Planning to Plan:
New Flexible
Navigation Interfaces

LOCUS

David V. Lu!!

ROSCon 2018

Central Dogma of ROS Navigation

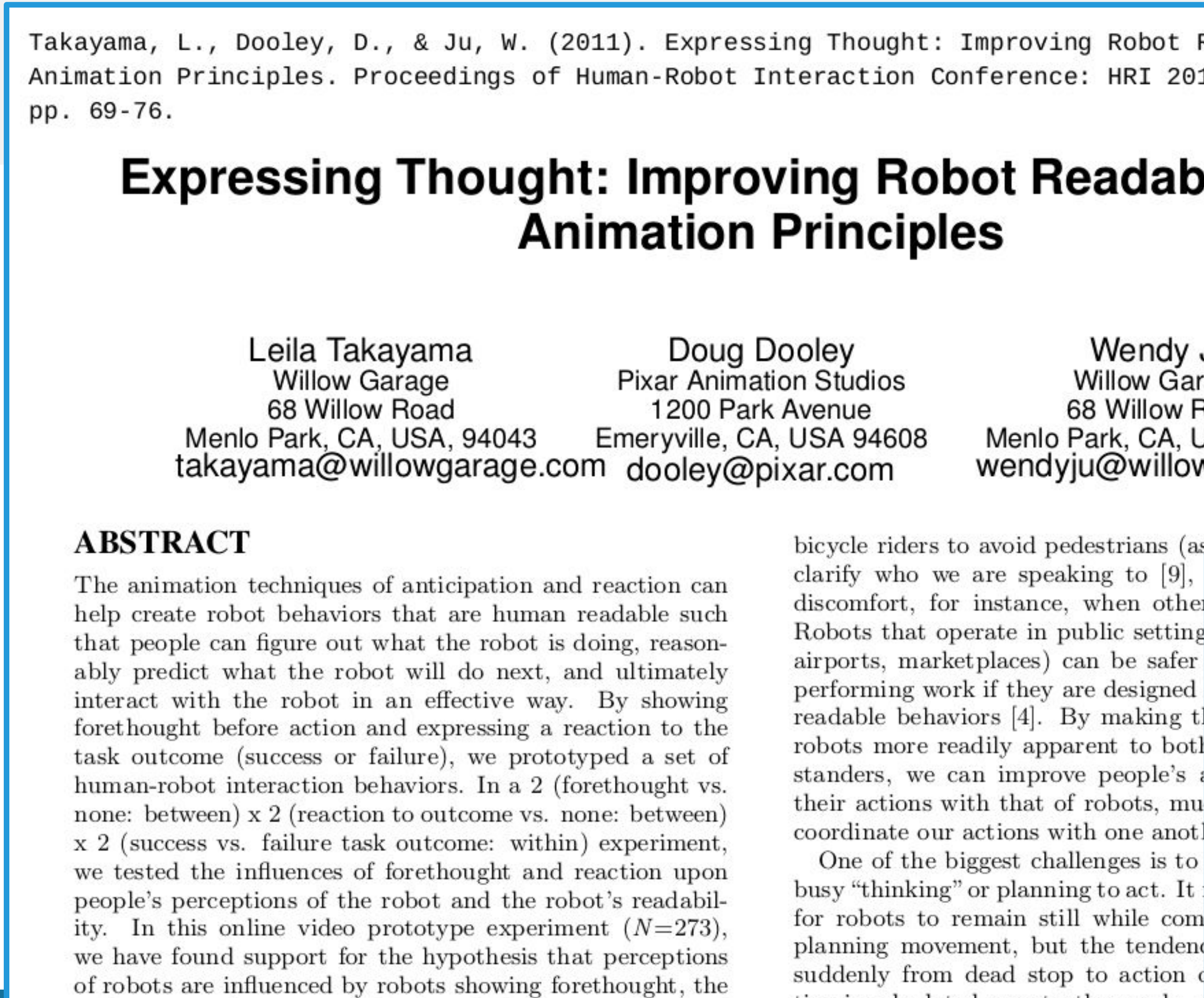
Current Location + Goal Location

Global Costmap + Planner

Global Plan

Local Costmap + Planner

Command Velocities



Takayama, L., Dooley, D., & Ju, W. (2011). Expressing Thought: Improving Robot Readability with Animation Principles. Proceedings of Human-Robot Interaction Conference: HRI 2011, Lausanne, CH, pp. 69-76.

Expressing Thought: Improving Robot Readability with Animation Principles

Leila Takayama
Willow Garage
68 Willow Road
Menlo Park, CA, USA, 94043
takayama@willowgarage.com

Doug Dooley
Pixar Animation Studios
1200 Park Avenue
Emeryville, CA, USA 94608
dooley@pixar.com

Wendy Ju
Willow Garage
68 Willow Road
Menlo Park, CA, USA, 94043
wendyju@willowgarage.com

ABSTRACT

The animation techniques of anticipation and reaction can help create robot behaviors that are human readable such that people can figure out what the robot is doing, reasonably predict what the robot will do next, and ultimately interact with the robot in an effective way. By showing forethought before action and expressing a reaction to the task outcome (success or failure), we prototyped a set of human-robot interaction behaviors. In a 2 (forethought vs. none: between) x 2 (reaction to outcome vs. none: between) x 2 (success vs. failure task outcome: within) experiment, we tested the influences of forethought and reaction upon people's perceptions of the robot and the robot's readability. In this online video prototype experiment (N=273), we have found support for the hypothesis that perceptions of robots are influenced by robots showing forethought, the

bicycle riders to avoid pedestrians (as noted by [19]), let us clarify who we are speaking to [9], discomfort, for instance, when other Robots that operate in public setting airports, marketplaces) can be safer performing work if they are designed readable behaviors [4]. By making t robots more readily apparent to both standers, we can improve people's their actions with that of robots, mu coordinate our actions with one anot

One of the biggest challenges is to busy "thinking" or planning to act. It for robots to remain still while com planning movement, but the tendenc suddenly from dead stop to action c

Animating with the Navigation Stack

Forethought

Get the Global Plan, Look that Direction, Start Driving

Reaction

If the robot failed, How it failed, When it failed

Planning

Plan around people, for people

Navigation is often about more than driving from point A to point B efficiently. Context is key.

