université de BORDEAUX

Collège Sciences et technologies

Introduction à la robotique par la pratique

Documentation de Projet

Étudiants :
Corentin Charles
Clément Renazeau
Þorsteinn Hjörtur Jónsson

Enseigneurs :
Rémi Fabre

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1 Introduction

This is the introduction.

2 Rotation

2.1 Description

To make Asterix do a rotation we need to define a circle of rotation, with regards to the center of the robot, on which the legs will move on. As we should always use inverse kinematics to decide the motor angles we will need to express the the circle of rotation in each legs' coordinate frame. To do this we'll need to translate the coordinates of the center system by the vector (x_{corr}, y_{corr}), i.e. a point (x_c, y_c) in the center system has the coordinates $(x_l + x_{corr}, y_l + y_{corr})$ with respect to the coordinate system of the leg.
The following table shows measurements of this vector.

Let R_c be the radius of the circle of rotation. We can define the circle of rotation by $(R_c \cos(\theta_c), R_c \sin(\theta_c))$ for $\theta_c \in [0, 2\pi]$.
Let R_l be the distance from the tip of a leg to the origin of the coordinate system which it defines and let $\theta_l \in [0, 2\pi]$ such that $(R_l \cos(\theta_l), R_l \sin(\theta_l))$ describes the tip of the leg.
Assume that the tip of a leg is on the circle of rotation. Then,

$$(R_c \cos(\theta_c), R_c \sin(\theta_c)) = (R_l \cos(\theta_l) + x_{corr}, R_l \sin(\theta_l) + y_{corr}).$$

So we have two equations :

$$R_c \cos(\theta_c) = R_l \cos(\theta_l) + x_{corr} \tag{1}$$

$$R_c \sin(\theta_c) = R_l \sin(\theta_l) + y_{corr} \tag{2}$$

By putting the both equations to the power of two and adding them with each other we obtain the following second degree polynomial equation :

$$R_l^2 + 2R_l\left(\cos(\theta_l) + x_{corr} + \sin(\theta_l) + y_{corr}\right) - R_c^2 + x_{corr}^2 + y_{corr}^2 = 0$$

The positive root of this equation is :

$$R_l = -x_{corr}\cos(\theta_l) - y_{corr}\sin(\theta_l) + \sqrt{x_{corr}^2\left(\cos^2(\theta_l) - 1\right) + y_{corr}^2\left(\sin^2(\theta_l) - 1\right) + x_{corr}y_{corr}\sin(2\theta_l)}$$

So this should give us the radius of each leg as a function of the correction and the angle given.

