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IPA

FRAUNHOFER INSTITUTE FOR MANUFACTURING ENGINEERING AND AUTOMATION IPA

1 *UR5e executing a pick & place task*

SELF-HEALING ROBOT SYSTEMS

Current situation

With the increasing use of robots in industry, our working world is undergoing dramatic changes. In the process, it is essential that the robots execute their tasks robustly. However, robots are susceptible to different kinds of errors. When programming an application, programmers have to consider all possible errors so that they can create a reliable program. Nevertheless, some errors are unknown or crop up unexpectedly and cannot be handled automatically. The standard procedure in such cases is to shut down the control system safely, but this increases the downtime. Using our effective assistance tool and consulting services, you can

– reduce programing efforts. We provide an automatic robot-program-generating tool and an automatic error handling tool to minimize programming work.
– improve your Overall Equipment Efficiency (OEE). The robot-program-generating tool creates robust robot programs. The error handing tool monitors the system, constantly learning new errors and recovery solutions during the runtime. This can greatly improve the performance of your robot system and allows errors to be rectified faster.

Our approach

The assistance tool for robotic self-healing is implemented in close cooperation with the customer and adapted to suit the production robots and the structure of the manufacturing system. The steps we take can be described as follows:

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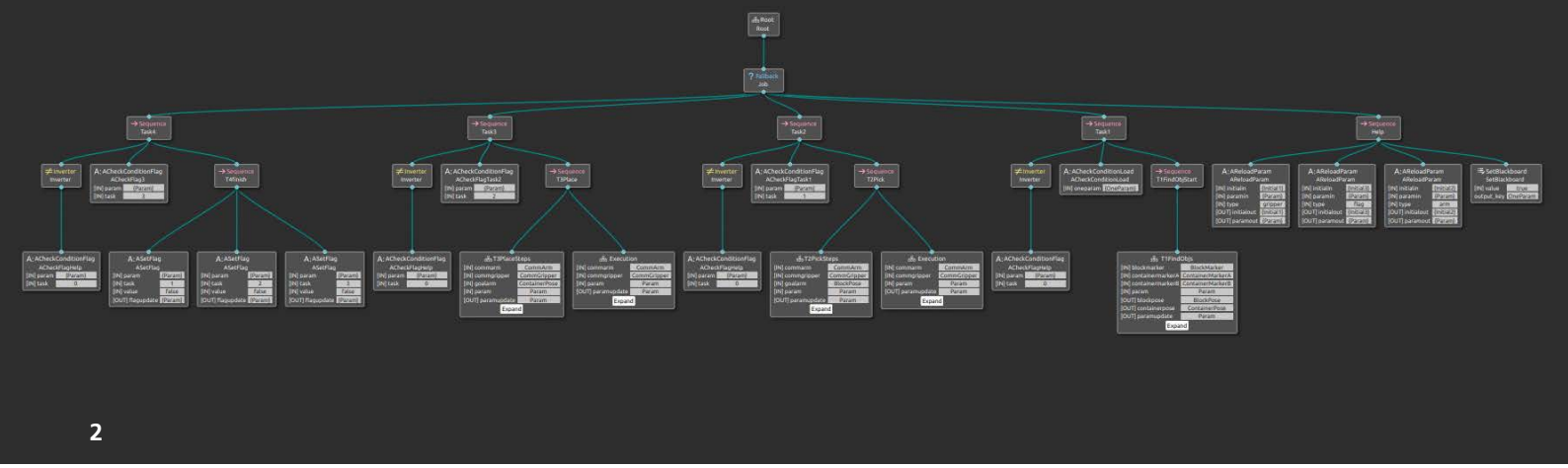

2

Investigation, development of ROS-based fault-tolerant applications and fast deployment

In workshops with robotic experts from Fraunhofer IPA and industrial customers, the criteria of the robot application and common errors are documented. Based on given boundary conditions, Fraunhofer IPA conducts a Failure Mode and Effects Analysis (FMEA). Our tools use the information gained from the FMEA to automatically generate ROS-based, error-tolerant applications. Fraunhofer IPA also provides ROS-on-Edge deployment technology that enables robot applications to be used in diverse embedded hardware and robots. Applications are deployed gradually so that they can be verified in simulations through version control. This also makes it easier to return to a working state should faults be found in an application.

Error-handling pipeline

For errors that cannot be covered or considered in the first place, Fraunhofer IPA's error-handling pipeline takes over during runtime. The pipeline consists of an error-monitoring module, error diagnosis module, and a recovery module. The monitoring module continuously surveys the robot's "state of health" and the services it provides. The module contains observers that can be automatically generated depending on the features to be monitored. Abnormal behavior conditions are detected using AI techniques, which trigger the error diagnosis system. The diagnosed error is automatically rectified by the error recovery system, thus returning the robot's state of health to normal.

When in operation, the robot learns continuously, allowing it to detect new errors and update the diagnosis model. To start with, aided by human workers or robotic experts, robots can find appropriate solutions to new errors, concretizing the structure of error diagnosis and the recovery network. The more the robot learns, the more intelligent it becomes and the less it needs to interact with humans.

Error diagnosis and recovery during runtime are achieved through:

1. an FMEA of the robot application, which identifies possible errors
2. continuous system monitoring
3. failure diagnosis and recovery during runtime based on machine learning

Typical errors handled using the strategy are:

1. incorrect parameter settings, e.g. approach distance to an object
2. fault in a peripheral device, e.g. defective camera.
3. hardware error, e.g. disconnected cable between gripper and robot arm.
4. environment settings, e.g. ambient light intensity, missing target object.

Your advantages

Combined with our expertise and experience in robotics, the described approach ensures that the assistance tool for robotic self-healing is tailored to customer-specific requirements and easily implemented in industrial processes.

The parts of the robot program related to error handling are created automatically based on an FMEA; this reduces set-up times, speeds up the commissioning process, and enables customers to use stable, fault-tolerant robot programs without prior knowledge of how to program error handling routines. The error-handling pipeline significantly reduces downtimes associated with error-related production interruptions. It also increases machine availability because robot fault conditions are automatically remedied. Thanks to the self-learning capability of robots, human beings are required to intervene less and less.

Our services

We will be happy to provide you with our tools for creating fault-tolerant robot programs and dealing with software/hardware errors arising during the execution of tasks by handling and assembly robots. In addition, we offer our research expertise regarding the use of the technology and tech-transfer projects. We also offer consulting services for FMEA solutions, the creation of reliable, state-of-the-art robot programs, and error-handling solutions tailored to your specific task. Please contact us to discuss your requirements.

2 *Behavior tree-based program flow for pick & place task. In line with to the user's specific description of the task, the system generates a robot program based on the behavior tree*