

PROJECT SUMMARY

Overview:

This planning grant is focused on the investigation of catoptric (mirror-based) systems for managing natural light in interior spaces. We are partnering with the 39 North Innovation District in St. Louis County to explore the benefits achievable when capturing natural light for three purposes: (1) illumination of human spaces, (2) heating buildings, and (3) growing plants.

39 North is a hub of AgTech intellectual activity in the St. Louis region, anchored by Bayer Crop Science (formerly Monsanto), the Donald Danforth Plant Science Center, and the startup incubators Bio-Research and Development Growth Park (BRDG Park) and Helix Center. A master plan for development has been prepared by the St. Louis Economic Development Partnership and St. Louis County, and major renovations to the intersection of the two major thoroughfares have been funded and construction will commence in 2020.

As a center of innovation with support from local government, 39 North is an ideal community for us as a partner. Three organizations within the community have already agreed to work with us on prototype systems (with installations at their sites). Attitudes towards new ideas are welcomed, and there is a spirit of investigation and exploration that is pervasive. The community has a research culture already in place.

The focus of this research is the effective capture and use of natural light via catoptric systems. Mirrors are strategically positioned to enable the redirection of sunlight in desirable ways, and the mirrors are under active control so as to do this most effectively as (1) the position of the sun changes, and (2) the need for light varies over time for all three purposes (illumination, heat, and plant growth).

Intellectual Merit:

The effectiveness of catoptric systems will be in significant part determined by the quality of the control used to manage their use. This involves appropriate utility functions for each use case (for humans, HVAC systems, and plants) as well as multi-objective optimization techniques to integrate all three. We will investigate the use of Markov Decision Processes (MDPs) and variations thereof (e.g., Partially Observable MDPs) as an approach to decision making and control that supports future benefits as an explicit consideration in the decision process.

In addition to one prototype system that is already in place (at Washington University), we will design and construct prototypes that enable experimentation with humans in an office environment (at VelociData, Inc.), HVAC systems (at BECS Technology, Inc.), and greenhouses (at the Donald Danforth Plant Science Center), all three of which are located in 39 North. The latter prototype will be the focus of this planning grant, with the other two to follow.

An essential piece of any control function is the need to ensure safe operation. We will explore the use of visual feedback for safety assurance, which has the potential to significantly decrease the cost of a catoptric system (reducing or eliminating the need for feedback on each control surface). Faculty from Saint Louis University with expertise in computational photography are members of the research team.

Broader Impacts:

The execution of this project will support increased use of natural light for illumination in human-occupied spaces, for heating of structures, and for growing plants for food. All three of these goals are important elements of a sustainable environment, and all three are well represented problems that are of interest to the research community in 39 North.

We will connect this project with the already well established education and outreach activities of the Donald Danforth Plant Science Center. Catoptric systems can be integrated into classrooms that have mini-greenhouses in place. Further, the vegetables that come from systems such as these can be utilized to partially ameliorate the lack of their availability in urban food deserts. We are consulting with faculty in the WU Brown School of Social Work and Public Health to investigate this opportunity.