Planning to Talk about "Planning to Plan"

- The State of Navigation
- Navigation Interface Design
- New Global Planner
- Locomotor
- ROS2: The Next Generation

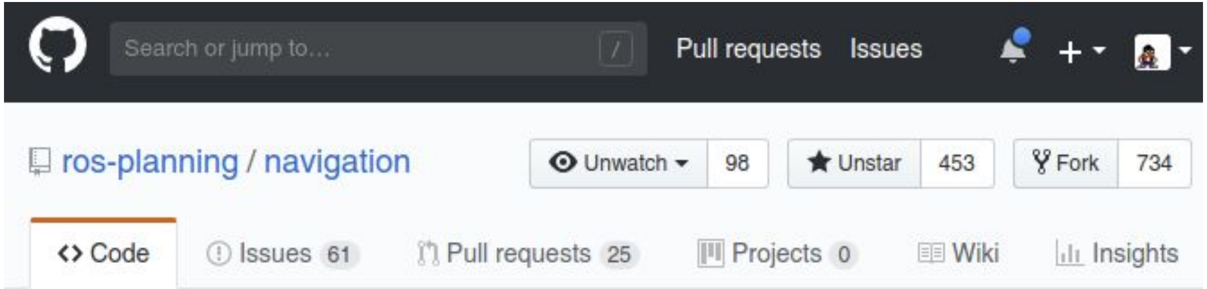
Why the fork?

Hard to swap out single components

Feature creep of the universal solution

Move slow and

don't break things



github.com/ros-planning/navigation

State of the Navigation Packages

6DOF Poses Everywhere

nav_core - Interfaces haven't changed much in almost a decade

costmap_2d - forces you to use layers, transmits OccupancyGrids

Global Planners - navfn is prematurely optimized, hard to edit
- global_planner has bugs

Local Planners - difficult to debug/customize

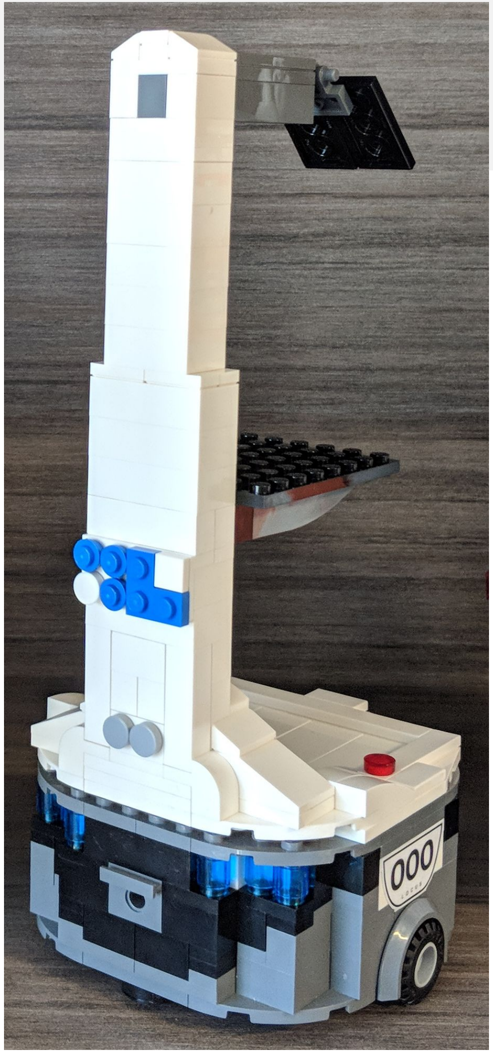
move_base - Black box, static list of recovery behaviors

Design Methodology

Build reusable pieces

Meant to be extensible

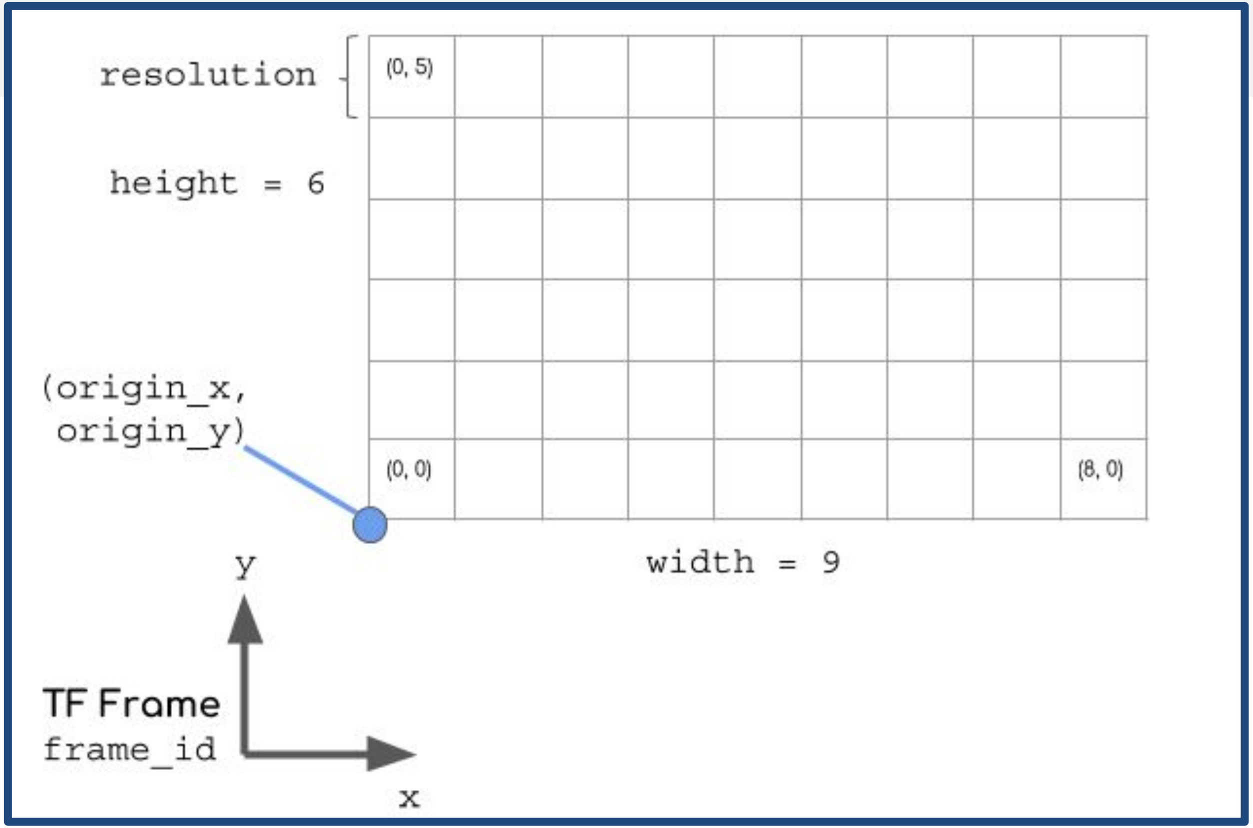
No black boxes



nav_grid

nav_grid::NavGridInfo

```
unsigned int width = 0;
unsigned int height = 0;
double resolution = 1.0;
std::string frame_id
             = "map";
double origin_x = 0.0;
double origin_y = 0.0;
```



relative of nav_msgs::MapMetaData

NavGrid<T> Operations

- Abstracted Data Storage
- Template Based Typing
- Coordinate Translation
- New Message Types
  - NavGridOfChars
  - NavGridOfCharsUpdate
  - NavGridOfDoubles
  - NavGridOfDoublesUpdate
- Iterators

nav_core2

it's plugins all the way down

BaseGlobalPlanner
BaseLocalPlanner
RecoveryBehaviors

CostmapLayer
DWBLocalPlanner

and more...