2.2 Program

```
import time #used for the sleep function
from pypot.dynamixel import autodetect_robot  #used to get the robot object
import pypot.dynamixel  #used to get the motors,legs etc.
import math #quite obvious
import json #to use a json file
from contextlib import closing  #to close properly the robot at  the end
import pypot.robot

asterix = None
legs = []
xCorrection = [10,-20,-20,10,-20,-20]
yCorrection = [0,-15,15,0,15,-15]



def leg_ik(x3,y3,z3,alpha = 20.69, beta = 5.06,l1=51,l2=63.7,l3=93):
    d13 = math.sqrt(x3*x3 + y3*y3) - l1
    d = math.sqrt(d13*d13 + z3*z3)
    tmp = (l2**2 + d**2 - l3**2)/(2*l2*d)
    a1 = z3 / d13
    a2 = (l2**2 + l3**2 - d**2)/(2*l2*l3)

    angles = (0,0,0)
    theta1 = angles[0]
    theta2 = angles[1]
    theta3 = angles[2]

    try:
        theta1 = math.degrees(math.atan2(y3,x3))   # OK
        theta2 = math.degrees(math.atan(a1) + math.acos(tmp))
        theta3 = 180 - math.degrees(math.acos(a2))
        # Corrections to the angles theta2 and theta3
        theta2 = -(theta2 + alpha)
        theta3 = -(theta3 - 90 + alpha + beta)
        angles = (theta1,theta2,theta3)
    except ValueError:
        print "The legs of the robot cannot go that far!!"

    return angles

def get_legs(obj):
    return [obj.leg1,obj.leg2,obj.leg3,obj.leg4,obj.leg5,obj.leg6]

def get_xCorrection(leg):
  i = int(leg[0].id*0.1)
  return xCorrection[i-1]

def get_yCorrection(leg):
  i = int(leg[0].id*0.1)
```

```
    return yCorrection[i-1]

"""---------------------- Rotation Functions ----------------------------"""
""" Written by Thor the 24/03/15 """
""" Tested by Corentin the 24/03/15 """


""" --------------------Mathematics to correct the rotation ------------"""
""" Written by Thor the 26/04/15"""
# This needs to be done so that we can define a common circle of rotation
# for all the legs. To communicate this common information to all the legs
# we need to express the radius of this common circle of rotation as a function of theta and the legs
""" I added the attributes needed to obtain this information to the json file
Currently these attributes are set to zero"""
def R_leg(theta,leg,R_center):
    xCorrection = get_xCorrection(leg)
    yCorrection = get_yCorrection(leg)
    cos = math.cos(math.radians(theta))
    sin = math.sin(math.radians(theta))
    tmp = (xCorrection**2)*((cos**2)-1)
    tmp += (yCorrection**2)*((sin**2)-1)
    tmp += xCorrection*yCorrection*math.sin(2*math.radians(theta))
    tmp += R_center**2
    return (-xCorrection*cos - yCorrection*sin + math.sqrt(tmp))


# This function takes care of 1 leg at a time
# This moves the leg given polar coordinates. Important because we when we need to do a rotation the legs should not move
# outside the circle of rotation. We want a perfect rotation!
# TEST : Working perfectly
def move_leg(theta,z,leg,R_center = 100):

    i=0
    # Tupl is a vector that carries the angles that represent the final position of the tip of the leg
    # The angles are calculated from the arguments of the function using inverse kinematics
    # R is the radius of the circle of rotation. Theta is given in degrees.
    # Lets transform our polar coordinates onto the Cartesian plane
    # print R_leg(theta,leg,R), " - ", leg[0].id
    x = R_leg(theta,leg,R_center)*math.cos(math.radians(theta))
    print x
    y = R_leg(theta,leg,R_center)*math.sin(math.radians(theta))
    motor_angles = leg_ik(x,y,z)
    for m in leg:
        m.goal_position = motor_angles[i]
        i+=1
    return (x,y,z)

# This should just give us our initial spider position
```

```
# We also use this function when rotating to refix the legs' frames of reference
"""SOLVED?"""
#TEST : We SHOULD NOT put negative value in this function (otehrwise the legs (except legs 1-4) will 'meet each other')
def initial_pos(asterix,theta,z):
  # Experiments have shown that using the values 100 and 30 for changing x and y respectively is working okay
  initial_position = []
  initial_position.append(move_leg(0,z,legs[0]))
  initial_position.append(move_leg(-abs(theta),z,legs[1]))
  initial_position.append(move_leg(abs(theta),z,legs[2]))
  initial_position.append(move_leg(0,z,legs[3]))
  initial_position.append(move_leg(-abs(theta),z,legs[4]))
  initial_position.append(move_leg(abs(theta),z,legs[5]))

  time.sleep(1)

  return initial_position

"""
TODO: make sure that this works. If it works than we can easily do experiments to find the highest value on alpha
If we know the highest value of alpha we can determine the number of turns needed to do an arbitrary amount of rotation by using Euclidean division
See the draft implementation for arbitrary_rotation above.
"""
# theta is the value we need to set the initial position
# alpha determines the amount of rotation (made by each call to the function) from this initial position
# alpha is physically limited because of the legs. We should define this limit as max_angle - see above.
# TEST : A value of 45 will make the legs (2-3 and 4-5) touch for a little while (actually until the next leg move)
def rotation_angle(asterix,alpha,theta,z):
  #clockwise 2 and 5 are limited
  breaklength = 1
  # Position 1: The 'spider' position. This position has a low center of gravity.
  # Here we define the initial position. i.e. the spider position
  # It is important to observe the x and y values of each leg in its own frame of reference

  # Position 2: Put legs 1, 3, 5 in the air and rotate at the same time
  move_leg(-abs(theta)+alpha,z+20,legs[1])
  move_leg(alpha,z+20,legs[3])
  move_leg(abs(theta)+alpha,z+20,legs[5])
  time.sleep(breaklength)

  # Position 3: Put legs 1,3 and 5 down
  move_leg(-abs(theta)+alpha,z,legs[1])
  move_leg(alpha,z,legs[3])
  move_leg(abs(theta)+alpha,z,legs[5])
  time.sleep(breaklength)
```

```

  # Position 4: Rotate legs 0, 2, 4
  move_leg(alpha,z+20,legs[0])
  move_leg(abs(theta)+alpha,z+20,legs[2])
  move_leg(-abs(theta)+alpha,z+20,legs[4])
  time.sleep(breaklength)

  # Position 5: Put legs 0, 2 and 4 down.
  move_leg(alpha,z,legs[0])
  move_leg(abs(theta)+alpha,z,legs[2])
  move_leg(-abs(theta)+alpha,z,legs[4])
  time.sleep(breaklength)

# max_angle = 20 is just a guess.
# TEST : Working not too bad. beta = 180 are doing a rotation of 90deg. It seems that we have to multiply the wanted value by 2 to have a proper rotation
"""SOLVED?"""
#TEST : If we put negative value fot the beta angle, this is just not working.
# TEST : If the value of max_angle is not 20, the rotation does not work proprely
# theta and z are simply values that determine the initial position
# Other parameters are to define the rotation
def arbitrary_rotation(asterix,beta, max_angle = 40, theta = 45, z = -60):
# Here we do euclidean division. We determine how often max_angle divides beta and the remainder of this division.
# This gives us the number of rotations we need to make by a predefined max_angle
# The remainder gives us the amount we need to rotate by to be able to finish the full rotation by an angle of beta
# i.e. beta = q*max_angle + r
  initial_pos(asterix,theta,z)
  if beta < 0:
    max_angle = -max_angle

  q = beta//max_angle
  r = beta%max_angle
  print q
  print r
  # rotate by max_angle q times
  for i in range(1,q):
    rotation_angle(asterix,max_angle, theta, z)
    initial_pos(asterix,theta,z)
  # finally rotate by r
  rotation_angle(asterix,r, theta, z)
  initial_pos(asterix,theta,z)

def moving_center(asterix,x,y,z,l=63.7):
  move_leg(100-x,y,z,legs[0])
  move_leg(100+x,-y,z,legs[3])
  move_leg(100-y,30-x,z,legs[5])
  move_leg(100-y,-30-x,z,legs[4])
  move_leg(100+y,30+x,z,legs[2])
  move_leg(100+y,-30+x,z,legs[1])
```

```
    time.sleep(2)
"""  ____________________________________________________________________________  """
```

