sim_traj_planning

October 4, 2020

In [8]:
```
# The autoreload extension will automatically load in new code as you edit files,
# so you don't need to restart the kernel every time
%load_ext autoreload
%autoreload 2

import numpy as np
from P1_astar import DetOccupancyGrid2D, AStar
from P2_rrt import *
from P3_traj_planning import compute_smoothed_traj, modify_traj_with_limits, Switching
import scipy.interpolate
import matplotlib.pyplot as plt
from HW1.P1_differential_flatness import *
from HW1.P2_pose_stabilization import *
from HW1.P3_trajectory_tracking import *
from utils import generate_planning_problem

plt.rcParams['figure.figsize'] = [14, 14] # Change default figure size
```

```
The autoreload extension is already loaded. To reload it, use:
  %reload_ext autoreload
```

0.0.1 Generate workspace, start and goal positions

In [29]:
```
width = 100
height = 100
num_obs = 25
min_size = 5
max_size = 30

occupancy, x_init, x_goal = generate_planning_problem(width, height, num_obs, min_size
```

0.0.2 Solve A* planning problem

In [30]:
```
astar = AStar((0, 0), (width, height), x_init, x_goal, occupancy)
if not astar.solve():
    print "No path found"
```

0.1 Smooth Trajectory Generation

0.1.1 Trajectory parameters

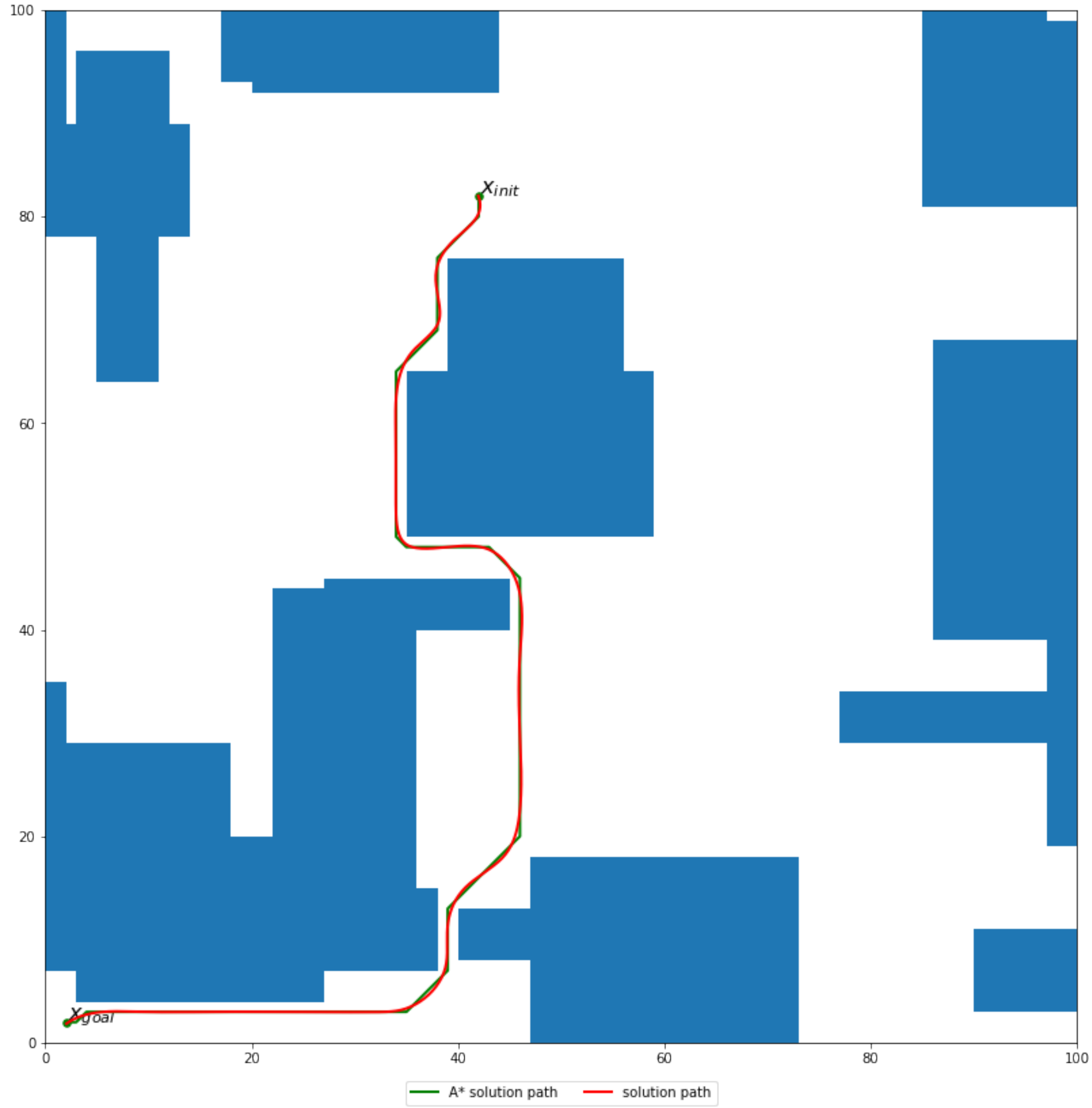
(Try changing these and see what happens)

```
In [31]: V_des = 0.3  # Nominal velocity
         alpha = 3.0   # Smoothness parameter
         dt = 0.05
```

