

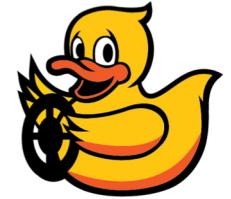


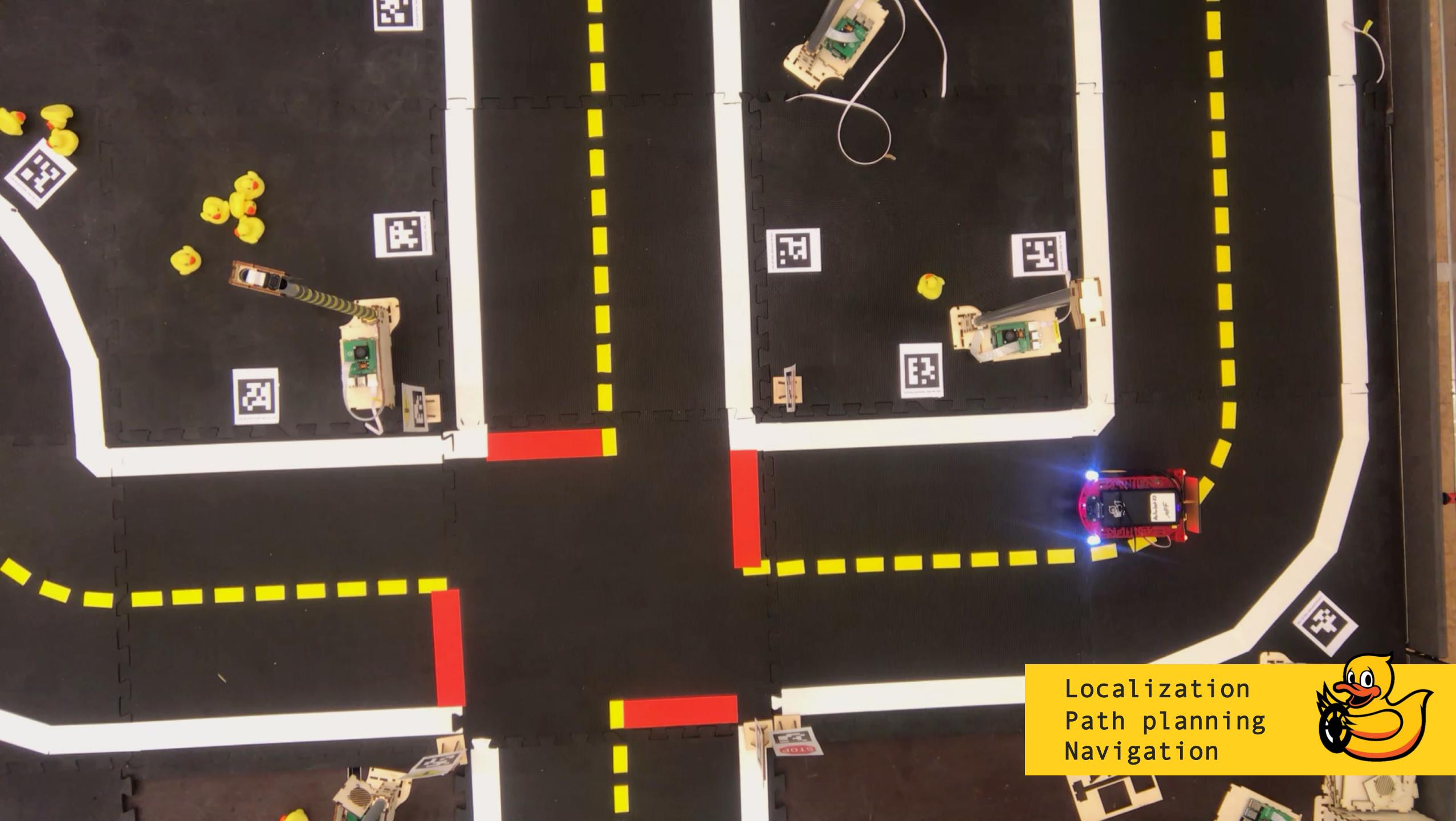
DUCKIETOWN

GLOBAL LOCALIZATION | GOTO - 1

J. BOGHAERT | M. HOSNER and G. ZARDINI

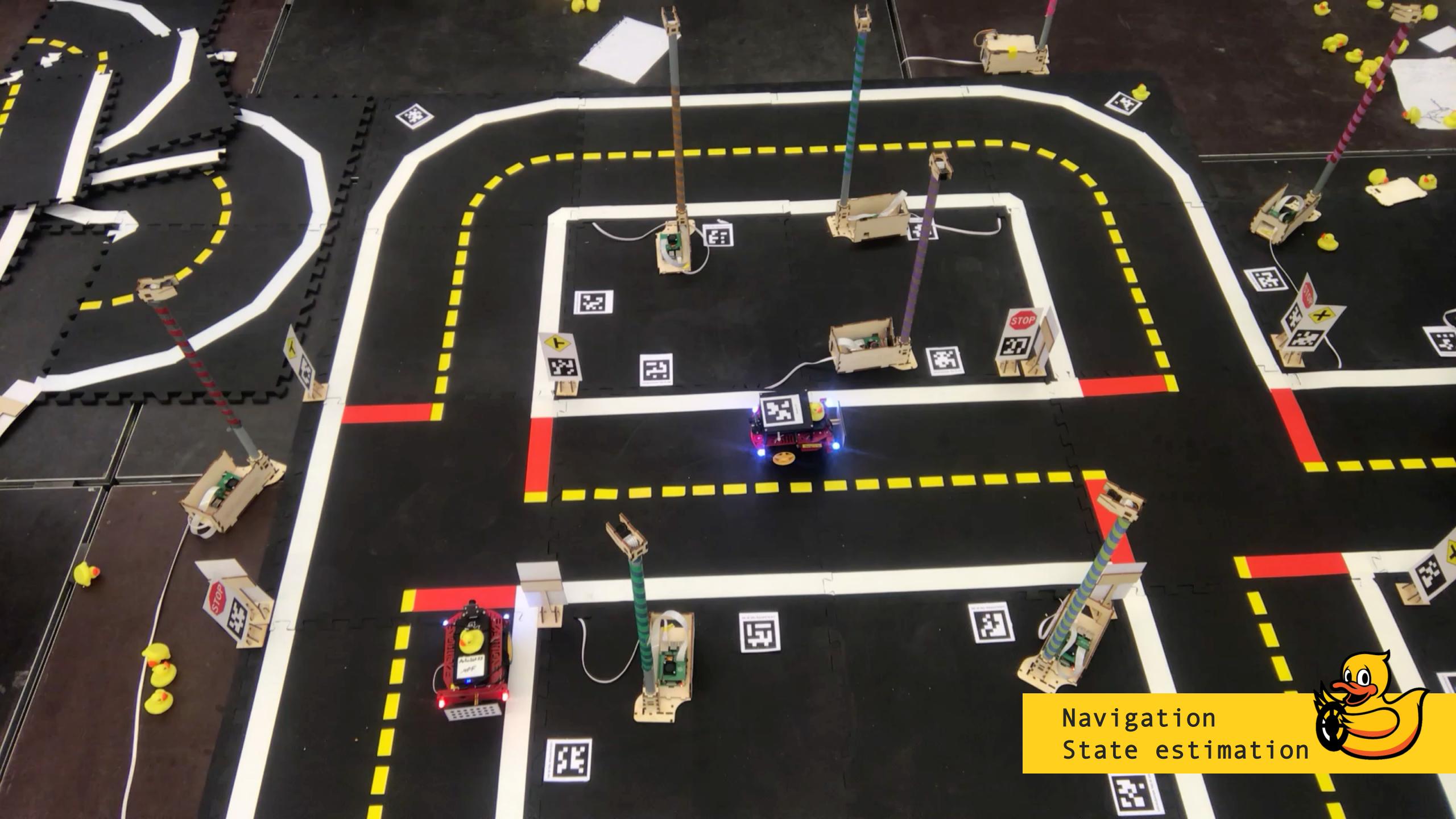
THE GRAND FINALE





Localization
Path planning
Navigation





Navigation
State estimation



THE MISSION

Objective: localize a Duckiebot within Duckietown, efficiently **navigate** between 2 randomly generated points, and **stop** with acceptable accuracy

Motivation:

- Private Duckieflow and commuting in Duckietown