rotation.py

3 Walk

3.1 Description

3.2 Program

```python
import time #used for the sleep function
from pypot.dynamixel import autodetect_robot  #used to get the robot object
import pypot.dynamixel  #used to get the motors,legs etc.
import math #quite obvious
import json #to use a json file
from contextlib import closing  #to close properly the robot at  the end
import pypot.robot
import rotation

import Tkinter as tk # to get the a graphic interface for the control function


asterix = None
legs = []
initial = []

def leg_ik(x3,y3,z3,alpha = 20.69, beta = 5.06,l1=51,l2=63.7,l3=93):
    d13 = math.sqrt(x3*x3 + y3*y3) - l1
    d = math.sqrt(d13*d13 + z3*z3)
    tmp = (l2**2 + d**2 - l3**2)/(2*l2*d)
    a1 = z3 / d13
    a2 = (l2**2 + l3**2 - d**2)/(2*l2*l3)

    angles = (0,0,0)
    theta1 = angles[0]
    theta2 = angles[1]
    theta3 = angles[2]

    try:
        theta1 = math.degrees(math.atan2(y3,x3))    # OK
        theta2 = math.degrees(math.atan(a1) + math.acos(tmp))
        theta3 = 180 - math.degrees(math.acos(a2))
        # Corrections to the angles theta2 and theta3
        theta2 = -(theta2 + alpha)
        theta3 = -(theta3 - 90 + alpha + beta)
        angles = (theta1,theta2,theta3)
    except ValueError:
        print "The legs of the robot cannot go that far!!"

    return angles

"""
Get the legs of the given robot object (from the json file).
"""
def get_legs(obj):
```

```
  return [obj.leg1,obj.leg2,obj.leg3,obj.leg4,obj.leg5,obj.leg6]

"""
  Makes one leg move.
  parameters:
    L -- The length between the start point and the end point (in a right line)
    leg -- The leg we want to move
    initial -- a tuple with three values wich correspond to the intial coordonnate of the end of the leg
"""
def move_leg(L,z,leg):
  num = int(leg[0].id*0.1)-1
  theta = math.atan(initial[num][1]/initial[num][0])
  hypo = math.sqrt(initial[num][0]**2 + initial[num][1]**2)
  x = math.cos(theta)*(hypo+L)
  y = math.sin(theta)*(hypo+L)
  z = z
  angles = leg_ik(x,y,z)
  i=0
  for motors in leg:
    motors.goal_position = angles[i]
    i+=1
""""
Make the robot move along his two separate legs
"""
def move_center_forward(L,z):
  break_length = 1
  theta = 20  #more than 20 would make the legs touch for a sec (because of the speed)
  order = [1,5,2,4]
  if L<0:
    order = [4,2,5,1]

  move_leg(L,z+40,legs[0])
  move_leg(-L,z+40,legs[3])
  time.sleep(break_length)

  move_leg(L,z,legs[0])
  move_leg(-L,z,legs[3])
  time.sleep(break_length)
  for i in order:
    if i==order[0] or i==order[2]:
      rotation.move_leg(-theta,z+40,legs[i])
    else:
      rotation.move_leg(theta,z+40,legs[i])
      time.sleep(break_length)
  for i in order:
    if i==order[0] or i==order[2]:
      rotation.move_leg(-theta,z,legs[i])
    else:
      rotation.move_leg(theta,z,legs[i])
      time.sleep(break_length)
```

```
    time.sleep(break_length)

"""
THEORICAL WORK: The order of the leg or the direction could be wrong...TO TEST
Make the robot move along its two legged side.
"""
def move_center_aside(L,z):

    break_length = 1
    theta = 20
    if L<0:
        theta = -theta

    initial = rotation.initial_pos(0,-60)
    time.sleep(break_length)
    move_leg(L,z+40,legs[1])
    move_leg(L,z+40,legs[2])
    time.sleep(break_length)
    move_leg(L,z,legs[1])
    move_leg(L,z,legs[2])


    move_leg(-L,z+40,legs[4])
    move_leg(-L,z+40,legs[5])
    time.sleep(break_length)
    move_leg(-L,z,legs[4])
    move_leg(-L,z,legs[5])
    time.sleep(break_length)

    rotation.move_leg(theta,z+40,legs[0])
    rotation.move_leg(theta,z+40,legs[3])
    time.sleep(break_length)
    rotation.move_leg(theta,z,legs[0])
    rotation.move_leg(theta,z,legs[3])
    time.sleep(break_length)

def moving_all_legs(L,z):
    move_leg(L,z,legs[0])
    move_leg(L,z,legs[1])
    move_leg(L,z,legs[2])
    move_leg(-L,z,legs[3])
    move_leg(L,z,legs[4])
    move_leg(L,z,legs[5])
```