0.1.2 Generate smoothed trajectory

```
In [32]: traj_smoothed, t_smoothed = compute_smoothed_traj(astar.path, V_des, alpha, dt)

         fig = plt.figure()
         astar.plot_path(fig.number)
         def plot_traj_smoothed(traj_smoothed):
             plt.plot(traj_smoothed[:,0], traj_smoothed[:,1], color="red", linewidth=2, label='
         plot_traj_smoothed(traj_smoothed)
         plt.legend(loc='upper center', bbox_to_anchor=(0.5, -0.03), fancybox=True, ncol=3)
         plt.show()
```



0.2 Control-Feasible Trajectory Generation and Tracking

0.2.1 Robot control limits

```
In [33]: V_max = 0.5 # max speed
         om_max = 1 # max rotational speed
```

0.2.2 Tracking control gains

Tune these as needed to improve tracking performance.

```
In [34]: kpx = 2
         kpy = 2
```

```
kdx = 2
kdy = 2
```

0.2.3 Generate control-feasible trajectory

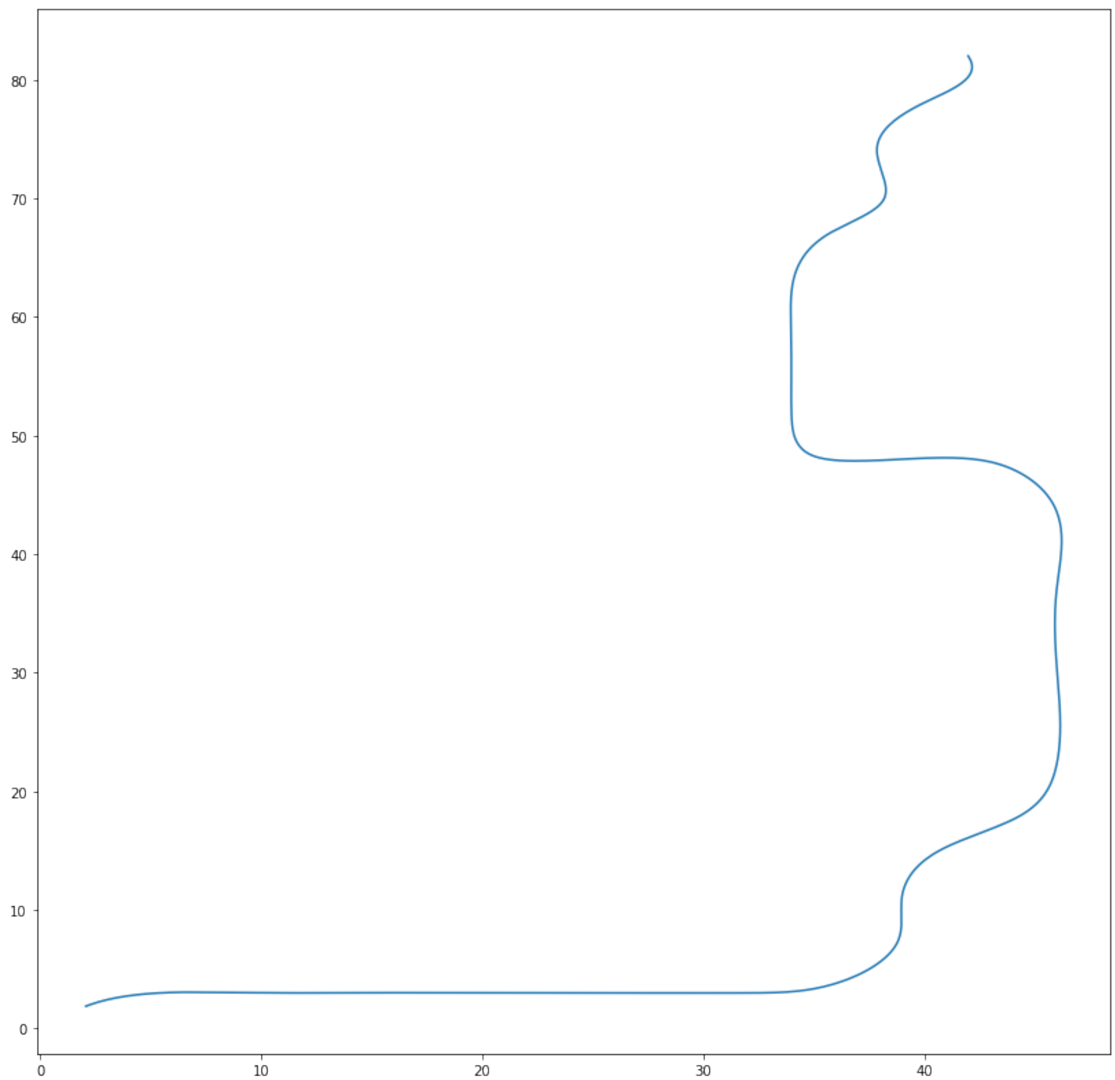
In [36]:
```
t_new, V_smooth_scaled, om_smooth_scaled, traj_smooth_scaled = modify_traj_with_limits

#TODO REMOVE BELOW
traj_t = traj_smooth_scaled.T
x = traj_t[0]
y = traj_t[1]

V_t = V_smooth_scaled.T

fig = plt.figure()
plt.plot(x, y)
```

