
Fundamentals of
Local Planning
David V. Lu!!
ROSCon2017
LOCUS

Central Dogma of ROS Navigation

Current Location + Goal Location

Global Planner

Global Plan

Local Planner

Command Velocities

Fundamentals of Local Planning

Fundamentals / Theory

ROS Navigation Today

ROS Navigation Tomorrow

What is the best command velocity?

What command velocities are available?

What would the commands do?

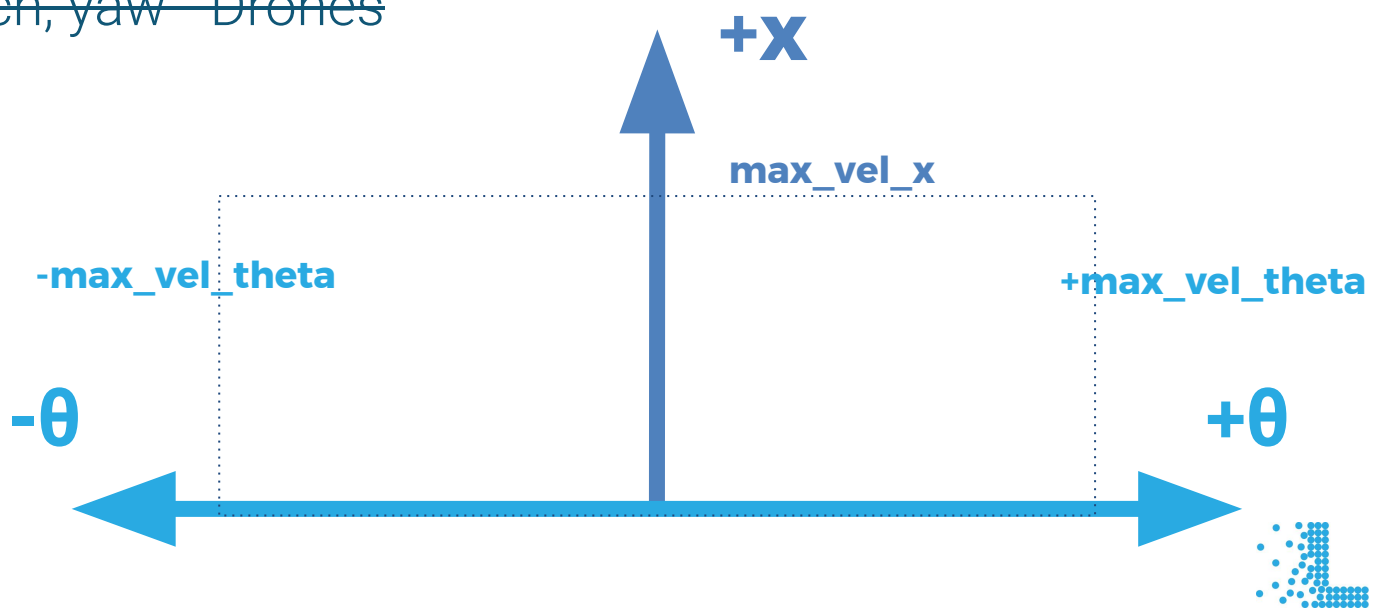
How do we define the "best" command?

What Command Velocities are Available?
Velocity Search Space

x, θ - Non-holonomic Robots

x, y, θ - Holonomic Robots

~~x, y, z, roll, pitch, yaw - Drones~~

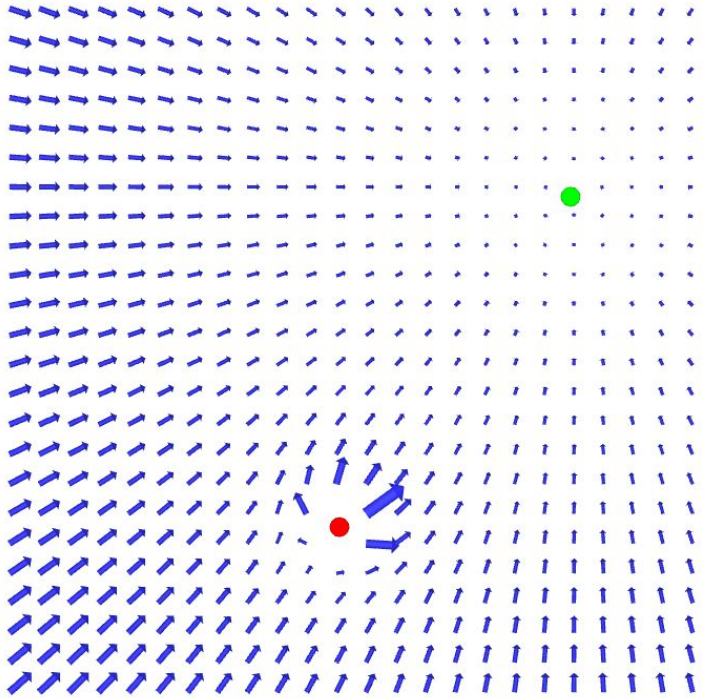


A Brief History Interlude:
Vector Fields - 1986

Oussama Khatib
Artificial Intelligence Laboratory
Stanford University
Stanford, California 94305

Real-Time Obstacle Avoidance for Manipulators and Mobile Robots

The International Journal of Robotics Research 5.1 (1986): 90-98.



