Trajectory Generator for Mobile Robot in Plane

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Trajectory generator for mobile robot in plane

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***Abstract*—The research presented in this article focuses on author's work that was done last year according to dissertation theses.**

***Keywords*—mathematical modelling, robotics, mobile robot, trajectory.**

I. Introduction

The application potential of artificial intelligence methods as an extension of classical modelling and control approach for robotic systems is the main subject of dissertation theses. This paper's topics describe new results and work already done in fulfilling author's dissertation theses, the continuous research is presented in previous articles [1], [2]. The last year's research covers various partial tasks like the mathematical modelling of more accurate simulation mobile robot model with friction, a generation of various testing trajectories together with their properties analysis. A space is also devoted to dissertation main control structure with reference robot along with the description of 3D environment for robotic systems virtualization.

II. Previous analysis and achieved results in research field

Research field of robotics systems has been subject of author's previous research under goals of project VEGA No. 1/0286/11 Dynamic Hybrid Architectures ot the Multiagent Network Control Systems. During the robotic systems analysis, a key models of further interest were identified - the robotic arm and mobile robot with differential chassis as representatives of stationary and mobile robotics.

The robotic arm OWI 535 model and its control using USB interface was discussed in [1]. In terms of hardware and programming, the experience gained during work with rather different Laboratory Hydraulic model was applied.

Multiple kinematic and simple dynamic models of mobile robots have been implemented in Simulink environment as a library of robotic systems, which was the main focus of [2], the library is still under development with respect to Technicom project goals. Simulation models were verified in point and posture control structures.

Artificial intelligence methods in modelling and control can applied on a variety of robotic systems, the analysis conducted in dissertation prospectus have revealed potential application of neural models, especially in trajectory following control tasks, that is reflected in future dissertation theses.

Part of the final solution will be the OpenGL based environment programmed in C# language, designed for visualization of robotic systems, especially for mobile robots. First version of this simulator was already programmed, but it still require further attention to increase it's robustness.

The program outputs falling below dissertation theses, are mainly carried out in simulation programming language MATLAB/Simulink and in object programming language C#, previous publications also support the KEGA 021TUKE-4/2012 project.

III. Solved tasks and results

This article summarize the main results of various research tasks realized in this study year.

A. Differential mobile robot with friction

A significant part of last year's research [2] were devoted to modelling of mobile robot with differential chassis. Within a created simulation models library in Simulink environment, that contains the kinematic models with wheel radius r and distance between wheels b, based on

$$\begin{bmatrix} \dot{x}(t) \\ \dot{y}(t) \\ \dot{\varphi}(t) \\ \dot{\theta}_R(t) \\ \dot{\theta}_L(t) \end{bmatrix} = \begin{bmatrix} \frac{r}{2}\cos\varphi & \frac{r}{2}\cos\varphi \\ \frac{r}{2}\sin\varphi & \frac{r}{2}\sin\varphi \\ \frac{r}{2b} & -\frac{r}{2b} \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \omega_R(t) \\ \omega_L(t) \end{bmatrix}, \tag{1}$$

were implemented additional mobile robot parametric models with more dynamic properties.

Since these robots will be used as a data source for neural models training [3] as mentioned in previous article [2], to get a data with better accuracy, an implementation of generalised friction model [4] was subject of research.

Achieved results were presented at a conference with a personal participation supported by the project VEGA in article [5], which extended version were sent to Lambert Academic Publishing for further publication.

B. Mobile robot reference trajectory generator

Mobile robot reference trajectory is usually defined as a set of $[x_r, y_r]$ position coordinates, that are sampled in reasonable rate. An interval of these points for motion in plane can be approximated as an arc or line, the reference trajectories, commonly used for control algorithms verification are patterns like 8-shape [6], because they contain dynamically changing line/arc combinations.

A generator of various reference trajectories, that will be used in further control experiments were designed as a part of simulation models library with an options to define required pattern characteristics and scale, an example of pattern generators are depicted on Fig. 1.

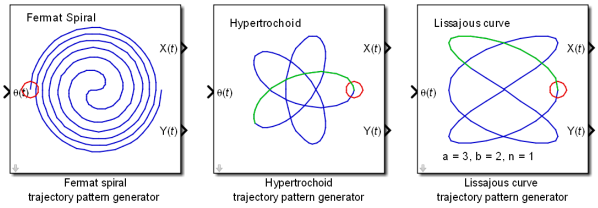

Fig. 1. Single trajectory generators - an example of created Simulink blocks.