nav_core2::Costmap

```
class Costmap : nav_grid::NavGrid<unsigned char>
{
    void initialize(NodeHandle parent, string name,
                    TFListenerPtr tf);
    void update();
    mutex_t getMutex();
    bool canTrackChanges();
    UIntBounds getChangeBounds(string ns);
};
```

Still Chars

No Required TFs

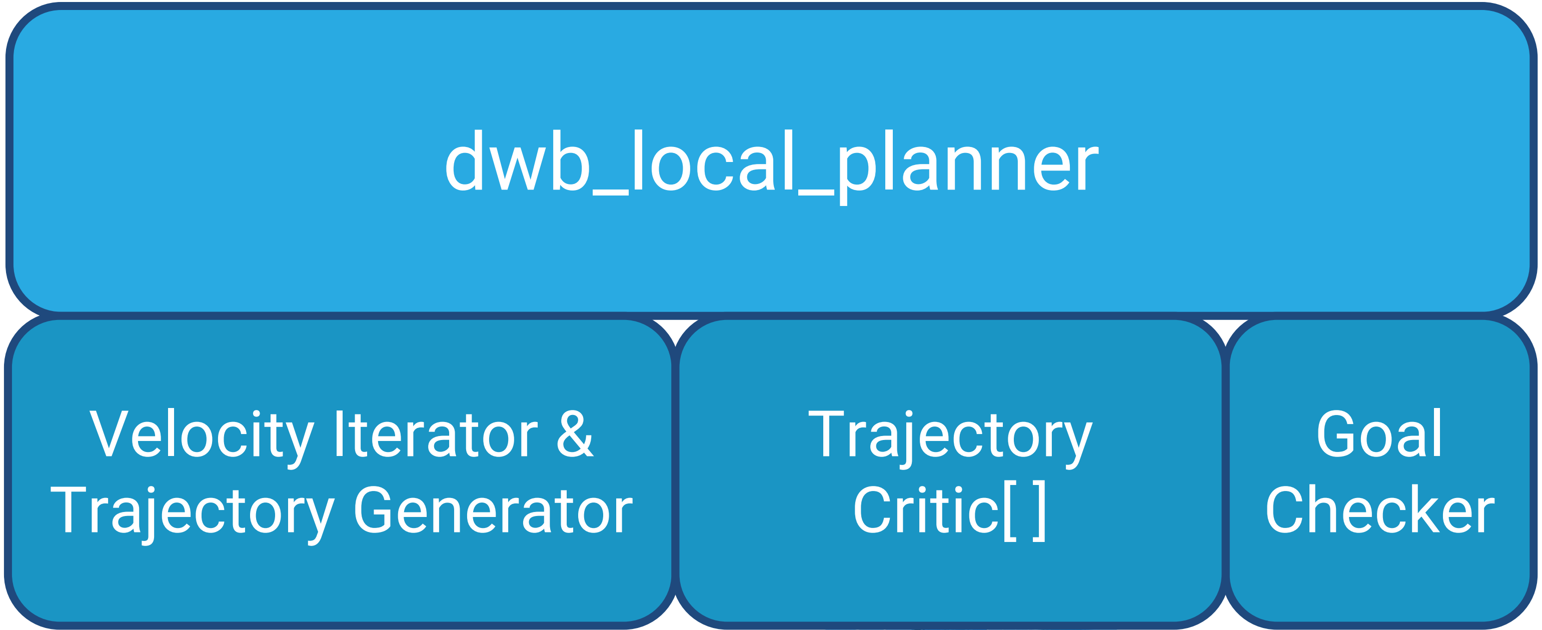
No Update Thread

Use Any Update Algorithm

Option to Track Changes

Compatible with Costmap2DROS

dwb_local_planner

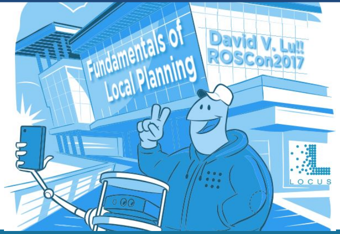


dwb_local_planner

Velocity Iterator & Trajectory Generator

Trajectory Critic[ ]