A Brief History Interlude:
DWA - 1997

The Dynamic Window Approach to Collision Avoidance

Dieter Fox† Wolfram Burgard† Sebastian Thrun†‡

†Dept. of Computer Science III, University of Bonn, D-53117 Bonn, Germany

‡Dept. of Computer Science, Carnegie Mellon University, Pittsburgh, P A 15213

Email: {fox,wolfram}@uran.cs.uni-bonn.de, thrun@cs.cmu.edu

IEEE Robotics & Automation Magazine 4.1 (1997): 23-33.

Figure 1. The robot RHINO, an RWI B21.

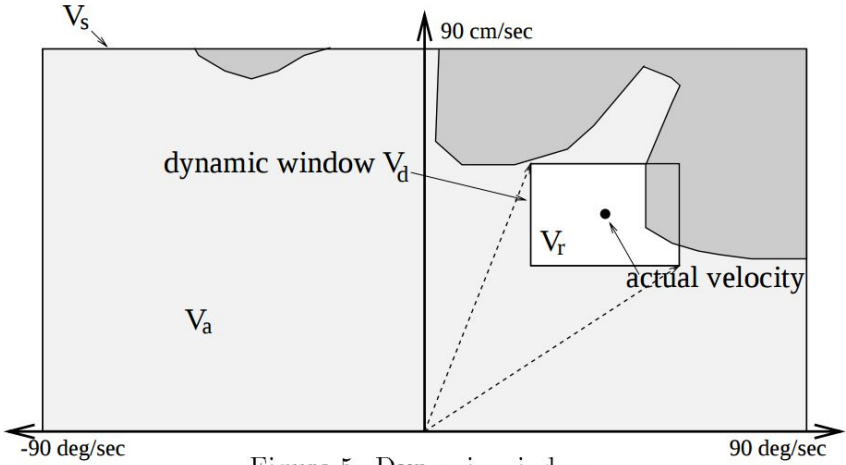
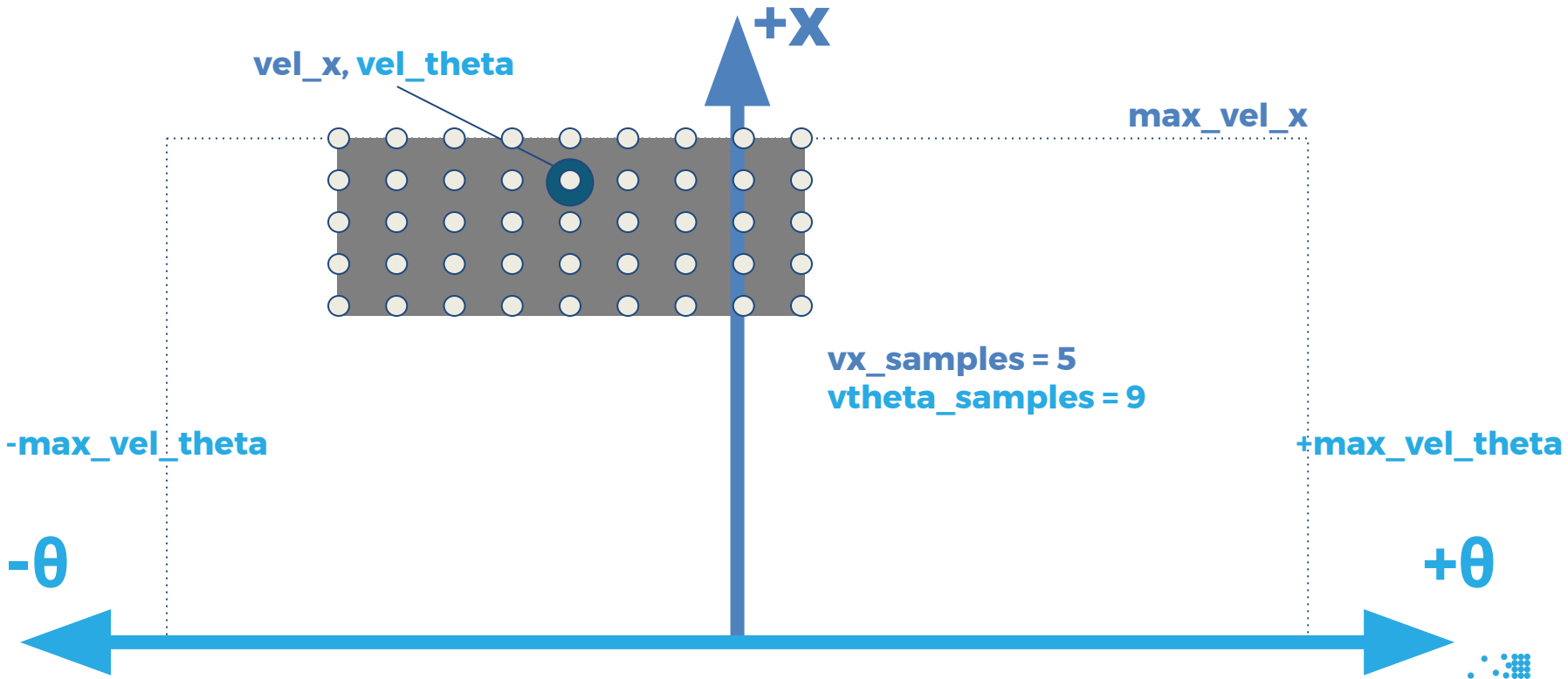


Figure 5. Dynamic window

$v_{min} = v_0 - a * t$

$v_{max} = v_0 + a * t$

What Command Velocities are Available?
Sampling Search



What is the best command velocity?

