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THE PROBLEM OF MOBILE ROBOTS MOVEMENT CONTROL

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The task of steering the movement of mobile vehicles has two components: planning desired motion trajectory and following the trajectory with the required accuracy by controlling the actuators.

Trajectory planning can be carried out without regard to design of a robot. It is important that robot is in principle able to work with desired trajectory from kinematics point of view. In this sense, robots, wheels of which can be deployed at any angle independently from one another, have no restrictions on shape of trajectory.

From dynamics point of view not every trajectory can be followed by a specific robot, as there are restrictions on amount of acceleration and minimum radius of curvature of trajectory due to finite value of traction coefficient and possibility of tipping. These limitations must be taken into account when calculating trajectory, ie in practice, the task of trajectory planning must be addressed to a particular robot, taking into account its characteristics and design features.

Even if these restrictions are satisfied, actual trajectory will always be different from preassigned due to inertia of wheel's drives. Error of trajectory following is determined by dynamic properties of drive and will obviously increase with speed increasing.

Thus, the solution of the problem involves development of an efficient algorithm for calculating desired trajectory based on the design parameters of mobile platform and synthesis of drive control system of robot with required dynamic characteristics. In general, the system should provide steering of wheels turn angles, and the speed of their rotation, ie speed of movement of the robot.

On first step of problem solution an adaptive algorithm for calculating trajectory that directs robot in a predetermined point at a predetermined angle has been developed. The algorithm showed acceptable accuracy for practical use (angle deviation does not exceed 1 ... 2 degrees, and position deviation 50 ... 100 mm) in simulation. Figure 1 shows effect of coefficient K2 on form of trajectories. By means of this coefficient desired trajectory can be achieved in order to bypass obstacles and meet certain conditions and restrictions.

This algorithm was used to develop control system of mobile robot with four motor units. Each module has two wheels independently driven by DC motors. This robot was designed and manufactured at High Technical School of Ravensburg-Weingarten (Germany), in cooperation with which this work was carried out.

Figure 2 shows arrangement of modules and direction of velocity vectors of platform motion in a circle. Required rotation angles of modules and wheel velocities can be easily expressed through radius of circle using kinematic relations. In fact, this allows us to calculate desired trajectory of motion of each module at a known path of movement of the platform. Thus, accuracy of motion of platform is determined by how well given trajectory is fulfilled by each module. This allows to initially treat each module as a separate motor subsystem such that output variables are angle and speed of motion, and input – motor currents, and apply known control theory calculation methods.

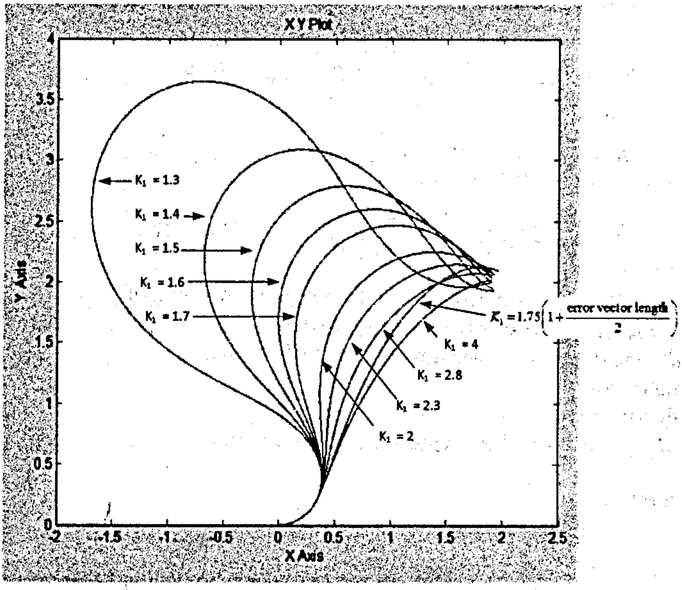

Figure 1 – Simulation of trajectory planning process

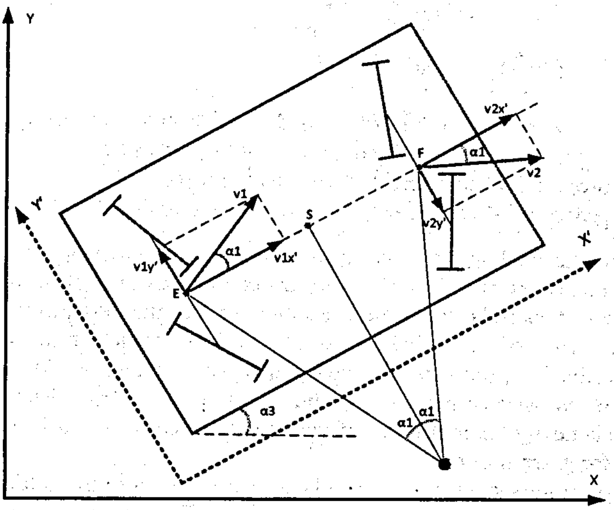

Figure 2 – Simplified kinematics of the robot

On second stage there was dynamic model of motor unit developed in a form of equations of state space model implemented later in SIMULINK application of MATLAB programming environment:

$$\dot{\omega}=-b_{11}I_{armature1}+b_{12}I_{armature2}+b_{13}L_{friction1}-b_{14}L_{friction2}, \tag{1}$$

$$\dot{v}=b_{21}I_{armature1}+b_{22}I_{armature2}-b_{23}L_{friction1}-b_{24}L_{friction2}, \tag{2}$$

$$\dot{\varphi}=\omega, \tag{3}$$

$$b_{11}=b_{12}=\frac{0.5adC_MU}{0.5Jd^2+J_{drive}a^2U^2}, \quad b_{13}=b_{14}=\frac{b_{11}}{C_MU},$$

$$b_{21}=b_{22}=\frac{0.25C_MU}{0.125d^2m+J_{drive}U^2}, \quad b_{23}=b_{24}=\frac{b_{21}}{C_MU},$$

where $I_{armature\ 1}$, $I_{armature\ 2}$ – electric current in armature winding of the motor 1, motor 2;
$L_{friction\ 1}$, $L_{friction\ 2}$ – torque of resistance of wheels;
a and d – the distance between wheels and wheel diameter;
C_M – motor constant;
U – reduction drive ratio;
m and J_{drive} – mass and moment of inertia of module.

Control mode:

$$I_{armature1}=I_{armature}-\Delta I_{armature}, \tag{4}$$

$$I_{armature2}=I_{armature}+\Delta I_{armature}, \tag{5}$$

$$I_{armature}=K_1\left(v_{preset}-v\right), \tag{6}$$

$$\Delta I_{armature}=K_2\left(\tau_d\cdot\dot{\varepsilon}+\varepsilon\right), \tag{7}$$

$$\varepsilon=\left(\varphi_{preset}-\varphi\right), \tag{8}$$

where φ_{preset} – preset angle of turning of module at the end of trajectory;
v_{preset} – preset linear velocity of module at the end of trajectory;
K_1 – proportional coefficient of velocity control circuit;
K_2 – proportional coefficient of angle control circuit.

Motion of the module was investigated using this mathematical model when following various types of trajectories with different types of control loops of rotation angle and speed controls. It has been established that the best quality of transient's processes is achieved using PD controller in module angle control loop. A proportional controller in speed control loop ensures good enough quality. Under types of controllers above with corresponding adjustment deviation from desired trajectory of the module is negligible in process of moving at a speed of up to 1 m / s. This speed is nominal for given design.

Simulation results suggest that calculated values of controller settings ensure normal operation of robot control system as a whole. The results obtained are expected to be tested experimentally on workable sample of robot.