The single trajectory generator summarize under one Simulink block multiple patterns:

- point / straight line / sine wave
- involute of circle / Fermat spiral,
- circle / ellipse / superellipse - rounded rectangle,
- 8-shape - lemniscate of Gerono / Bernoulli,
- epitrochoid / hypertochoid / Lissajous curve and more.

The parametric definition of each trajectory used to program generator ensure ability to modify the final shape by changing parameters. Dynamic mask of Simulink block enables to plot updated chosen trajectory after every change in parameters even before simulation.

These reference trajectory patterns will be used for testing of mobile robot classical and intelligent [3] control structures, however they can find an application with robotic arms or ball and plate model trajectory tasks.

C. Trajectory for mobile robot analysis

In terms of mobile robotics, the trajectory planning require a significant attention and importance. Mobile robots with dynamics have specific construction limits and therefore the required trajectory has to be analysed in advance - the robot must be able to realize defined trajectory.

Taking into account it's maximum linear and angular velocities together with sample rate, it is possible to calculate approximate linear velocity $v_r(t)$ for changing position coordinates $[x_r, y_r]$ as

$$v_r(t) = \pm\sqrt{\dot{x}_r^2(t) + \dot{y}_r^2(t)}, \tag{2}$$

where $\pm$ defines direction of robot's motion. The orientation angle φ_r for each trajectory point can be obtained as

$$\varphi_r(t) = \text{arctan2}(\dot{y}_r^2(t), \dot{x}_r^2(t)) + k\pi, \tag{3}$$

and $k = 0$ or $k = 1$ defines the selected rotation direction. The robot's approximate angular velocity $\omega_r(t)$ can be obtained from derivation of (3) as

$$\omega_r(t) = \frac{\dot{x}_r^2(t) \cdot \ddot{y}_r^2(t) - \ddot{x}_r^2(t) \cdot \dot{y}_r^2(t)}{\dot{x}_r^2(t) + \dot{y}_r^2(t)} = v_r(t) \cdot \kappa(t) \tag{4}$$

where $\kappa(t)$ denotes the path curvature. For trajectories generated from parametric definition applies that, with an exception of straight line and circle, the euclidean distances between two points are not equal - this is reflected in lower linear velocity $v_r(t)$ with greater angular velocity $\omega_r(t)$ for larger curvature $\kappa(t)$ and vice versa. These trajectory properties should be also taken into account during neural models training and experiments.

D. Trajectory tracking control for mobile robot

There are multiple approaches and control structures for mobile robot trajectory tracking. As mentioned in previous article [2], the control structure with a reference model, that includes feed-forward and feedback control was chosen as dissertation main control structure, depicted on Fig. 2.

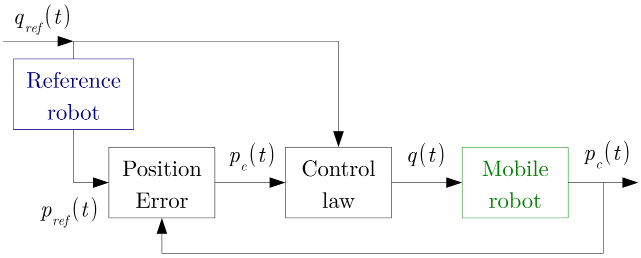

Fig. 2. Mobile robot with friction as simulink block.

The control law $q(t)$ is a combination of feed-forward part $q_{ref}(t)$, that can be obtained from defined reference trajectory using (2), (4) and feedback part, that depends on position error $p_e(t) = p_{ref}(t) - p_c(t)$. The simple kinematic model, mobile robot with dynamics and friction extended by internal PI control loop or trained neural model can be used as reference or controlled mobile robot.

IV. Proposal for next steps

In terms of mobile robot control, the priority is to include methods of artificial intelligence [3] into classical control structures, mainly to control structure with reference robot. Another important step is to modify reference trajectory to equidistant step, which will enable usage of additional control structures and can provide interesting results in comparison between classical and intelligent control approaches. At the same time, another task is to enhance OpenGL based environment for efficient visualisation of robotic systems.

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