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predictive control of a mobile robot

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Abstract

In this work, we are looking forward to control the lateral motion of a mobile robot vehicle type, which allows to tracking a trajectory in a best possible way, by applying the Non-linear Continuous-time Generalized Predictive Control (NCGPC)

Introduction

Mobile robots are taking an important place in our world from their services in many domain, industrial, hospital, transportation and so on, since its invention; scientists have always sought to make the robot smarter and smarter, which led them to develop control algorithms. The control application always needs a mathematical model that represents the target system to deal with. The dynamic model of the four-wheel vehicle by the state space model is enough representation to represent the vehicle's behavior , this model allows to applicate the various control laws including the predictive control, in this work we will try to apply the Non-linear Continuous-time Generalized Predictive (NCGPC) algorithm , and the goal is to make the robot follow a certain goal or given path With reducing the error between the target and the output .

General definition for robots

By strict definition, a robot is a mechanical or virtual agent, controlled by a computer program or other electronic circuitry. Autonomy, either fully or partly, is a prerequisite to the definition of a robot

Robot types

In this work we classed robot types into two large parts ,fixed-base robots (manipulators) and mobile robots

fig.1 -a manipulator arm

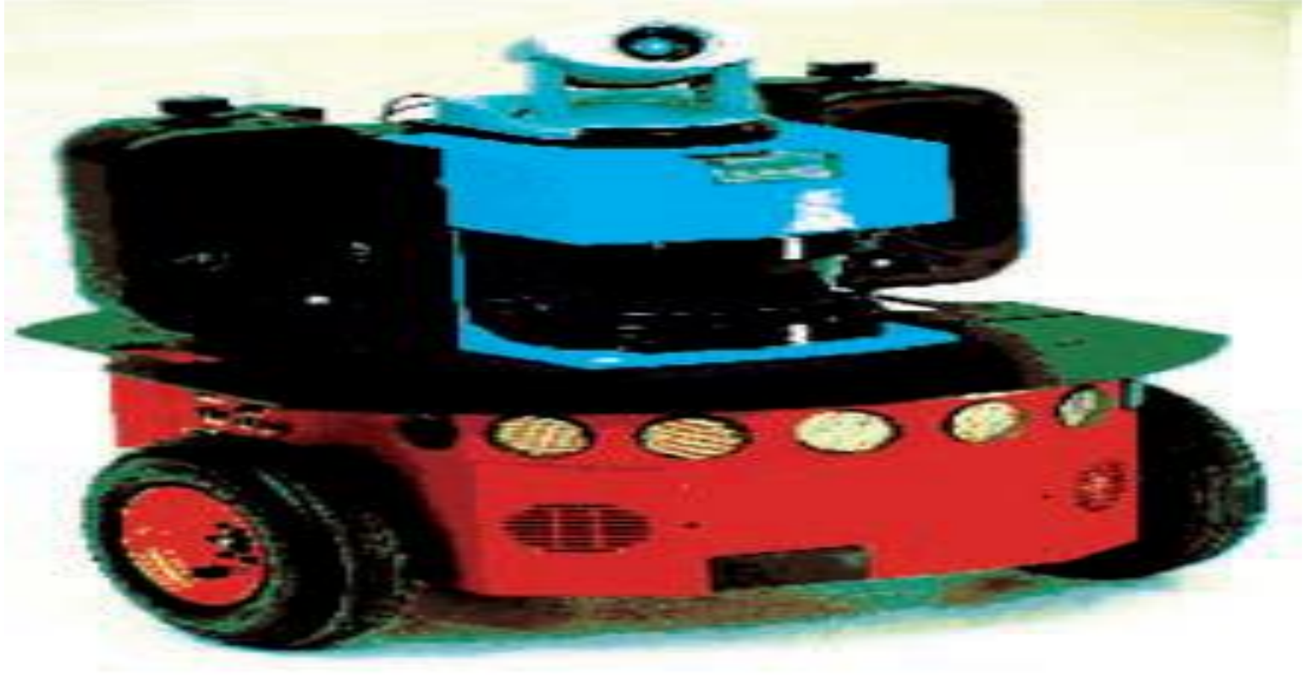

fig.2 -differential drive wheeled mobile robot

mobile robots types

Mobile robot types are classified into three main parts**:**

1. Underwater Robots
2. Flying Robots
3. Ground Robot

Ground Robot

ground mobile robots is distinguished in :
1. Legged robots: Legged robots are distinguished in two main categories:
Two-legged (bipedal) robots & Many-legged robots
2. Wheeled mobile robots (WMRs)

