Robot Development and Path Planning for Indoor Ultraviolet Light Disinfection

Jonathan Conroy[1], Christopher Thierauf[1], Parker Rule[1], Evan Krause[1], Hugo Akitaya[2], Andrei Gonczi[1], Matias Korman[3], and Matthias Scheutz[1]

[1]Tufts University, MA, USA.
[2]University of Massachusetts, Lowell, MA, USA.
[3]Siemens Electronic Design Automation, OR, USA.

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Motivation and Related Work

- UVC light already in use to deactivate contaminants[1,2]

[1] Xenex's "ADAMMS-UV", Rovenso, Tru-D, UVD

[2] Mahida, Vaughan, and Boswell, "First UK evaluation of an automated ultraviolet-C room decontamination device (Tru-D™)".

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  - Discuss a novel algorithm for formal guarantees of disinfection

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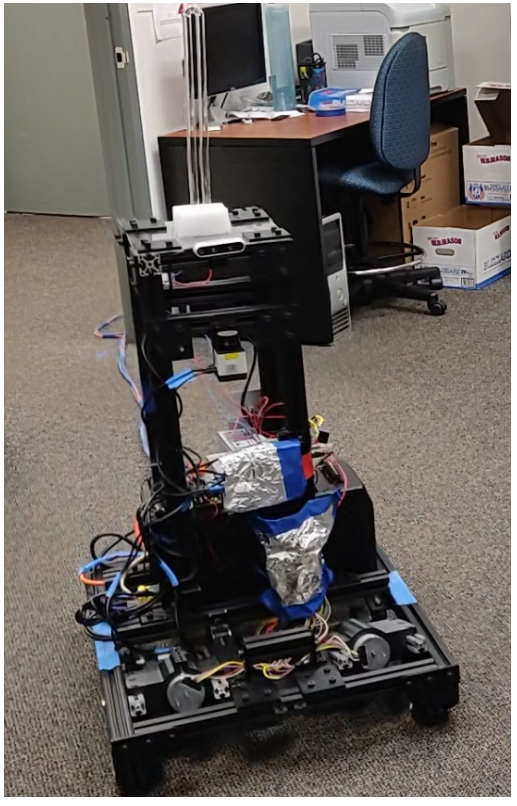
  - Intel Realsense D435i improves obstacle avoidance



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  - UPS provides hot-swappable power in readily available package

Navigation Software

- ROS provides navigation stack

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- Stack is capable of autonomous navigation and map production

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Disinfection Algorithm - Model

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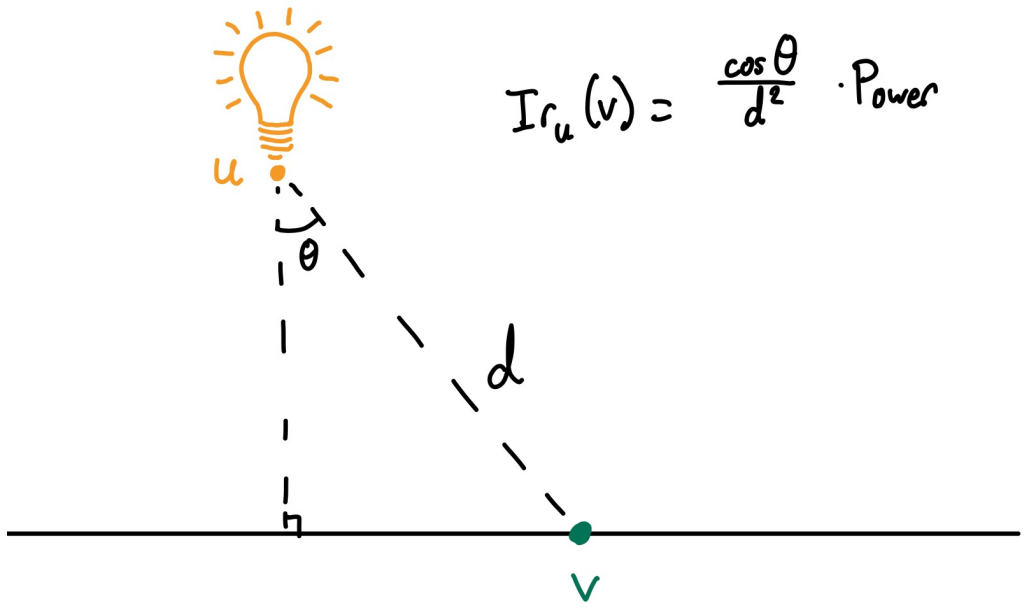

