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Condition Monitoring and Cloud-based Energy Analysis for Autonomous Mobile Manipulation - Smart Factory Concept with LUHbots

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Abstract

In this paper, a smart factory concept for autonomous mobile robots is presented. The main purpose is to increase productivity of the transport in machine-floor. It is based on advanced methods for failure handling and prevention, leading to increased robustness, less downtime and less effort in maintenance [1], [2]. Therefore, condition data and states of the robot are collected by Robot Operation System (ROS) and transferred to a factory hub (server). The collected data, e.g. voltages, currents, set points, velocities and accelerations are used to identify important system parameters, e.g. moving masses and friction parameters to enable the proposed smart factory concept. Further aim is to let the factory hub control a group of mobile robots using a self-organizing algorithm for different tasks.

Due to the increasing customization of products causing smaller lot sizes [3], manufacturers of mobile robotic production systems have developed a diversity of flexible robots [4], [5], [6], [7], [8]. Mobile robots inside the production line allow for collecting and evaluation of system-inherent data e.g. handling and transportation time, wheel friction, workpieces mass, center of gravity and energy consumption during trajectory execution.

In general, mobile robots are electrically driven. Hence, an estimation of the battery state is essential in order to automatically plan charging cycles and to organize and optimize the cooperation behavior of a group of mobile robots. In this proposed approach, mobile robots are equipped with a measurement system and connected via Bluetooth to a factory hub, providing monitoring, analyzing and planning tools. The battery states of all robots are considered in the process planning.

The robots are based on the KUKA youBot, equipped with a soft gripper and a RealSense camera. A condition monitoring system measures the energy consumption of all components and transfers the information to the factory hub. The state of charge limits the number of executable operations. Therefore, in a first step the power consumption of all individual consumers is captured, e.g. EC-Maxxon base motors, PC, gripper, camera and five-axis arm. Experimental results show, that the youBot requires 46 W in standstill plus the drive power depending on the movement. Here, the results for mobile manipulation in industrial scenarios during preparation for the RoboCup@Work 2016 will be presented. The transfer of raw measurement data to the hub is shown, as well as

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the proposed algorithms allowing for range prediction and optimized set point generation. The concept provides excellent capability in data collection, analysis of existing production and production planning.

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Keywords: Mobile Robotics; Condition Monitoring; Cloud-based Energy Analysis; Logistic Handling

1. Introduction

For mobile robots, energy is the determinative factor of every action. The variation of actions is considerably greater and it is not only necessary to optimize the trajectories of the arm and the base, but also to regard the current battery state in the planning of next actions. With the combination of energy, position, velocity and acceleration values, it is possible to identify parameters for the robot model. Deviations from the model can be indicators, which show that a robot component diverges from its specification, or may be in faulty operation. Measuring these deviations cannot only help to optimize the movement, but also help protecting the hardware from damage. In autonomous robotics, these indicators are eminently important to reduce necessary human interference.

This paper presents the implemented state machine with condition monitoring to achieve increased robustness against e.g. grasping failures of workpieces. In the RoboCup, the LUHBots team started using an energy model of the arm movement to prevent hardware damage. If the electric current exceeds the calculated value during the movement, the arms stops and enters a gravity compensation mode. This is a new approach to collect the raw data from several robots at the same time and analyze the behavior in the background during a competition. The main goal is to improve pre-maintaining, save time and money by intelligent data analysis and to transfer the new knowledge to industrial robots for the integrated industry. The first section describes the scenario in the RoboCup competition and the team's current approaches. In the second part of the paper, a newly developed energy measurement system is introduced and the measured results are presented. Finally, the paper describes possibilities how to use the obtained data for optimized robot operation and task planning.

1.1. KUKA youBot

The robot is based on the KUKA youBot mobile robot [9]. It consists of a platform with four Mecanum wheels and a five-degrees-of-freedom (DoF) manipulator. Commutated DC motors (EC-Motors) are integrated into the joints and

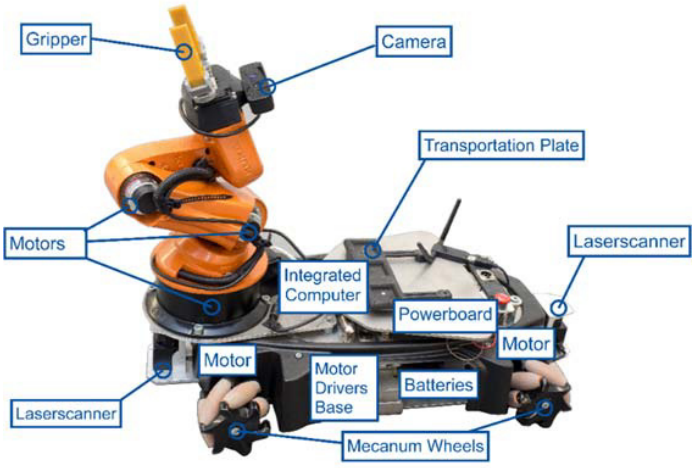

Fig. 1 The modified KUKA youBot used by LUHbots for mobile manipulation tasks.