What command velocities are available?

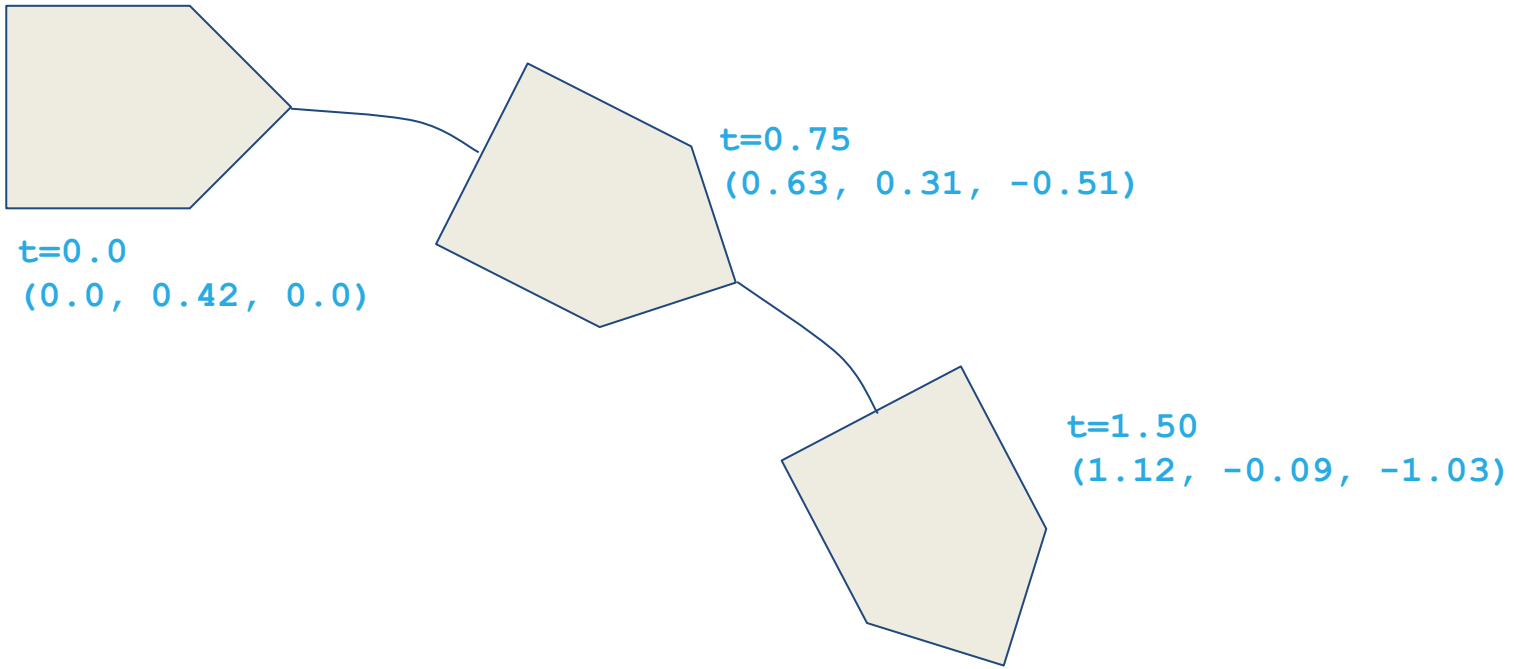
What would the commands do?

How do we define the "best" command?

What would the commands do?
Trajectory Generation

```
pose:    (0.0, 0.42, 0.0) /map
vel:     (0.0, 0.0, 0.0)
cmd_vel: (1.0, 0.0, -0.8)
```

Key Parameters:
sim_time (`t=1.5`)
discretization parameters



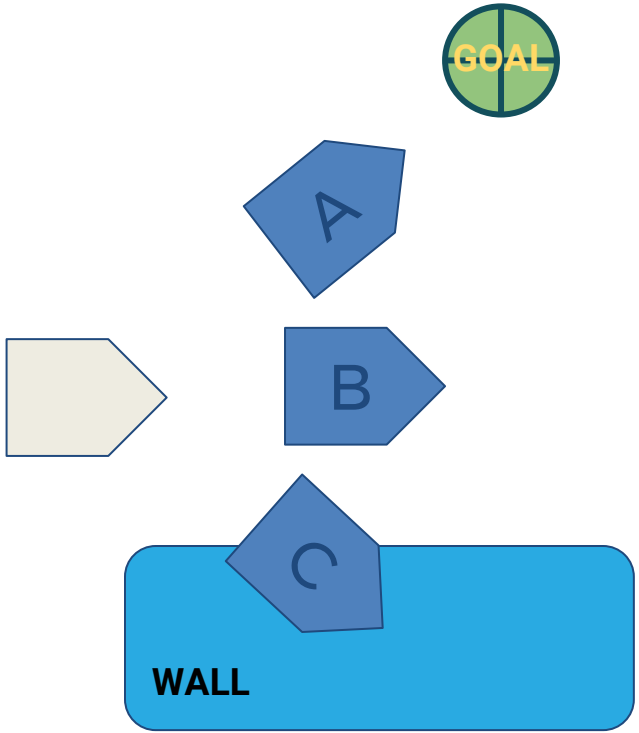
What is the best command velocity?

What command velocities are available?

What would the commands do?

How do we define the "best" command?

