Best Viewpoints for External Robots or Sensors Assisting Other Robots

(DOE NRI: Collaborative Visual Assistant for Robot Operations in Unstructured or Confined Environments)

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Standard Practice: One Robot to Perform the Task, A Second Robot to Provide External View

Fukushima Daiichi nuclear accident (courtesy of iRobot)

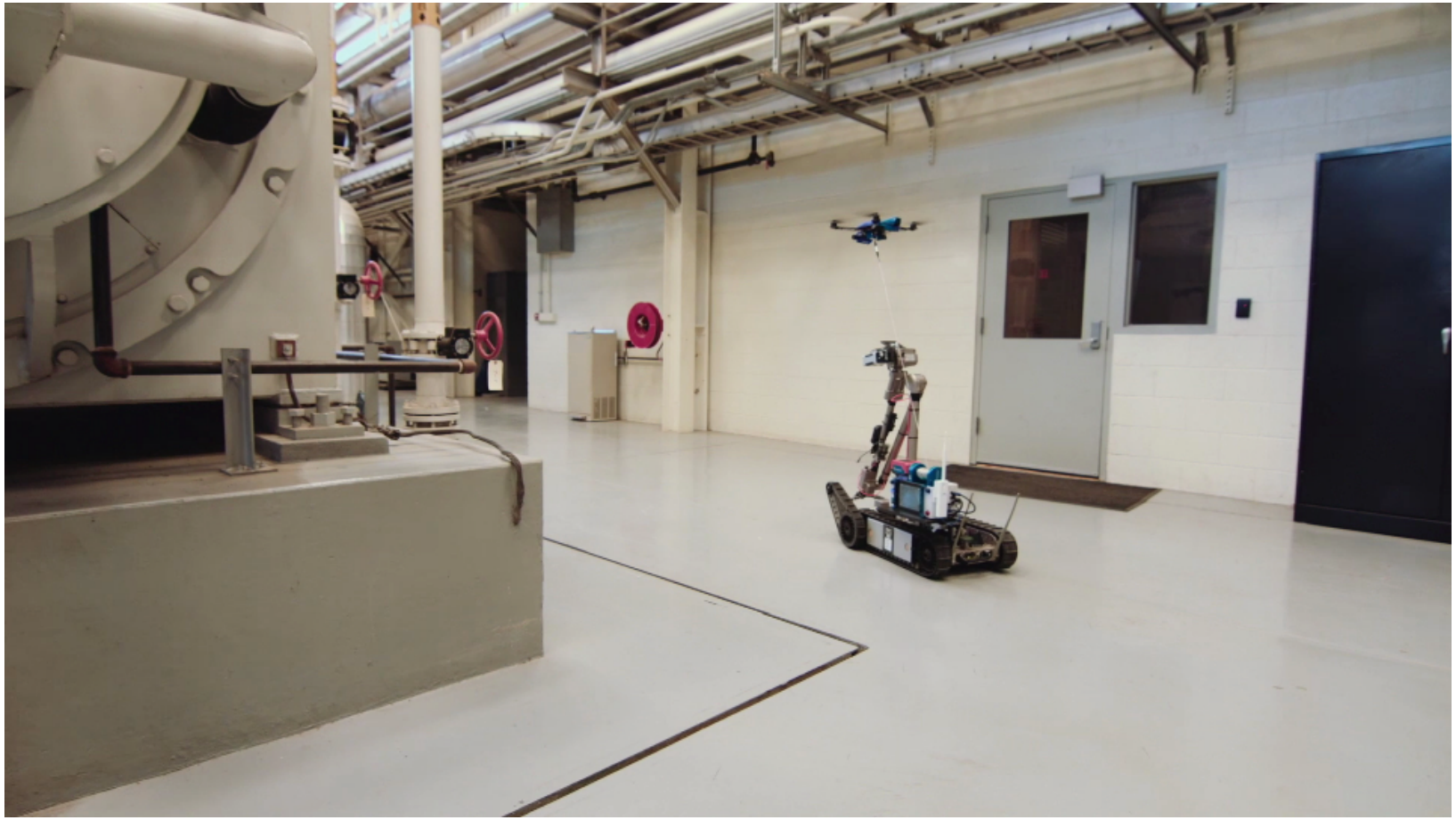
If Don't Use Second Robot…

Fukushima Decommissioning: Warrior robot attempted to cross barrier without visual assistant robot (courtesy of Prof. Hajime Asama)

