Robotics Middleware for Healthcare

RoMi-H

18 August 2020

Centre for Healthcare Assistive & Robotics Technology
CHART

HOPE technik

IHiS
Because IT's in Healthcare

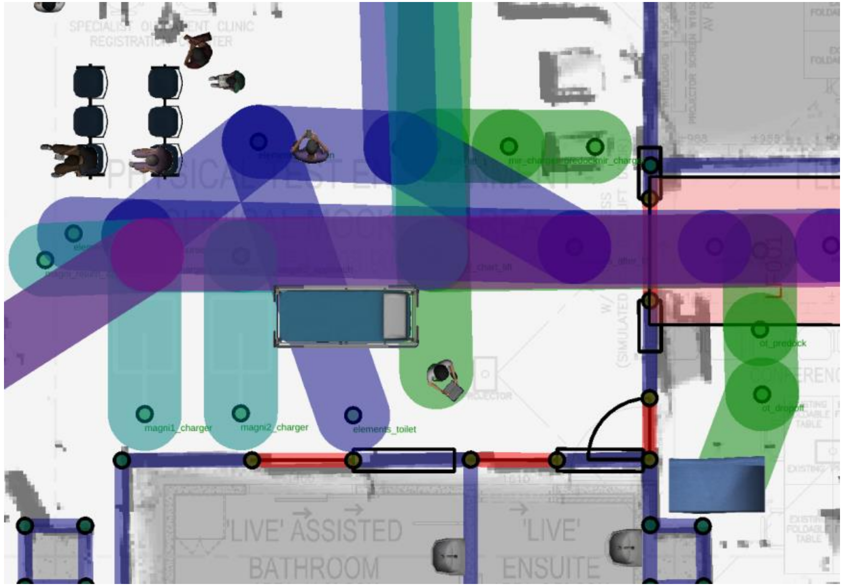
open robotics

Functionalities, Tools & Utilities

Traffic editor| simulation tools | RMF core| UI | BOK | RAMP

RoMi-H allows fleets to co-exist

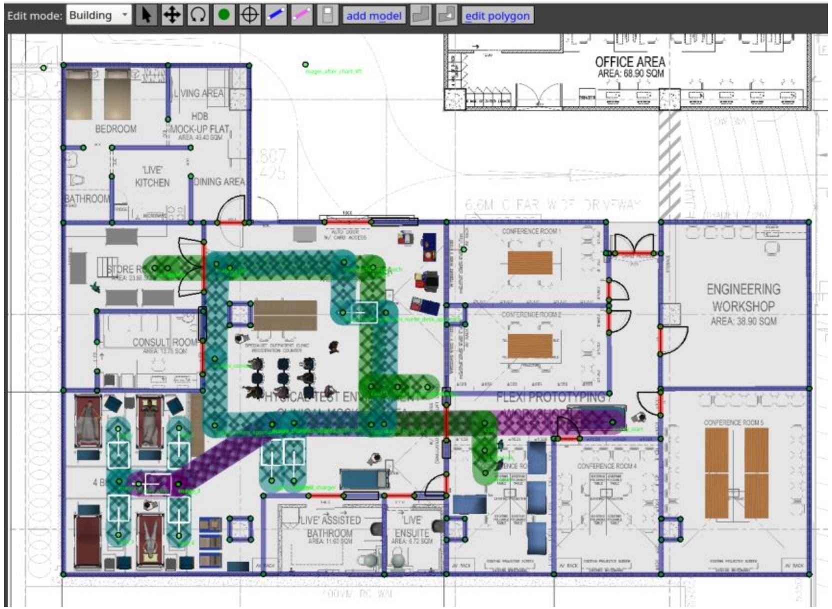
- fleets negotiate their traffic flow
  - share space by scheduling motions
  - all fleets see the combined schedule
- fleets share mechanical infrastructure
  - access to elevators/doors is provided by RoMi-H
- fleets implement behaviors for emergencies
  - code blue, fire alarm, etc.
  - typically "find a nearby parking spot"

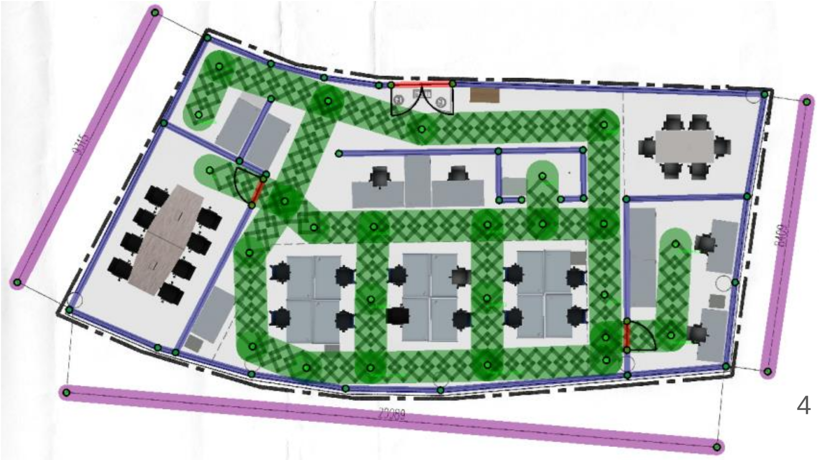


http://github.com/osrf/traffic-editor

Traffic Editor: Goals

- annotate floor plans
  - walls
  - doors
  - lifts
- place simulation models
  - static model placements
  - dynamic models (humans, etc.)
- import/export traffic lanes to vendor-specific Fleet Adapters