How do we define the "best" command?
Trajectory Scoring



- Moves towards goal
- Doesn't hit obstacles

A: 10.0
B: 40.0
C: -1.0

Score Rules:
Negative is Invalid
Lower is Better

How do we define the "best" command?
Critics and Scores

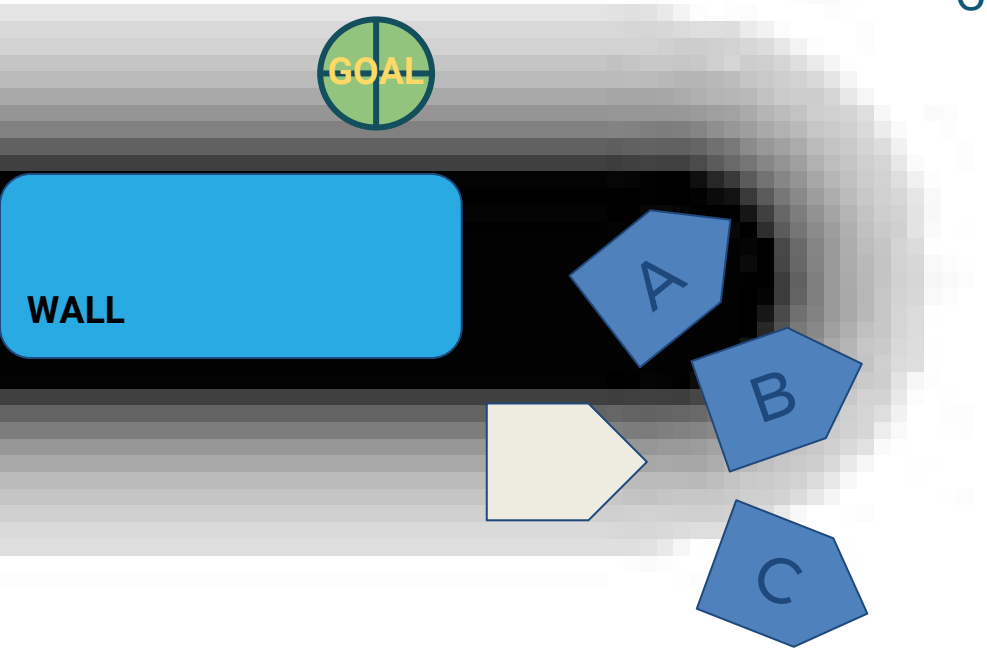
Critics produce scores

Final Score = Weighted Sum of Scores

For each critic:

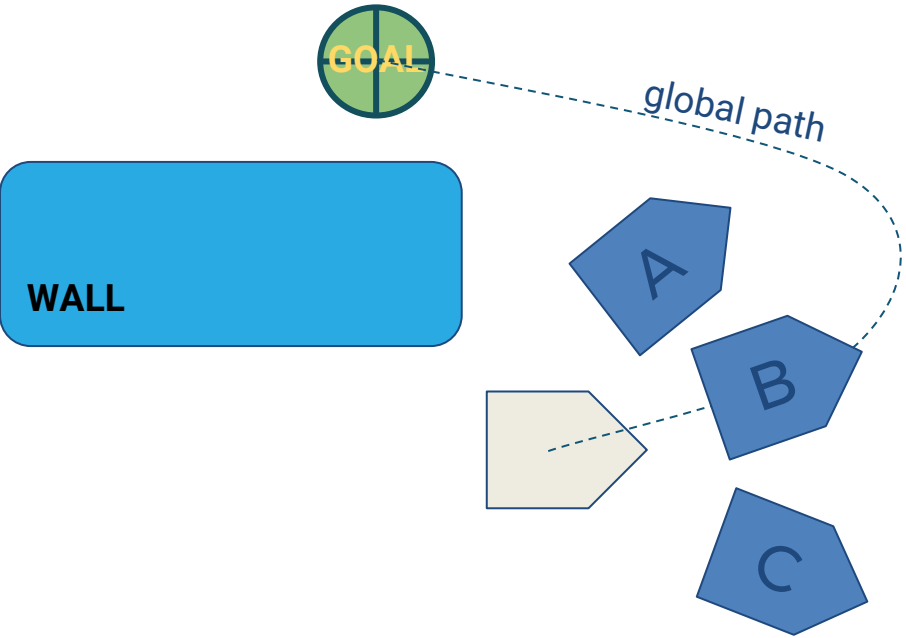
```
if critic.raw_score < 0: return critic.raw_score
score += critic.scale * critic.raw_score
```

How do we define the "best" command?
Example Critics



Cost on the Costmap (Obstacles)