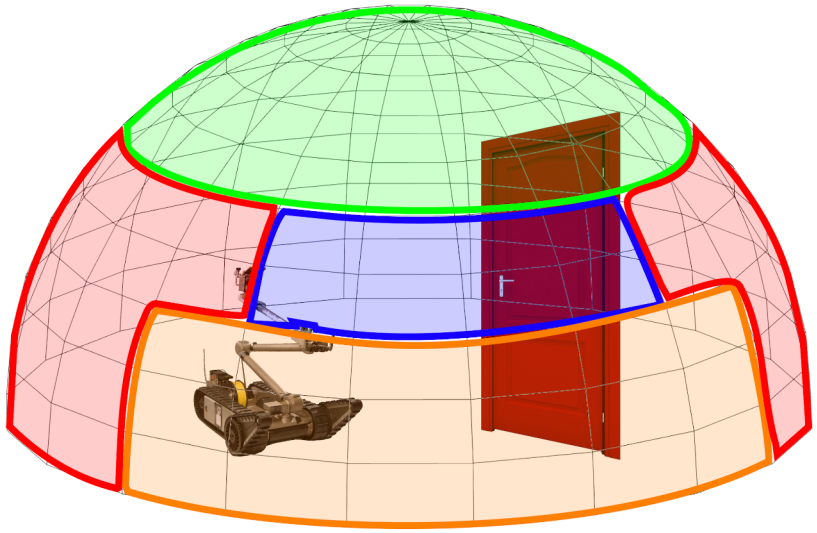
But it doesn't have to be another UGV…

tethered is more acceptable for process safety

hemispherical coverage



1. What is the perceptual optimal viewpoint?



People pick the viewpoint they like but it doesn't necessarily lead to optimal performance *(McKee, Brooks & Schenker 2003)*