Kinematic and Dynamic lateral motion modeling

A model is a mathematical representation of a given system, which allow to handle any system in practical way.

in this work we modeled the lateral motion of a vehicle in a kinematic model .this model based on a bicycle model as shown in the fig(3) , In this model , instead of the two front wheels there is only one wheel present the two wheels at a point , the same thing with the rear wheels.

from the bicycle model we get the overall equations of the lateral motion.

Table .1- summary of kinematic model equations

SUMMARY OF KINEMATIC MODEL EQUATIONS		
Symbol	Nomenclature	Equation
X	Global Xaxis coordinate	$\dot{X}=V\cos(\psi+\beta)$
Y	Global Y axis coordinate	$\dot{Y}=V\sin(\psi+\beta)$
ψ	Yaw angle; orientation angle of vehicle with respect to global Xaxis	$\dot{\psi}=\frac{v\cos(\beta)}{lf+lr}(\tan(\delta f)-\tan(\delta r))$
β	Vehicle slip angle	$\beta=\tan^{-1}\left(\frac{lf\ \tan\delta r+lr\tan\delta f}{lf+lr}\right)$

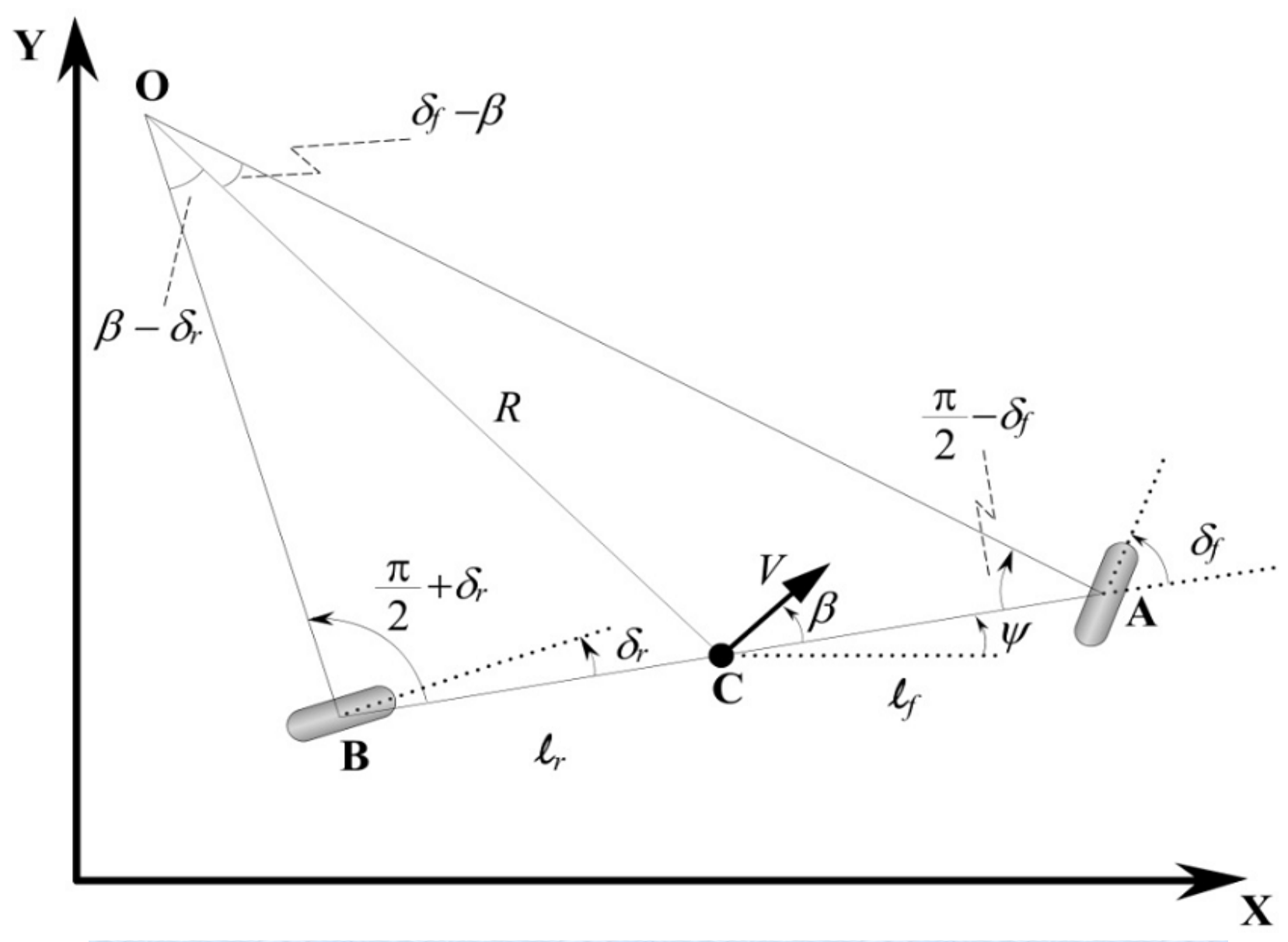

fig .3- Kinematics of lateral vehicle motion