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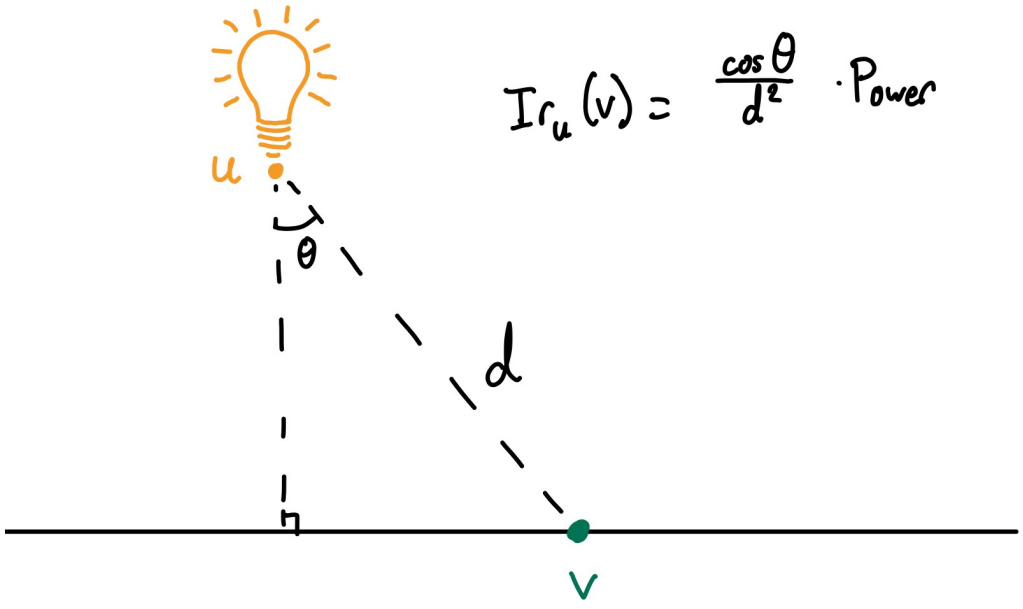
- Irradiance depends on a nonlinear relationship with distance.
- **Disinfection guarantee**:

$$\int \text{Irradiance} \cdot \text{Time} \geq \text{Threshold}$$



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- Given a polygon, find a path for the robot that minimizes time while guaranteeing every point in the room is disinfected.

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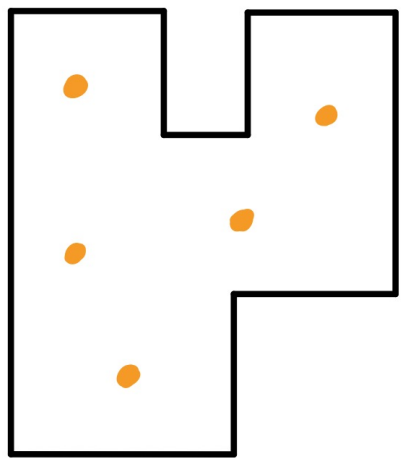
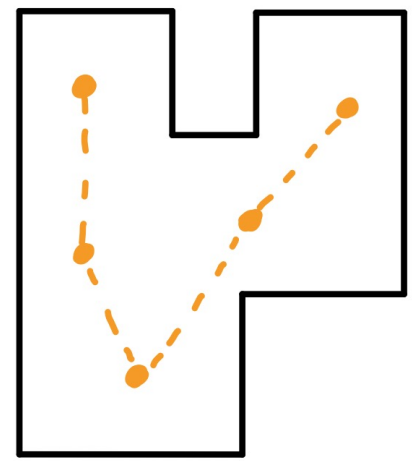
- Difficulties:
  - Visibility
  - Irradiance is nonlinear

