Automated Planning final assignment

Anderson Antonio do Nascimento da Silva
Pontifical Catholic University of Rio Grande do Sul
andersonnascimento@ymail.com
Brazil

Abstract

This paper proposes ~~an POMDP~~ model for solving traction control problem. The model is based on sensoring using an equation to detect the right moment when a wheel loses traction to the ~~soil. It is expected with this approach to achieve fuel economy and also making safe to the robot to walk in off-road ground.~~

Introduction

Traction control systems are often used in vehicles for safety reasons, to improve the driver's ability to handle the vehicle under adverse external conditions. The base of TCS is to prevent the wheel from slipping ~~then~~ improving the vehicle stability. Traction control systems are also very important when ~~walking~~ over off-road ground, in addition to that, traction control systems can also be used as a tool to achieve fuel economy as recent~~ly~~ research ~~have~~ shown [2]. The main goal of a traction control system is to prevent a wheel from losing traction to the ~~soil~~. This event happens when the torque force applied to the wheel becomes stronger than the coefficient of friction between the wheel and the soil, since the vehicle is often placed on different kind of grounds the coefficient of friction can not be a pre-defined constant. As an alternative to overcome this challenge is detecting the right moment when the wheel loses traction to the soil and further the system can learn how to better adapt itself to the different type of grounds. The fuel economy is achieved by enabling the vehicle to use ~~only~~ the right amount of torque in each wheel, thus avoiding the waste of energy when the wheel is slipping resulting in no movement.

The slide/slip condition can be determined by (1) where V is the vehicle velocity and (V_w) is the velocity of the wheel [1].

$$S = \frac{(V - V_w)}{V} \tag{1}$$

From this equation is possible to identify three basic states *slip*, *slid* and *roll*. The slip condition is determined when the value of S is ~~lower~~ than 0, the slide condition is determined when the value of S is ~~higher~~ than zero and the goal of any traction system is to achieve S equals 0, when the traction force applied to the wheel is resulting in a wheel velocity equals to the vehicle velocity representing the last state *roll*.

It is important to have an overview and understand the variables, constraints and physics involved in a traction system problem in order to achieve a good result. The first Newton's law is given by the definition of an object at rest tends to keep at rest and an object in movement tends to keep at constant movement unless acted upon an external force. The second newton's law defines force (F) as its mass (M) multiplied by the acceleration vector (A), which is defined by the equation (2).

$$F = A * M \tag{2}$$

Torque is defined by the relation between force (F) and distance in this case the radius of the wheel (r_w).

$$T = F * r_w \tag{3}$$

In the real world there are forces ~~which~~ act against an object in movement tending to cease the movement. The normal force (4) is one of these forces, which is represented by the relation of the mass (M) of the object and the gravity (g). Air resistance, the coefficient of friction and the aerodynamic downforce are also some examples of forces acting against an object in movement. Many of theses forces are not constant depending on other variables like the velocity of the object and even weather conditions like wind, temperature that affects the coefficient of friction. In order to keep the vehicle moving, the torque force applied to the vehicle should be equal to all those forces acting against the movement, once the torque force is higher than the forces acting against it, the result will be acceleration and when the torque is lower the results is deceleration.

$$N = M * g \tag{4}$$

In a four wheel vehicle where each wheel has an actuator providing an independent torque, is then assumed the vehicle's torque is the sum of all wheel's torque as shown in the equation (5). Where (T_v) is the torque of the vehicle and (T_w) is the torque of each wheel. In this context is the traction control responsibility to plan and control the amount of torque applied to each wheel to achieve best acceleration possible due to the desired torque.

$$T_v = T_{w1} + T_{w2} + T_{w3} + T_{w4} \tag{5}$$

The paper is organized as follows. The partially observable Markov decision process model is presented in section 2, where is also described the sensoring required from the robot to operate using the proposed model. In section 3 is presented the experiments and analysis of the results obtained following the future work and improvements in section 4 then conclusions in section 5.

Model

The TCS system is based on sensoring due the dynamics of the problem. Then is required to rig the robot with the following sensors:

- Acceleration sensor: Required to check whether the robot is moving or is only the wheels that are rolling without traction. This could happen when the robot gets jammed for example.
- GPS: As the acceleration sensor GPS helps to identify whether the robot is in movement or not and provide the velocity of the robot.
- Gyroscope sensor: Each wheel has one of ~~this~~ ~~sensor~~ to track the wheel rotation, thus calculating the velocity of the wheel.
- Gravitational axis sensor: With this sensor is possible determine the gravitational force applied to each wheel in case the robot is placed in up-hill or down-hill.

The traction system model is abstracted in two layers, ~~at~~ the first layer defines the strategy to prevent a wheel from slipping and sliding, increasing the torque when sliding and decreasing the torque when slipping, since each wheel is placed in a different ~~soil~~ they can face different coefficients of friction, is then required that each wheel has its own control over the torque. The second layer is responsible to distribute the torque over the wheels respecting the maximum torque possible in order to keep the wheel away from slipping. As defined previously the torque of the vehicle is the sum of the torque applied over the wheels, which is often demanded or controled by another agent, for instance a driver or an IA system, this agent has a goal to achieve, could it be achieve a certain speed or moving uphill. To achieve the agent's goal it demands to the vehicle's traction control to provide the total torque distributed over all the wheels.