The kinematic model can no longer be used in the higher vehicle speeds, and with taken into account the dynamic vehicle's parameters mass, inertia, as well as tire contact conditions on the ground, and therefore, we modeled the lateral motion of the vehicle by a dynamic model ,which can handle all those parameters.

From the vehicle representation as shown in the fig (4) we got this state space representation of our system .

$$\begin{bmatrix}\dot{v}_y\\ \dot{v}_\psi\end{bmatrix}=A\begin{bmatrix}v_y\\ v_\psi\end{bmatrix}+B\begin{bmatrix}\delta_f\\ \delta_r\end{bmatrix}$$

The general purpose from this modeling is to control the position and the heading of the vehicle by controlling angles of the wheels.

Table .2- summary of Dynamic model equations

SUMMARY OF DYNAMIC MODEL EQUATIONS		
Symbol	Nomenclature	Equation
v_y	The lateral velocity at c.g. of vehicle (same as $\dot{y}$)	$\dot{v}_y=A_{11}v_y+A_{12}v_\psi+B_{11}\delta_f+B_{12}\delta_r$
v_ψ	The yaw	$\dot{v}_\psi=A_{12}v_y+A_{22}v_\psi+B_{21}\delta_f+B_{22}\delta_r$
ψ	The yaw angle of vehicle in global axes	$\dot{\psi}=v_\psi$
X	Global Xaxis coordinate	$\dot{X}=v_x\cos\psi-v_y\sin\psi$
Y	Global Y axis coordinate	$\dot{Y}=v_x\sin\psi+v_y\cos\psi$