Disinfection Algorithm - High Level Idea

1. Select robot waypoints
2. Find fastest route that visits all waypoints

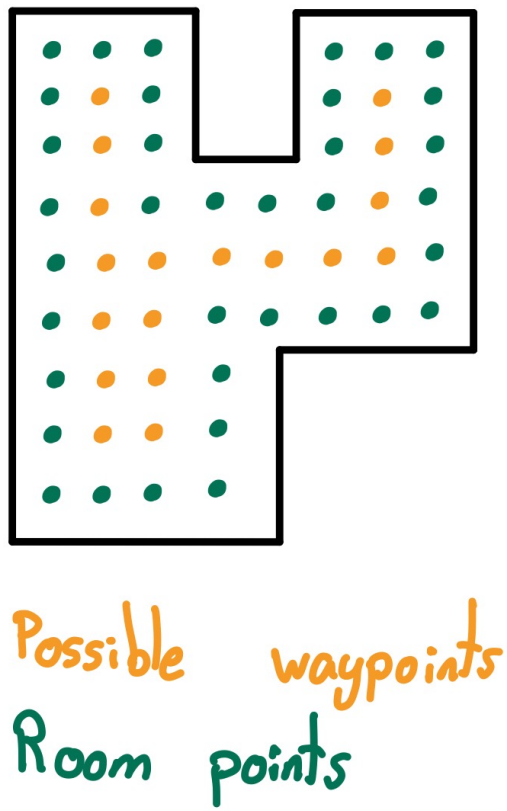




Disinfection Algorithm - LP Solution

First, solve a simpler *discrete* problem:

- Represent room with two sets of points:
  1. Points that need to be disinfected ("room points")
  2. Points where the robot can be ("waypoints")



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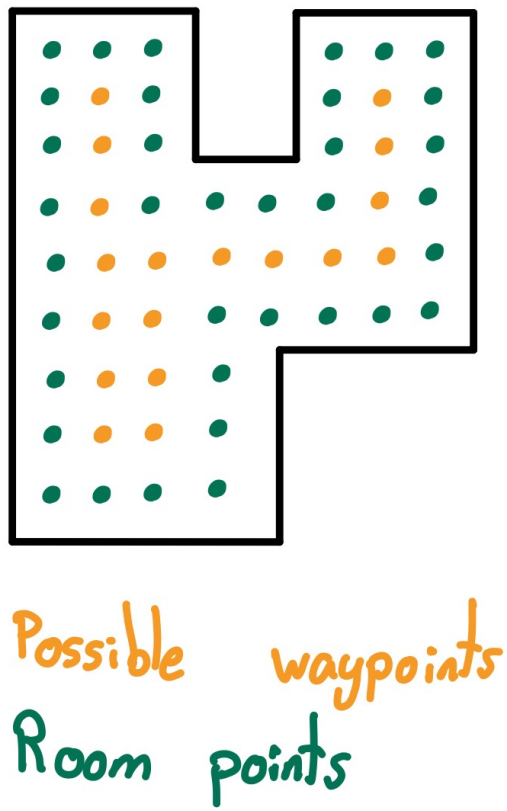
- Discrete solution: tuple of times $(t_1, t_2, ..., t_n)$



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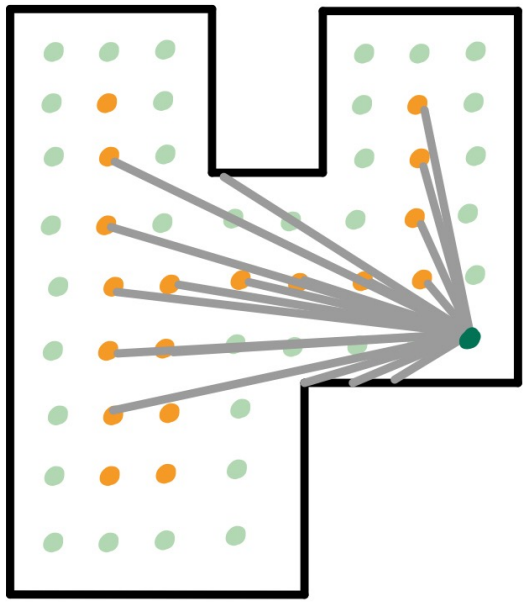
- Each point in the room enforces a constraint on $(t_1, t_2, ..., t_n)$. For every v in the room point set:

$$\sum_{u \in \text{Waypoints}} Ir_u(v) \cdot t_u \geq \text{Threshold}$$

- This defines a *linear programming* problem

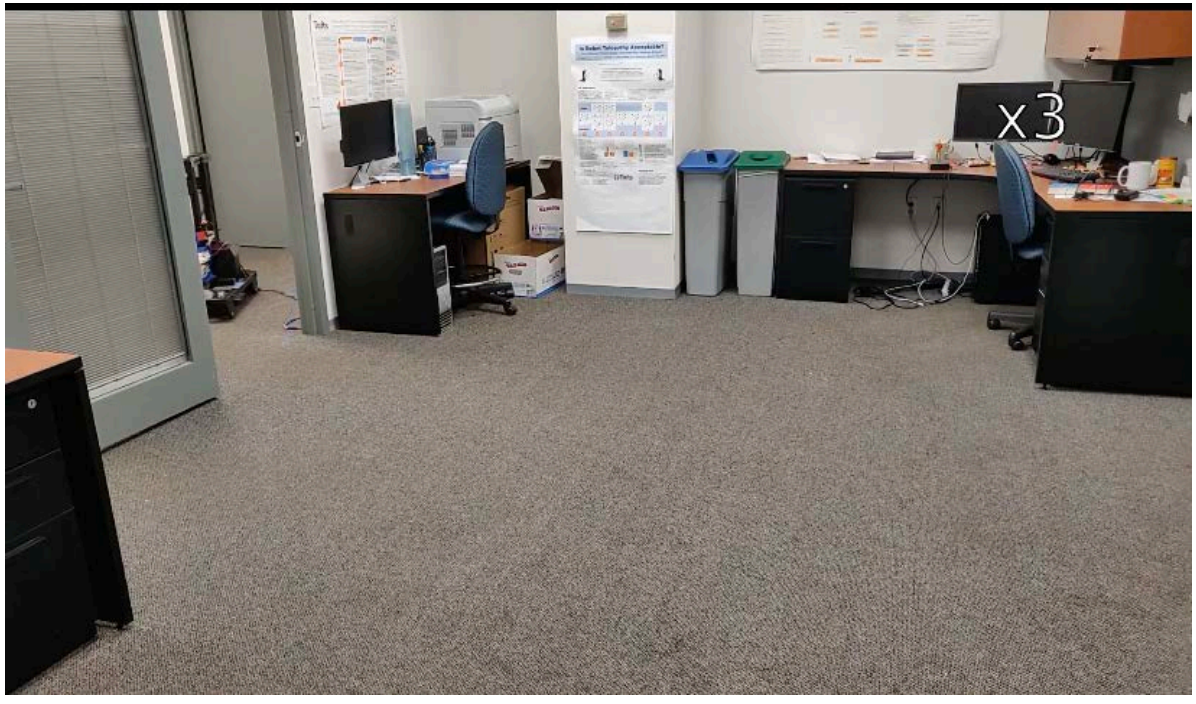


Experiments - Simulation

- Using scanned room data, compute disinfection time
- Compare with naive stationary solution
- On average, 30% speedup with 35% coverage increase

Experiments - On Real Hardware

- Fully integrated platform is run in an office environment



Future Work

- Hardware improvements
- 3D room data
- Stronger theoretical guarantees on optimality

Thank you

Jonathan Conroy, Christopher Thierauf, Parker Rule, Evan Krause, Hugo Akitaya, Andrei Gonczi, Matias Korman, and Matthias Scheutz:
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Presented by
{Jonathan.Conroy, Christopher.Thierauf}@tufts.edu