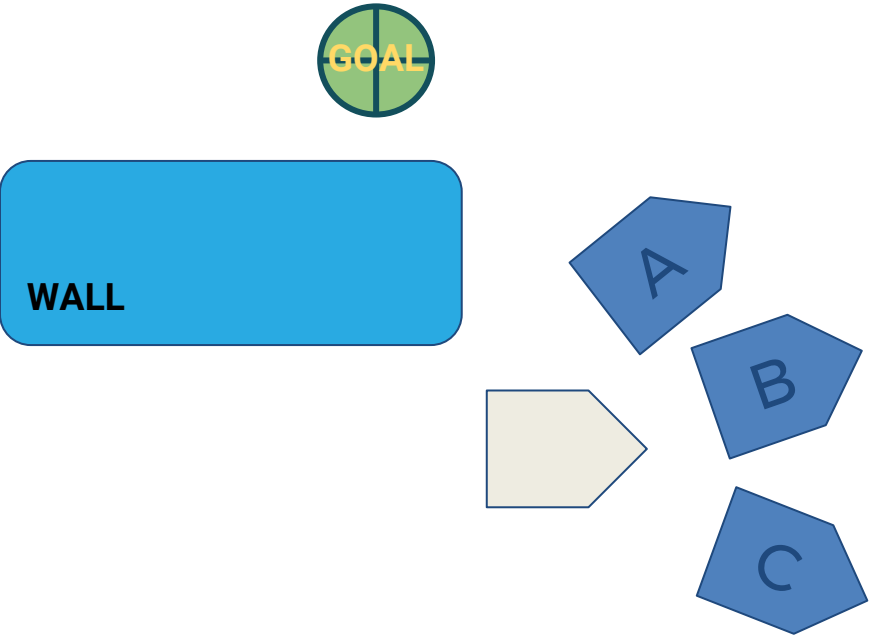
How do we define the "best" command?
Example Critics



Cost on the Costmap (Obstacles)

Distance to Global Path (PathDist)

How do we define the "best" command?
Example Critics

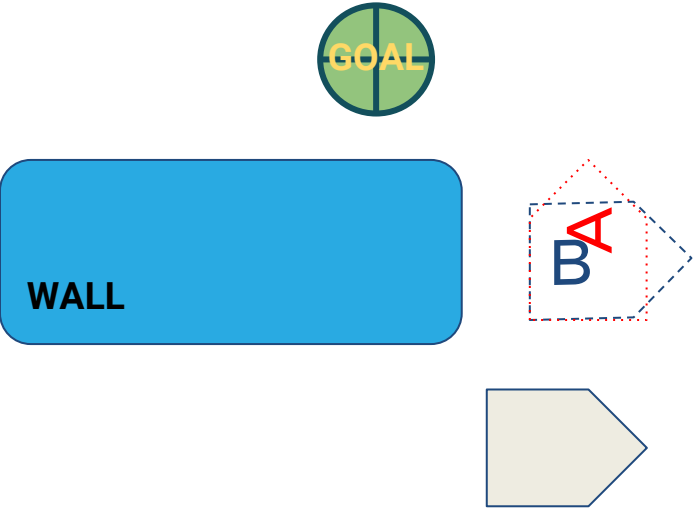


Cost on the Costmap (Obstacles)

Distance to Global Path (PathDist)

Distance to Goal (GoalDist)

How do we define the "best" command?
Example Critics



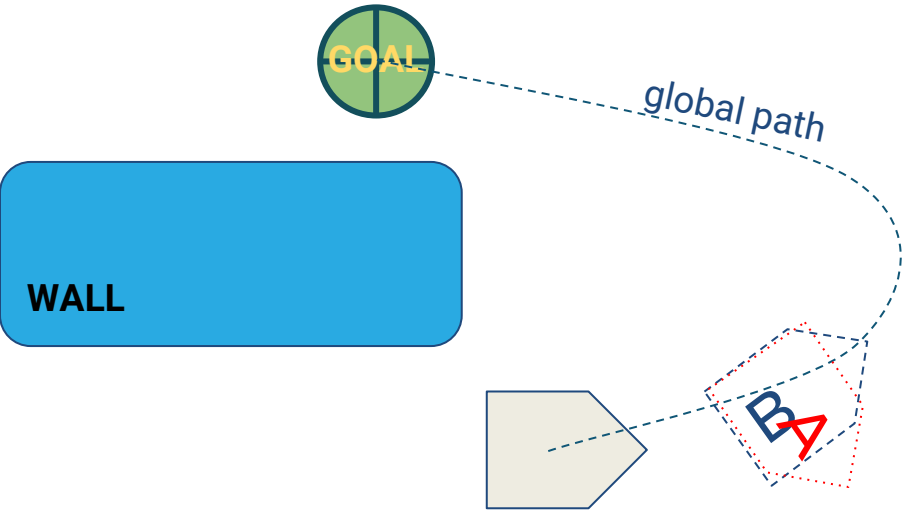
Cost on the Costmap (Obstacles)

Distance to Global Path (PathDist)

Distance to Goal (GoalDist)

Orientation To Goal (GoalAlign)

How do we define the "best" command?
Example Critics



Cost on the Costmap (Obstacles)

Distance to Global Path (PathDist)

Distance to Goal (GoalDist)

Orientation To Goal (GoalAlign)

Orientation To Path (PathAlign)

What is the best command velocity?

What command velocities are available?

Sampling search in dynamic window

What would the commands do?

Trajectory generation with kinematic model

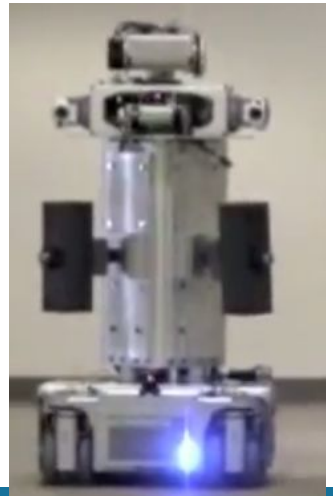
How do we define the "best" command?

Critics implementing heuristic scoring functions.

ROS Navigation Today:
Theory vs. Practice

Theory:

ROS Navigation is a universal black box that runs robot navigation for hundreds of robots.