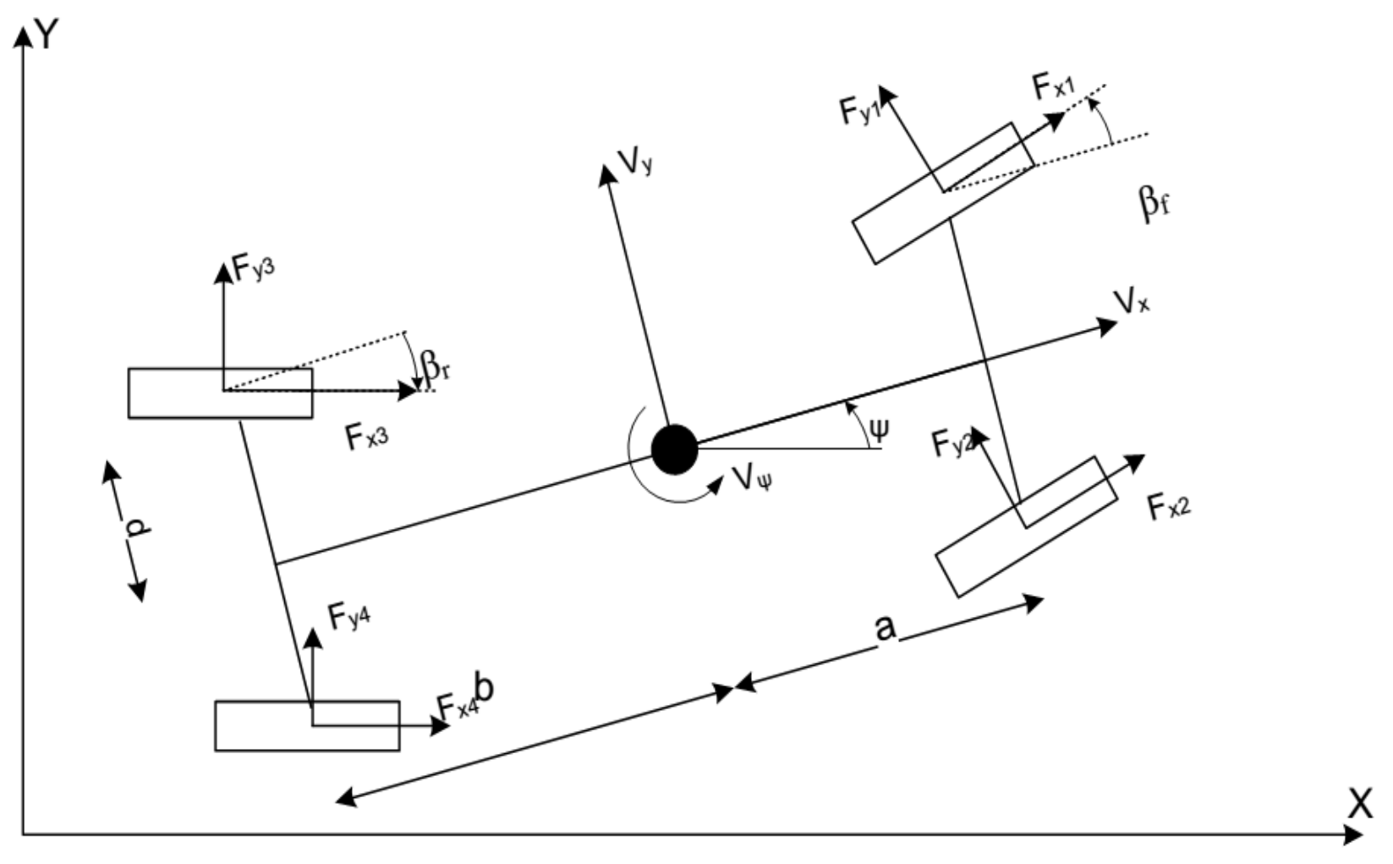

fig.4- Vehicle model in the yaw plane

Generalized Predictive Control (GPC)

The general design objective of model predictive control is to compute a trajectory of a future manipulated variable u to optimize the future behavior of the plant output y.

Predictive control law has the following main components; those components are required to apply any predictive control algorithms:

1 prediction 2 receding horizon 3 modeling 4 performance index

The predictive control is based on the prediction of the future behavior of the process in a limited horizon time.

Receding horizon is a range of a time whish we make into it our prediction, is always related to the current position and always keep the same length.

The modelling is one of the most important step in the predictive control , and to automate the predictive control ,it is necessary to present the concepts of this control in mathematical terms,our work is based on the state space model of Non-linear Continuous-time Generalized Predictive Control (NCGPC).

$$\dot{x}=f(x)+g(x)u$$
$$y=h(x)$$

our goal is to find a control law such that .the output y follow up asymptotically for a fixed prediction horizon, the reference signal ω **.**when the time t goes to infinity ,to reach this goal ,define the error e as: $e(t)=y(t)-\omega(t)$

We consider the quadratic criterion J defined as follows:

$$J(t)=\frac{1}{2}\int_0^T[\hat{e}(t+\tau)]^2\,d\tau$$

The control law is developed from the minimization of the criterion with respact to the command u from where:

$$\frac{\partial J}{\partial U}=0$$

At the end we get the control law :

$$u=D^{-1}\left(\Pi_{ss}^{-1}\ \Pi_s\right)\begin{bmatrix}\omega-h\\ \vdots\\ \omega^{(\rho)}-l_f^{\rho}h\end{bmatrix}$$

Conclusion

In this work, a nonlinear predictive controller that ensures path tracking task for a mobile robot. we present a new approach to solve a tracking path problem by applying (NCGPC) the controller is based on the dynamic model of a bicycle like vehicle .The prediction model allows to anticipate future changes in setpoints in accordance with the dynamic constraints of the system.

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