Out[36]:
```
[<matplotlib.lines.Line2D at 0x263e73c8>]
```



0.2.4 Create trajectory controller and load trajectory

```
In [45]: traj_controller = TrajectoryTracker(kpx=kpx, kpy=kpy, kdx=kdx, kdy=kdy, V_max=V_max, o
         traj_controller.load_traj(t_new, traj_smooth_scaled)
```

0.2.5 Set simulation input noise

(Try changing this and see what happens)

```
In [46]: noise_scale = 0.05
```

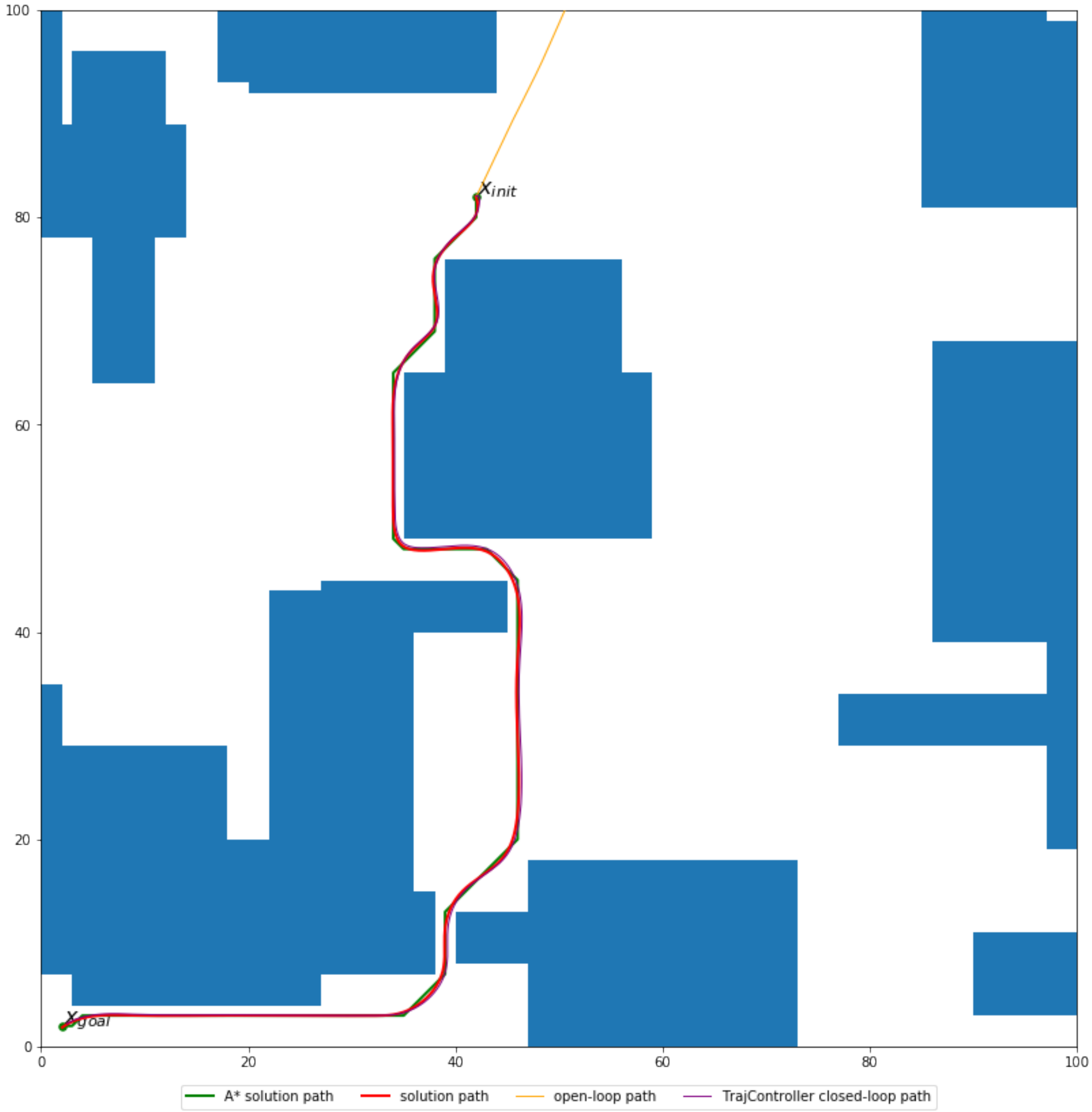
0.2.6 Simulate closed-loop tracking of smoothed trajectory, compare to open-loop

```
In [47]: tf_actual = t_new[-1]
         times_cl = np.arange(0, tf_actual, dt)
```

```
s_0 = State(x=x_init[0], y=x_init[1], V=V_max, th=traj_smooth_scaled[0,2])
s_f = State(x=x_goal[0], y=x_goal[1], V=V_max, th=traj_smooth_scaled[-1,2])

actions_ol = np.stack([V_smooth_scaled, om_smooth_scaled], axis=-1)
states_ol, ctrl_ol = simulate_car_dyn(s_0.x, s_0.y, s_0.th, times_cl, actions=actions_
states_cl, ctrl_cl = simulate_car_dyn(s_0.x, s_0.y, s_0.th, times_cl, controller=traj_

fig = plt.figure()
astar.plot_path(fig.number)
plot_traj_smoothed(traj_smoothed)
def plot_traj_ol(states_ol):
    plt.plot(states_ol[:,0],states_ol[:,1], color="orange", linewidth=1, label="open-l
def plot_traj_cl(states_cl):
    plt.plot(states_cl[:,0], states_cl[:,1], color="purple", linewidth=1, label="Traj(
plot_traj_ol(states_ol)
plot_traj_cl(states_cl)
plt.legend(loc='upper center', bbox_to_anchor=(0.5, -0.03), fancybox=True, ncol=4)
plt.show()
```

