Using Robots to Save Lives during Emergencies

NRI: INT: COLLAB: Interactive and collaborative robot-assisted emergency evacuations

CNS-1830390, 09/18/18

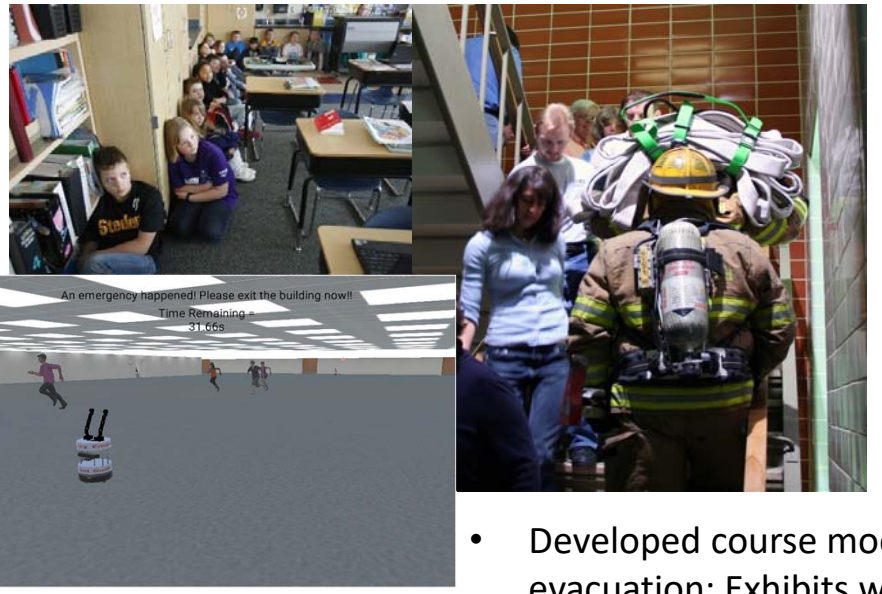
Alan R. Wagner, Penn State; Minghui Zhu, Penn State; Hai Lin, Notre Dame

Goals

- Develop methods to optimize evacuation time and safety
- Synthesize motion controllers to avoid high-density areas
- Evaluate with crowds of people

Challenges

- Emergencies are dynamic, unexpected
- Environment is unstructured, difficult to navigate
- People are confused, distracted, emotional



Scientific Impact

- Algorithms developed offer new methods for rapid robot deployment
- HRI evaluations provide insight into how people react in high stress situations

Broader Impacts

- Save lives in a wide variety of different environments
- Developed course modules related to robot guided emergency evacuation; Exhibits with children; Undergraduate engagement
- Trying to quantify impact experimentally now.

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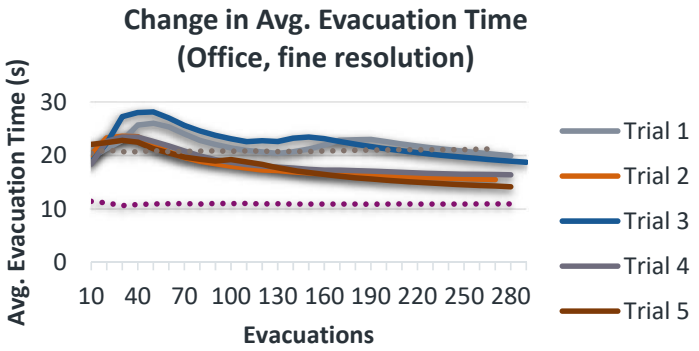
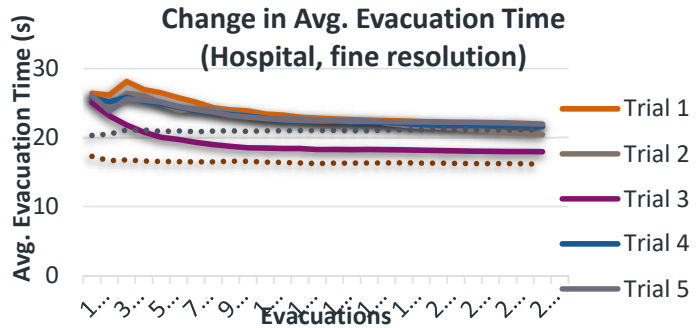
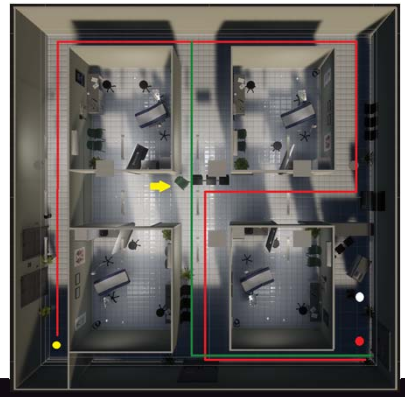
Solutions: HRI

- Build evacuation robots.
- Test in realistic environments with different group sizes. (On hold because of pandemic)
- Simulation testing to guide hypotheses
- Currently developing robots that can remove blockages to allow for easy access to exit
- Object detection used to identify movable objects
- Tested in different types of environments

Object detection to identify movable objects







Scalable Distributed Motion Coordination

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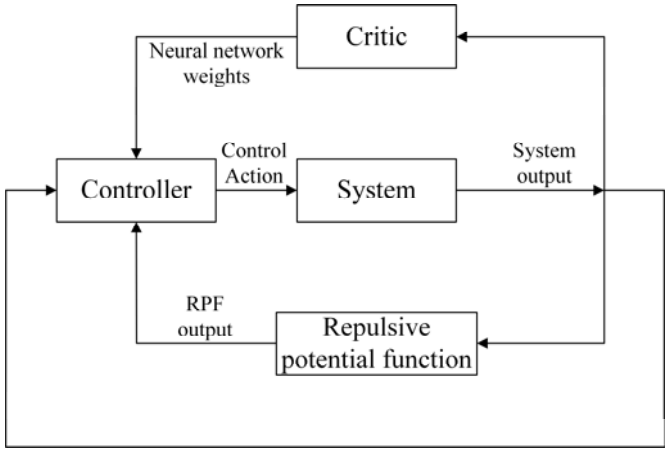
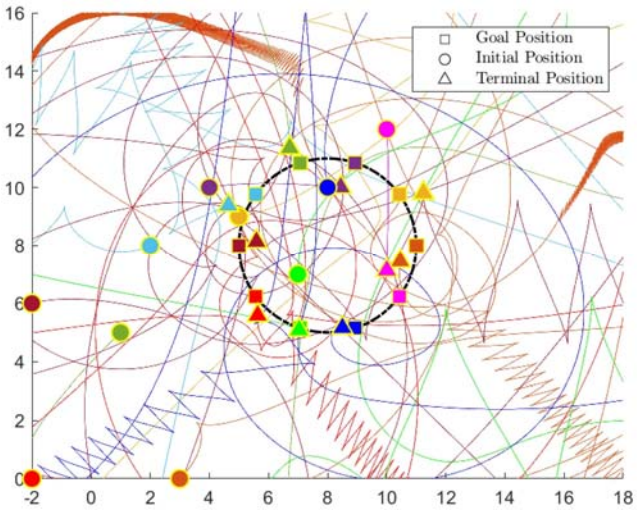
Solutions: Motion Coordination

- Develop a scalable distributed safe reinforcement learning algorithm.
- Anytime collision avoidance is guaranteed as well as learning errors and tracking errors are analytically quantified.





Density feedback control

Task level:

SpaTeL
Patten planning
$\phi = \Diamond_{[0,T_1]}(\psi_1) \wedge \Diamond_{[0,T_2]}(\psi_2)$

Reference signal $p^*(x,t)$

Macro-level:

Mean-field PDE
Density feedback
$\partial_t p = -\nabla \cdot (\mathbf{v}p) + \Delta(gp)$

Linking macro- and micro-dynamics

$\mathbf{v} = -\dfrac{\nabla\left[\alpha(p-p^*) - gp\right]}{p}$

Micro-level:

Robot dynamics
Distributed control
$dX_i = \mathbf{v}dt + 2\sqrt{g}dB_t$

Optimally deploy robots using SpaTeL to create reference densities, density feedback control based on mean-field PDEs to generate velocity fields for individual robots.

Novelty: Top-down, provable, closed-loop, distributed, scalable, robust to density estimation error.