Practice:

ROS Navigation was built nearly 9 years ago to control the PR2, and it working well for other platforms is almost incidental.

ROS Navigation Today
Current core local planners

base_local_planner - 2009 - Eitan Marder-Eppstein

Pre-turtle-names

dwa_local_planner - 2011/2012 - Eitan & Thibault Kruse

Diamondback

ROS Navigation Today
Sources of Data

Current Location
Current Velocity

Global Plan
Goal Location

Costmap2D

nav_core/base_local_planner.h

```
void initialize(string name, TransformListener* tf,
                Costmap2DROS* costmap_ros);
bool setPlan(vector<PoseStamped> plan);
bool computeVelocityCommands(Twist& cmd_vel);
bool isGoalReached();
```

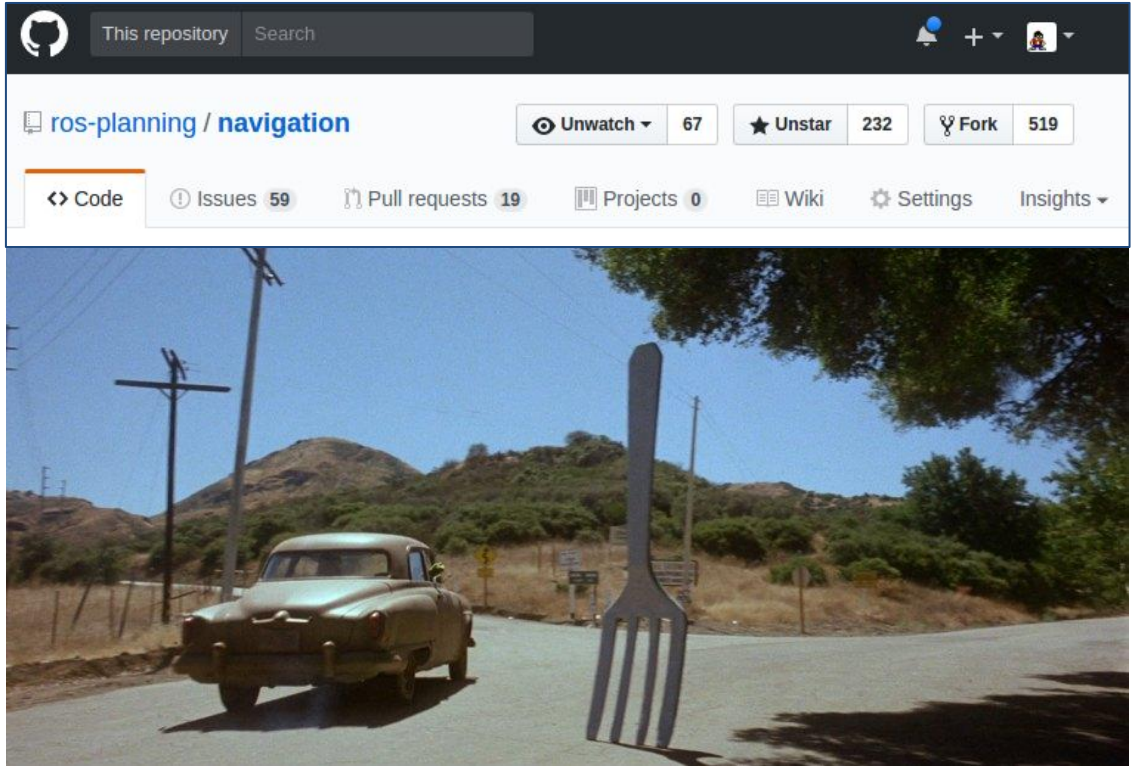
ROS Navigation Tomorrow
Why the fork not?

Testable

Customizable

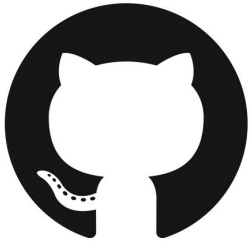
Backwards Compatible

Clean



The structure of the classes in the code should match
the conceptual pieces of the algorithm,
which should match
the ROS interfaces.

ROS Navigation Tomorrow
The Next Generation



github.com/locusrobotics/robot_navigation

ROS Navigation Tomorrow
nav_core2

```
void initialize(string name, TransformListener::Ptr tf,
                Costmap2DROS::Ptr costmap_ros);
void setPlan(Path2D path);
Twist2DStamped computeVelocityCommands(
            Pose2DStamped pose, Twist2D velocity)
bool isGoalReached(Pose2DStamped pose,
                   Twist2D velocity);
```

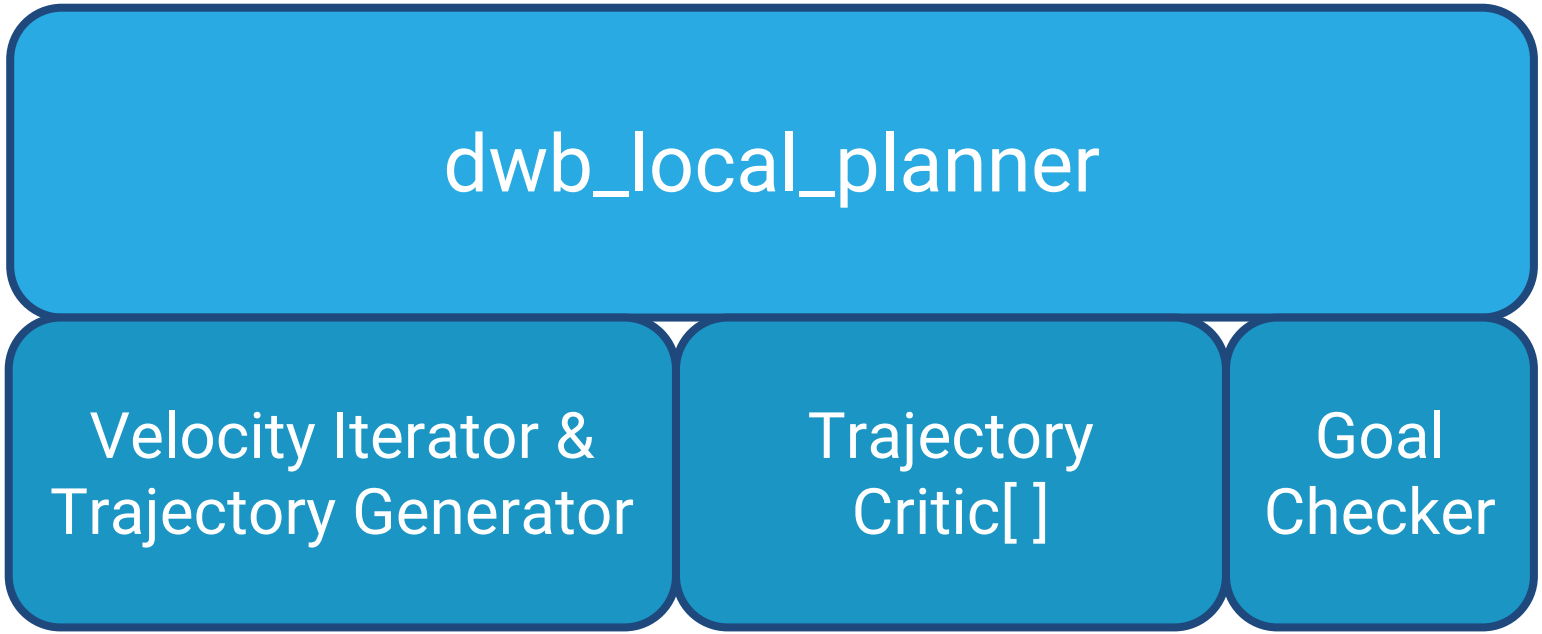
nav_2d_msgs

More explicit
computeVelocityCommands

Error handling
via Exceptions

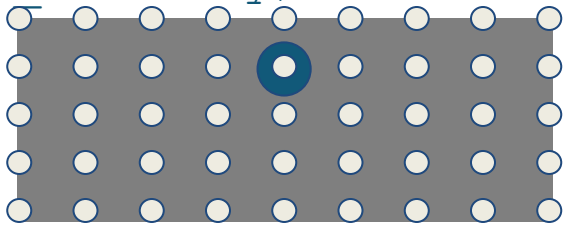
Parameterized
isGoalReached

ROS Navigation Tomorrow
dwb_local_planner

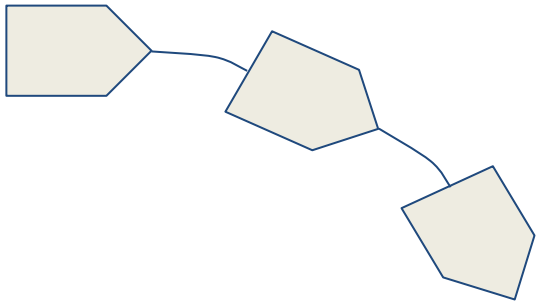


dwb_local_planner
TrajectoryGenerator

```
void startNewIteration(Twist2D current_velocity);
bool hasMoreTwists();
Twist2D nextTwist();
```

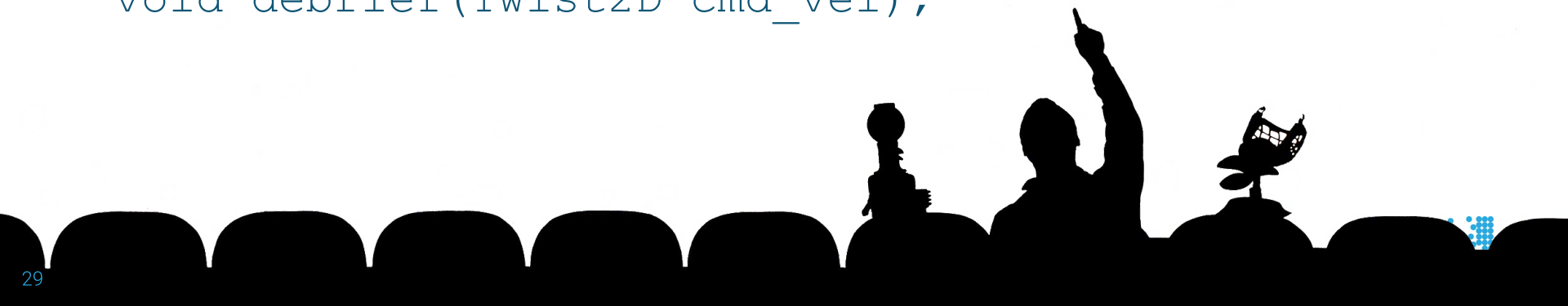


```
Trajectory2D generateTrajectory(Pose2D start_pose,
Twist2D start_vel, Twist2D cmd_vel);
```



dwb_local_planner
TrajectoryCritic

```
void onInit();
bool prepare(Pose2D pose, Twist2D vel,
             Pose2D goal, Path2D global_plan);
double scoreTrajectory(Trajectory2D traj);
double getScale();
void debrief(Twist2D cmd_vel);
```



dwb_local_planner
plugins. plugins everywhere.