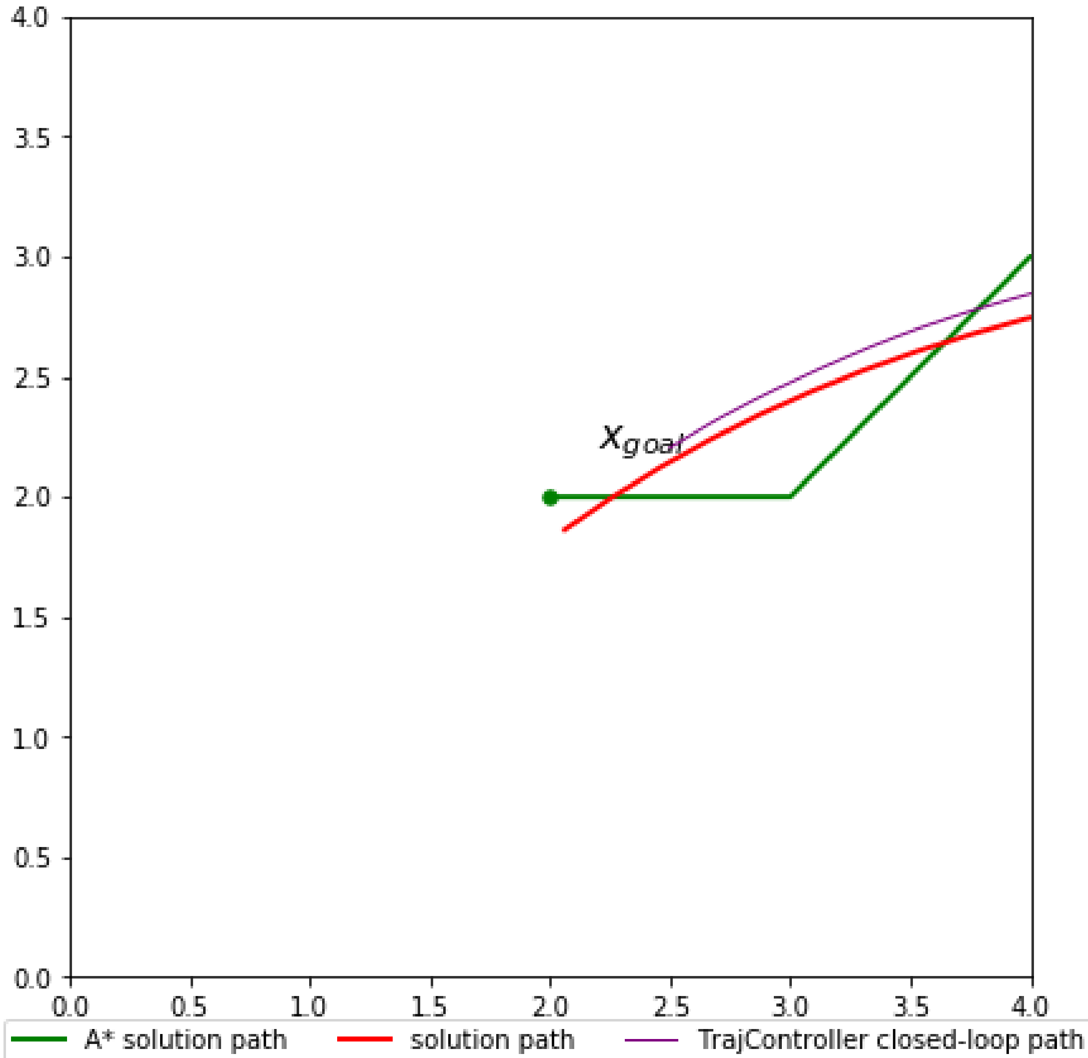


0.3 Switching from Trajectory Tracking to Pose Stabilization Control

0.3.1 Zoom in on final pose error

In [48]:
```
l_window = 4.

fig = plt.figure(figsize=[7,7])
astar.plot_path(fig.number)
plot_traj_smoothed(traj_smoothed)
plot_traj_cl(states_cl)
plt.legend(loc='upper center', bbox_to_anchor=(0.5, -0.03), fancybox=True, ncol=3)
plt.axis([x_goal[0]-l_window/2, x_goal[0]+l_window/2, x_goal[1]-l_window/2, x_goal[1]
plt.show()
```



0.3.2 Pose stabilization control gains

Tune these as needed to improve final pose stabilization.

```
In [49]: k1 = 1.
         k2 = 1.
         k3 = 1.
```

0.3.3 Create pose controller and load goal pose

Note we use the last value of the smoothed trajectory as the goal heading θ

```
In [50]: pose_controller = PoseController(k1, k2, k3, V_max, om_max)
         pose_controller.load_goal(x_goal[0], x_goal[1], traj_smooth_scaled[-1,2])
```

0.3.4 Time before trajectory-tracking completion to switch to pose stabilization

Try changing this!