Goal Checker



nav_core2::GlobalPlanner

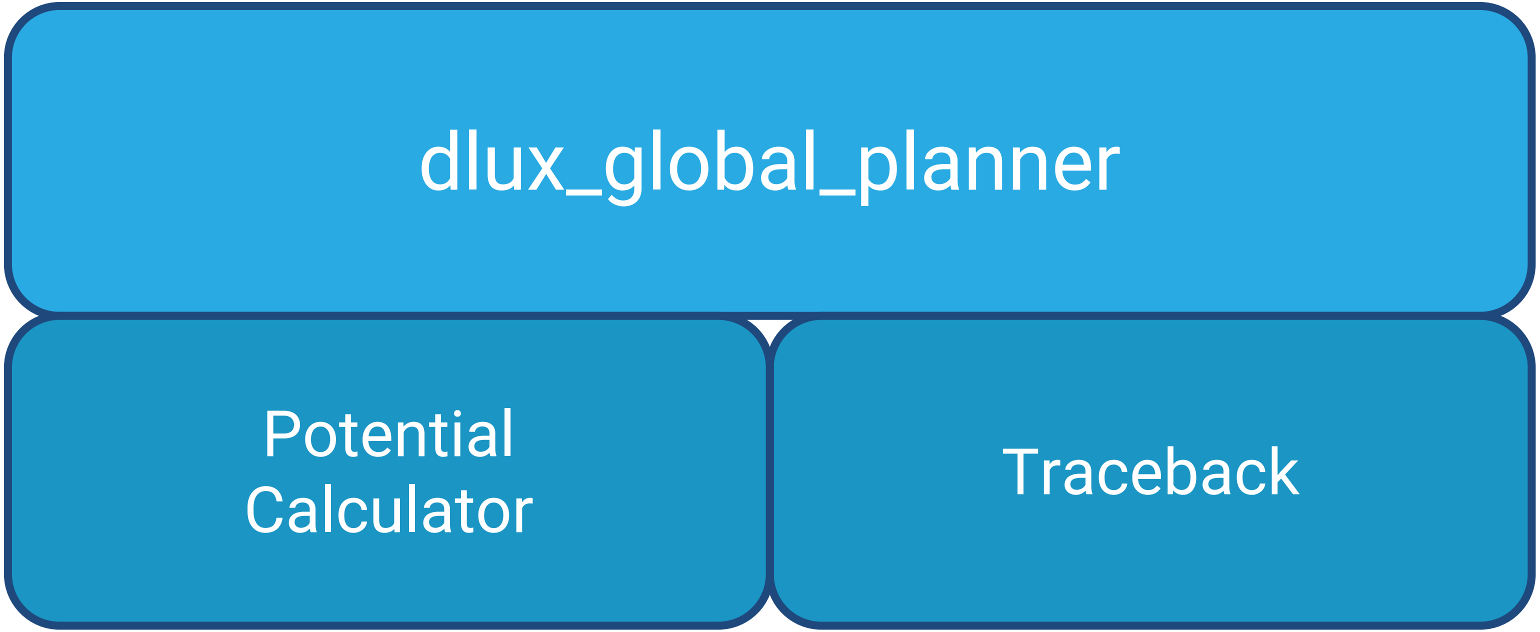
```
class GlobalPlanner
{
public:
    void initialize(   NodeHandle parent,
                       string name,
                       TFListenerPtr tf,
                       Costmap::Ptr costmap);


    Path2D makePlan(   Pose2DStamped start,
                       Pose2DStamped goal);
};
```

nav_2d_msgs

Throws Exceptions

dlux_global_planner



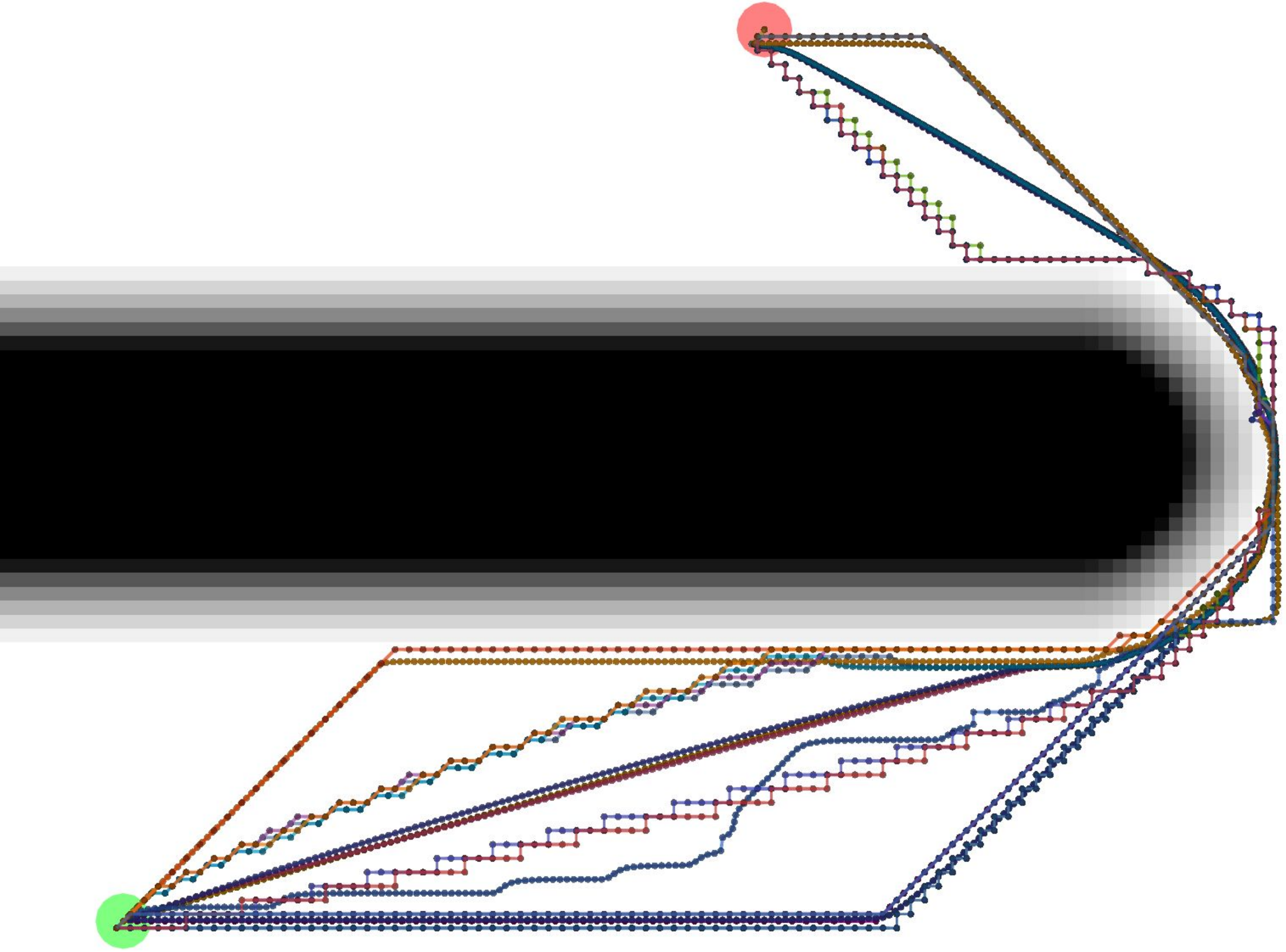
dlux_global_planner

Potential Calculator

Traceback

`dlux_plugins::Dijkstra`
`dlux_plugins::AStar`

`dlux_plugins::VonNeumannPath`
`dlux_plugins::GridPath`
`dlux_plugins::GradientPath`