- Representation of current navigation (single-fleet) systems
- Added functionality to dt-project

THE MISSION



Assumptions:

- Known (hardcoded) map
- Minimal disturbance (other AT's, lighting, obstacles)
- Acceptably functioning indefinite_navigation

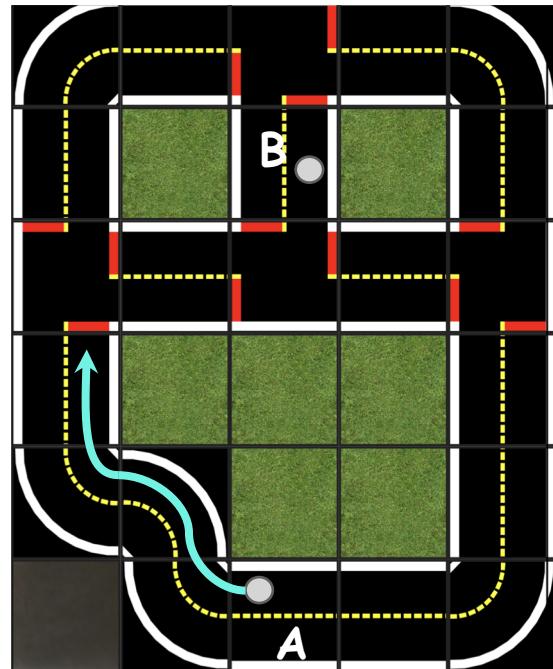
Restrictions:

- Limited AT density (no non-standard visual marks)
- Traffic rules (stay within lanes, stopping, driving direction, no U-turns)

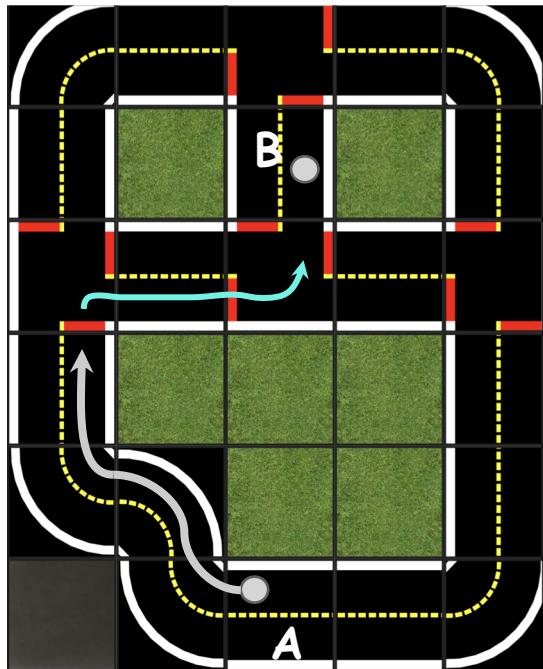
THE PROBLEM



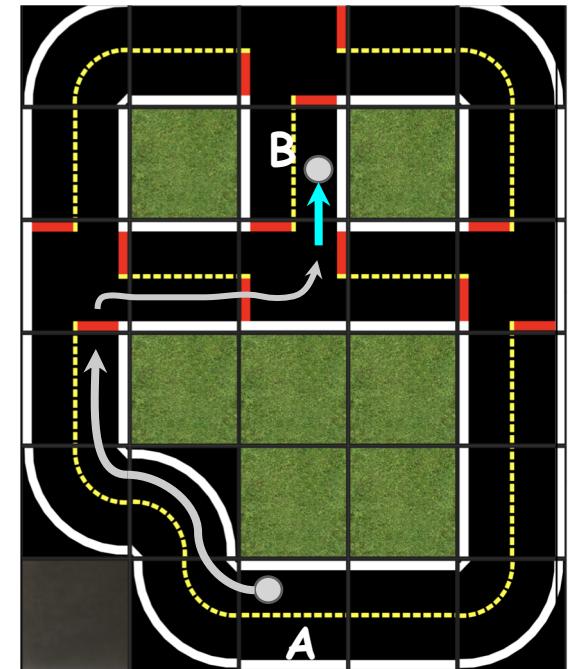
Task decomposition:



Localization



Navigation



Arrival

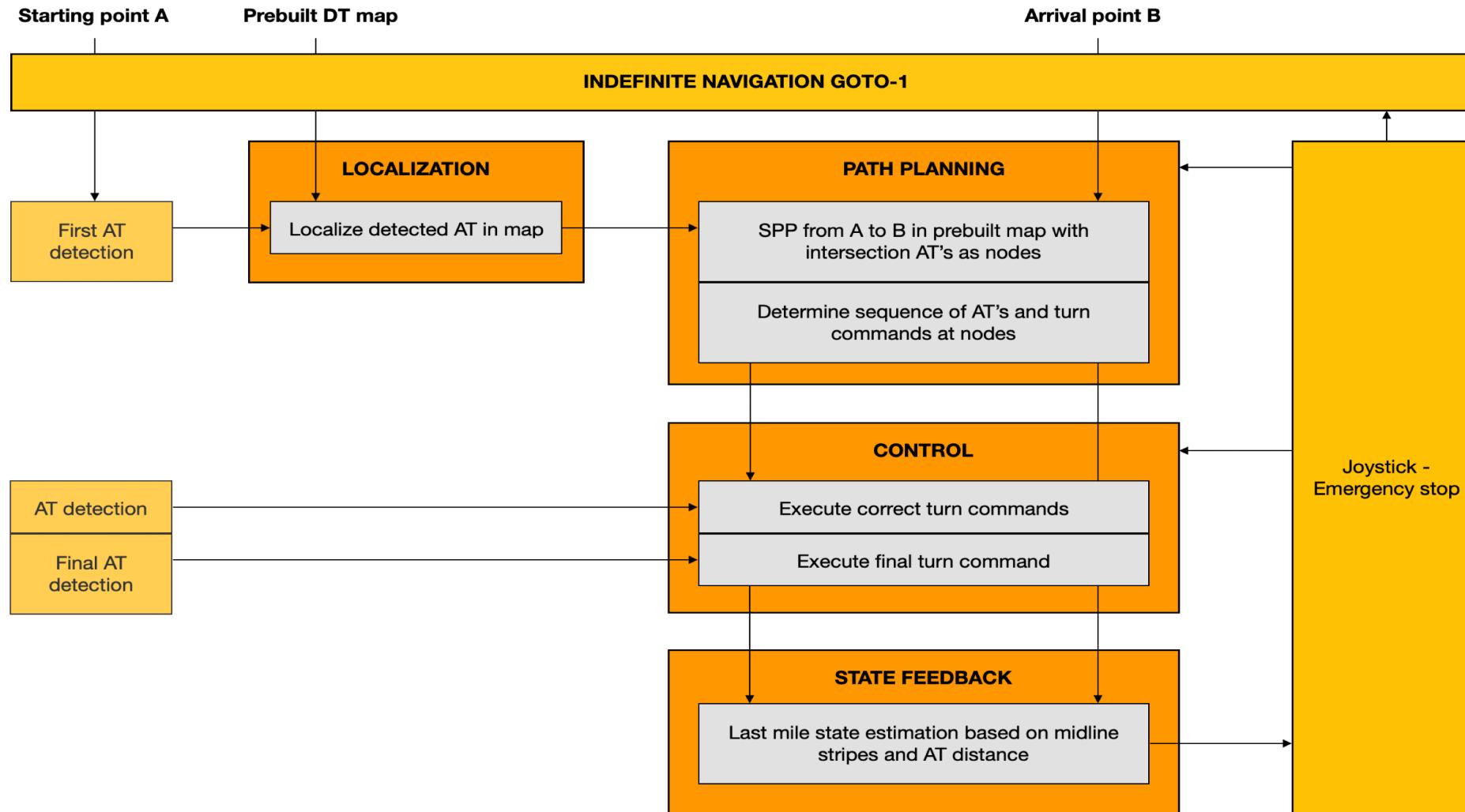
THE PROBLEM



Performance metrics:

- Localize within a given Duckietown configuration
- Navigate as efficiently as possible
- Stop with highest level of accuracy possible

THE PIPELINE



THE PIPELINE



Inputs:

- goal_input: AT defining final lane
- goal_distance: distance between last intersection and arrival point B
- Prebuilt Duckietown map (next)
- Tuning values

Framework: indefinite_navigation

- AT detection
- Intersection navigation
- Lane following



THE PACKAGE

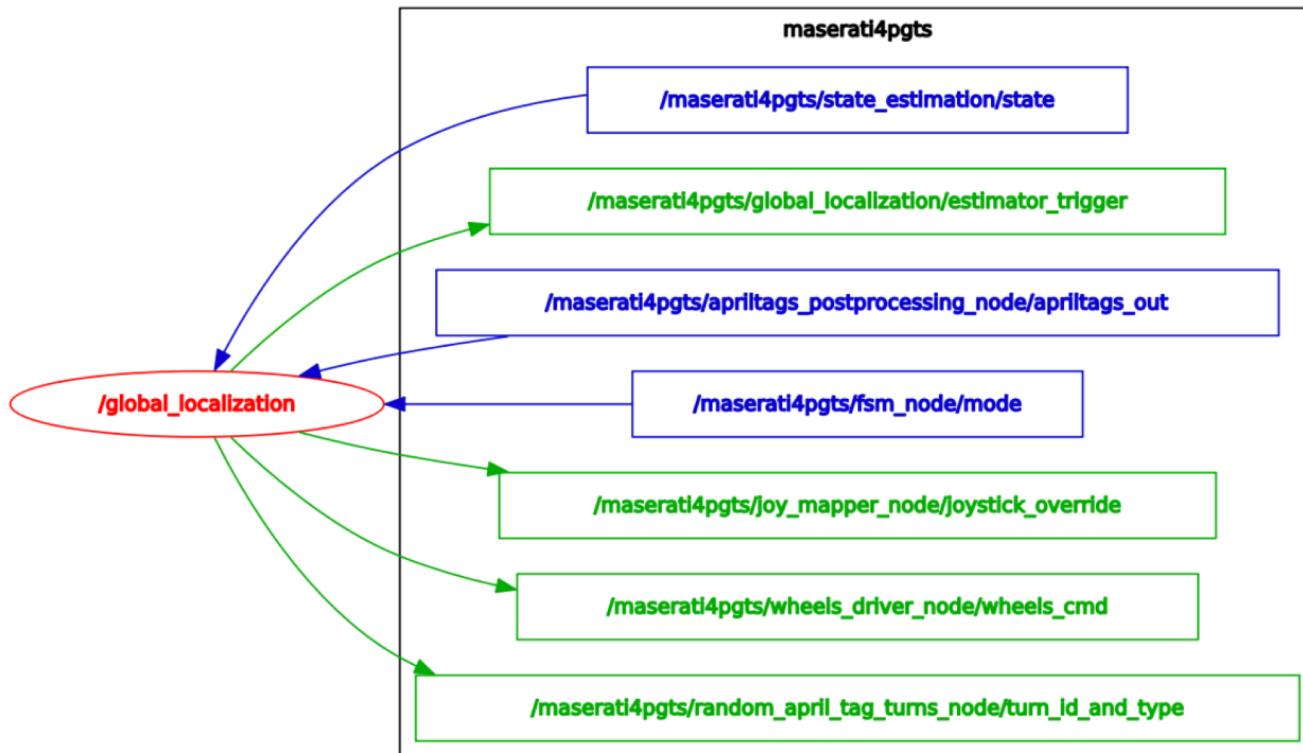
#global_localization_node: Reads out and checks AT to localize using path_planning class, subsequently navigate in Duckietown, and stop upon arrival with feedback from state_estimation node