Seems to vary by task

Close enough seems good enough, just getting near the optimum may be sufficient

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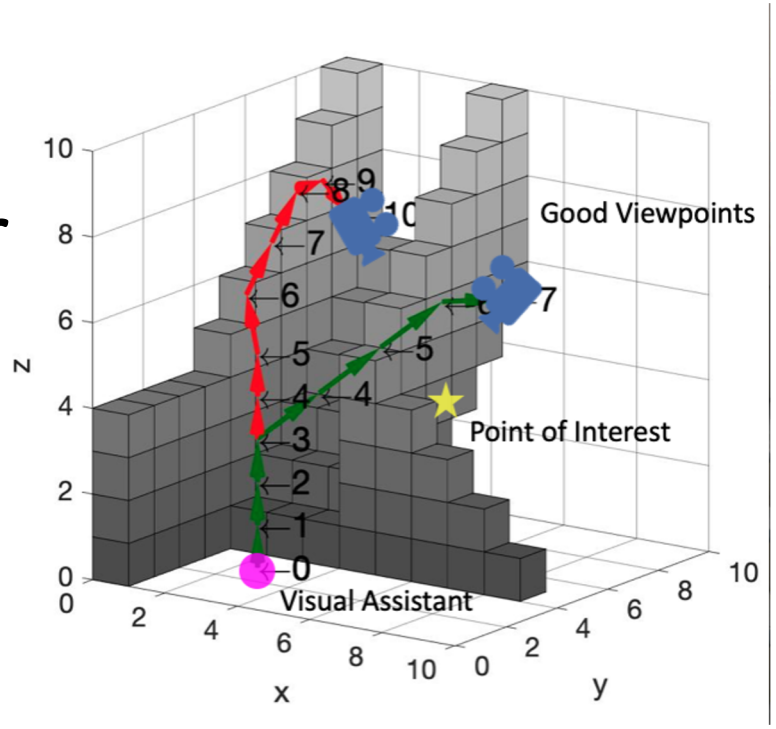
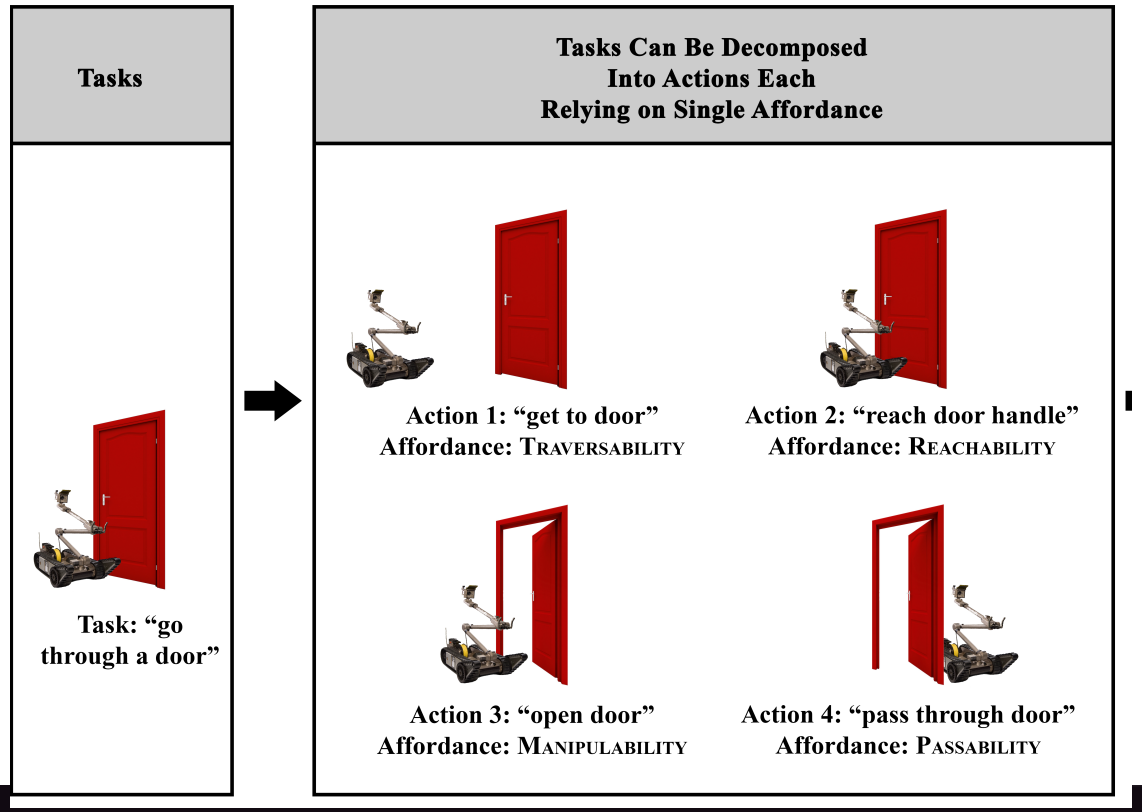
2. What viewpoint is the safest to reach or to be at?



3. How to plan paths with tethers and contact points?

Viewpoints for a Task: Gibsonian Affordances

(after T. Murphy 2013)



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Hypothesis: Viewpoints Can Be Grouped into Ranked Manifolds of Equivalent Performance

Tasks

Task: "go through a door"

Tasks Can Be Decomposed Into Actions Each Relying on Single Affordance

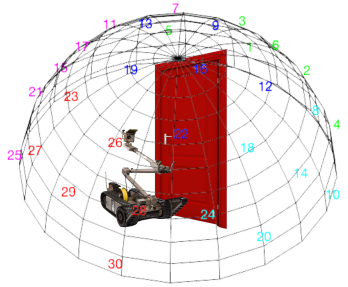
Action 1: "get to door"
Affordance: TRAVERSABILITY

Action 2: "reach door handle"
Affordance: REACHABILITY

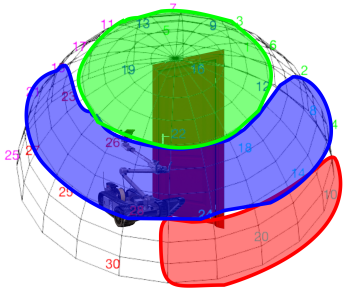
Action 3: "open door"
Affordance: MANIPULABILITY

Action 4: "pass through door"
Affordance: PASSABILITY

Viewpoints Around Actions Can Be Represented by Hemisphere And Quantified For Each Affordance Based on Psychophysical Behavior



