The service robot Care-O-bot 4

Service robots offer support in manufacturing and logistics as well as in everyday life situations. The open source Robot Operating System ROS and CANopen simplify the engineering and development process.

The market for service robots – robot systems installed out of production environments – has been on the rise for quite some years. In 2014, the global sales of consumer products as well as of robots in professional application fields raised considerably, as presents the study World Robotics 2015, published by the International Federation of Robotics (IFR) and edited by Martin Hägele, head of the department robot and assistive systems at Fraunhofer IPA. Based on a survey of 300 companies worldwide, the forecasts for 2015 to 2018 estimate 25 million units sold for domestic robots and 150 000 units for professional service robots. The IFR-analysis reveals also that about 15 % of the companies are start-ups. The companies are highly technology-driven and were founded no longer than five years ago. This trend highlights the market potential that investors and entrepreneurs are seeing in the domain.

On the one hand, this remarkable development is due to technological advancements and cost reductions. Both "push" for newer application domains alongside manufacturing and industrial automation. Also, it helps service robots to become more accepted. On the other hand, new application scenarios in different fields "pull" for flexible robot systems that are easy to build, program, and (re-) configure. In order to supply this rising demand, developers and engineers are already and will be even more in need of appropriate system components and their drivers. The open source software framework Robot Operating System (ROS) offers many of them.

ROS gained much popularity in service robotics. It became the de-facto communication standard for mobile manipulation platforms and features a wide range of hardware drivers and higher level functionalities for navigation, manipulation, and perception. These building blocks enable manufacturers to reduce time and complexity for developing new robot systems. Instead of developing everything from scratch, system integrators benefit from a variety of compatible programs and services that follow consistent standards and can be issued independently from a specific hardware. The service robot Care-O-bot is a good example to explain how complex robot systems can profit from ROS.

The developement of Care-O-bot

Assistive robots represent one of the upcoming markets. They could help elderly or handicapped people and undertake several tasks in the service sector. At Fraunhofer IPA, the scientists already started in the early '90s to work on service robotics technologies. The name Care-O-bot should reflect the capacities to help in a variety of everyday life situations. The first generation was introduced in 1998. At the beginning of 2015, Care-O-bot 4, which has been developed in cooperation with the company Schunk, was presented (Figure 1). While its predecessors were used primarily in the development of technological fundamentals, Care-O-bot 4 is a modular product family providing the basis for commercial service robot solutions. This system is setting new standards in technological aspects as well as in the design.

Figure 1: The construction of Care-O-bot 4 allows individual robot platforms to be established for a range of applications (Source: Fraunhofer IPA/Photo: Rainer Bez)

A service robot shares its environment with humans. For this reason, a friendly and likeable appearance of the robot is important, because otherwise people would not easily accept it in their vicinity. That is why the scientists developed a unique design concept together with the design studio Phoenix Design located in Stuttgart. The result is a characteristic shape with slender forms and clear lines. Both designers and scientists had to cope with one of the most important challenges: Creating a friendly, gentleman-like robot, a new archetype for such devices and at the same time developing a form under which all technical components find their place and that allows a wide range of motion, e. g. bending down. This successful liaison of form and function of Care-O-bot 4 was awarded with the Red Dot Award: Product Design in 2015. It is part of only 1,6 % of the submitted products which received the label “best of the best”.

One main criterion for the fourth generation of Care-O-bot was to build a modular system that can be configured according to the particular application scenario. The complete system has up to 31 axes, 28 degrees of freedom, weighs 140 kg, and measures 158 cm. Many modules communicate via CANopen or Gigabit Ethernet. To meet the safety requirements, the robot has three safety laser scanners and several emergency stops. Integrated in both grippers are RGB-D cameras with a range of 15 cm to 200 cm and a special LED light system (Figure 2). Whereas the configured robot with two arms and grippers, user interface on its head, and sensor ring enables the maximum of tasks, it is also possible to use only the omnidirectional base as a serving trolley. If the intended purpose is to serve drinks, a tray replaces one hand. This targeted adaption for specific tasks reduces costs.

The various hardware modules are encapsulated and can be composed with the help of custom connectors that provide communication, power, and safety interfaces. With exception of the grippers, all actuators are connected with CAN internally. CAN was chosen because it is very robust and less susceptible to electromagnetic interferences. In particular, some signals had to be routed via slip rings right next to the motor currents. Depending on the configuration, the robot has up to 21 axes that are driven by CiA 402-compliant controllers distributed over up to five networks.

ROS and CANopen software stack

As mentioned above, ROS is currently the most widely used software framework or middleware for robotics. It has been available since 2007 and was developed by researchers from Stanford University in order to create a standardized architecture for service robots. Even though ROS is open source, a commercial usage is possible and, in fact, has already been pursued by many organizations. Since ROS runs under the BSD license (Berkeley Software Distribution), everybody can change and use the code for commercial purposes as long as the original copyright is kept.

