significant part of the lab. In the past, the lab has developed automated data collection, sampling protocols, wireless data transfer and storage for several state agencies. SAFL provides a number of cutting-edge facilities for the proposed research including an atmospheric boundary layer wind tunnel (https://www.safl.umn.edu/facilities/wind-tunnel) that can be used for testing the performance of our device under different wind and temperature conditions, and distributed data servers (https://www.safl.umn.edu/facilities/computational).