In this paper, it is being defined the first layer leaving the second layer as future work. The model is represented in the figure-1. The basic three states available are slipping, sliding and rolling, which are detectable by sensoring using the equation (1).

The model is composed ~~by~~ four actions that represent~~s~~ the amount of torque applied ~~on~~to the wheel at certain moment in time, each action has a probablity of achiving the next state receiving a proper reward. In order to represent the recursiveness present in the figure-1, and also for enabling the usage of the rewards is required not only the three basic states presents in the image, but is required a 3x3 grid of states which contains the transition between one state to another, which is shown in table-1. For example, once a wheel is at sliding state, the chosen action increases the torque achieving as outcome a transition from the sliding

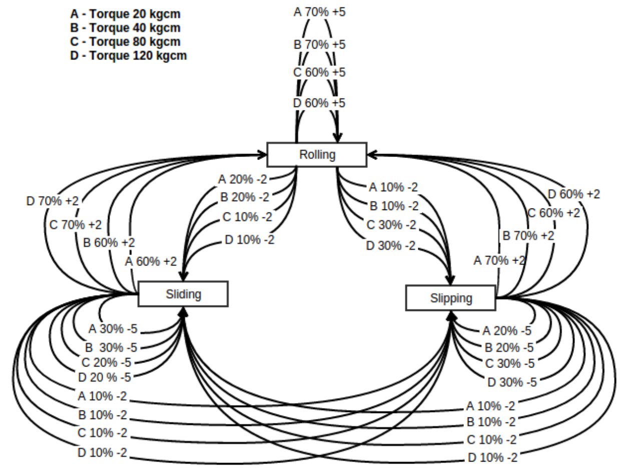

Figure 1: Model

state to the rolling state, thus receiving a reward of +2. Now, on the next round when the outcome of the action results in the rolling state, the reward this time will be +5, the same strategy is used for penalties, when an outcome of the action is sliding or rolling state. This strategy will increase the complexity and also the number of states, on the other hand it will make the system more adaptive in relation to the changes in the coefficient of friction. An important aspect about the table of states is the sequence of the transitions, the relation between a state *A* transitioning to another state *A'* is given by the columns storing the last state and the lines storing the current state.

Sliding	-2	-2	-5
Rolling	2	5	2
slipping	-5	-2	-2
	Slipping	Rolling	Sliding

Table 1: Table of rewards

Experiments and Results

In order to evaluate the model, it was developed using Java application with the support of AIMA3e-Java project which has the implementation of all the algorithms presented in the book Russell's Artificial Intelligence - A Modern Approach 3rd Edition. The code of the specified project seemed to be easy to read and it fairly documented. In order to implement the proposed model was required to extend and implement few classes like implementing the world of states, set of actions and the transitional functions used to navigate among the states. However dificults were faced during the development, mostly related to the transitional function and the world of states that was mapped in the model. Some strategies used to define the model resulted in very small set of states while others in too complex set of states and transitions, for instance, modeling the world of states including the slip/slid condition for all four wheel results in a combinatorial set of states between the wheel states and wheels. In this context finding a model that was complex and simple enough to validate the viability of modeling a traction control system using Markov decision process have shown to be harder than expected.

The results obtained after running the value iteration algorithm are shown in ~~table 2~~. The conversion was achieved after 2430 iterations and the time required to execute the algorithm took in average 30 milliseconds. These numbers seem~~s~~ very reasonable due the simplicity of the first modeling.

-1.9804353267	-1.9804353267	-4.98043532
2.3126896022	5.312689602	2.3126896022
-4.957077035	-1.9570770351	-1.9570770351

Table 2: Result of value iteration algorithm

Future work

As briefly explained earlier, this paper proposes a two layered model to solve the traction control problem using POMDP and the paper covers mostly the first layer. The following items are defined as future work.

- Second layer TCS: Is required to model the second layer of the traction control system, which has the responsibility of this distribute a given torque among the wheels respecting the capacity of traction available in each wheel.
- Integrate the two layers: Is also included in this task to define the online planning strategy. Is very likely to increase the number of states.
- Simulate the model: The plan is to use ROS in order to run the experiments verifying the viability of the model, especially due to the reduced amount of computational power available in a robot. It's also important to retrieve metrics on the response time upon a change in the environment.
- Reinforcement learning: Research the viability of using reinforcement learning to deal with the dynamics of the environment.

Conclusion

The great contribution of this paper consists in the usage of partially observable Markov decision process in order to plan the actions required to avoid the slip/slide condition of a wheel. Also is defined the sensoring required in a vehicle in order to make use of the proposed traction control system and mapping some of the variables and abstractions involving such complex problem. However is needed more research in order to define the effectiveness of the proposed model.

References K. Noori, K. Jenab, "Fuzzy Reliability-Based Traction Control Model for Intelligent Transportation Systems," IEEE Trans. Systems Man Cybernetics, 2013, 43(1): 229-234.

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