CostmapLayer
TrajectoryGenerator
TrajectoryCritic
GoalChecker

dwb_local_planner
ROS Interface Example

[dwb_msgs/GenerateTrajectory.srv]:

```
geometry_msgs/Pose2D start_pose
nav_2d_msgs/Twist2D start_vel
nav_2d_msgs/Twist2D cmd_vel
---
dwb_msgs/Trajectory2D traj
  nav_2d_msgs/Twist2D velocity
  duration duration
  geometry_msgs/Pose2D[] poses
```

dwb_local_planner
Debug Local Plan

[dwb_msgs/LocalPlanEvaluation.msg]:

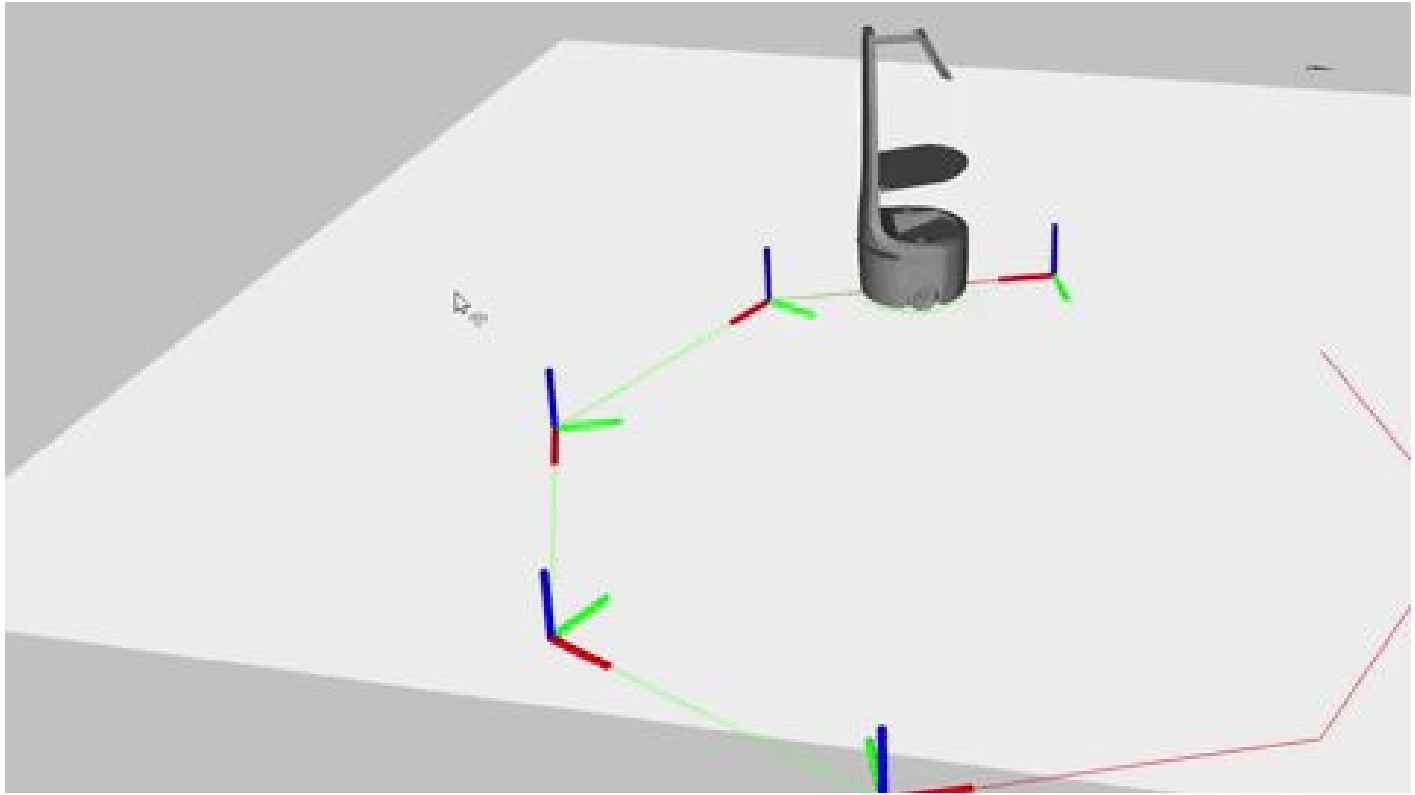
```
std_msgs/Header header
dwb_msgs/TrajectoryScore[] twists
  dwb_msgs/Trajectory2D traj
  dwb_msgs/CriticScore[] scores
    string name
    float32 raw_score, scale
  float32 total
uint16 best_index, worst_index
```

ROS Navigation Tomorrow
Backwards Compatibility

- Interface Compatibility
  - Use `nav_core2` local planners as a `nav_core` plugin using `nav_core_adapter/local_planner_adapter`

- Parameter Compatibility
  - By default, will load plugins needed to replicate `dwa_local_planner`.

DWB Example
Precise Plan Following



DWB Example
Drunken Path Planning

github.com/locusrobotics/robot_navigation

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LOCUS

LocusRobotics.com/careers