Viewpoints With Similar Value Can Be Clustered Into Ranked Manifolds



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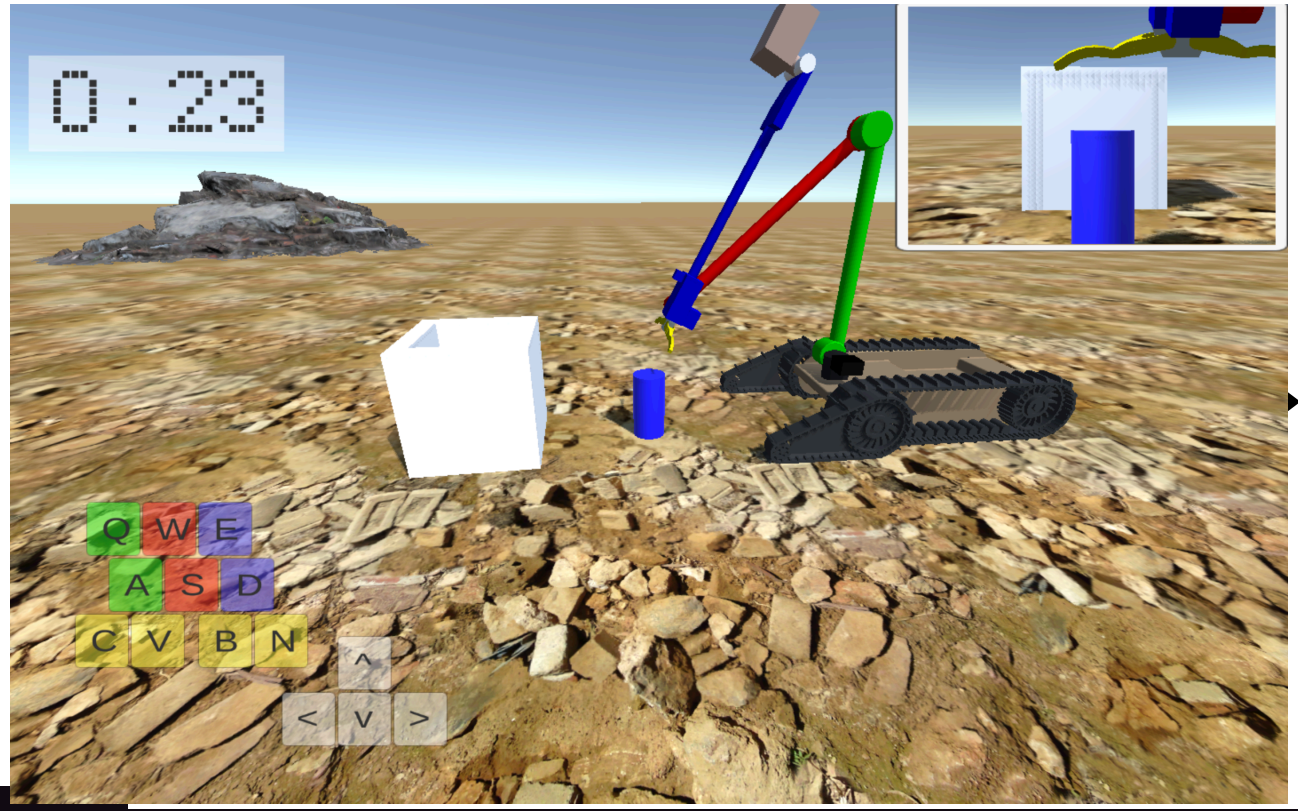
Quantify Via Learning from Simulation Study With 30 Bomb Squad Robot Operators



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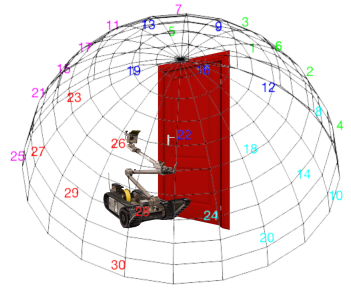

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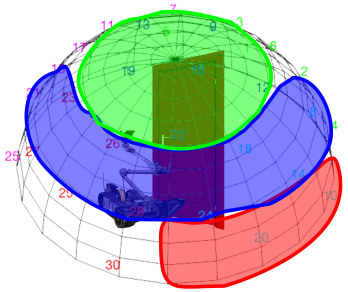

