

Toward Human-Robot-Teaming for Mobile Robot Navigation Using Remote control, Digital Twin, and Transversability Map

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Abstract—Collision prediction and avoidance is essential for the autonomous navigation of mobile robots. A transversability map is a way to achieve this objective. However, this approach might fail when the environment is subject to dynamic motion of living or artificial entities. Included are pedestrians, animals, and other vehicles that the robot cannot handle. In this paper, we embrace this challenge by achieving a flexible human-robot teaming that leverages a shared control of the robot. A human operator can remotely supervise and actively guide the robot as well as share or leave full control to the robot that autonomously moves toward a desired goal. For this purpose, a situation-aware control signal balances the input of the autonomous robot and the cognitive input of the remote human operator. The robot employs a transversability map to autonomously evolve in unstructured environments. In critical situations, the human operator can intervene and seamlessly operate the robot from everywhere by using any web-capable device. Such a human-in-the-loop control is realized through a bidirectional wireless communication between the physical robot and its multi-modal digital twin. The human-robot teaming enhances the likeliness of a successful navigation even without pre-defined goal and dynamics obstacles. The paper outlines the conceptual architecture and shares preliminary results of our approach.

I. INTRODUCTION

The navigation of mobile robot in unstructured environments requires the detection, interpretation, and avoidance obstacles. Combining RGB and depth images, semantic segmentation, intrinsic and extrinsic camera parameters to predict a bird's-eye-view transversability map is an approach to cope with obstacle during navigation [1]. The underlying model obtained through self-supervised training is fed with sensed images. It returns an array of parameters that describe the linear and angular

Geometric navigation approaches that are for example LiDAR based, are especially limited outdoors [1]. Self-supervised autonomous navigation systems such as BADGR [2], WayFAST [1] or the successor model WayFASTER [3], are therefore used to estimate the traversability with regard to bumps and navigable objects such as tall grass. Even though these neural networks excel in a static environment, they are constrained in a dynamic and busy environment where people, animals or other objects such as cars are moving. Furthermore, not all parameters can be taken into account in these models. Parameters such as battery state of charge (SoC) or engine temperatures of the robot are equally important to ensure successful and safe navigation. It is therefore common for robots to be additionally monitored

and controlled by a human operator. For these reasons, it is advantageous for a person with better situational awareness to take back control for a certain action or period of time. In this respect, shared autonomy describes a robotic system that independently adapts its autonomy level to the given environmental factors [4]. To support this physical robot-human interaction (pHRI), intuitive control and monitoring of critical data is required. We therefore provide the robot operator with a web-based interface that reflects the perception of the robot, visualizes its critical data and offers multiple control options. Security aspects such as login and persistent data storage via a database are also integrated. In addition, a concept for shared autonomy with the Husky UGV mobile robotic platform from Clearpath [5] and WayFASTER are presented.

A. Web Framework, Wiederholung aus MMAR24 Paper?

The web framework is used to control and monitor the Husky, which runs on ROS2 Humble and is platform-independent. Due to the web-based approach, all devices with a browser can access the app.

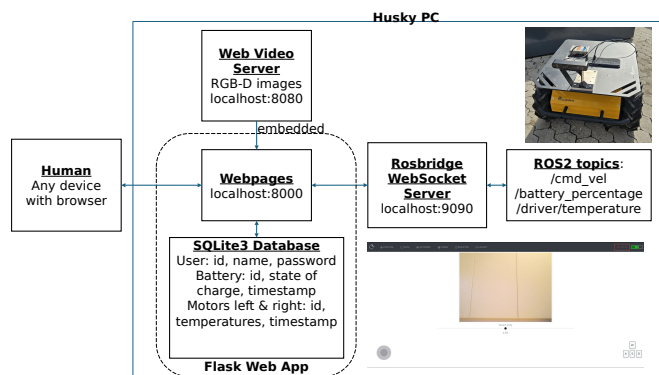


Fig. 1. Backend architecture of the web app with a Screenshot of the frontend

II. PLACEHOLDER

III. RELATED WORK

- Shared Autonomy - Presentation of BADGR and WayFASTER - Web based UI Apps?

IV. METHODOLOGY AND CONCEPT

We propose a shared autonomy approach of the guidance of a robot such as the Husky UGV from Clearpath. The idea is to let the robot take over initial control through a self-supervised navigation system such as WayFASTER. The

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kino-dynamic model of a skid-steered Robot, such as the Husky, is given below: [3]

$$x_{k+1} = \begin{bmatrix} p_{x_k} \\ p_{y_k} \\ \theta_k \end{bmatrix} + \begin{bmatrix} \mu(p_{x_k}, p_{y_k}) \cdot \cos(\theta_k) & 0 \\ \mu(p_{x_k}, p_{y_k}) \cdot \sin(\theta_k) & 0 \\ 0 & v(p_{x_k}, p_{y_k}) \end{bmatrix} \begin{bmatrix} v_k \\ \omega_k \end{bmatrix}$$

where x_k is the state vector, p_x and p_y are the coordinates and θ_k is the orientation (heading angle) of the robot. The $\cos(\theta_k)$ and $\sin(\theta_k)$ functions describe the movement in x- and y-Axis depending on the orientation. $\mu(p_x, p_y)$ and $v(p_x, p_y)$ are outputs (traversability coefficients) of the WayFASTER model TravNet and have a value between 1 and 0 respectively. They indicate how well the robot can move across the terrain and are associated with the control inputs v_k and ω_k , which are the linear and angular velocities. In ROS terms these are what a Twist Message contains.

We plan to integrate the transversability coefficients into our web framework. Since these coefficients have a value of 1 for good transversability and 0 for poor transversability, a threshold can be specified. A value of 0 (for both coefficients) would mean that the robot stops. To ensure a more seamless transition from autonomous control to human control, falling below the defined threshold will result in a warning in the web app. This is intended to indicate the human operator to take control within the app. The app is programmed in such a way that human input always has top priority. Specifically, this can be achieved with Husky by sending control commands (geometry_msgs/Twist.Message) in different topics with different priorities [source].

We suggest that you use a text box to insert a graphic (which is ideally a 300 dpi TIFF or EPS file, with all fonts embedded) because, in an document, this method is somewhat more stable than directly inserting a picture.

Fig. 2. Inductance of oscillation winding on amorphous magnetic core versus DC bias magnetic field

V. TRANSVERSABILITY-BASED SHARED CONTROL

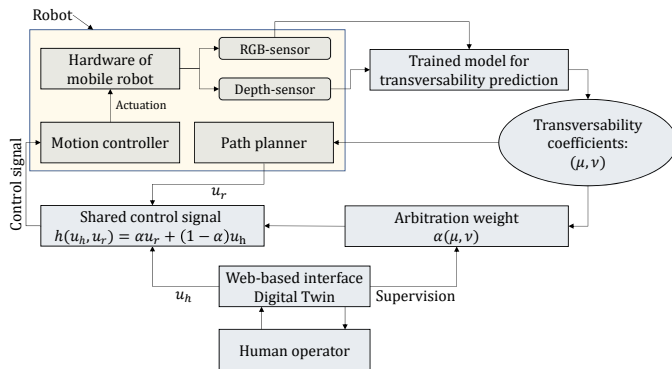


Fig. 3. Shared Control

VI. CONCLUSIONS

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