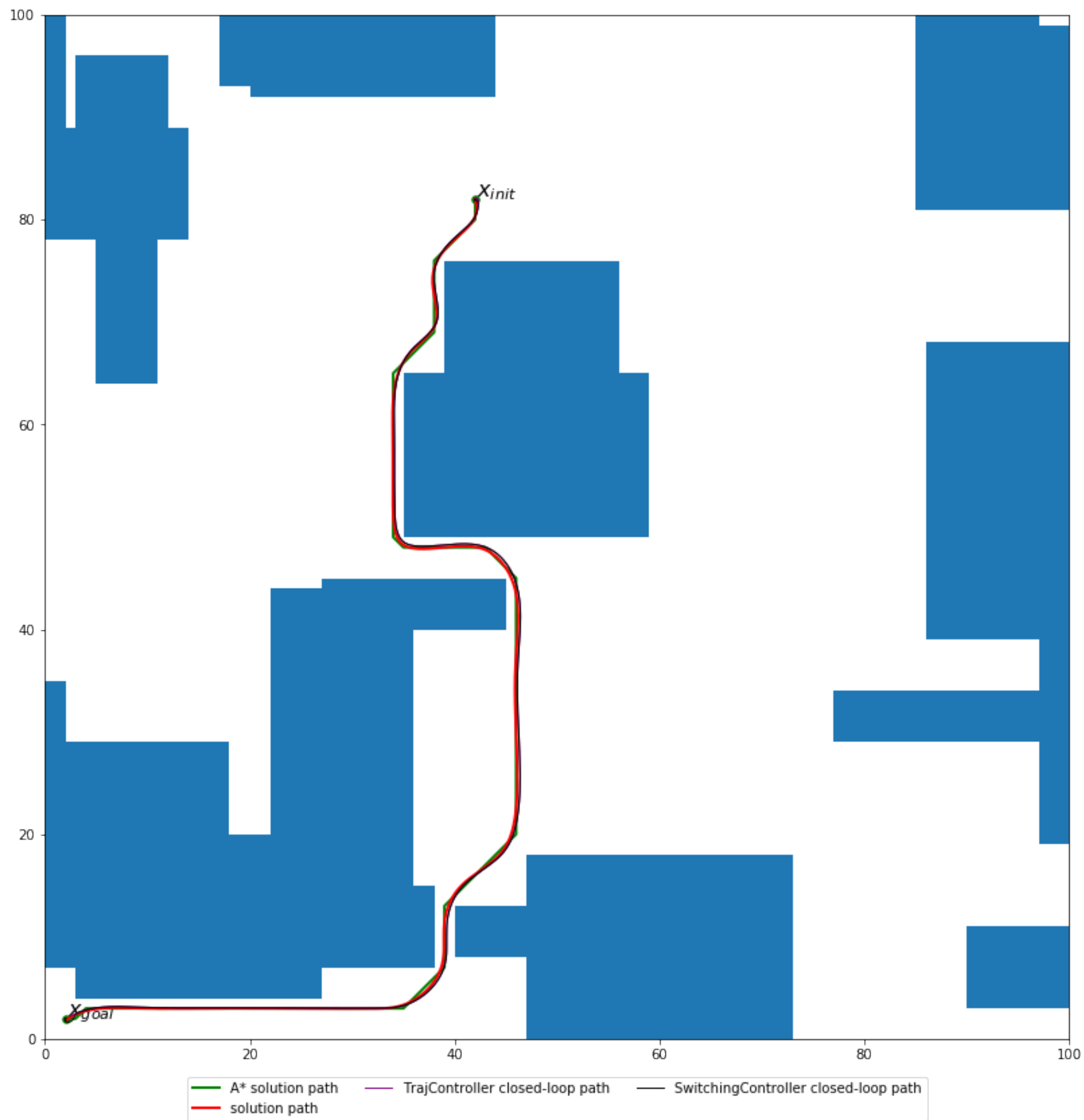
```
In [58]: t_before_switch = 3.0
```

0.3.5 Create switching controller and compare performance

```
In [59]: switching_controller = SwitchingController(traj_controller, pose_controller, t_before_

         t_extend = 60.0 # Extra time to simulate after the end of the nominal trajectory
         times_cl_extended = np.arange(0, tf_actual+t_extend, dt)
         states_cl_sw, ctrl_cl_sw = simulate_car_dyn(s_0.x, s_0.y, s_0.th, times_cl_extended, 

         fig = plt.figure()
         astar.plot_path(fig.number)
         plot_traj_smoothed(traj_smoothed)
         plot_traj_cl(states_cl)
         def plot_traj_cl_sw(states_cl_sw):
             plt.plot(states_cl_sw[:,0], states_cl_sw[:,1], color="black", linewidth=1, label="
         plot_traj_cl_sw(states_cl_sw)
         plt.legend(loc='upper center', bbox_to_anchor=(0.5, -0.03), fancybox=True, ncol=3)
         plt.show()
```