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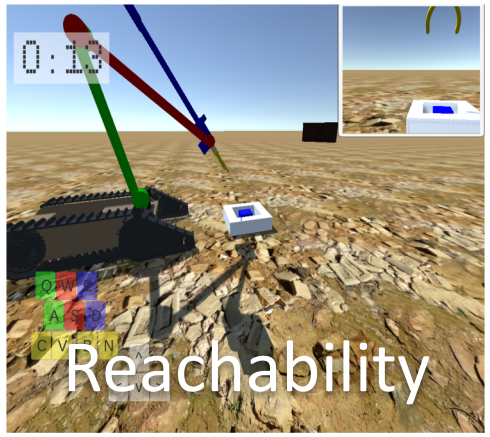
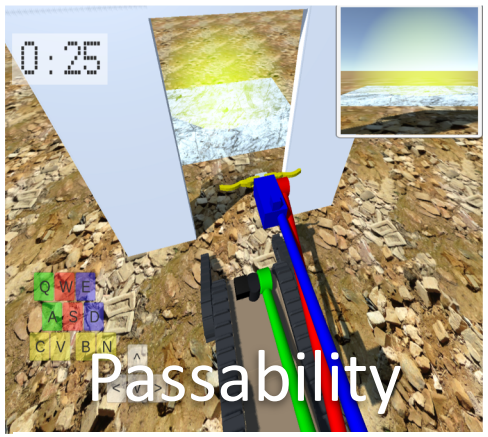
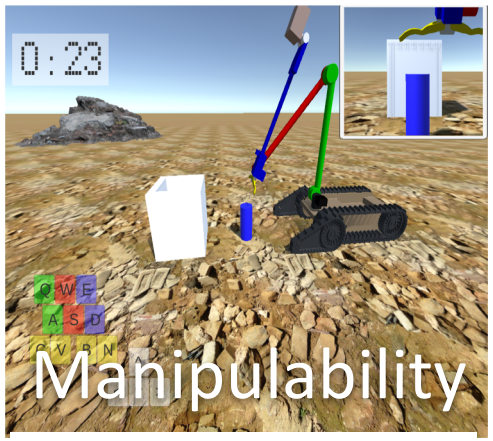
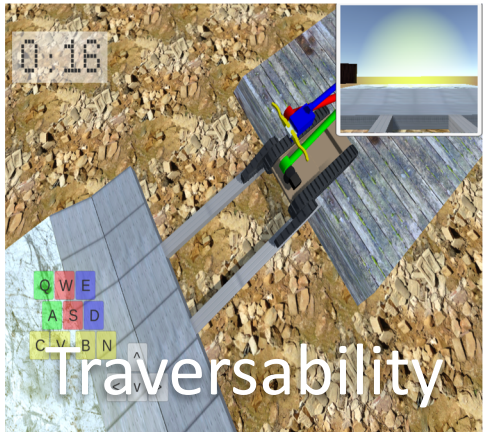
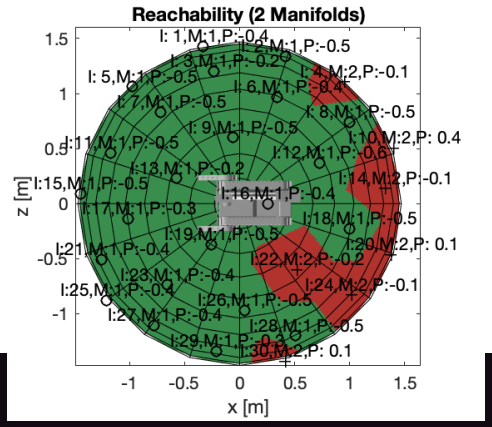
Yes, Each Affordance Does Have Distinctive # and Shape of Manifolds!

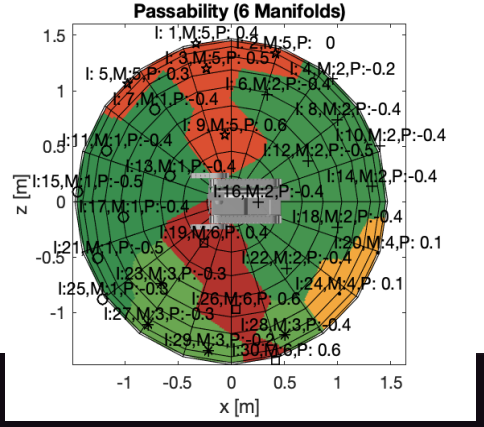


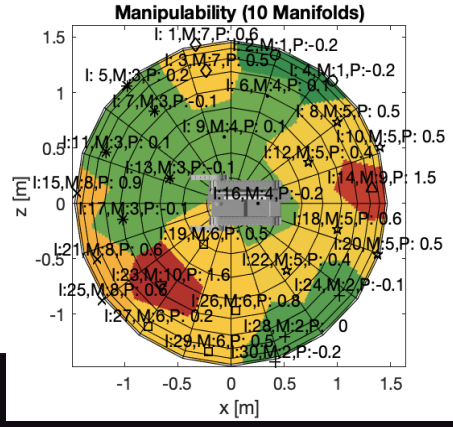


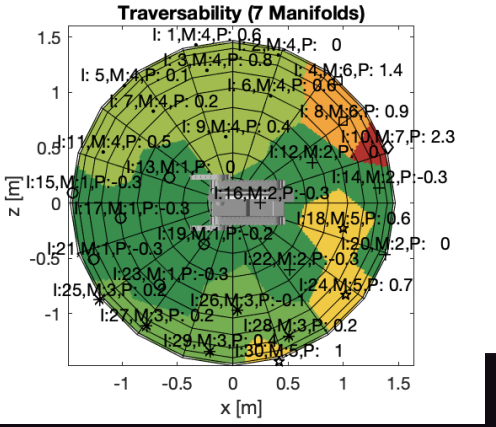












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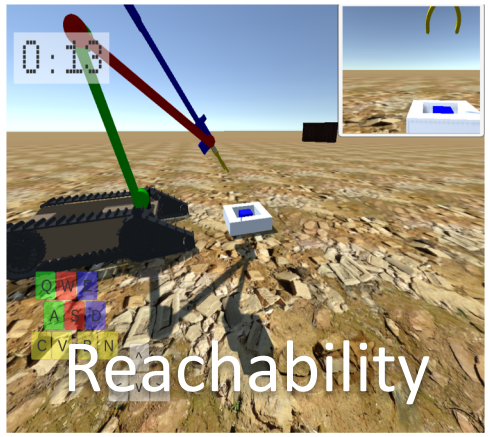
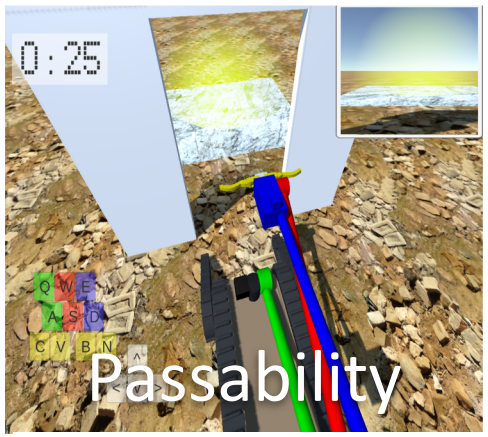
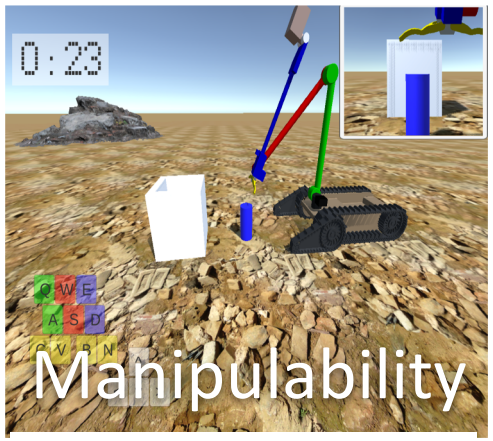
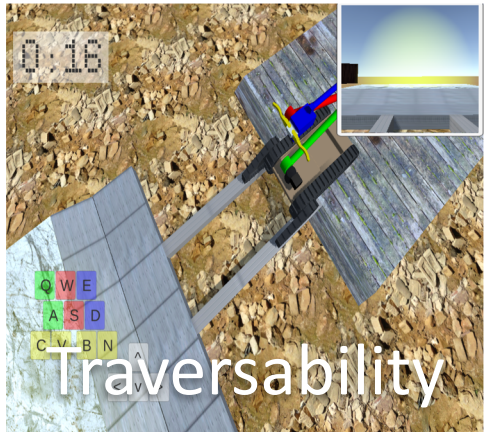
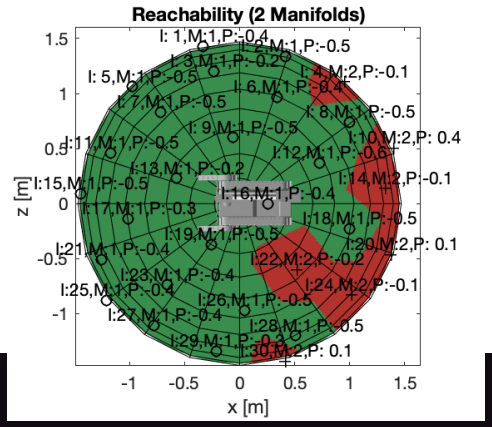
Decreases time to perform a task 18%-52%
Eliminates or reduces errors by 87%

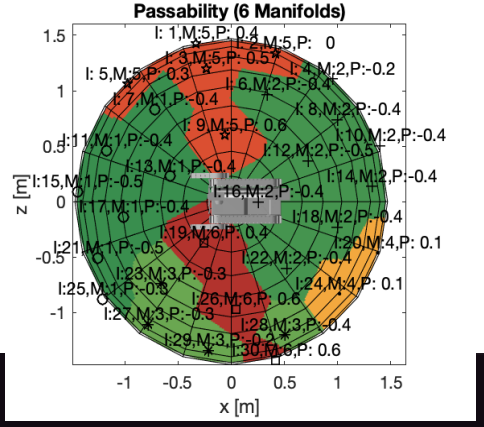


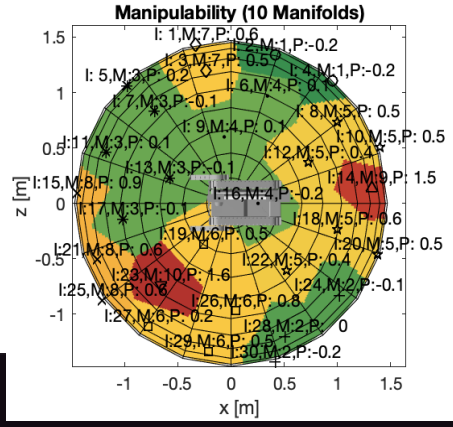


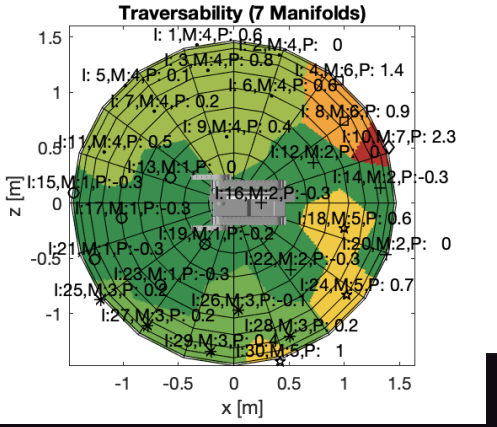












In Conclusion

- Viewpoint really does matter and it does vary with affordance
- *Can project risk and balance with viewpoint*
- *Can plan for tethers*
- More work
  - Visual stability when tracking movement or over a sequence of affordances
  - Autonomous visual assistant following and communicating with primary

"Robot Risk-Awareness by Formal Risk Reasoning and Planning", X. Xiao, J. Dufek, R. Murphy, RA-Letters and ICRA 2020

"Autonomous Visual Assistance for Robot Operations Using a Tethered UAV, X. Xiao, J. Dufek, R. Murphy, ArXiv 2019

"Explicit Motion Risk Representation," X. Xiao, J. Dufek, R. Murphy, SSRR 2019

"Benchmarking Tether-Based UAV Motion Primitives," X. Xiao, J. Dufek, R. Murphy, SSRR 2019

"Indoor UA Localization Using a Tether," Xiao, X., Y. Fan, J. Dufek, and R. Murphy, SSRR 2018

"Motion Planning for a Uav with a Straight or Kinked Tether." Xiao, X., J. Dufek, M. Suhail, and R. Murphy, SSRR 2018

Visual Servoing for Teleoperation Using a Tethered UAV, X. Xiao, J. Dufek, R. Murphy, SSRR 2017

Also Breakthrough in Projection of Risk

Planning with Tethers with 2 or More Contact Points