- Input: Detected AT / goal_input / goal_distance / state feedback
- Output: Turn command / safety overrides / state estimation trigger

THE PACKAGE



ROS graph:



THE PACKAGE



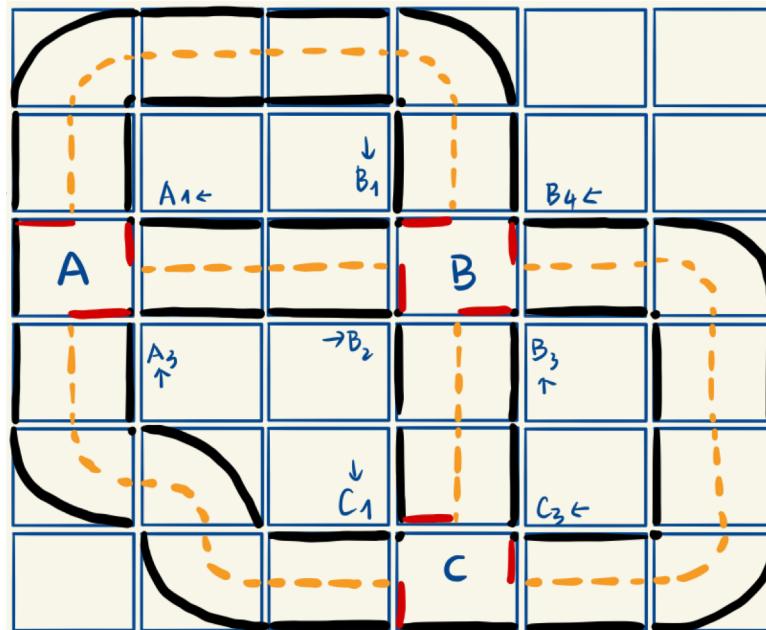
`#path_planning_class`: based on Dijkstra algorithm, calculates shortest path and returns sequence of nodes for navigation (`global_localization`)

- Input: Detected AT
- Output: Shortest path as sequence of AT's and turn commands

THE PACKAGE



Dijkstra graph: hardcoded graph with cost ~distance and number of turns



Duckietown configuration

AT	8	15	199	231	63	66	59	9	61	11
8	∞	∞	∞	∞	3.7	∞	2.9	∞	∞	∞
15	∞	2.9	2.7	∞						
199	∞	6.8	∞	6.7						
231	∞	∞	∞	∞	8.4	7.5	∞	∞	∞	∞
63	∞	7.3	8.0							
66	∞	2.9	3.0	3.7	∞	∞	∞	∞	∞	∞
59	6.7	6.8	7.5	∞						
9	∞	∞	∞	∞	∞	6.4	6.5	∞	∞	∞
61	8.4	9.1	∞	8.3	∞	∞	∞	∞	∞	∞
11	3.7	∞	2.9	3.0	∞	∞	∞	∞	∞	∞

Cost matrix

AT	8	15	199	231	63	66	59	9	61	11
8	∞	∞	∞	∞	0	∞	2	∞	∞	∞
15	∞	2	0	∞						
199	∞	1	∞	0						
231	∞	∞	∞	∞	1	0	∞	∞	∞	∞
63	∞	1	2							
66	∞	2	1	0	∞	∞	∞	∞	∞	∞
59	2	1	0	∞						
9	∞	∞	∞	∞	2	1	∞	∞	∞	∞
61	1	0	∞	2	∞	∞	∞	∞	∞	∞
11	0	∞	2	1	∞	∞	∞	∞	∞	∞

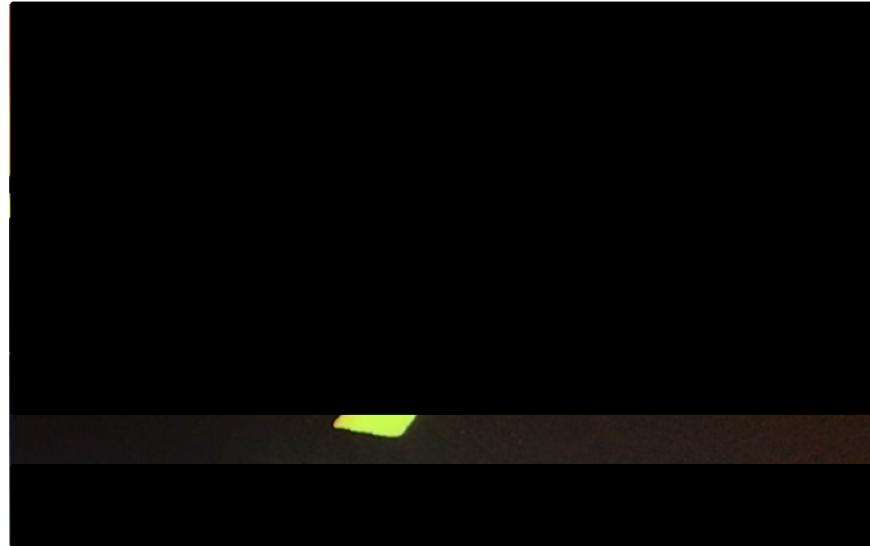
Allowable turn commands

THE PACKAGE



#state_estimation_node: Once active, counts the number of midline stripes converted from goal_distance (in cm)

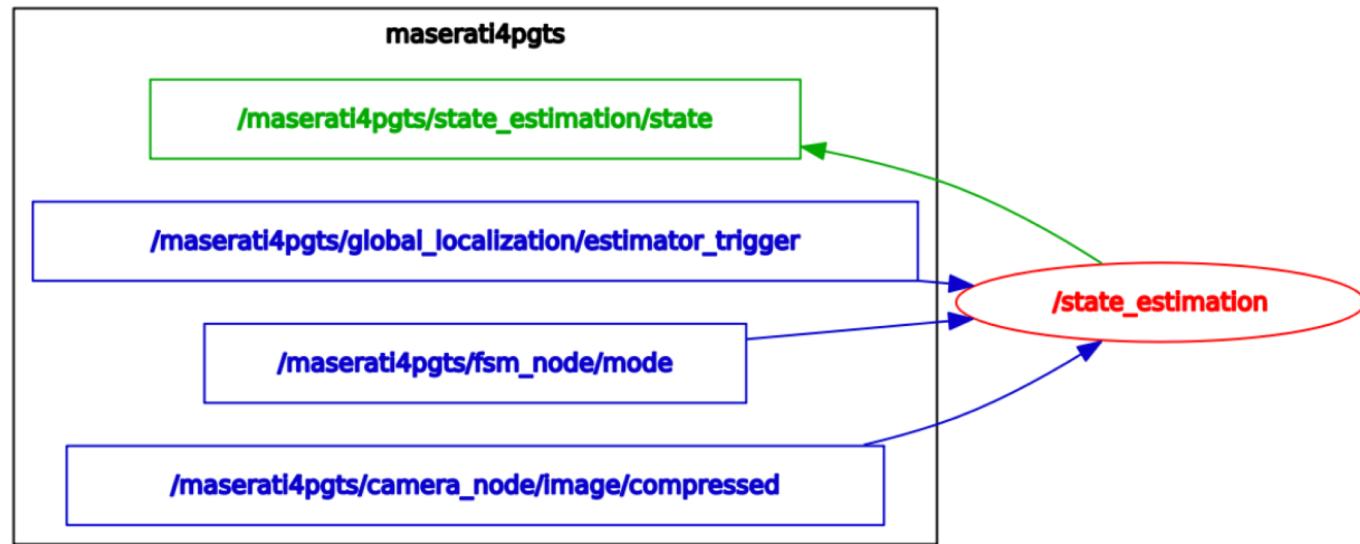
- Input: Camera images / state estimation trigger
- Output: State feedback





THE PACKAGE

ROS graph:

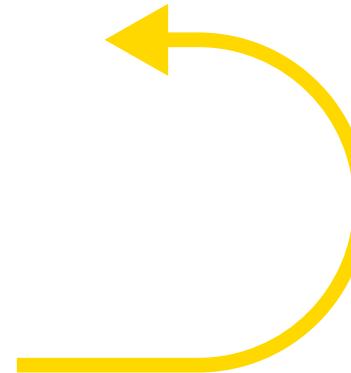


TESTING & BUILDING



Bottom-up approach: modular/incremental and based on logging services

- AT readings
 - Dijkstra algorithm (SPP)
 - Implementation in `indefinite_navigation`
 - Turn command execution
-
- Running pipeline until last mile
 - Last mile and state estimation



Debug
Iterate
Stabilize

TESTING & BUILDING



Wrong:

```
ROS_MASTER_URI=http://192.168.1.116:11311/
process[localization_node_test-1]: started with pid [66]
[INFO] [1574504713.293344]: [/localization_node_test] Initializing...
[INFO] [1574504713.322009]: [localization_node_test] Initializing.
[INFO] [1574504713.406805]: [localization_node_test] Initialized.
[INFO] [1574504741.588358]: AT successfully detected, localized duckiebot in map ... proceeding to path planning
[INFO] [1574504741.595054]: Starting path planning
Shortest distance is 7.5
And the path is [66, 231]
And the sequence of wheel cmd is[0]
... waiting for confirmation from path_planning module ...
[INFO] [1574504741.600419]: Confirmation: Path successfully generated !
[INFO] [1574504741.607205]: Turn left
[INFO] [1574504742.483137]: AT successfully detected, localized duckiebot in map ... proceeding to path planning
[INFO] [1574504742.485833]: Starting path planning
Path not reachable
[ERROR] [1574504742.495346]: bad callback: <bound method LocalizationNode.callback of <__main__.LocalizationNode object at 0x75a877b0>>
Traceback (most recent call last):
  File "/opt/ros/kinetic/lib/python2.7/dist-packages/rospy/topics.py", line 750, in _invoke_callback
    cb(msg)
  File "/code/catkin_ws/src/dt-gotoi-test/packages/my_package/src/localization_node_test.py", line 80, in callback
    path, cmd = self.path_planning(trigger, starting_point)
  File "/code/catkin_ws/src/dt-gotoi-test/packages/my_package/src/localization_node_test.py", line 160, in path_planning
    path, cmd = self.pp.dijkstra(start, goal)
  File "/code/catkin_ws/src/dt-gotoi-test/packages/my_package/src/path_planning_class.py", line 105, in dijkstra
    if shortest_distance[goal] != infinity:
KeyError: 231

[INFO] [1574504743.312651]: AT successfully detected, localized duckiebot in map ... proceeding to path planning
[INFO] [1574504743.316008]: Starting path planning
Path not reachable
[ERROR] [1574504743.321046]: bad callback: <bound method LocalizationNode.callback of <__main__.LocalizationNode object at 0x75a877b0>>
Traceback (most recent call last):
  File "/opt/ros/kinetic/lib/python2.7/dist-packages/rospy/topics.py", line 750, in _invoke_callback
    cb(msg)
  File "/code/catkin_ws/src/dt-gotoi-test/packages/my_package/src/localization_node_test.py", line 80, in callback
    path, cmd = self.path_planning(trigger, starting_point)
  File "/code/catkin_ws/src/dt-gotoi-test/packages/my_package/src/localization_node_test.py", line 160, in path_planning
    path, cmd = self.pp.dijkstra(start, goal)
  File "/code/catkin_ws/src/dt-gotoi-test/packages/my_package/src/path_planning_class.py", line 105, in dijkstra
    if shortest_distance[goal] != infinity:
KeyError: 231
```

TESTING & BUILDING



Correct:

```
SUMMARY
-----
PARAMETERS
  * /global_localization/goal_distance: 40
  * /global_localization/goal_input: 199
  * /global_localization/inter_nav_ff_left: 0.4
  * /global_localization/inter_nav_ff_right: -0.6
  * /global_localization/inter_nav_time_left_turn: 3.2
  * /global_localization/inter_nav_time_right_turn: 1.5
  * /global_localization/se_switch: True
  * /rosdistro: kinetic
  * /rosversion: 1.12.14
  * /state_estimation/new_v_bar: 0.15

NODES
/
  global_localization (my_package/global_localization.py)
  state_estimation (my_package/state_estimation.py)

ROS_MASTER_URI=http://192.168.1.116:11311

process[global_localization-1]: started with pid [433]
process[state_estimation-2]: started with pid [434]
[INFO] [1576581329.897496]: [/global_localization] Initializing...
[INFO] [1576581329.947050]: [global_localization] Initializing.
[INFO] [1576581331.332611]: [/state_estimation] Initializing...
[INFO] [1576581331.410792]: [state_estimation] Initializing.
[INFO] [1576581331.849457]: [global_localization] Initialized.
[INFO] [1576581332.166129]: [state_estimation] Initialized.
[INFO] [1576581345.786706]: Incoming AT, starting callback ...
[INFO] [1576581345.789999]: Proceed: #0
[INFO] [1576581345.798044]: Starting detection if AT is readable
[INFO] [1576581345.806681]: Readable AT [59] successfully detected, proceeding to localization/execution ...
[INFO] [1576581345.813221]: Starting localization module ...
[INFO] [1576581345.816789]: Starting path planning
[INFO] [1576581345.819898]: Starting path planning, using Dijkstra ...
[INFO] [1576581345.824235]: Shortest distance is 13.3
[INFO] [1576581345.826278]: And the path is [59, 9, 199]
[INFO] [1576581345.829370]: And the sequence of turn cmds is [1, 1]
[INFO] [1576581345.835812]: Path successfully generated with starting point AT 59
[INFO] [1576581345.840490]: Go straight
[INFO] [1576581345.845625]: Published turn_cmd
[INFO] [1576581345.852402]: Updated remaining path and cmd
```