walk.py

4 Main

4.1 Description

4.2 Program

```python
import walk as walk
import rotation as rotation

import itertools
import time
import numpy
from pypot.dynamixel import autodetect_robot
import pypot.dynamixel
import math
import json
import time
from contextlib import closing
import Tkinter as tk

import pypot.robot

asterix = None
legs = []


def get_object():
  asterix = pypot.robot.from_json('my_robot.json')
  legs = get_legs(asterix)
  rotation.legs = get_legs(asterix)
  walk.legs = get_legs(asterix)

  return asterix

def detection():

  my_robot = autodetect_robot() #detect al the legs of the robot. Might take a while to operate
      .

  #write the configuration found into a json file. We shouldn't use the complete detection
      whith this json file.
  config = my_robot.to_config()
  with open('my_robot.json', 'wb') as f:
      json.dump(config, f)

  with closing(pypot.robot.from_json('my_robot.json')) as my_robot:
      # do stuff without having to make sure not to forget to close my_robot!
      pass

def initialize():

```

```
  asterix = get_object()
  # print asterix
  # Note that all these calls will return immediately,
  # and the orders will not be directly sent
  # (they will be sent during the next write loop iteration).
  for m in asterix.motors:
      m.compliant = False   # <=> enable_torque.
     # m.goal_position = 0

  time.sleep(2)
  return asterix
"""
  if asterix['motorgroups'] == None:
    asterix['motorgroups'] = {
    'leg1': ["motor_11","motor_12","motor_13"],
    'leg2': ["motor_21","motor_22","motor_23"],
    'leg3': ["motor_31","motor_32","motor_33"],
    'leg4': ["motor_41","motor_42","motor_43"],
    'leg5': ["motor_51","motor_52","motor_53"],
    'leg6': ["motor_61","motor_62","motor_63"]
    }
"""

def get_legs(obj):
    return [obj.leg1,obj.leg2,obj.leg3,obj.leg4,obj.leg5,obj.leg6]

if __name__ == '__main__':

  # asterix = get_object()
  initialize()
  walk.initial = rotation.initial_pos(asterix,30,-60)
  rotation.arbitrary_rotation(asterix,360)
  # time.sleep(2)
  # walk.move_leg(30,0,rotation.legs[0])
  # time.sleep(1)
  # walk.move_leg(30,-60,rotation.legs[0])
  # time.sleep(1)

  # while 1:
  #   move_center_aside(10,-60)

  # while 1:
  #   walk.initial = rotation.initial_pos(asterix,0,-60)
  #   time.sleep(0.2)
  #   walk.move_center_forward(30,-60)
  #   walk.initial = rotation.initial_pos(asterix,0,-60)
  #   time.sleep(0.2)

    # print rotation.legs[0][0].id
  #rotation.move_leg(0,-60,rotation.legs[0])
```

main.py