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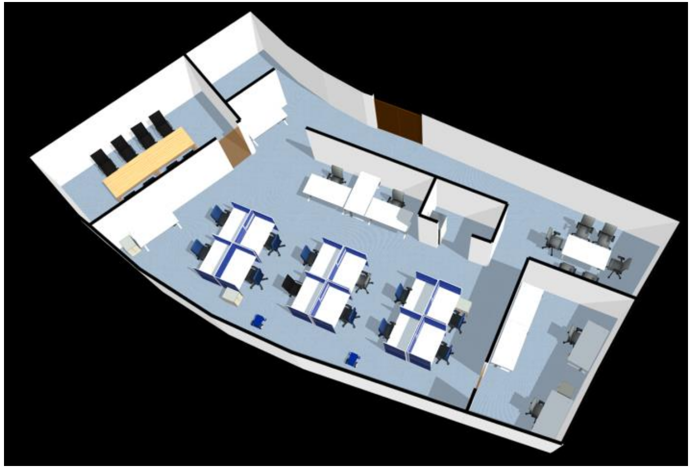
Building map tools

Annotated map in ***traffic_editor***

building_map_tools

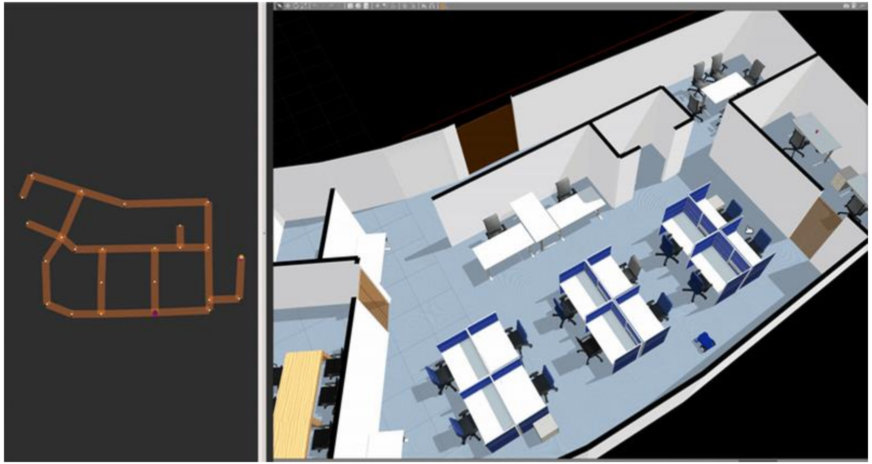


Physics-based simulation world with
3d assets, robots, doors, plugins

http://github.com/osrf/rmf_demos

Testing in simulation is extremely important

- Time saving
- Fine tune algorithms
- Testing
  - Extended operation duration
  - Scalability
  - Debug edge cases
  - Vendor integration
- Using ROS and Gazebo, the code running in simulation is identical to that running in actual hardware!



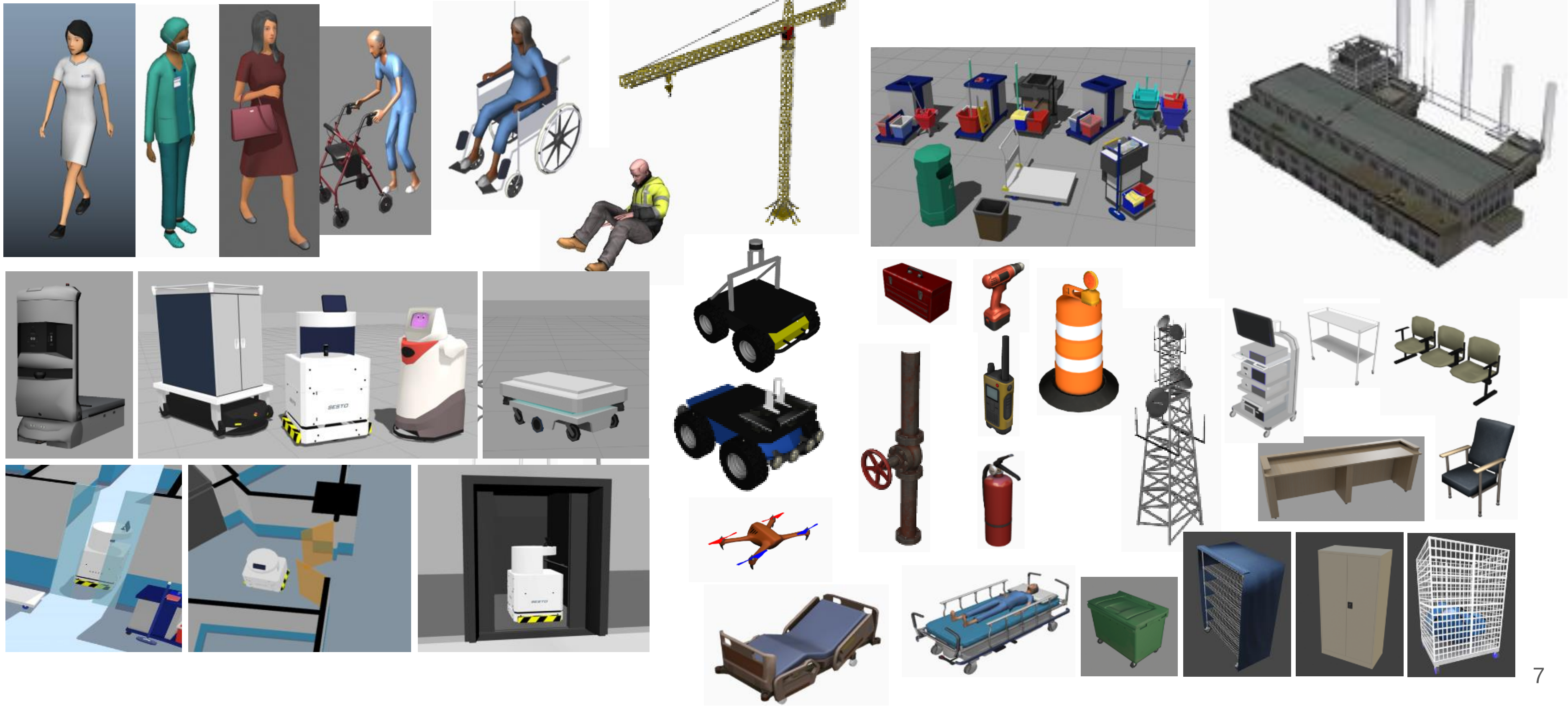
Loop Request Scenario: Robots loop between waypoints while resolving conflicts in their paths and interacting with doorways

