World-in-the-Loop Simulation for Autonomous Systems Validation

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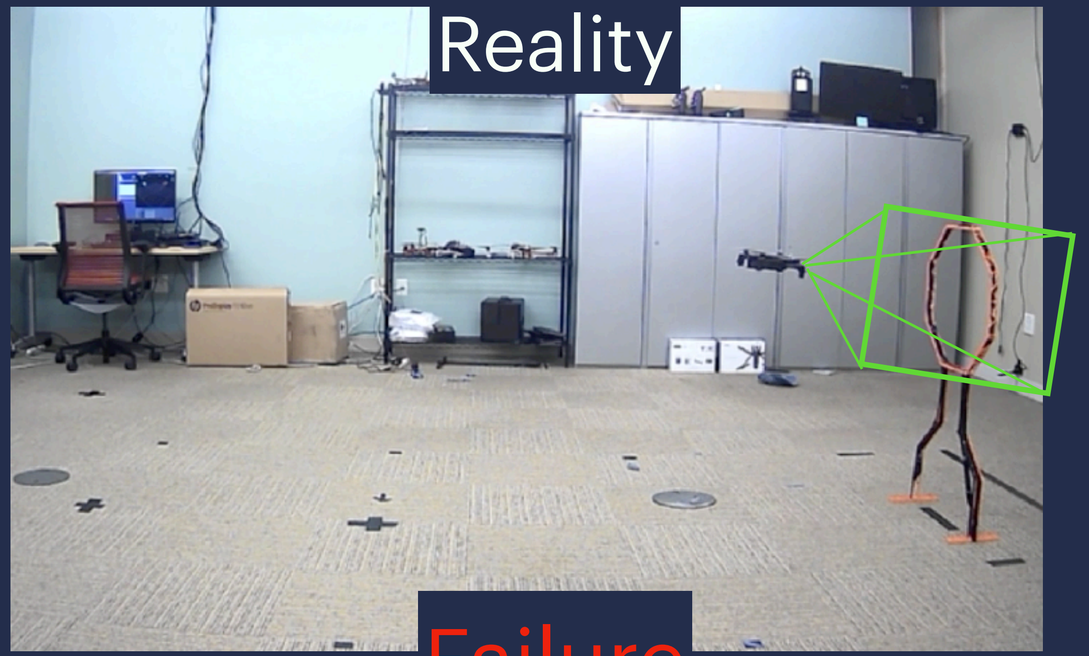
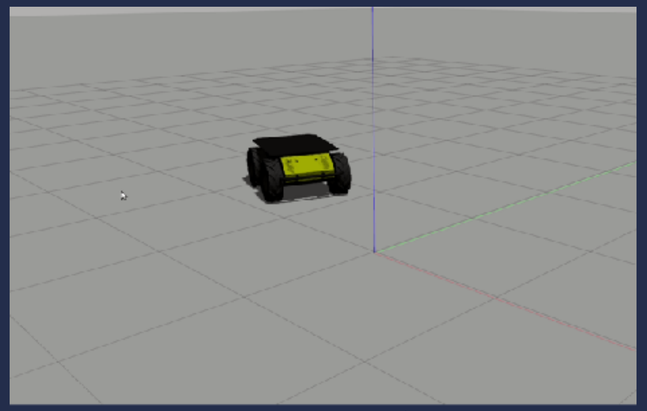
Problem



Related Work



Software in the Loop Simulation

?

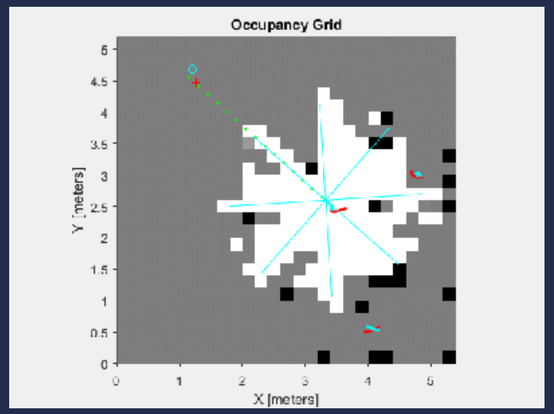
Simulation

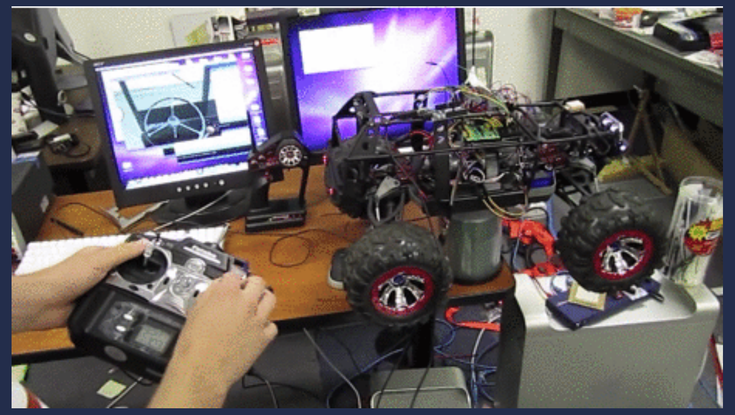
Reality

Low-Fidelity Simulation

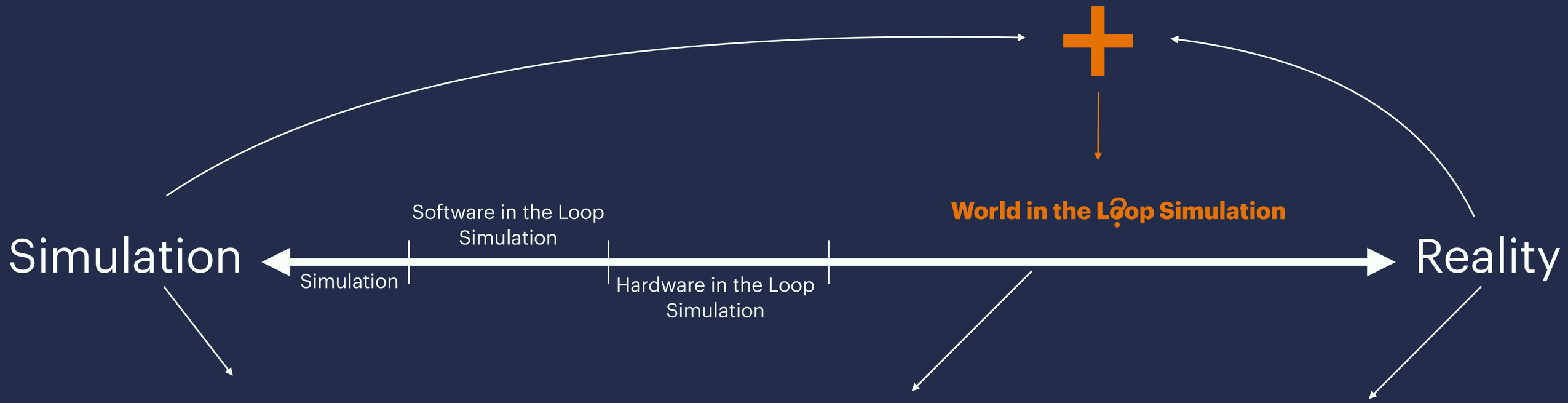
Hardware in the Loop Simulation

Simulation Reality Gap



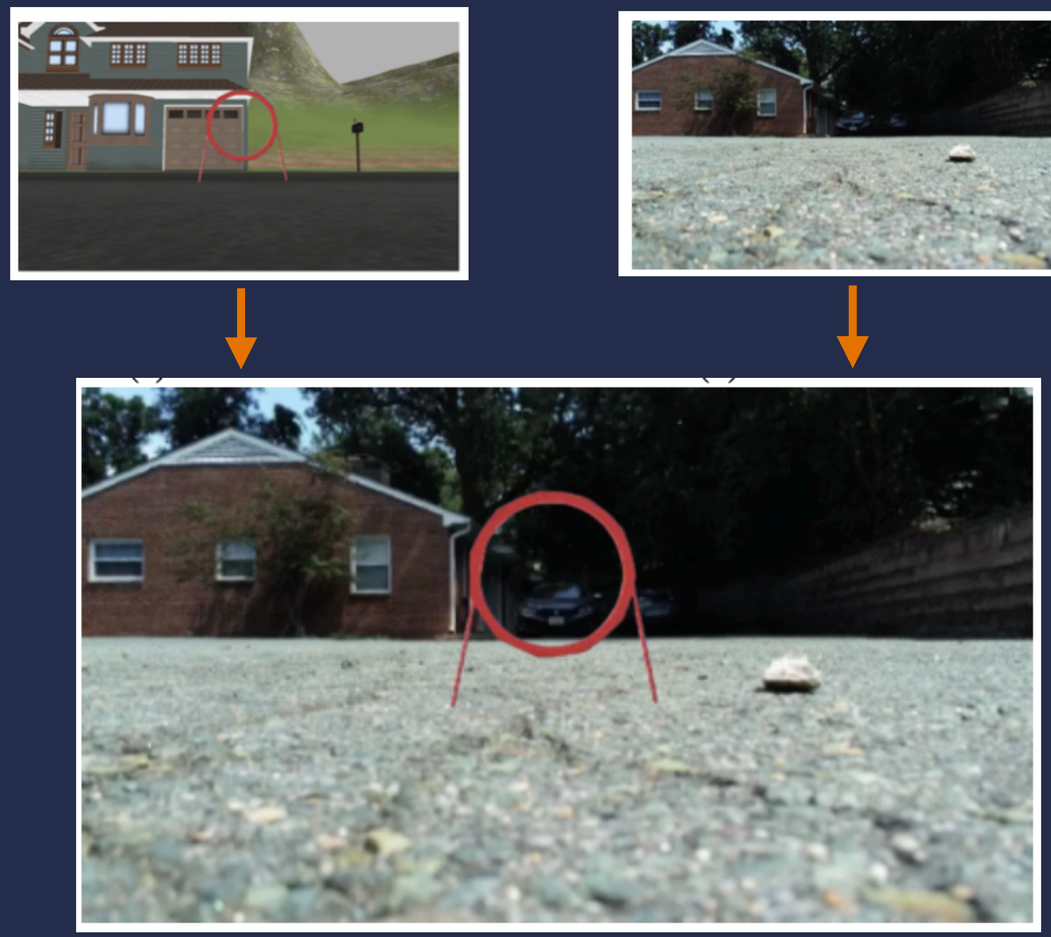


World in the Loop Simulation

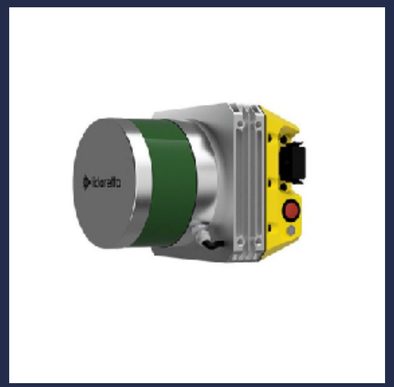


Challenges

Sensor and Actuation Synchronization



Diversity of Sensors

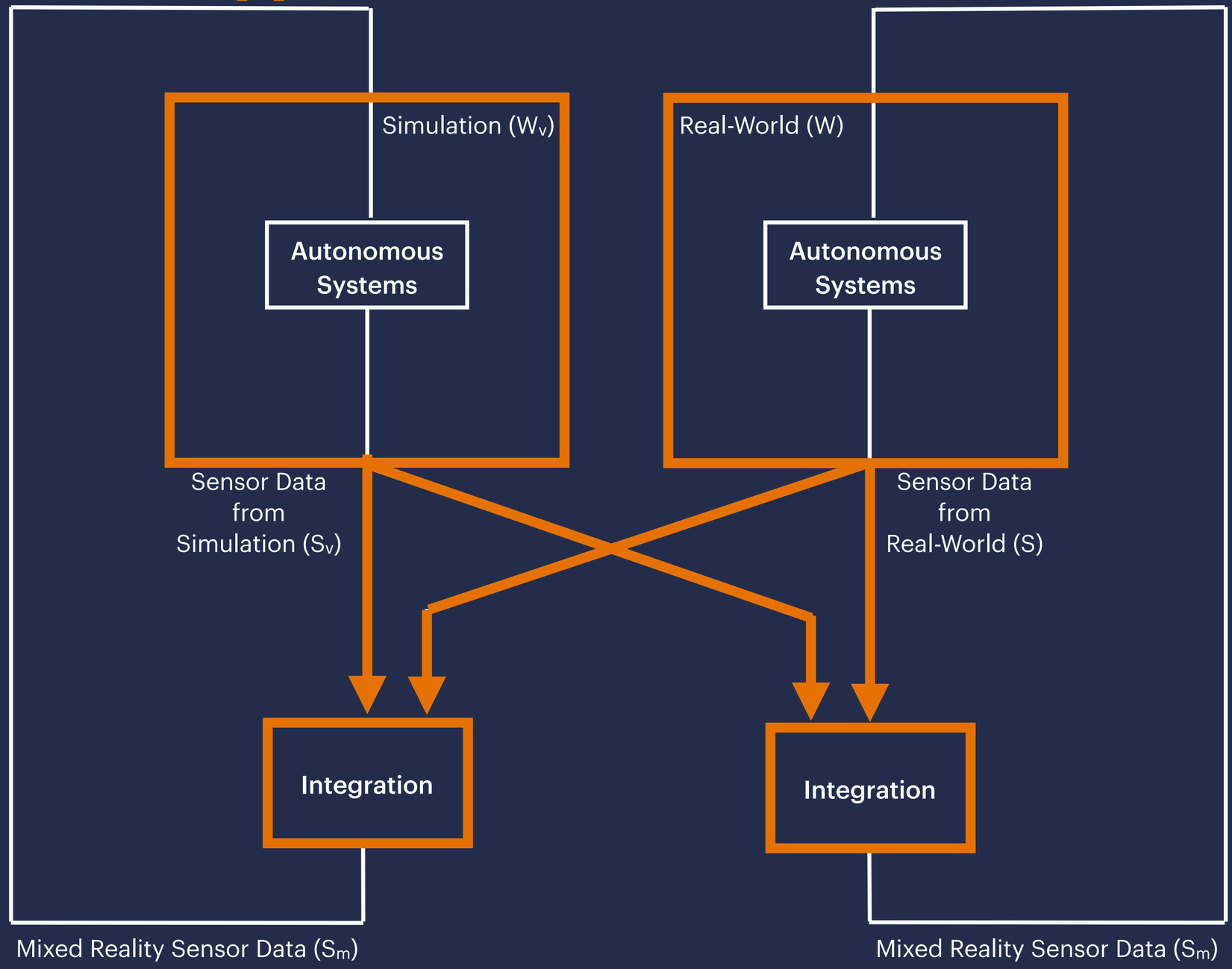


- IMU’s
- GPS
- Pressure
- Temperature
- Compass
- ...

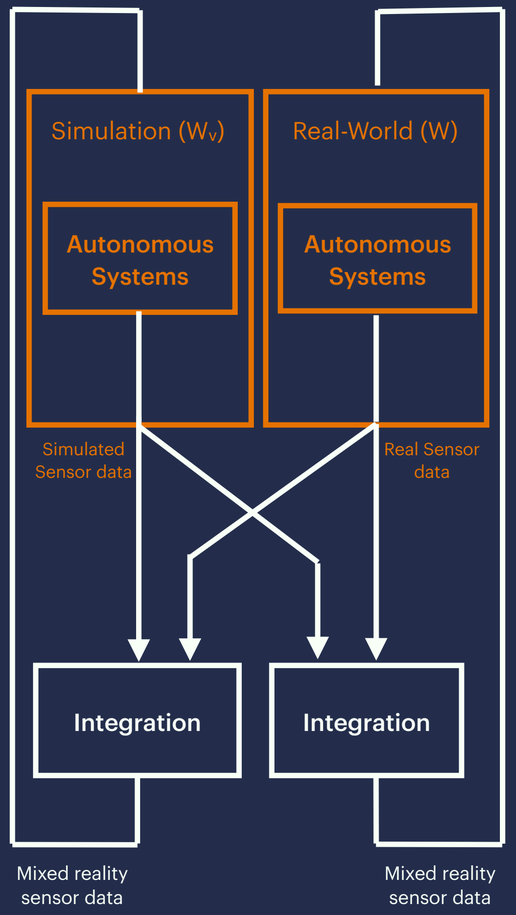
Approach

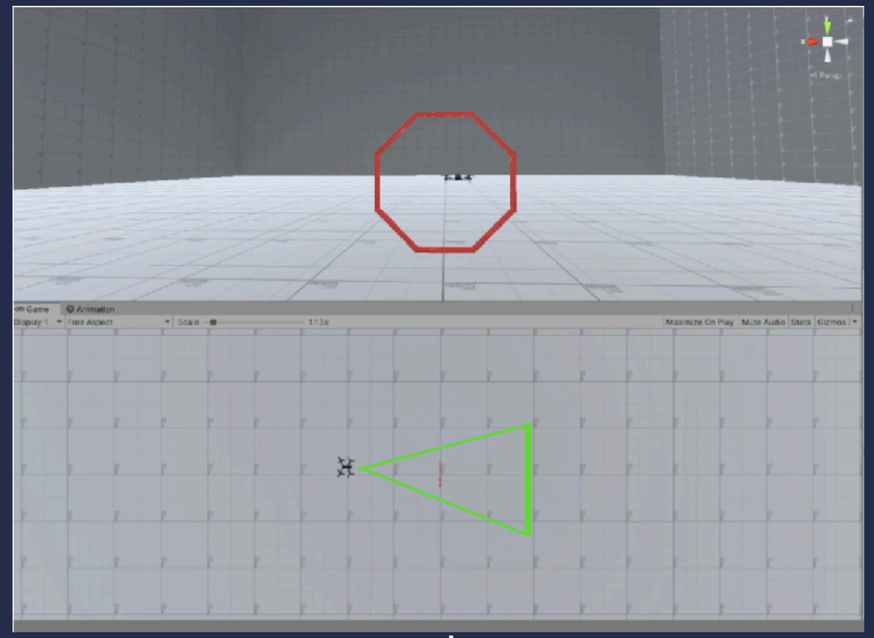
Major components

- Parallel execution
- Pipeline for collecting sensor data
- Integration mechanisms

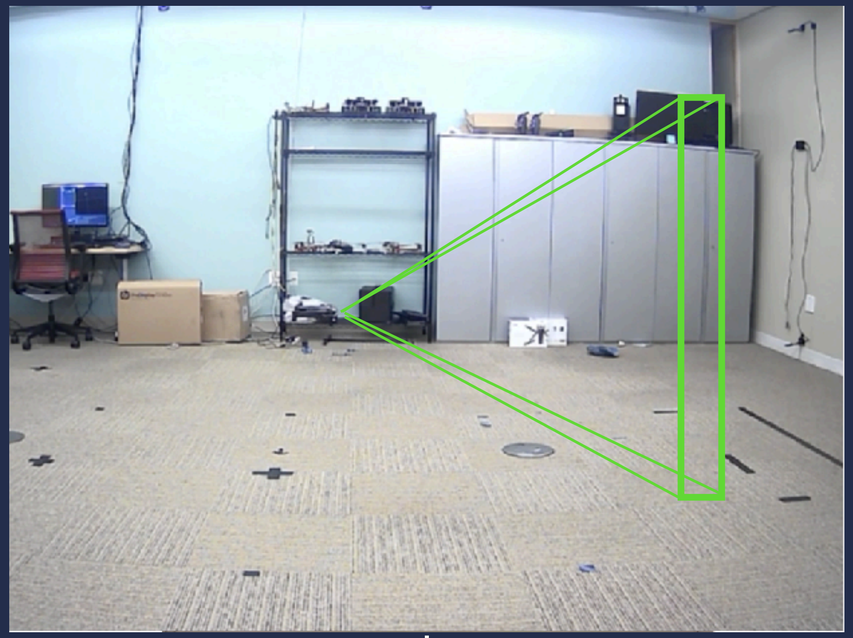


Approach





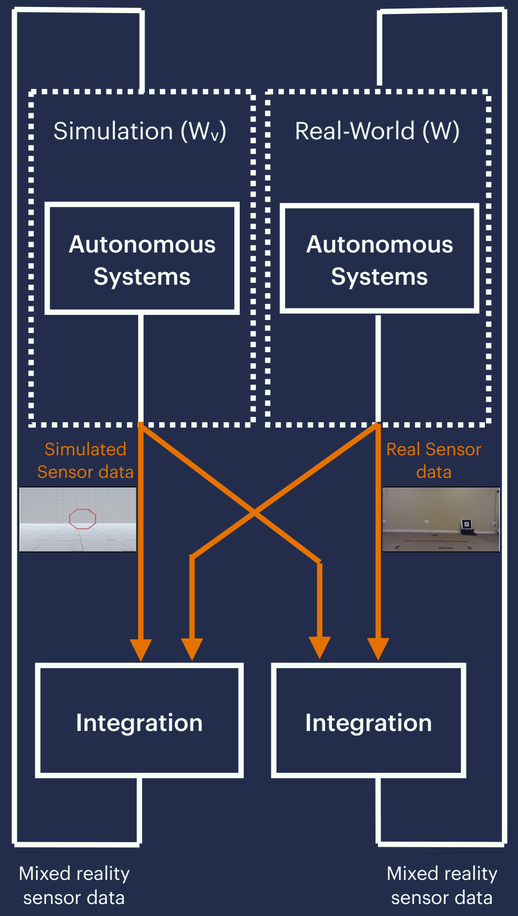
S_v



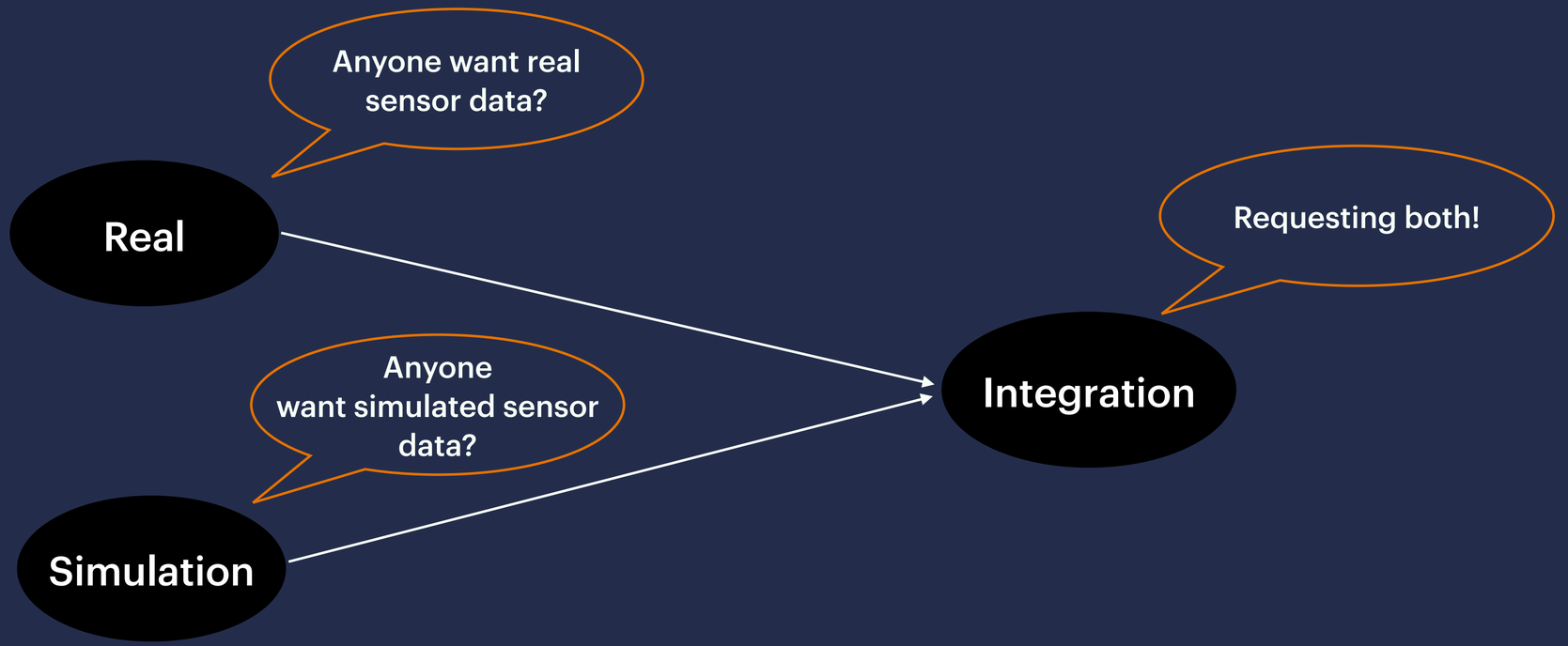
S

~~Sensor Synchronization~~

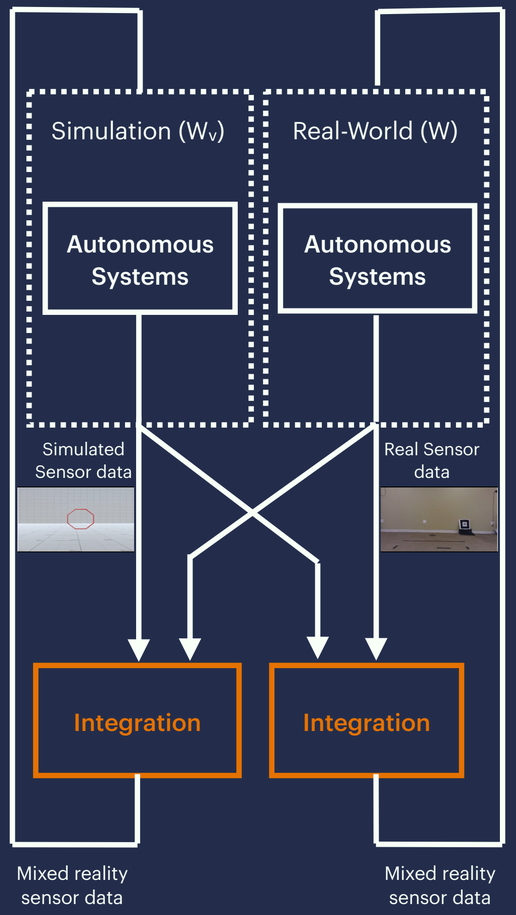
Approach



ROS

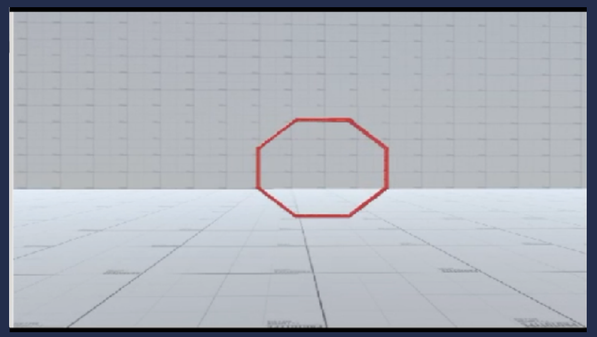


Approach



1) Transform

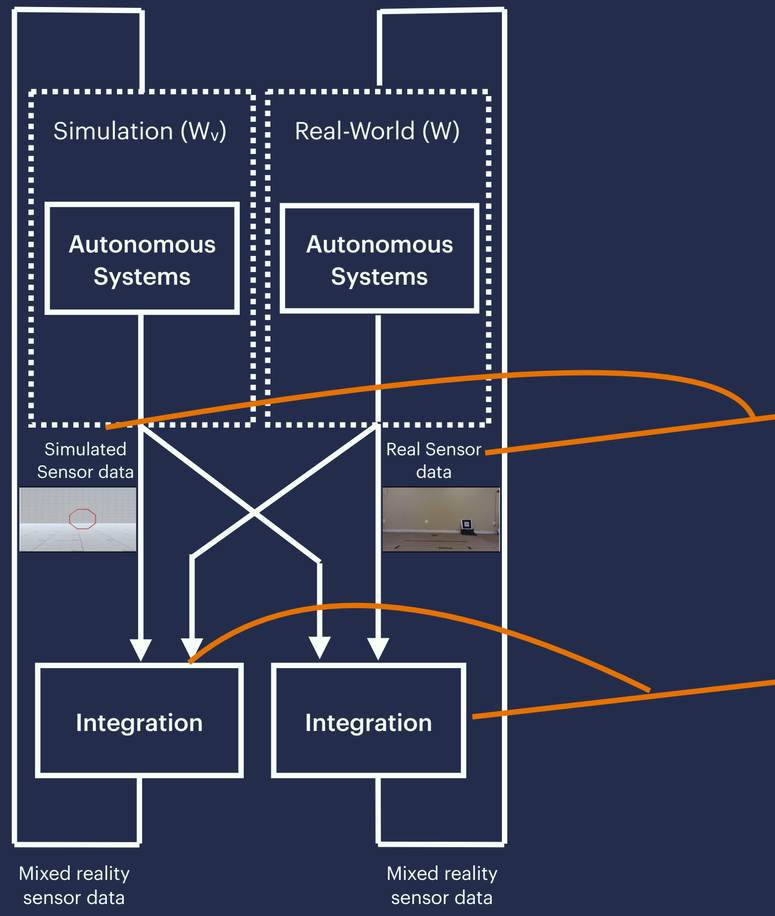
Simulation (W_v)



Real-World (W)

~~Diversity of Sensors~~

Implementation



Listing 1: An example recipe file

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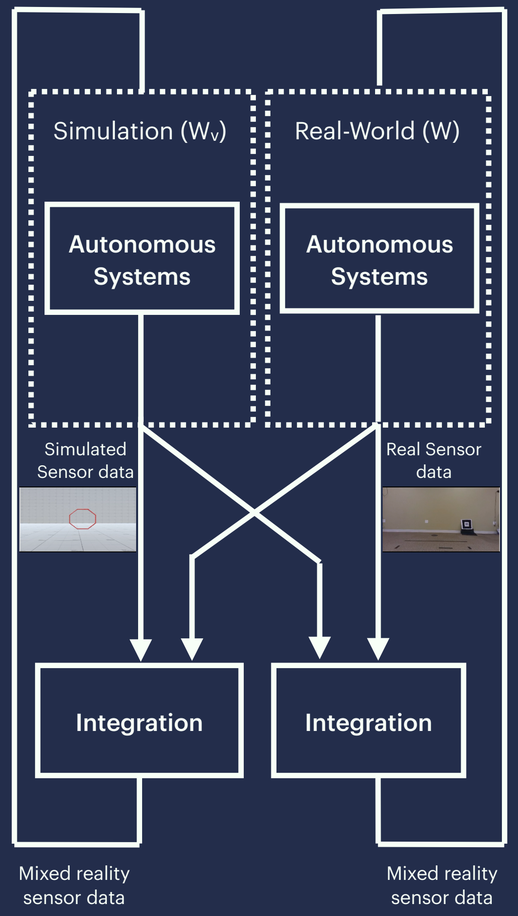
<recipe file >
    <AS sensors>
        <Camera id="camera1"/>
        <Camera id="camera2"/>
        <Lidar id="lidar1"/>
        < .../ >
    </AS sensors>
    <combine id="camera1">
        <transform> camera_transform.py </transform>
        < filter > color_isolation .py </ filter >
        <merge> prioritize_overlay .py </merge>
    </combine>
    ...
    <combine id="lidar1">
        ...
    </combine>
</recipe file >
```

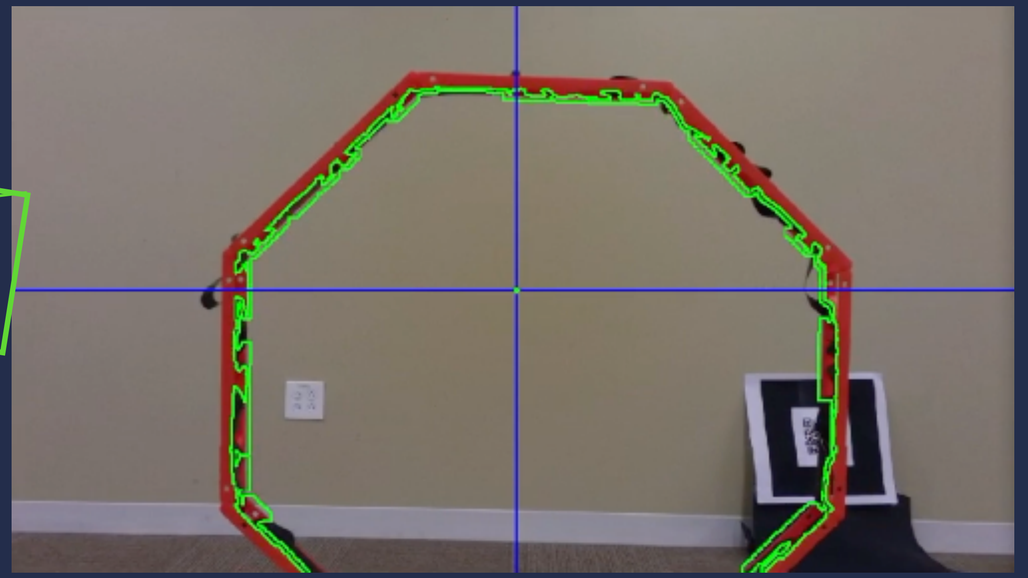
https://github.com/hildebrandt-carl/MixedRealityTesting

Implementation - Limitations



Simulators required to have read and write access

Current implementation only focus's on Cameras

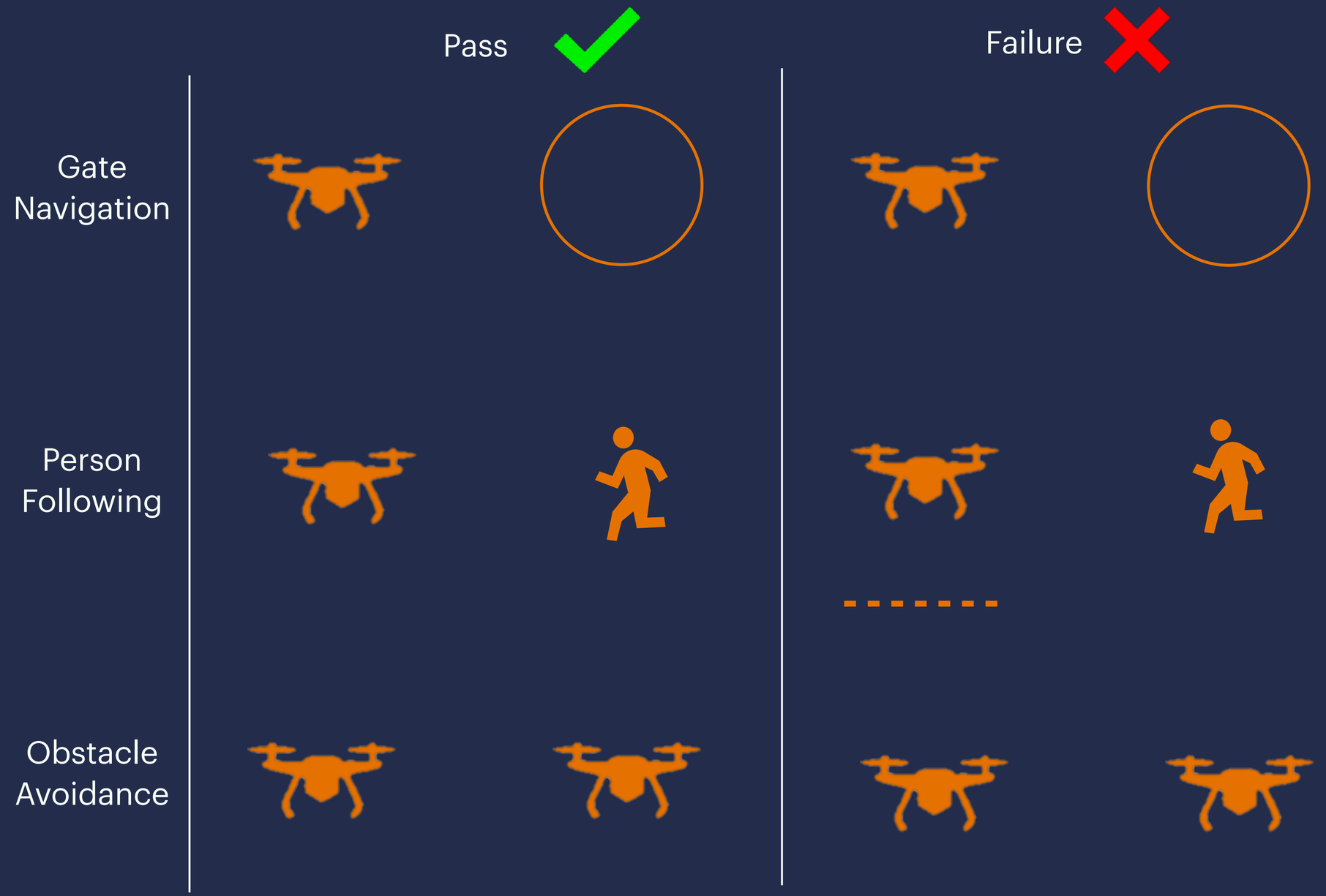


https://github.com/hildebrandt-carl/MixedRealityTesting

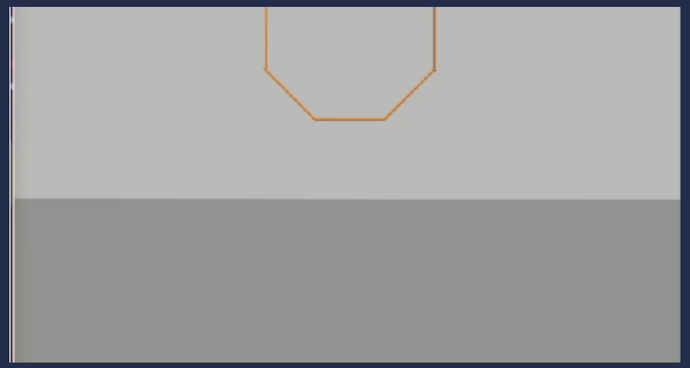
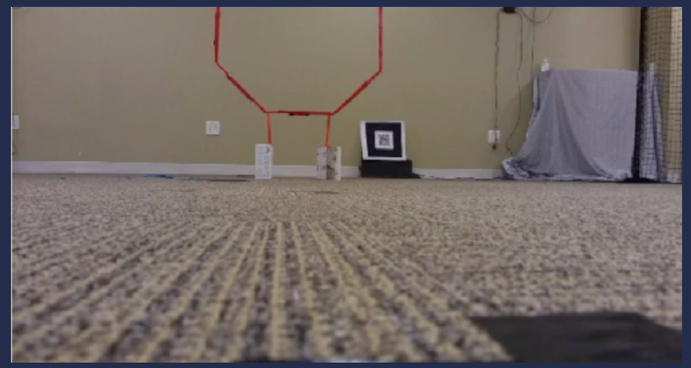
Study - Question

The aim was to assess the potential of WIL to reduce the simulation-reality gap and uncover the implications such as failure detection before real-world deployment

Study - Setup


Pass
Failure
Gate Navigation
Person Following
Obstacle Avoidance

Study - Setup

	Simulation	Reality
Gate Navigation		
Person Following		
Drone Avoidance		

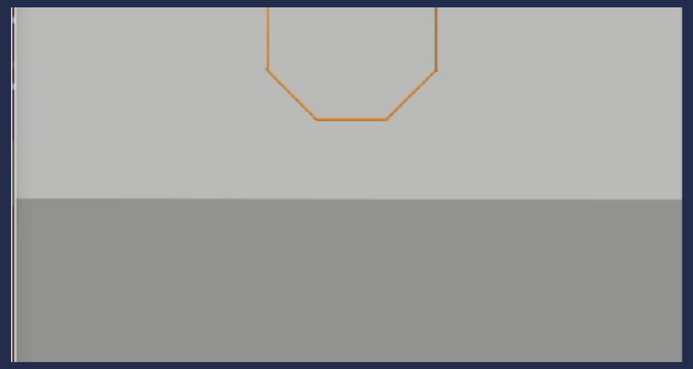
Study - Setup

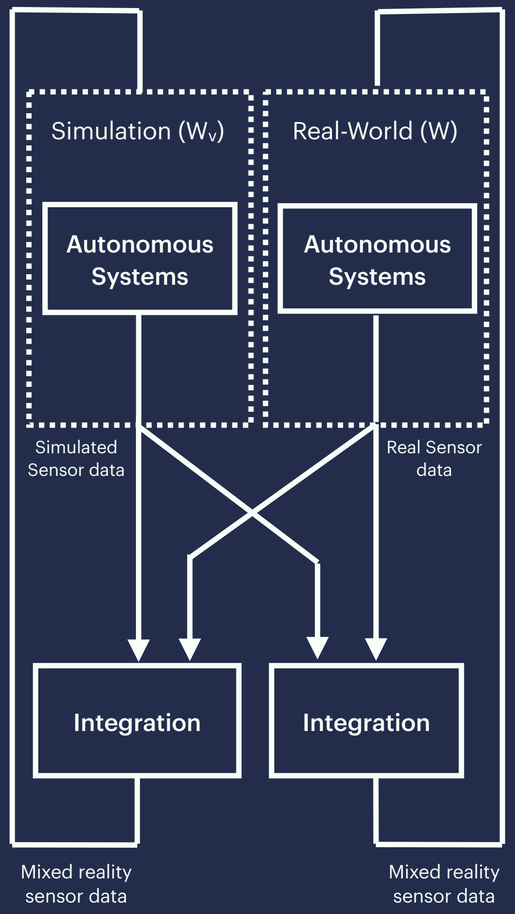
Simulation

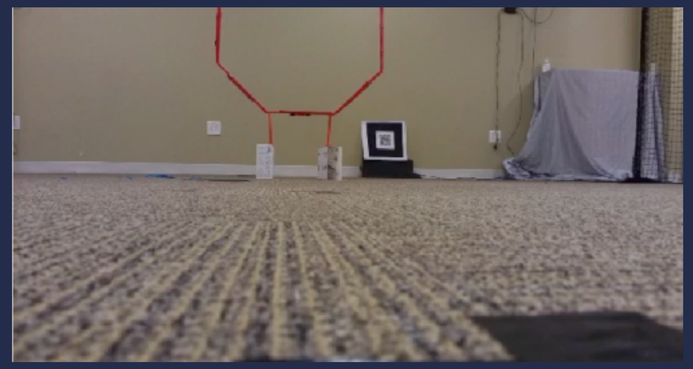
WIL

Reality

Gate Navigation

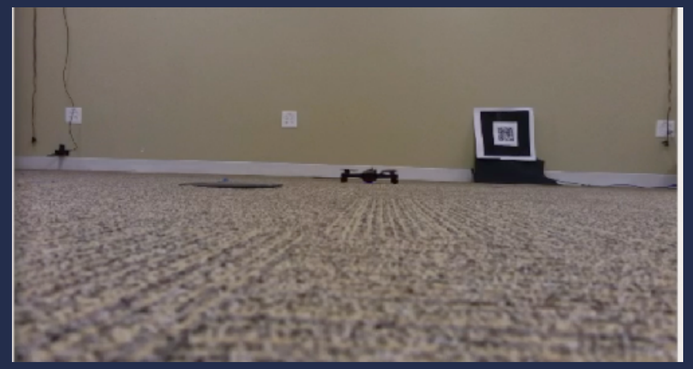




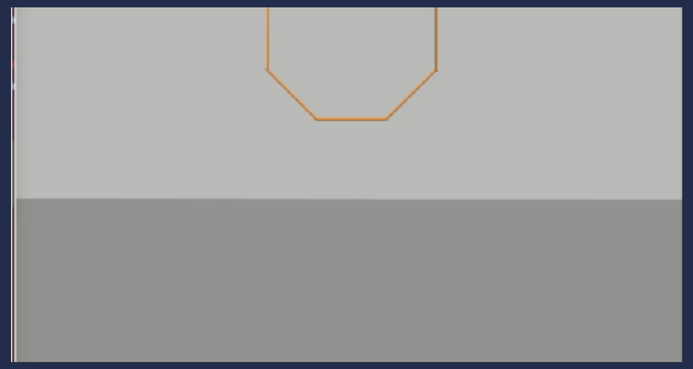
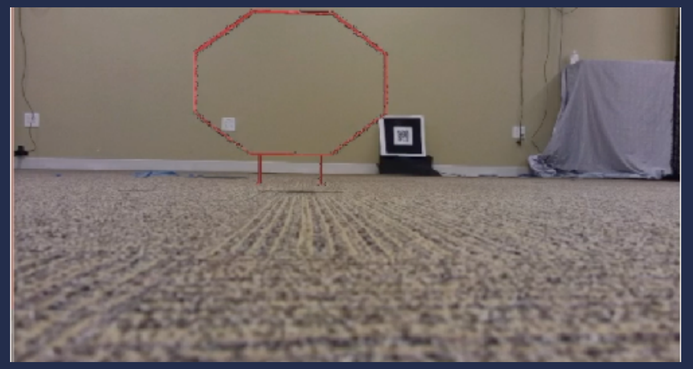
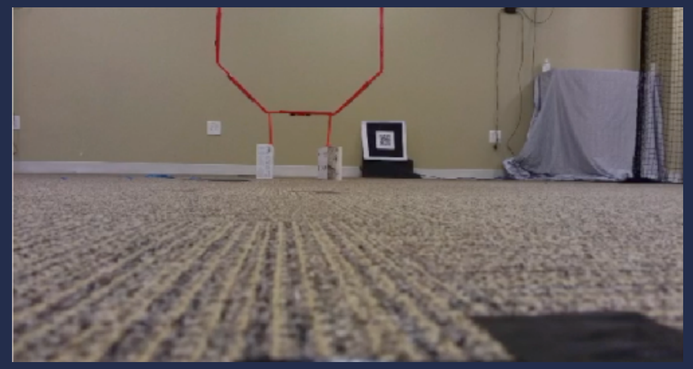
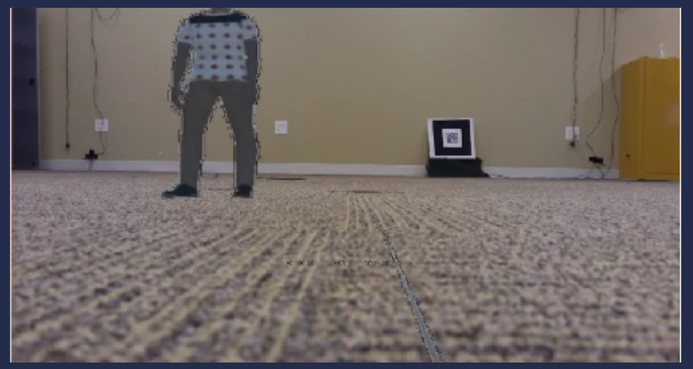
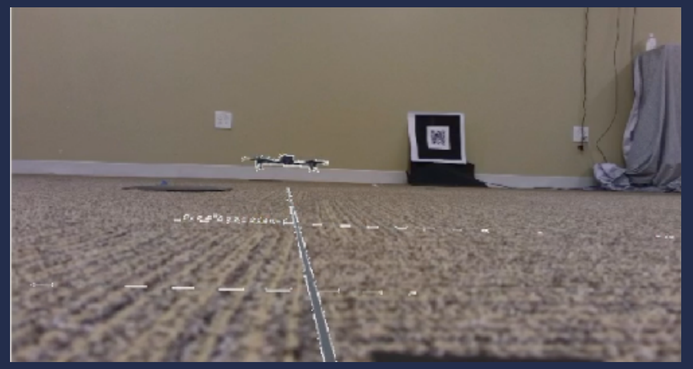
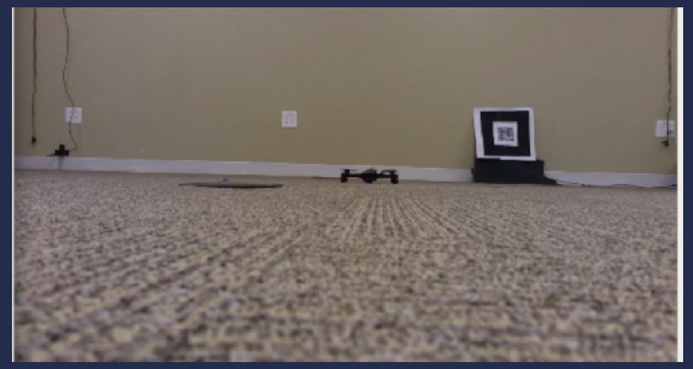


Person Following

Drone Avoidance



Study - Setup

	Simulation	WIL	Reality
Gate Navigation			
Person Following			
Drone Avoidance			

Results

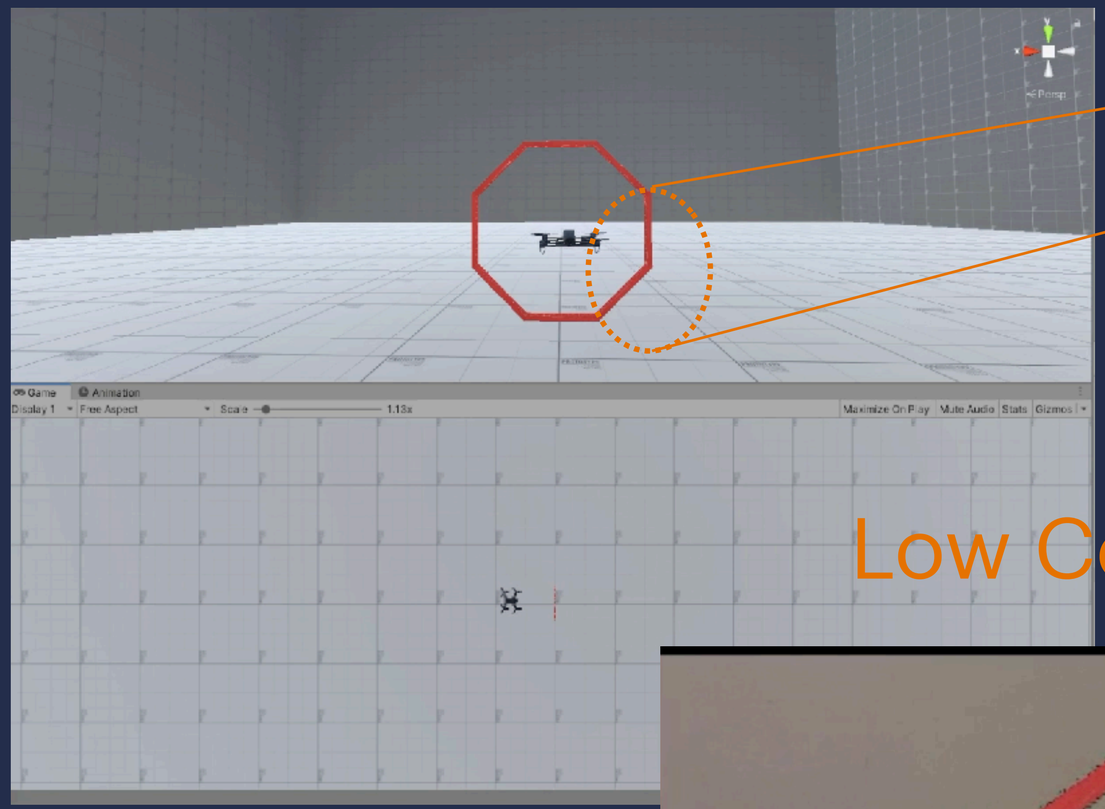
Question: Can we reduce the simulation reality gap?

Scenario	Test Case	Simulation	WIL	Reality
Gate Navigation	Large			
	Small			
Person Following	Walking			
	Running			
Drone Avoidance	Slow			
	Fast			Too Costly

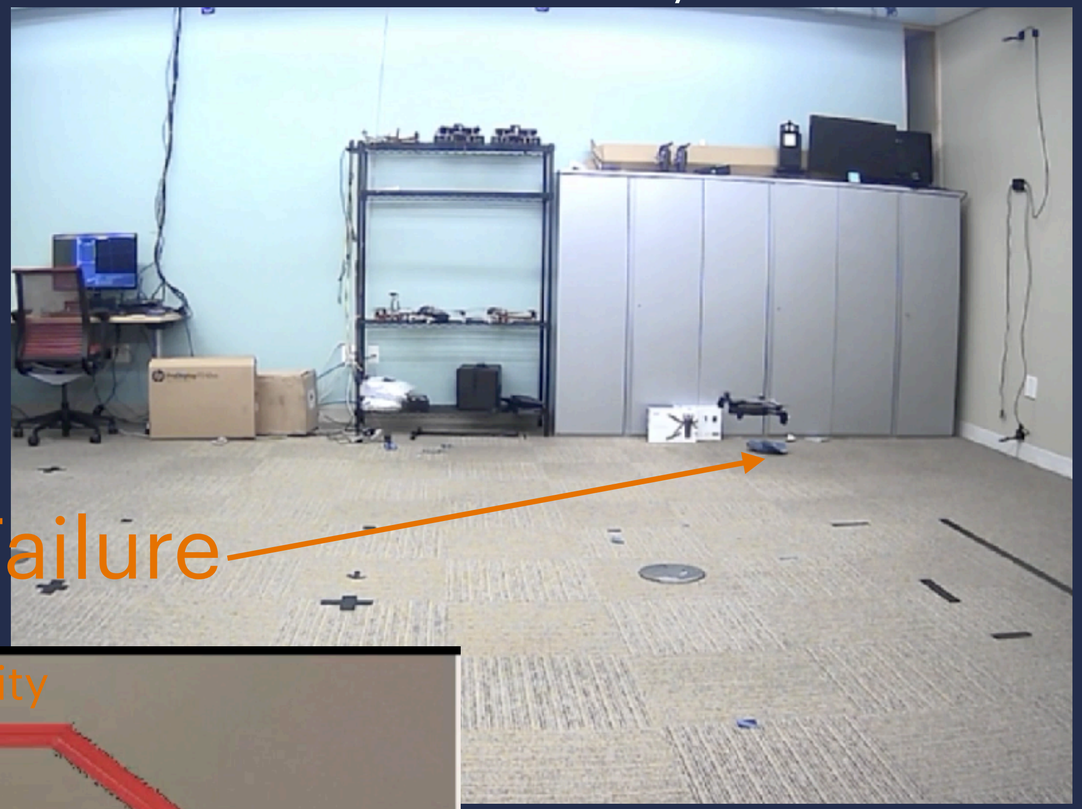
Cost of Failure

Simulation

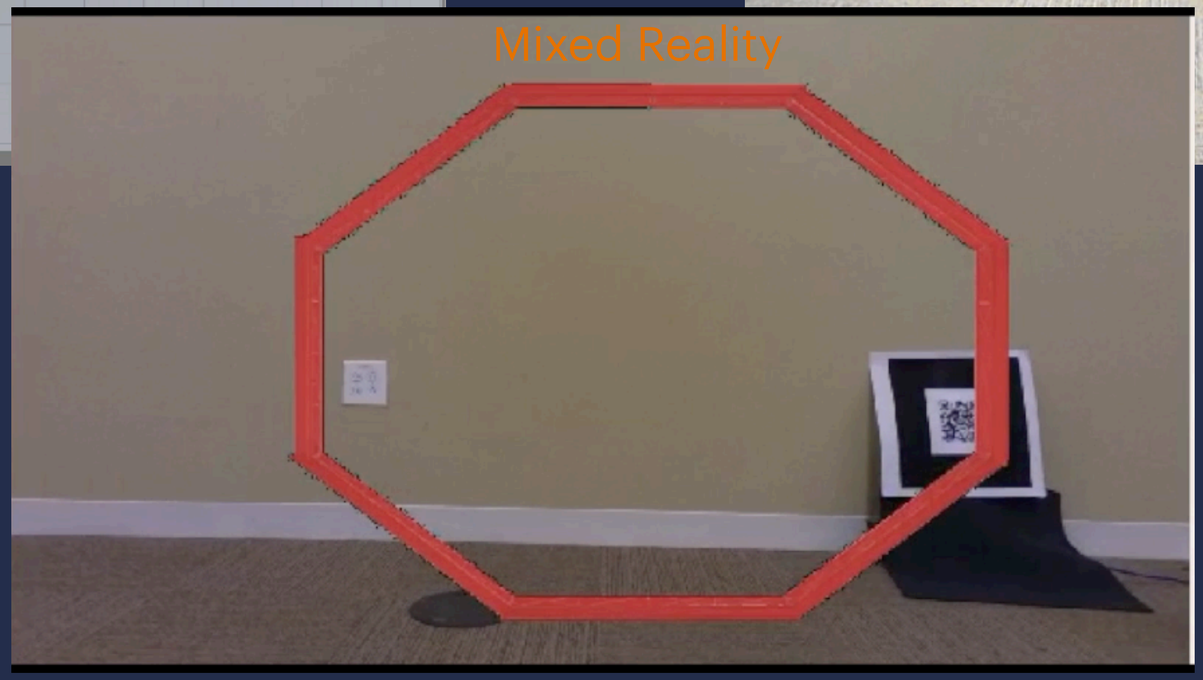
Reality



Failure



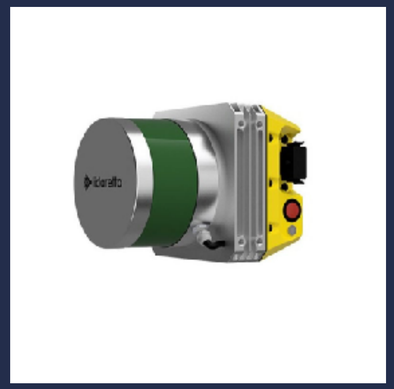
Low Cost of Failure



Cost of Failure

Future Work

More Sensor Types



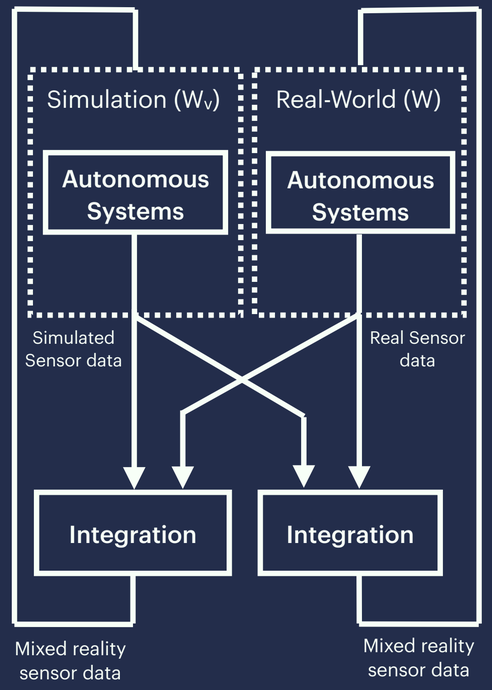
Simulating More of the World

More Simulators

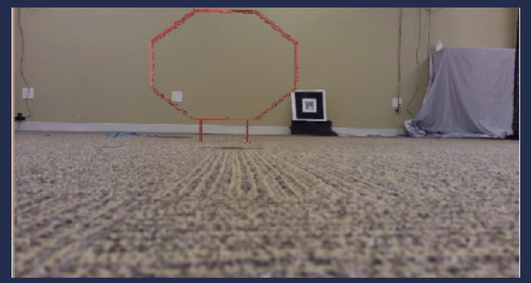
Conclusion

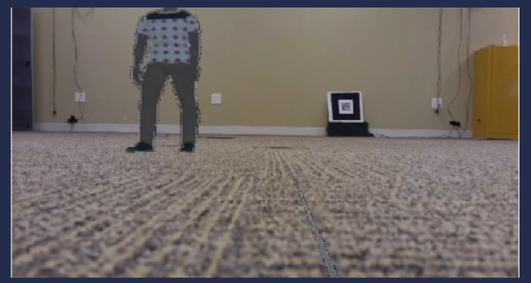
World-in-the-Loop Simulation for Autonomous Systems Validation

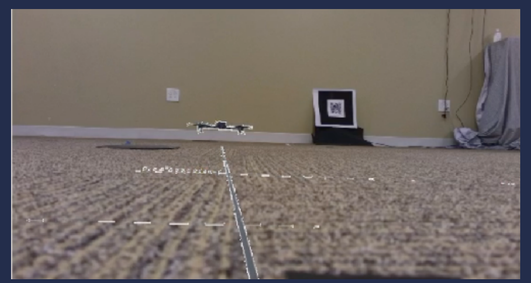
A novel approach to narrow the simulation-reality gap by integrating sensing data from simulation and the real world.



Scenario	Test Case	Simulation	WIL	Reality
Gate Navigation	Large	P 5 0 F	P 5 0 F	P 5 0 F
	Small	P 5 0 F	P 1 4 F	P 1 4 F
Person Following	Walking	P 5 0 F	P 4 1 F	P 0 5 F
	Running	P 5 0 F	P 4 1 F	P 1 4 F
Obstacle Avoidance	Slow	P 5 0 F	P 5 0 F	P 5 0 F
	Fast	P 5 0 F	P 2 3 F	Too Costly







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