Input parameters

Tuning parameters

Localization /
Path planning

TESTING & BUILDING



Correct:

```
[INFO] [1576581752.862599]: self.new_AT = True with id [9]
[INFO] [1576581752.873094]: Starting execution module ...
[INFO] [1576581752.875586]: Go straight
[INFO] [1576581752.890682]: Published turn_cmd
[INFO] [1576581752.896770]: Updated remaining path and cmd
[INFO] [1576581752.902528]: Continue to StateEstimator
[INFO] [1576581757.933146]: Ignore AT during state_estimation
[INFO] [1576581757.935430]: Trigger = True
[INFO] [1576581757.935876]: Ignore AT during state_estimation
[INFO] [1576581757.939185]: Ignore AT during state_estimation
[INFO] [1576581757.949780]: Ignore AT during state_estimation
[INFO] [1576581757.953730]: Ignore AT during state_estimation
```

Navigation

```
[INFO] [1576581781.263240]: Preparing image
[INFO] [1576581781.329418]: Encountered fully black image from mask
[INFO] [1576581781.332958]: Reached [-- 6 --] stripes, encountering ...
[INFO] [1576581781.342249]: Done #3
[INFO] [1576581781.343980]: We reached now 6 stripes, out of 7
[INFO] [1576581781.450524]: Preparing image
[INFO] [1576581781.498275]: Encountered fully black image from mask
[INFO] [1576581781.501402]: Check this out - unidentified behaviour
[INFO] [1576581781.506287]: Done #3
[INFO] [1576581781.623990]: Preparing image
[INFO] [1576581781.689931]: Done #3
[INFO] [1576581781.844405]: Preparing image
[INFO] [1576581781.890089]: Encountered fully black image from mask
[INFO] [1576581781.899599]: Reached [-- 7 --] stripes, encountering ...
[INFO] [1576581781.913294]: We reached now 7 stripes, out of 7
```

State Estimation

```
[INFO] [1576583625.255655]: Reached [-- 7 --] stripes, encountering ...
[INFO] [1576583625.265062]: Done #3
[INFO] [1576583625.269452]: We reached now 7 stripes, out of 7
[INFO] [1576583625.277118]: Published stop_cmd
[INFO] [1576583625.286344]: You have reached your destination
[INFO] [1576583625.292370]: Thank you for driving with maserati4pgts in Duckietown, enjoy your stay!
[INFO] [1576583625.292592]: Trigger = False
[INFO] [1576583625.300642]: override = True
[INFO] [1576583625.306705]: Published stop_cmd
[INFO] [1576583625.311887]: [global_localization] Shutting down.
[INFO] [1576583625.315934]: [global_localization] Shutdown.
```

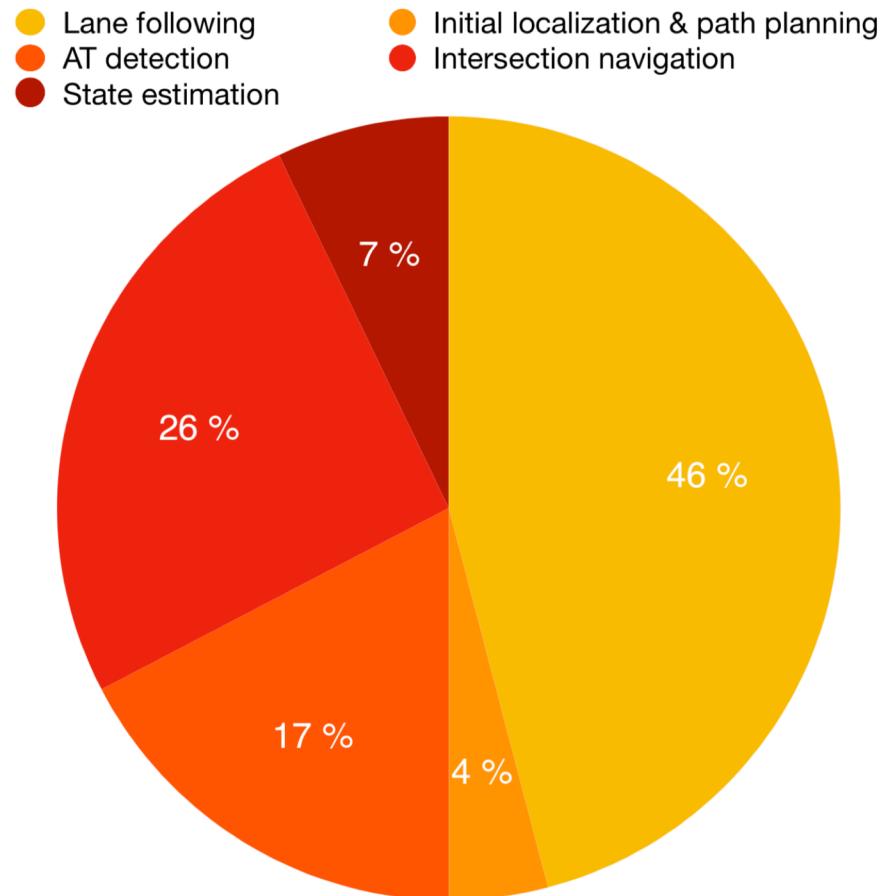
Goodbye

EVALUATION



Time allocation:

- start = id 59
- goal = id 199
- goal_distance = 40 cm



EVALUATION



Accuracy:

- tile level accuracy
- sub-tile level accuracy

Precision:

- Unstable

EVALUATION



Conclusion:

- Submodules/algorithms work
 - Localizes (given correct AT)
 - Finds optimal path (efficiency)
 - Navigates and executes commands correctly
 - Enters in state estimation
- Dynamic (modular and run-time changes possible)
- Finetuning works on a 1-on-1 basis
- Implementation in suboptimal framework
- Intervention needed (not demo viable)

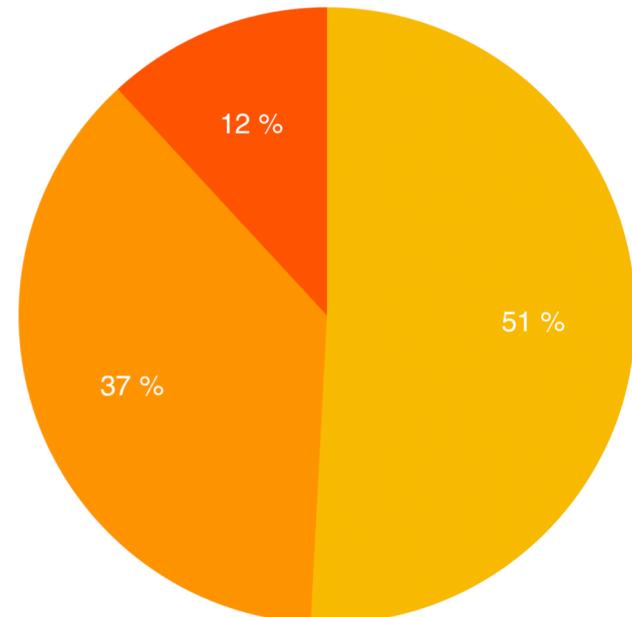
IMPROVEMENTS



AT detection:

- Upon arrival at intersection
- Highly volatile (frame rate, velocity, pose,)
- Improve by using pose in apriltag_detection
- Visually categorize AT's with correct pose:
 - Left/red (stop AT)
 - Right/yellow (intersection AT)

● Correct (readable) ● Incorrect (readable) ● Unreadable

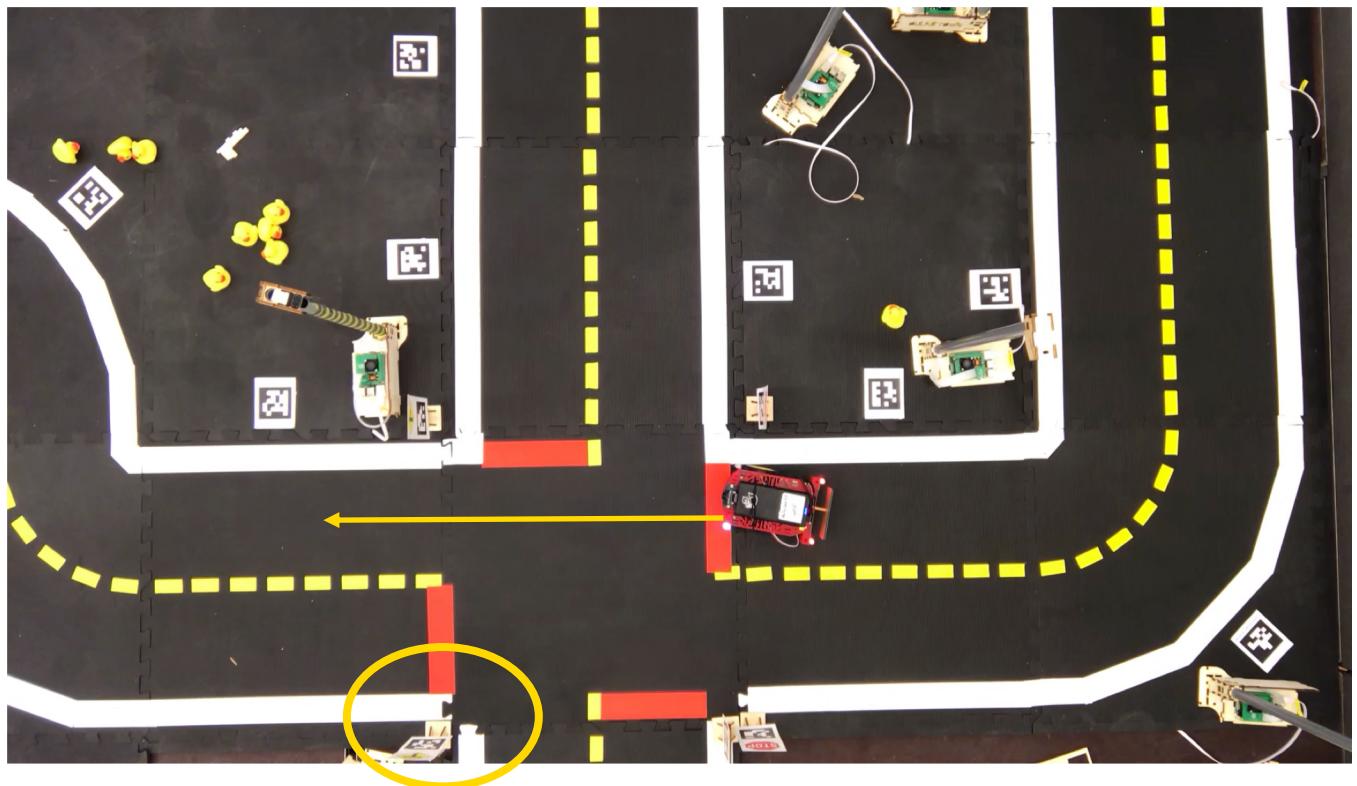


IMPROVEMENTS



AT detection:

- Highly volatile (frame rate, velocity, pose,)

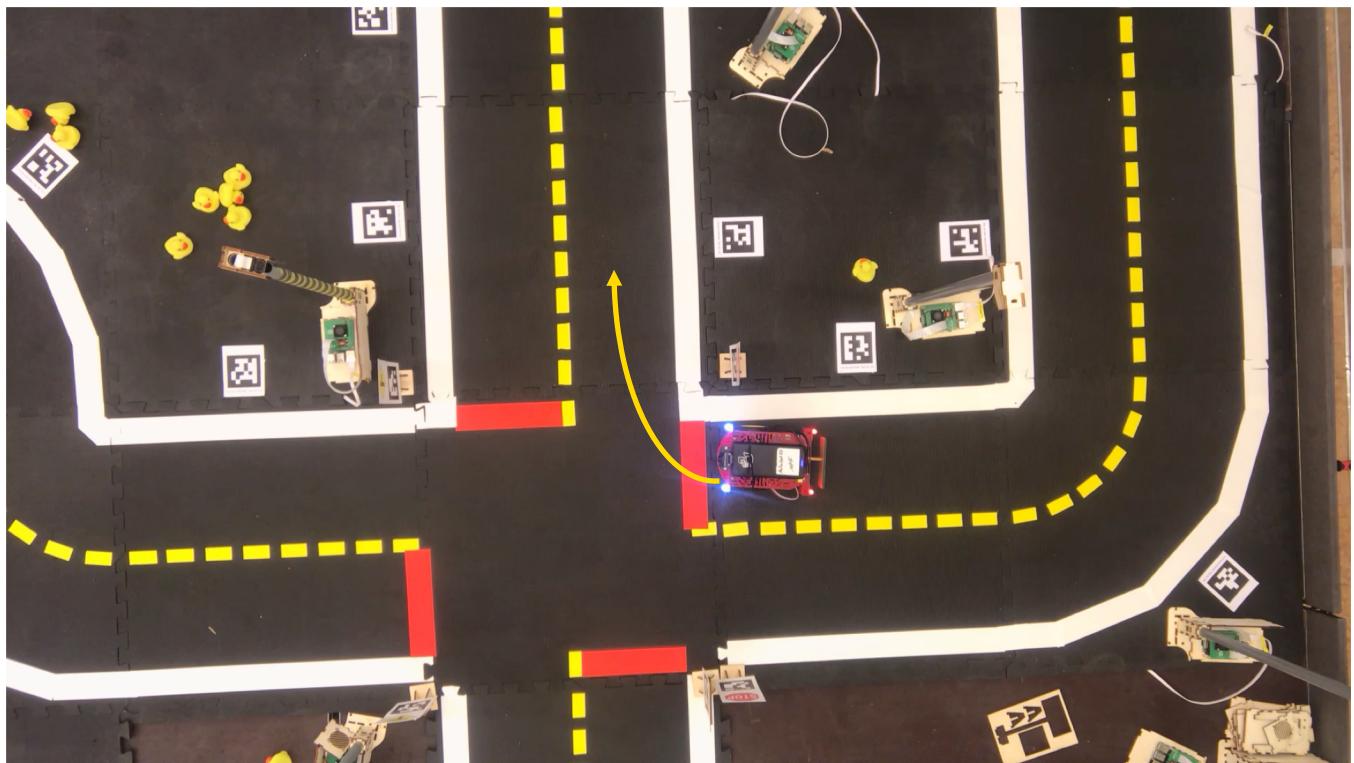


IMPROVEMENTS



Intersection navigation:

- Highly volatile (velocity, pose, gain, feedfwd commands)
- Improve in **separate project**



IMPROVEMENTS



State estimation:

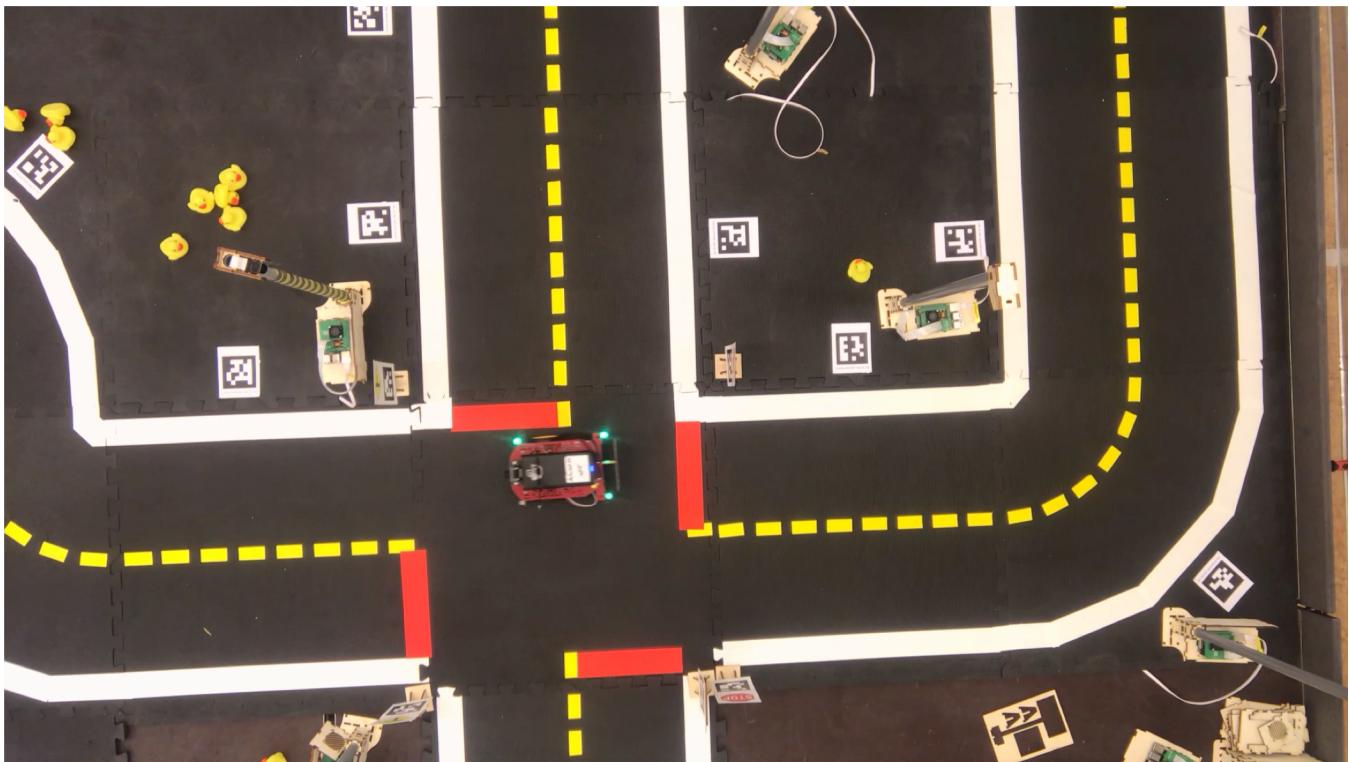
- Strong potential (yet to be finetuned for longer distances)
- Too relying on lane_following - issues with lowered velocity
- Resolve by allowing for a feedforward timer option
(switch already implemented)

IMPROVEMENTS



Lane following:

- Highly volatile (velocity, pose, gain, trim)
- Improve in **separate project**



IMPROVEMENTS



So ultimately: merge with newest frameworks, improve AT detection and state estimation nodes

ANY QUESTIONS



! ?





DUCKIETOWN

GLOBAL LOCALIZATION | GOTO - 1

THERE AND BACK AGAIN | A TALE OF DEATH AND REBIRTH



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