This is a physics-based simulation running the actual rmf_core software!

https://app.ignitionrobotics.org/fuel

Many open-source simulation assets are available

(This is only a very tiny sample)



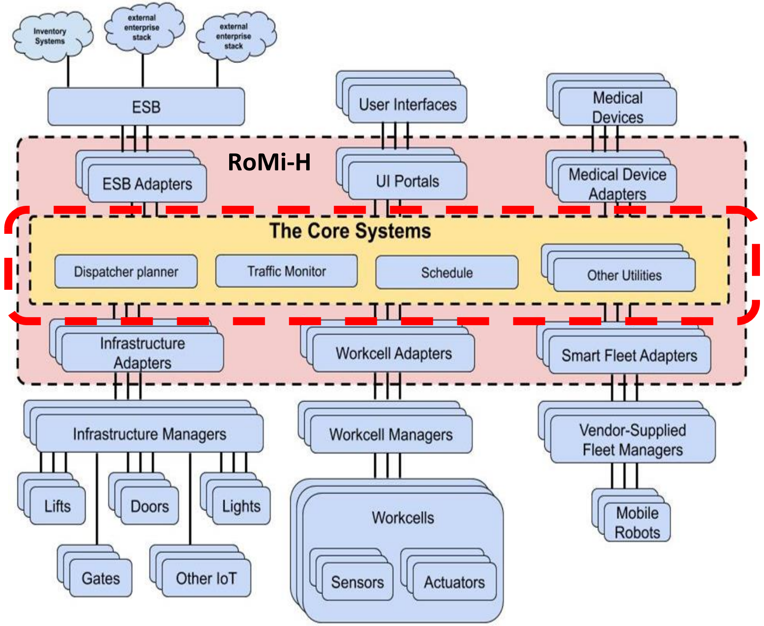
http://github.com/osrf/rmf_core

RMF Core is the brain of RoMi-H

A collection of libraries and utilities for assisting vendors integrate with RMF

- Pure C++ libraries for
  - Trajectory interpolation
  - Path planning
  - Schedule database management
  - Conflict detection and resolution

- Templates and examples of
  - Smart Fleet Adapters for fleets with various levels of control for interoperability of OT/IT/IoT systems
  - Lift/Door adapters
  - Abstract task configurations



Fleet APIs

- Available in C++17 or Python 3.7

- "Full Control" Category
  - Input
    - Current robot location
  - Receive
    - Conflict-free itinerary for your robot
    - Stop request
    - Docking request

Fleet APIs

- Available in C++17 or Python 3.7

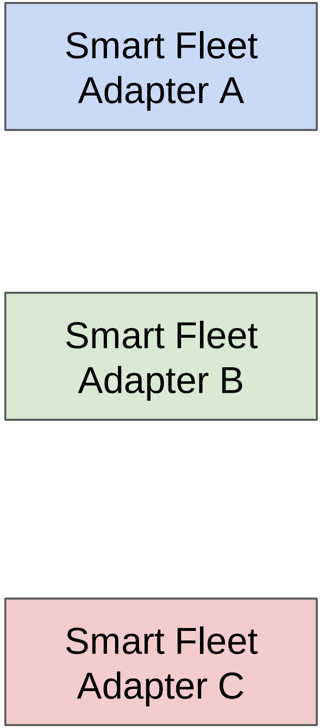
- "Traffic Light" Category
  - Input
    - Current robot location
    - Intended path
  - Receive
    - Conflict-free path timing

Fleet APIs

- Available in C++17 or Python 3.7

- "Read-Only" Category
  - Input
    - Current robot location
    - Intended path
  - Receive
    - **Nothing**