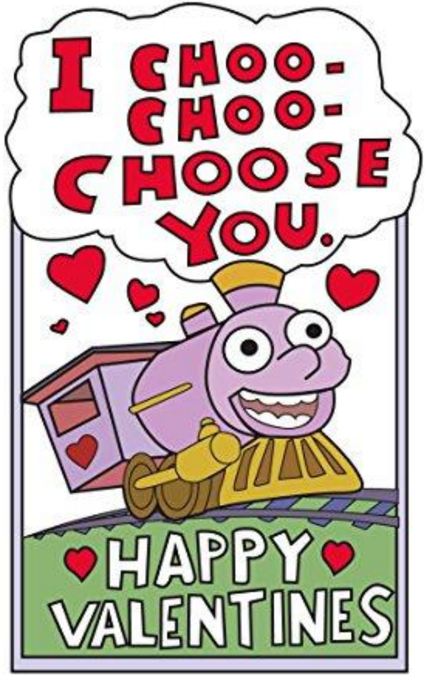


The many paths of dlux global planner

move_base

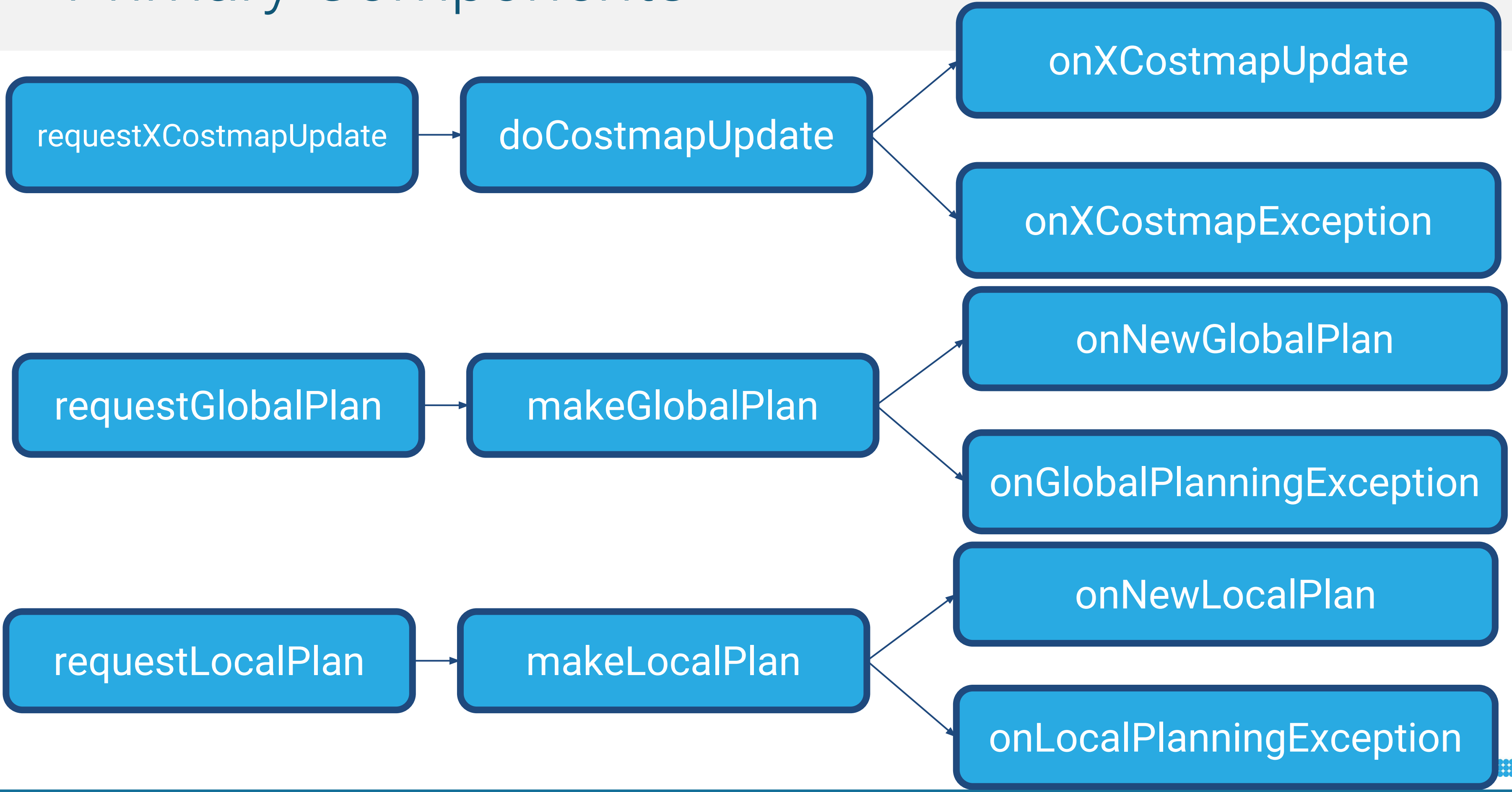
- Four Components
    - Global Costmap
    - Global Planner
    - Local Costmap
    - Local Planner
- Pass Global Plan to Local Planner
- Try to Recover when Planning Fails

locomotor

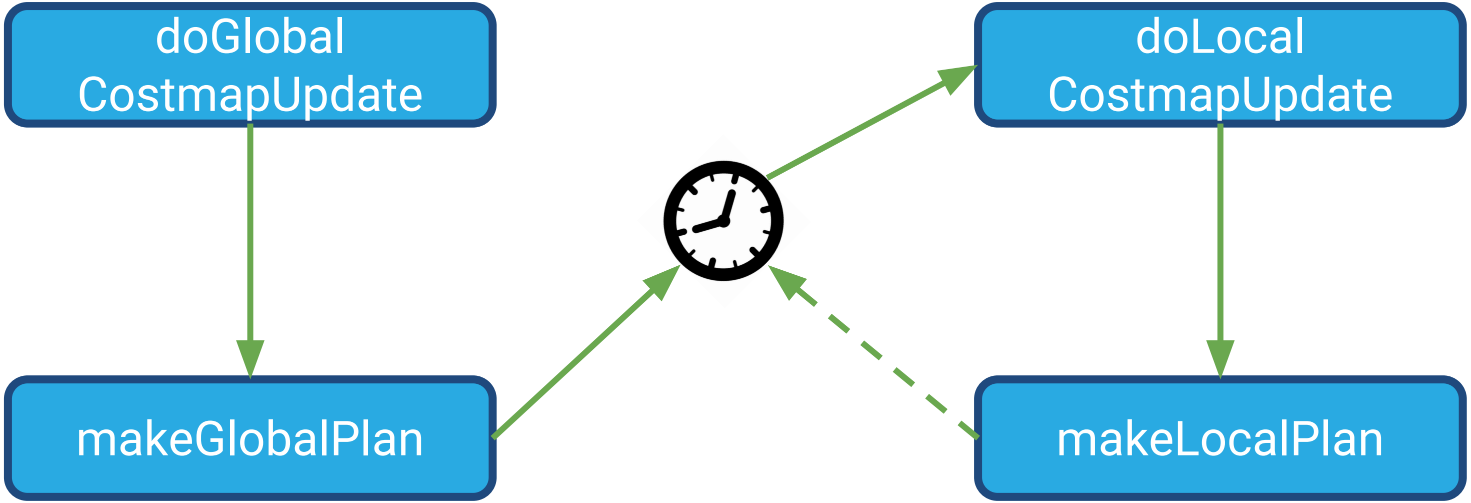


- Extensible Path Planning Coordination Engine
- Control what to do when path planning succeeds and fails
- Built on nav_core2 Interfaces
- Leverages ROS Callback Queues

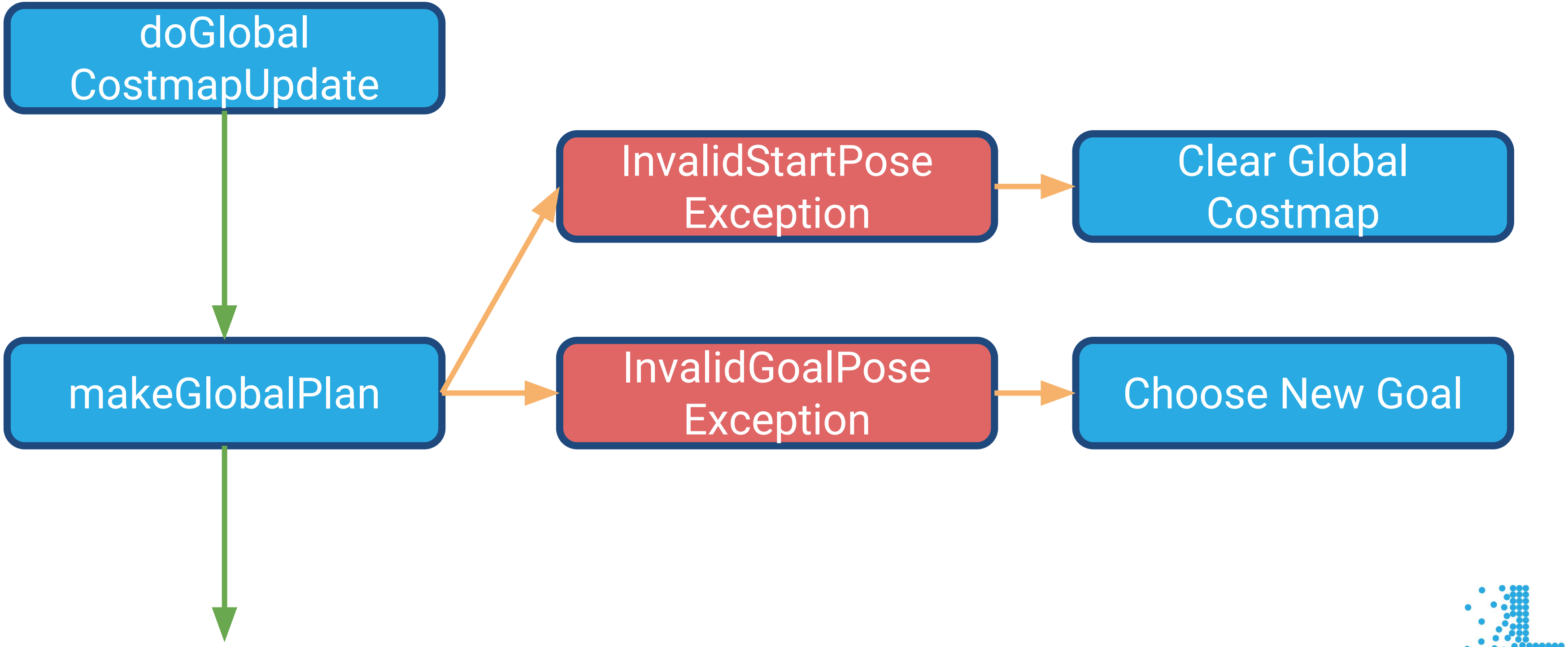
Primary Components



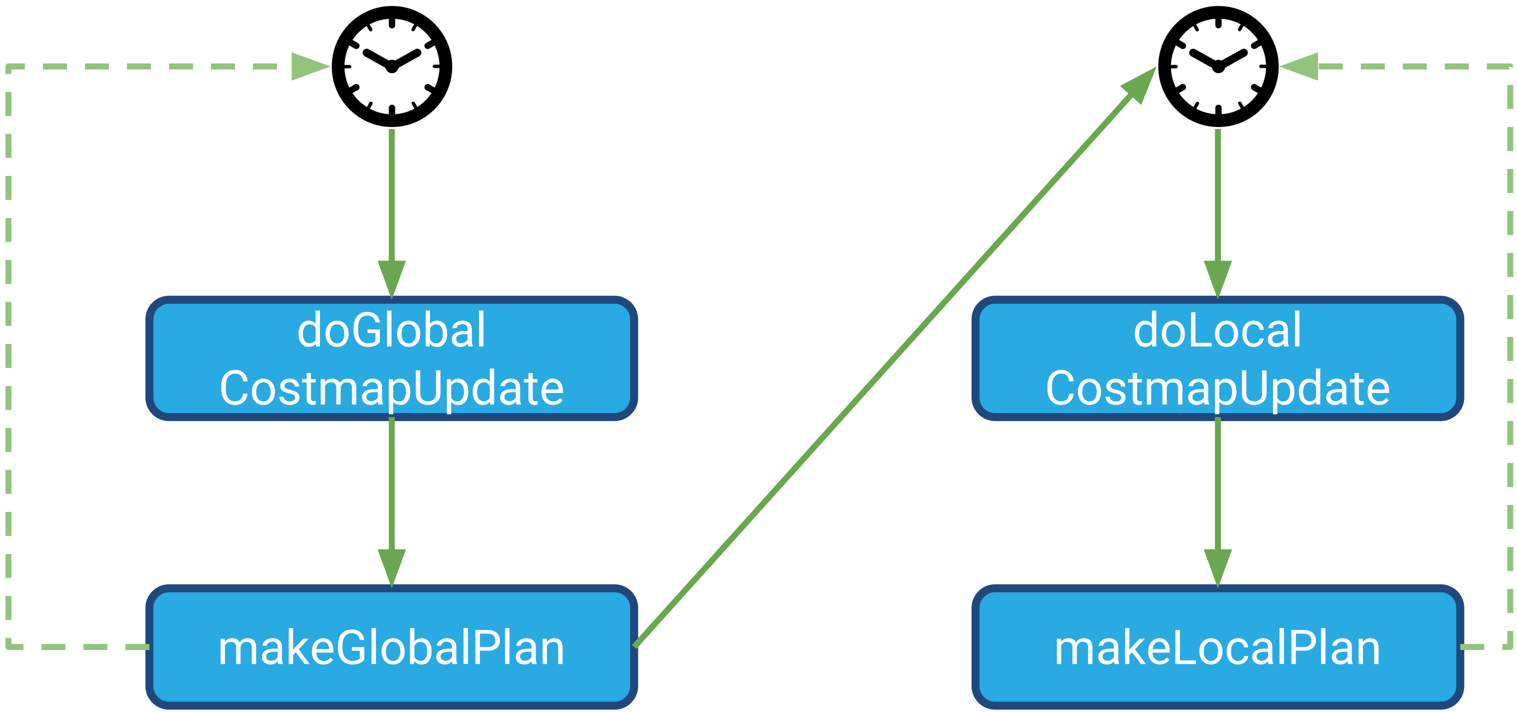
Single Thread Control Flow



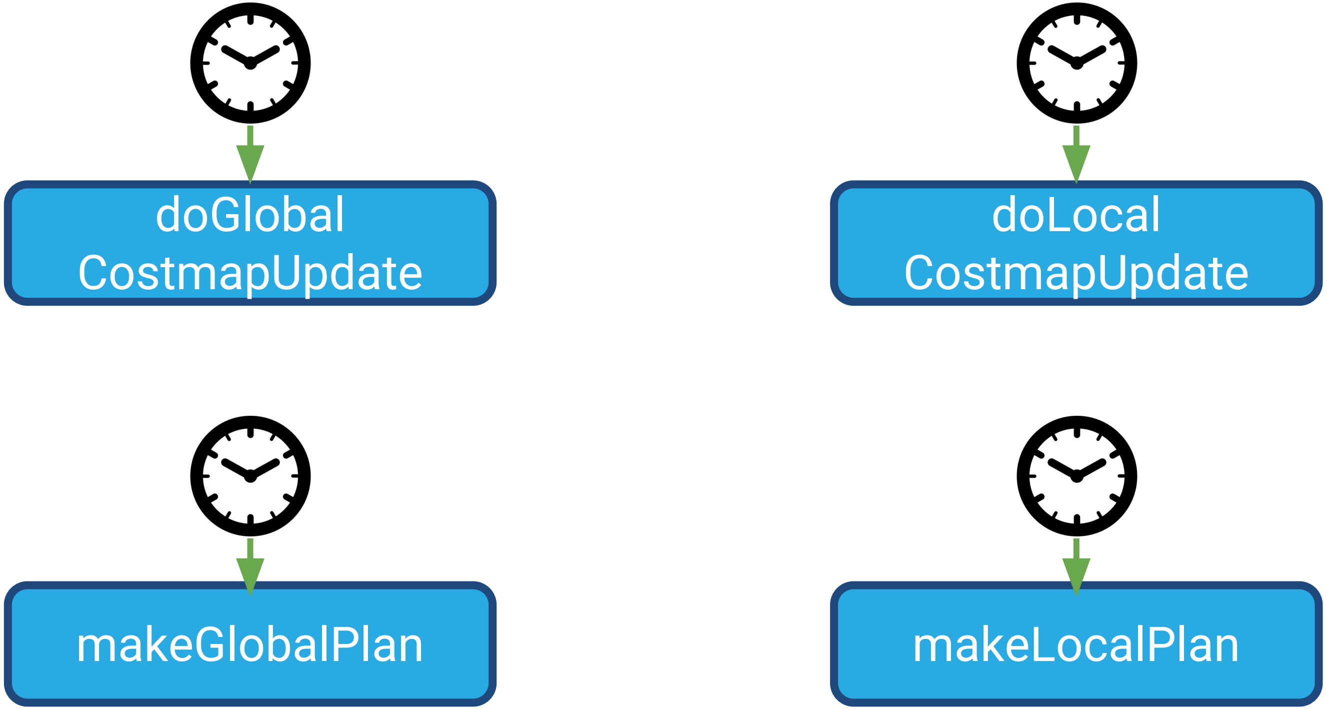
Dealing with Failure



Double the Threads - Double the Fun

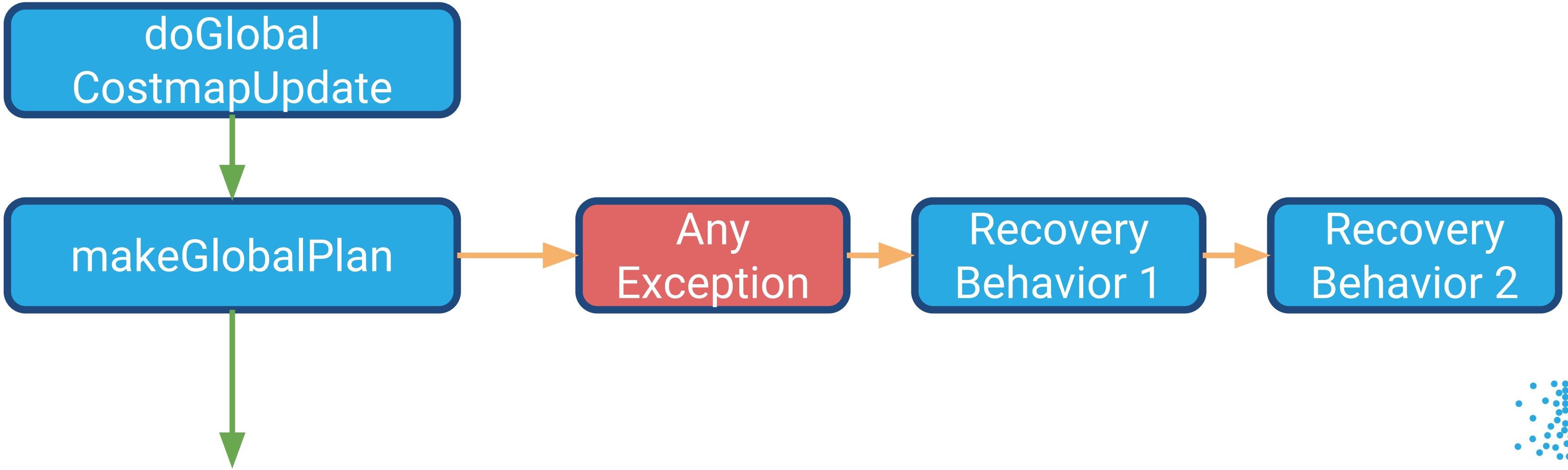


Four Shall Be the Number of the Timers



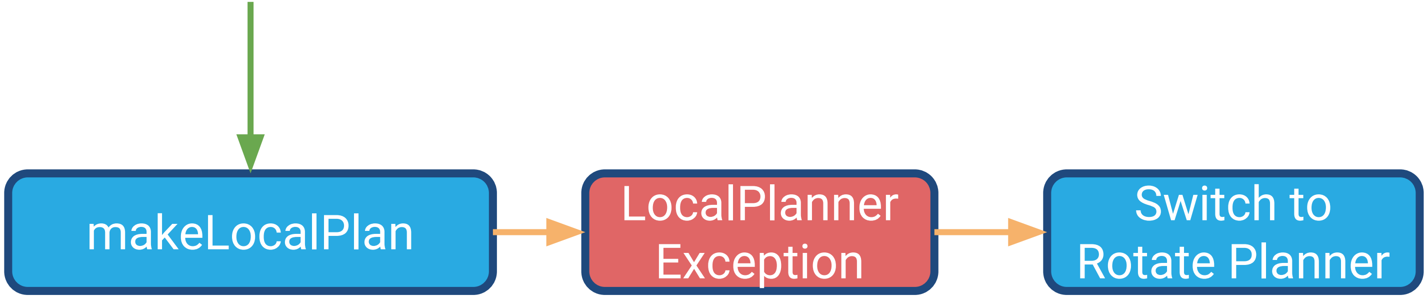
locomove_base

- Drop in replacement for move_base
- Uses nav_core_adapter::CostmapAdapter
- Loads nav_core::RecoveryBehaviors



Plugin Mux

- Load Multiple Pluginlib Plugins
- Not nav_core2 specific
- Switch Plugin via C++ method or ROS Service
- Triggers Callback when Switching

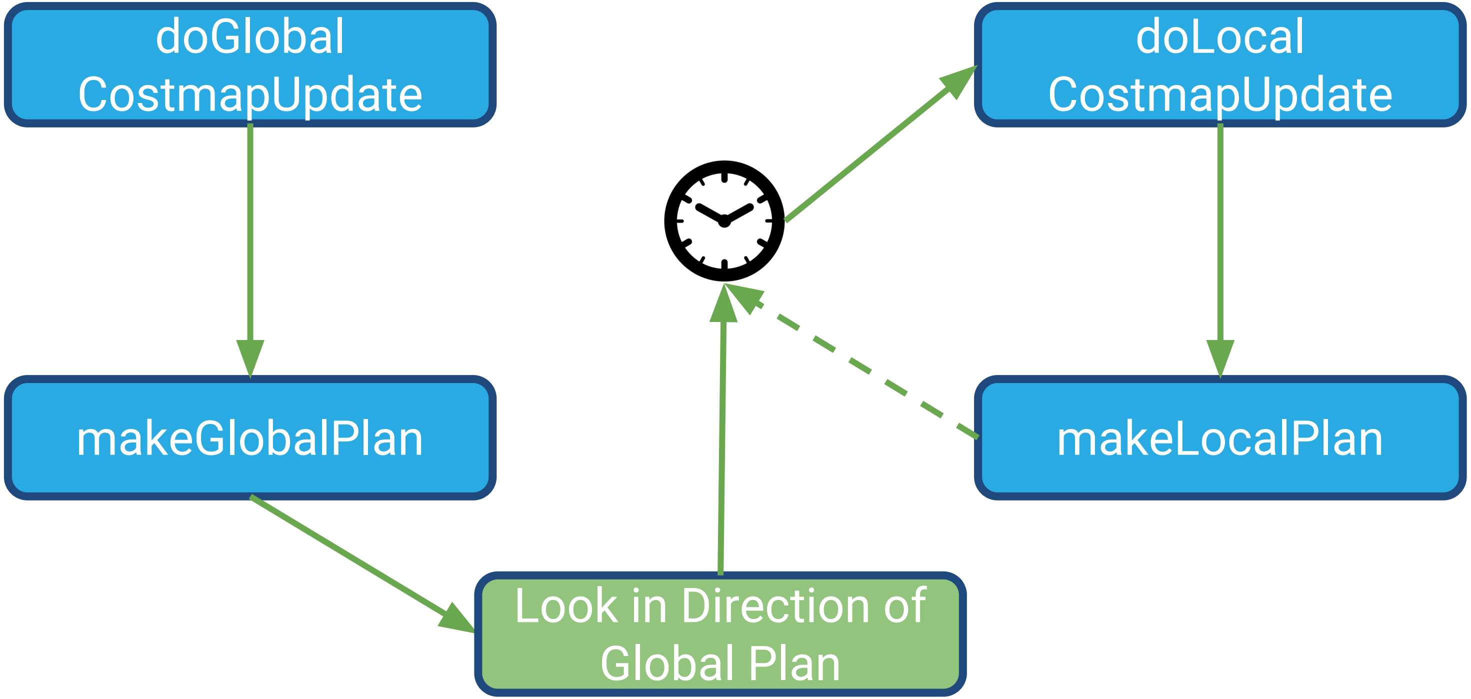


makeLocalPlan

LocalPlanner Exception

Switch to Rotate Planner

Showing Forethought in Navigation



doGlobal CostmapUpdate

makeGlobalPlan

Look in Direction of Global Plan

doLocal CostmapUpdate

makeLocalPlan

move_base Actions

```
# move_base_msgs/MoveBase.action
geometry_msgs/PoseStamped target_pose
---
---
geometry_msgs/PoseStamped base_position
```

Locomotor Action

```
nav_2d_msgs/Pose2DStamped goal
---
int64 state_info
---
nav_2d_msgs/Pose2DStamped current_position
nav_2d_msgs/Twist2D current_speed
nav_2d_msgs/Path2D global_plan
float32 percent_complete
float32 distance_traveled
float32 estimated_distance_remaining
int64 state_info
```

ROS 2

- Full reimplementation of navigation stack
  - DluxGlobalPlanner
  - DWBLocalPlanner
  - Locomotor
  - LayeredCostmap and CostmapLayers
  - NavGridServer / Saver
- Out by year's end

https://github.com/ros-planning/navigation2

Matt Hansen, Intel

Planning to Plan:
New Flexible
Navigation Interfaces

David V. Lu!! ROSCon 2018

github.com/locusrobotics/robot_navigation

davidvlu@gmail.com

@probablydavid
@LocusRobotics

LOCUS

LocusRobotics.com/careers