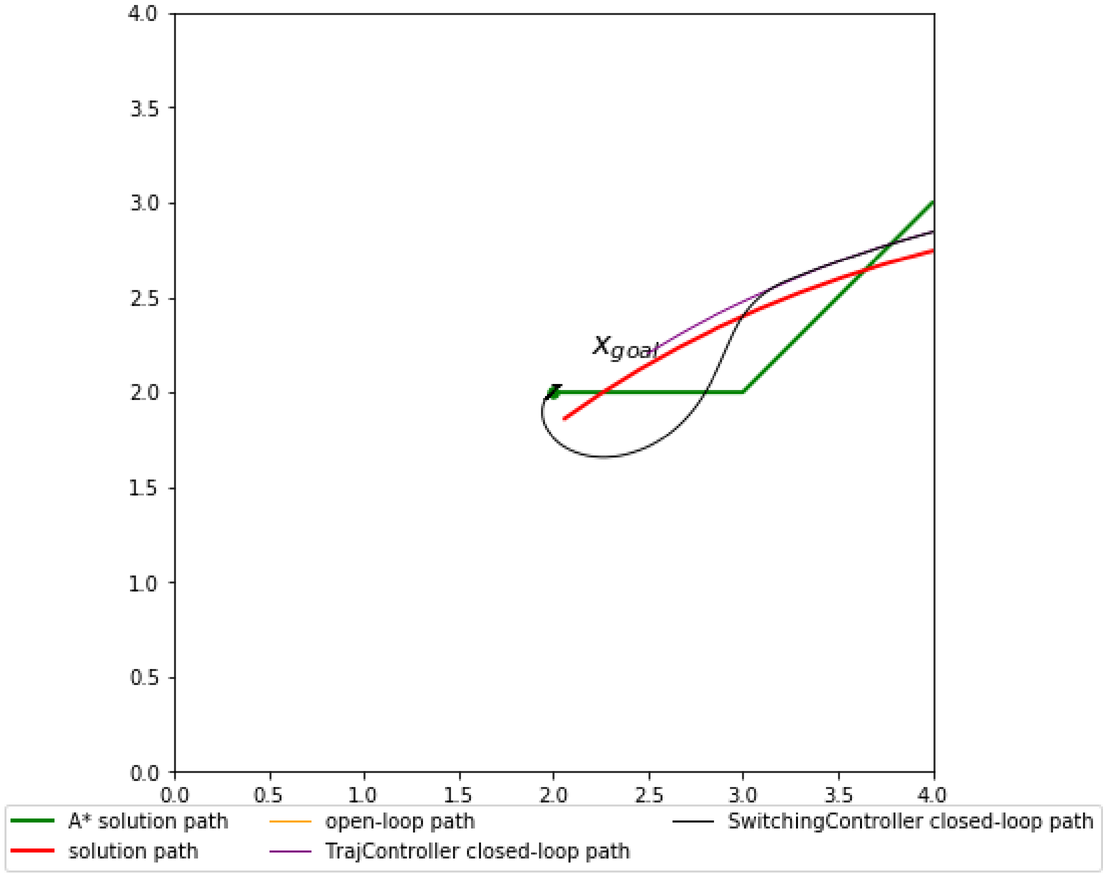


0.3.6 Zoom in on final pose

In [60]:
```
l_window = 4.

fig = plt.figure(figsize=[7,7])
astar.plot_path(fig.number)
plot_traj_smoothed(traj_smoothed)
plot_traj_ol(states_ol)
plot_traj_cl(states_cl)
plot_traj_cl_sw(states_cl_sw)
plt.legend(loc='upper center', bbox_to_anchor=(0.5, -0.03), fancybox=True, ncol=3)
```

```
plt.axis([x_goal[0]-l_window/2, x_goal[0]+l_window/2, x_goal[1]-l_window/2, x_goal[1]+
plt.show()
```