Traffic Negotiation

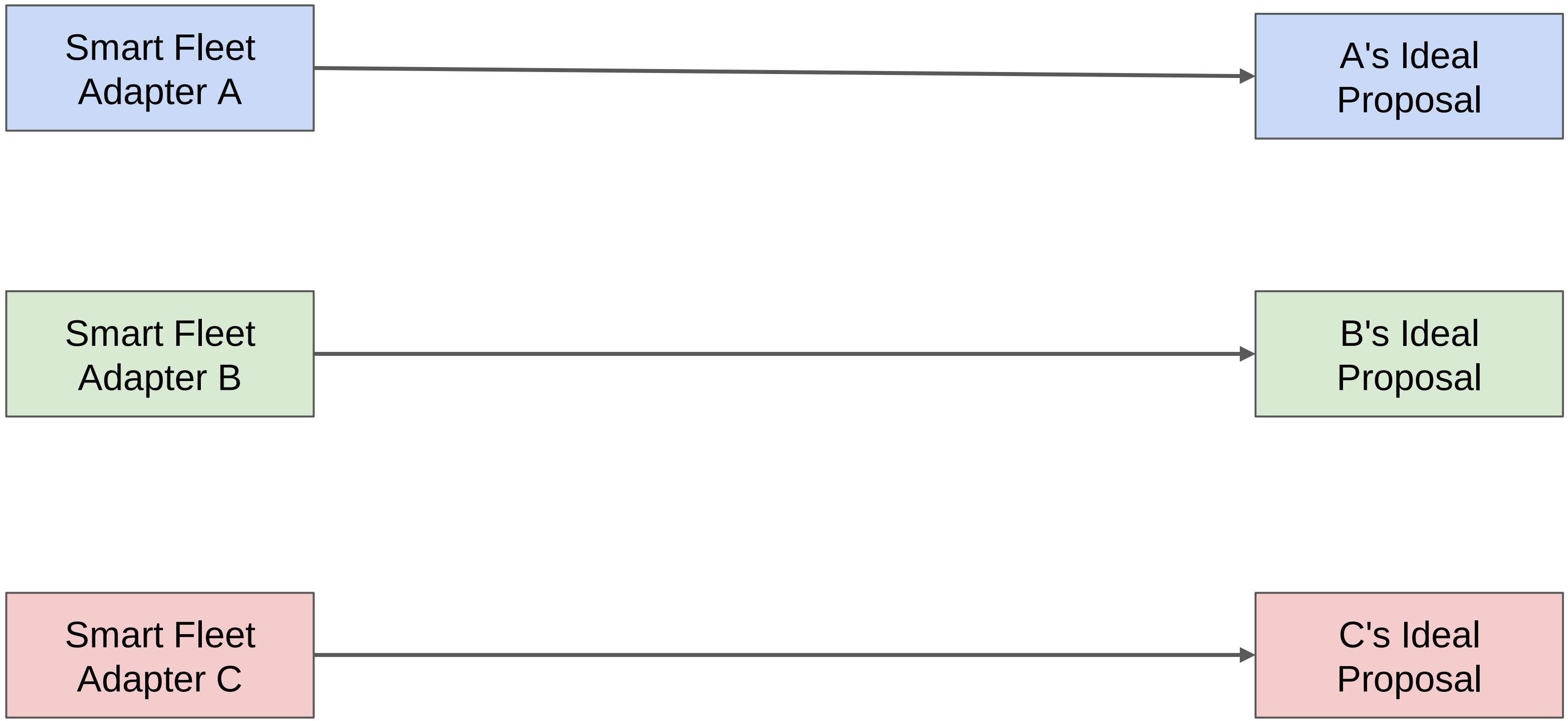


Assumptions:

- Each fleet does NOT know what the other is capable of
- Each fleet can communicate a plan that is feasible for itself
- Each fleet can see the other's plans and attempt to plan around it

Traffic Negotiation

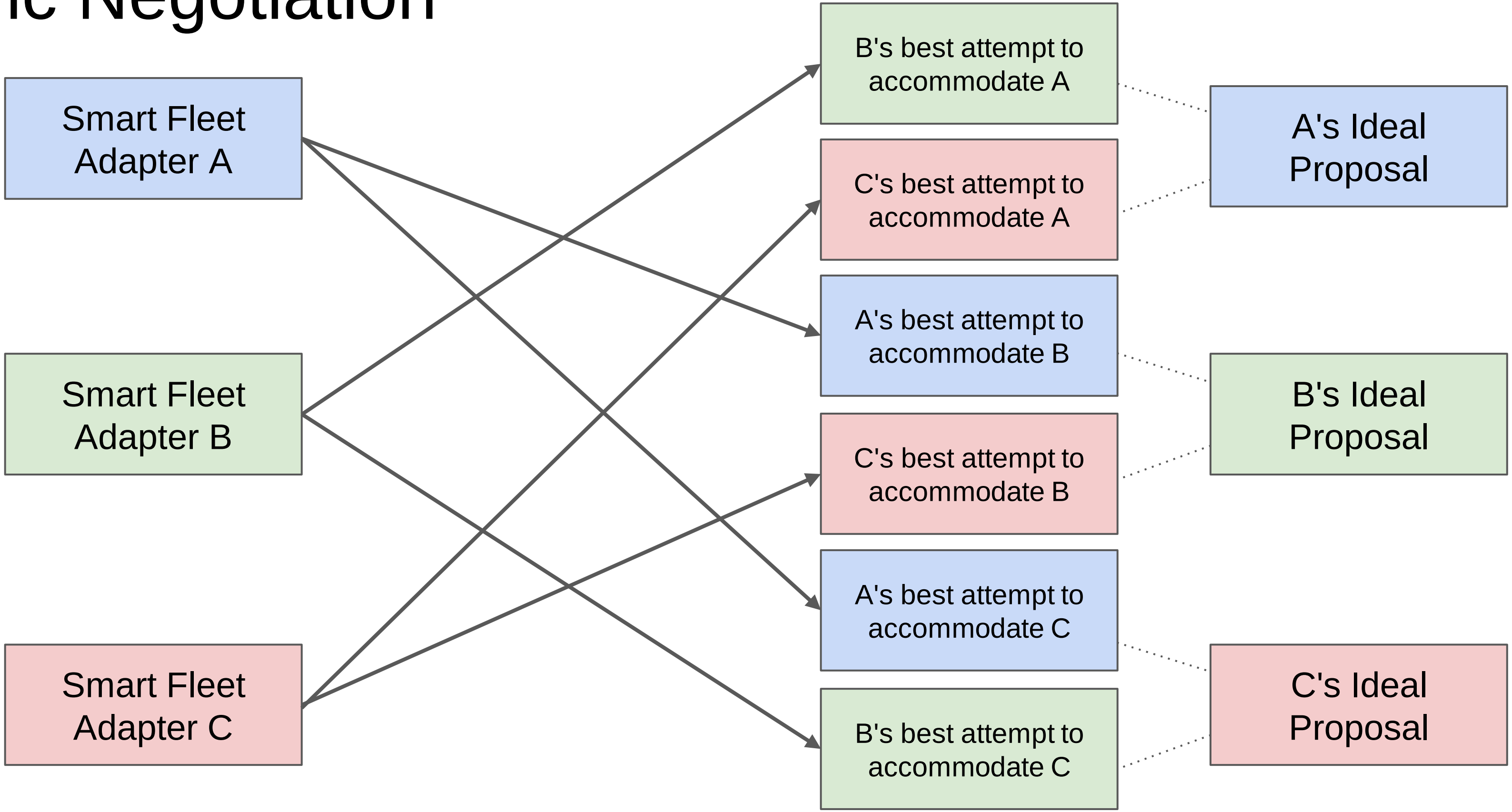
Each fleet proposes the itinerary they would like to follow



http://github.com/osrf/rmf_core

Traffic Negotiation

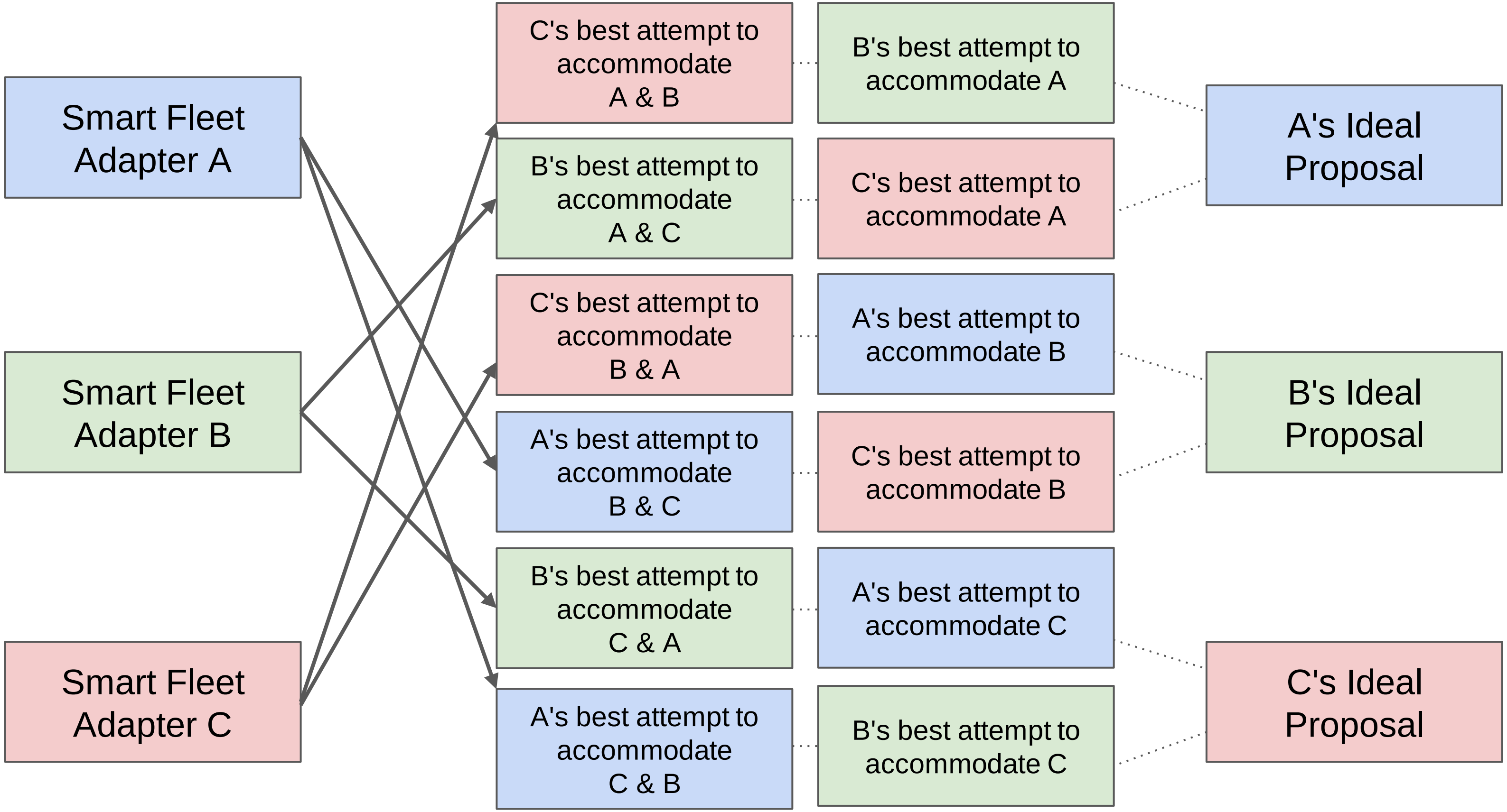
Each fleet responds to the ideal itineraries of the others with an itinerary that is feasible for itself while accommodating the other



http://github.com/osrf/rmf_core

Traffic Negotiation

Each fleet responds to each combination of the others' proposed itineraries with an itinerary that would be feasible for itself

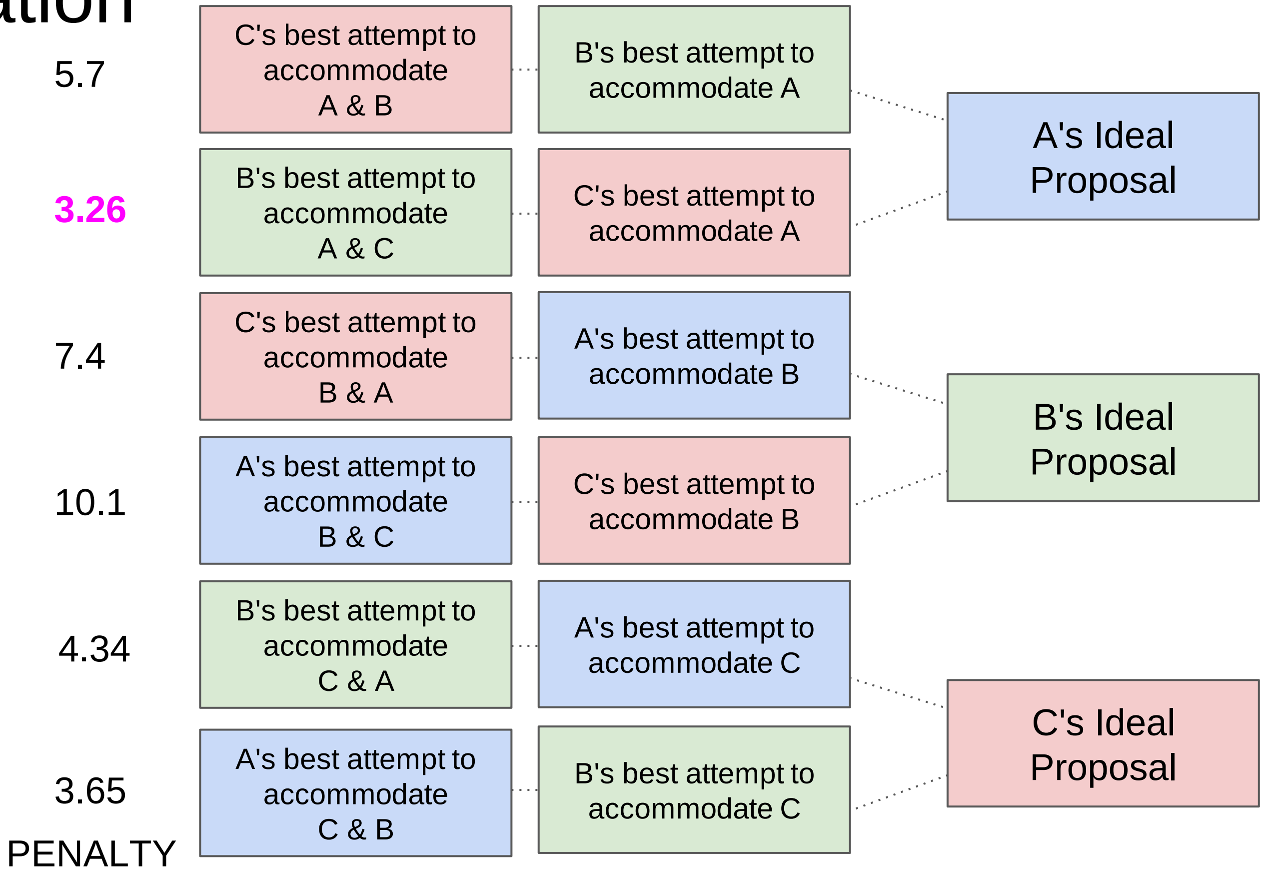


Traffic Negotiation

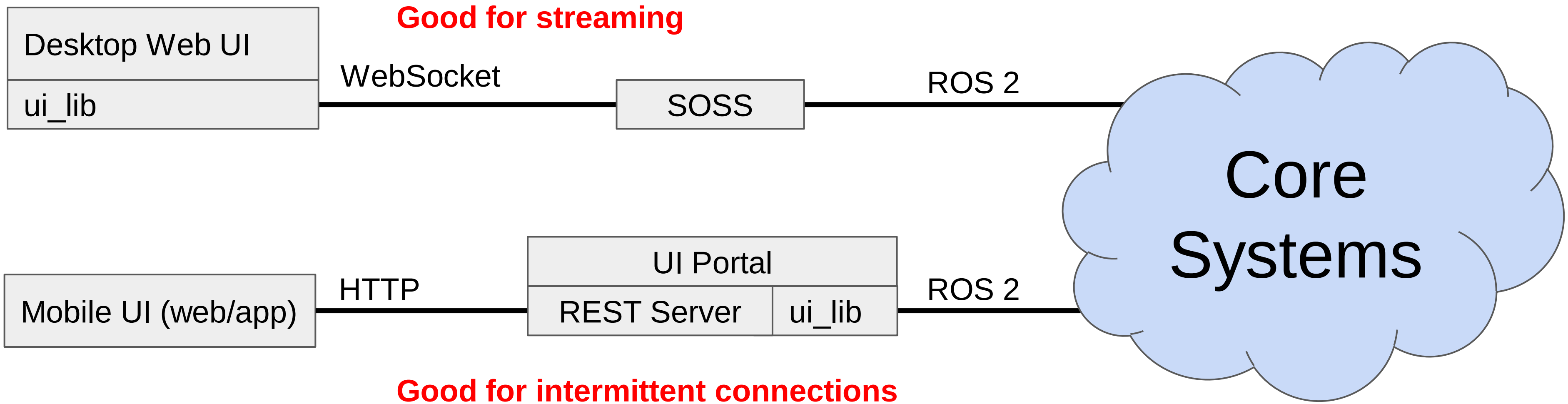
A third-party judge measures the penalty of each set of proposals.

The plan with the lowest penalty is chosen.

The penalty may be measured by the sum of the delays in completing all of the tasks. The sum may be weighted by the importance of each task.

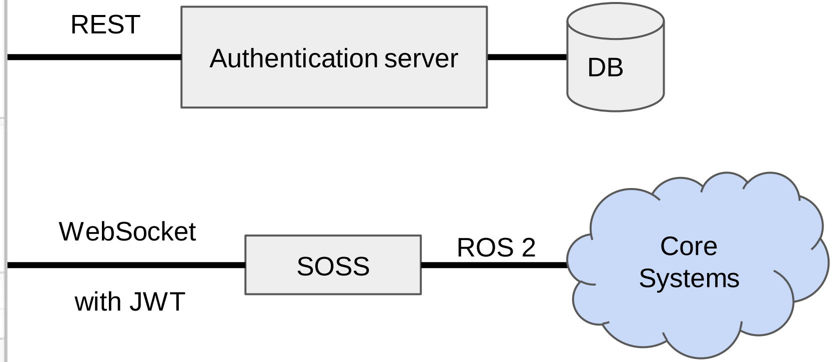


UI Signal Paths



https://github.com/osrf/romi-dashboard

Generic Operations Dashboard



- Robot fleet, door and lift state monitoring
- Schedule and trajectory visualization
- High-level commands to controllable assets, eg. robots, doors, dispensers, etc.

Bolt on Kit (BOK)

Problem Statement

- AMRs have to navigate dynamic hospital environments comprising heavy human (healthcare professionals, caregivers, employees) and object traffic (trash bins, wheelchairs, beds, trolleys)
- Navigation with inanimate objects can be particularly challenging as their location & trajectory are often unpredictable

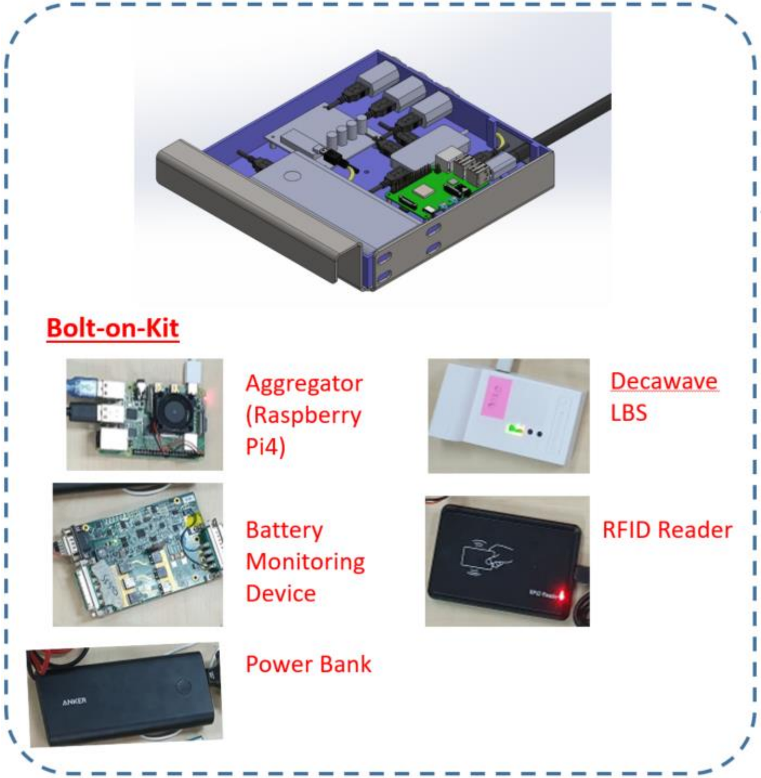
Bolt on Kit (BOK)

Solution: Bolt-on-kit

Allows inanimate objects to become “trackable assets” that can interoperate with robots. Our developed BOK comprises:

1. Aggregator (raspberry pi)
2. Battery Monitoring device
3. Power bank
4. Decawave LBS for location-tracking (UWB)
5. RFID reader- for authentication

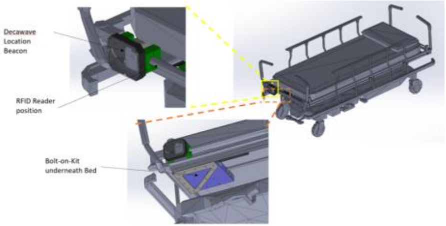
Integrate with Tablet - Nurse UI for display of Patient information

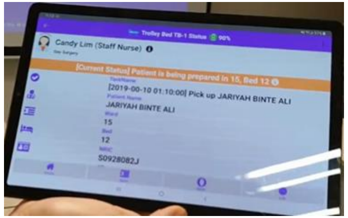


Bolt on Kit (BOK)

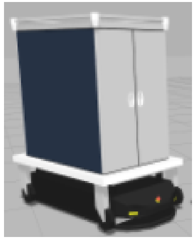
Potential applications

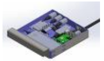
1. BOK attached to a hospital bed





2. BOK attached to a case-cart





- **Use-case: Patient ID authentication & location tracking during transfers**
  Nurse scans BOK attached to hospital bed using tablet to authenticate patient ID

- **Use-case: Prioritization of hospital bed over delivery AMRs**
  BOK relays location information to RoMi-H and RoMi-H helps coordinating traffic between AMRs and hospital bed; if hospital bed is transporting a patient, RoMi-H gives it priority over an AMR

- **Use-case: Location, nurse ID authentication and temperature tracking during transportation**
  - Authentication for door opening of case-cart transporting sensitive payloads (e.g. certain types of medication)
  - Temperature sensor added to BOK to monitor changes; if the temperature crosses a certain threshold, an alert can be routed via RoMi-H to nurse console

Robot Agnostic Mapping Platform (RAMP)

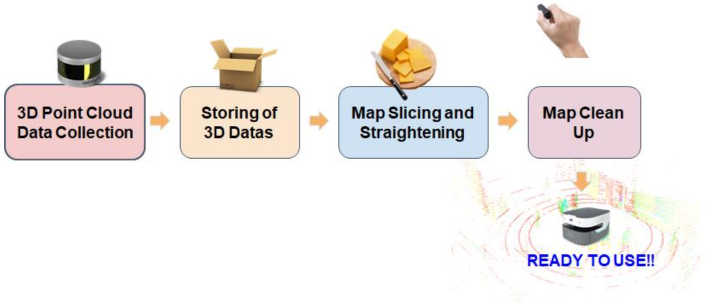
Problem statement

- Mapping process necessary to construct the map of operating facility prior to the deployment of a new robotics system
- In environments with multiple robots, mapping process is done individually and repetitively, wasting significant system integrator time & effort

Robot Agnostic Mapping Platform (RAMP)

Solution

- Product that can be used to create an Agnostic Map (3D map) which can be used by various AGVs for localization.
- 3D LiDar on a mobile base with IMU and Odometer
- 2D map is 'sliced' out from the 3D map after a height range is specified by the user
- The generated 2D map can be used by different AGV/AMR navigation systems



Robot Agnostic Mapping Platform (RAMP)

Implementation process

1. 3D map reconstruction

Use a 3D mapping tool to reconstruct the environment

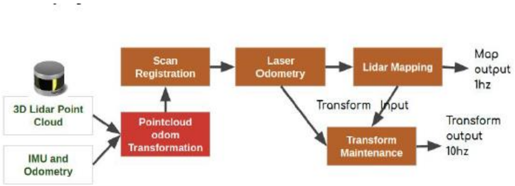


Figure 4-2: Original Nodes in LOAM (Brown boxes), Add-on point cloud transformation node (Red box).

2. 3D map straightening

Use a straightening tool to fix drift

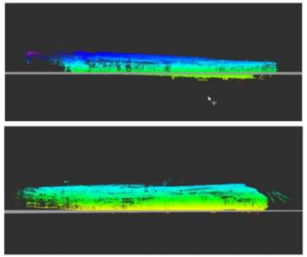


Figure 4-4: Before straightening (top), and after straightening (bottom)

3. 3D map conversion & slicing

Output to voxelized format; use a ROS file to slice 3D map to 2D map

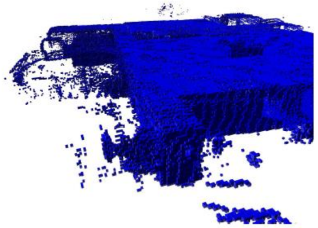


Figure 4-5: Voxelized 3D map of Hope Technik's Office

4. 2D map clean-up

Use a photo editing tool to touch-up for better performance on localization & navigation

Figure 4-6: Occupancy map with Z_min: 0.2m, Z_max: 1.2m, above ground, with 0.05m map resolution

Robot Agnostic Mapping Platform (RAMP)

Application

- Different AMR has their own map orientation and reference point
- Creation of a single "datum" reference map in RoMi-H core, for all robot maps to “reference" for each PHI (operating environment)
- All AMRs can use this master reference map which saves System Integrators days of mapping effort for each new AMR fleet

Closing Remarks

Centre for Healthcare Assistive & Robotics Technology (CHART)

https://www.cgh.com.sg/chart/sharp/romi-h

IHiS — Because IT's in Healthcare

https://www.ihis.com.sg/

open robotics

https://www.openrobotics.org/

HOPE technik

https://www.hopetechnik.com/

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