Figure 2: With its arms and one-finger-hands the robot can handle even difficult objects (Source: Fraunhofer IPA/Photo: Rainer Bez)

Care-O-bot 4 demonstrates different use cases for ROS: About one third of the robot's components are already existing open components. The engineers have access to established solutions. Another third of the code was developed by experts at Fraunhofer IPA and then made freely available for the community. Fraunhofer IPA developed also the remaining code, which is marketed via licenses. This shows how ROS enables technical progress. Thanks to the community-driven development, every programmer can focus on its special expertise and improve the open source code for all users. At the same time, the usage as "closed source" is also possible, which encourages companies to adopt ROS. Thereby, they can benefit from standardized tools and vendor independency.

Part of the freely available ROS components that run on the service robot is the driver framework ros_canopen. The stack is running under Linux, with or without linkage to ROS. It has been implemented in C++ and is divided into several layers (Figure 3) in order to enhance its flexibility and extensibility. The connection to the CAN network is enabled by SocketCAN, which is included in the mainline kernel and supports an increasing number of interface devices. Regarding the CANopen master implementation, the driver is automatically configured based on the EDS files for the slave devices. It supports most services like Network Management (NMT), Service Data Objects (SDO), Process Data Objects (PDO), Synchronization Objects (SYNC), Emergency Objects (EMCY), or Heartbeats. On top of it, a ROS interface was implemented that provides further configuration and introspection functionalities.

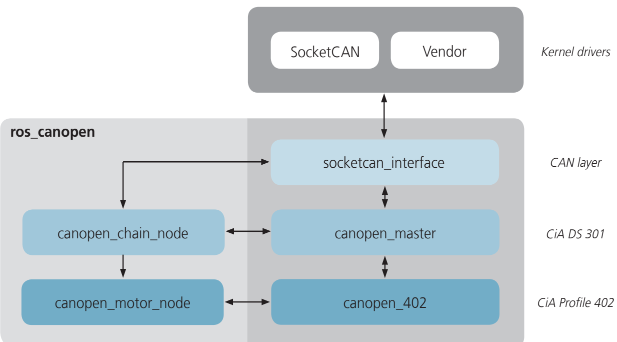

Figure 3: Software package structure of the ros_canopen stack (Source: Fraunhofer IPA)

CAN Newsletter Online

The CAN Newsletter Online sister publication provides brief product-related information. For more details please visit www.can-newsletter.org.

Expertdays: Mobile robots are the future

Schunk has organized the 6th Expertdays in its facilities in Lauffen (Germany). More than 100 service robot experts participated in this annual 2-days event, which took place end of February.

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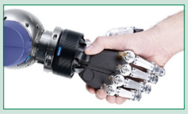

5-finger gripper hand

Almost human

The mechatronic SVH 5-finger gripper hand from Schunk, designed for service robot applications, is ready for serial production. The grippers are very similar to the human model.

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Parallel gripper

Reducing cycling times

The Schunk (Germany) EGL 70 mechatronic parallel gripper comes with variable gripping force between 50 N and 600 N. It was specifically developed for industrial applications.

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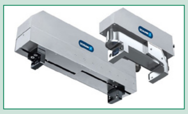

Two-finger parallel gripper with CAN

Schunk (Germany) has launched its WSG-32 gripper dedicated for handling small components. It provides optionally a CAN interface.

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Other protocol layers can be integrated via a protocol stack concept. As a reference implementation, the CANopen 402 device profile for drives and motion control is available. Its basic features like command forwarding and drive mode switching are accompanied by enhanced ROS functionalities in a separate software package. It virtually represents a group of drives as a kinematic chain and provides synchronous access to its components. Furthermore, it is fully integrated with another software framework, ros_control, which abstracts the controller interface from the actual hardware implementation. The ROS community provides different software packages for multi DOF-trajectory execution and differential wheel control that can be used out of the box. ▷

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ROS-Industrial initiative

The ros_canopen driver is being promoted by the ROS-Industrial initiative, and especially within the two ROS-I Consortia in North America and Europe. The ROS-I initiative aims at easing the adoption of ROS for industrial settings and applications. Although the licensing is suitable for industrial usage, and ROS itself has been extensively used in practice (especially in the fields of research and service robotics), other aspects are also important for companies intending to adopt ROS within their technology stacks. These include e.g. matters of liability, hardware support and quality assurance.

In order to fill this gap and to provide financial and managerial support to the initiative, the ROS-I consortium North America was founded in 2013. Under the head of Dr. Ulrich Reiser, group leader at Fraunhofer IPA, a European consortium was launched one year later in 2014. The consortia act as mediators between the open source community and more traditional industrial institutions. The number of members is rising very quickly: as of January 2016, 38 organizations, including research institutions and commercial companies, are part of the two consortia. With the financial resources provided also through their membership fees, joint technical projects (Featured Technical Projects or FTPs) of special interest and directed towards industrial applications can be financed, as well as the general management of the industry-specific parts of the ROS codebase. Fraunhofer IPA is not only managing the European consortium, but it contributes as well to both the development of new components, like the ros_canopen driver, and to the maintenance of existing ROS software. Furthermore, it is an independent technology partner suitable for all projects concerning the planning, conception, and developing of service robot technologies.

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