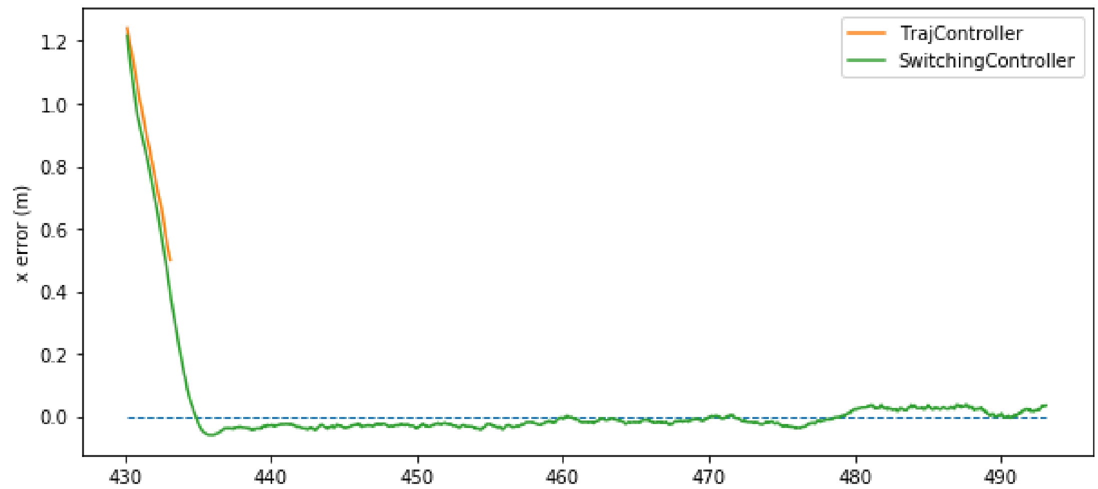
0.3.7 Plot final sequence of states

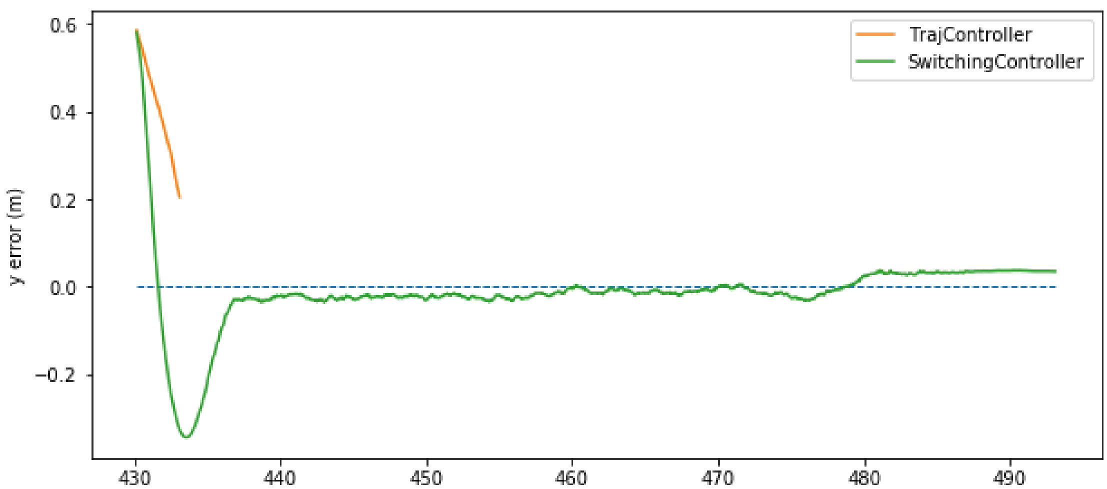
To see just how well we're able to arrive at the target point (and to assist in choosing values for the pose stabilization controller gains k_1, k_2, k_3), we plot the error in x and y for both the tracking controller and the switching controller at the end of the trajectory.

```
In [61]: T = len(times_cl) - int(t_before_switch/dt)
         fig = plt.figure(figsize=[10,10])
         plt.subplot(2,1,1)
         plt.plot([times_cl_extended[T], times_cl_extended[-1]], [0,0], linestyle='--', linewid
         plt.plot(times_cl[T:], states_cl[T:,0] - x_goal[0], label='TrajController')
         plt.plot(times_cl_extended[T:], states_cl_sw[T:,0] - x_goal[0], label='SwitchingContro
         plt.legend()
         plt.ylabel("x error (m)")
         plt.subplot(2,1,2)
         plt.plot([times_cl_extended[T], times_cl_extended[-1]], [0,0], linestyle='--', linewid
         plt.plot(times_cl[T:], states_cl[T:,1] - x_goal[1], label='TrajController')
```

```
plt.plot(times_cl_extended[T:], states_cl_sw[T:,1] - x_goal[1], label='SwitchingContr
plt.legend()
plt.ylabel("y error (m)")
```

Out[61]: Text(0,0.5,'y error (m)')





In [ ]: