Robotic arms and end-of-arm tooling

Some service robots are equipped with robotic arms and end-of-arm tools for different purposes. Some of them provide CAN connectivity.

Service robots are increasingly used to serve human beings and are applied in agriculture and in healthcare as well as in other application domains. Some of them have a robotic arm similar to robots suitable for factory automation. The same is true for the end-of-arm tools.

To control the robot arm movements, there are four types of applications, according to an Advantech whitepaper [1]:

- Single operation
- Vision integration
- Multi-tasking collaboration
- High-precision control

Normally, service robots do not require high-precision control and, in most cases, they are moving slowly, especially, if they interact with human beings. Single-operation tasks, repeating something, is also not done by service robots; they collaborate with human beings or distribute meals and medicine, for example. Vision integration is a need in dedicated applications.

Moving the robot arm is implemented in the robot control software. Standardized communication is more than helpful, to reduce programming effort. The CiA 402 profile for drives and motion control internationally standardized in the IEC 61800-7 series (Part 201/301) is a common approach used for controlling robot arm joints. CiA 402 software can be easily integrated into the open-source Robot Operating System (ROS) middleware.

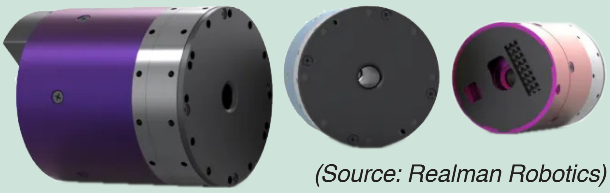
The latest version, ROS2, provides a set of frameworks for robot control. These frameworks cover a range of robot control applications, including:

- Positioning
- Low-level motion execution and interaction with other devices
- Perception via sensors and/or cameras

A data bus based on DDS (Dynamic Distribution Service), a middleware protocol, and an API (application programming interface) provide both modularity and flexibility. The ROS2 software typically sits on top of a real-time Linux environment. Appropriate software drivers and a CANopen protocol stack can control the robot arm peripherals that include motor controllers. If there is one drawback with ROS2, deploying it on hardware can prove ▷

Lightweight robot arm

Realman Robotics (China) has developed the ECO65 series of robotic arm joints designed for humanoid robots. The products feature CAN FD connectivity. The used higher-layer protocol is manufacturer-specific. It is called Tiny Mighty Dynamic Joint Actuator CANFD Communication Protocol. It is a simple commander/responder protocol. The commander message is structured as follows: The first byte contains the command type, the second byte provides the control table index, and the third and fourth byte are the command parameter. The read command has one byte of data representing the number of memory table registers to be read; and the write command consists of two data bytes, which are the contents to be written to the memory table, with the lower bits coming first.



(Source: Realman Robotics)

The response message has the same format as the command message. If the joint device receives a read command, the response message provides the data with the specified length.

If the joint device receives a write command, the response message indicates whether the operation was successful, with 01_h meaning successful, and 00_h meaning failed. When the transmitted command message does not meet the protocol requirements, the actuator returns a CMD_ERR response message. *hz* challenging. The advice here is to seek out a pre-integrated and pre-validated ROS2 bundle that also contains useful packages like MoveIt for motion planning. Advantech recommends to choose host controllers, which support for example Codesys, in order to reduce development effort. This enables the control of robot arms in real-time, regardless of the selected operating system (i.e., Linux, Ubuntu, or Windows). For future service robot application, AI (artificial intelligence) routines need to be integrated on top of the motion control software. Marc Segura, president of the ABB Robotics Division said, AI is enhancing robots' ability to grip, pick, and place. This is also true for service robots. Advantech offers ROS2 software suites supporting CANopen and CiA 402 for industrial robots, which can also be used for service robots.

Communication between robot-arm controller and tools

Usually, at the robot arm's end is applied a tool. This can be a gripper or any kind of tool, including sprayers and dispensers. The tool has impacts on the arms kinematics. In case, the end user can change the tool, the kinematics need to be adapted automatically. As the robot moves, the physical forces at work around it affect the inertia, although often simultaneously creating undesired effects in the settling time and precision, and causing torque sensors to read problematic motion and faults on the motors. The tool always has some weight. When the arm swings, the motors must deliver more torque (and current) to accelerate to the given velocity and keep it constant. If too much current is required, this can be interpreted as a collision, and the robot shuts off power to the motor. This should be avoided. Therefore, the tool provider should provide the weight and the center of mass details to the robot, in order to calculate, how much current is required to move the joints. If the end user changes the tool, this information needs to be communicated by some means to the robot arm controller. CAN is an option. A CANopen profile for end-of-arm tools would enable interoperable communication with the arm controller. This would reduce integration effort.

Collaborative service robots require a functional-safe arm movement and also functional-safe end-of-arm tools. This can include used embedded communication networks. CANopen Safety as standardized in EN 50325-5 fulfills this requirement. ◀

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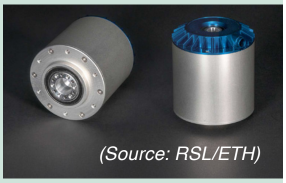
Elastic CANopen joints


(Source: RSL/ETH)

Already in 2016, Robotic Systems Lab of ETH Zuerich university developed the Anydrive joint applied to the four legs of the Anymal robot. The joint unit is built upon high-torque motors and harmonic drive gears in series with a rotational spring. Joint output position and spring deflection are measured using absolute position sensors providing a position accuracy of 0,025° and a torque resolution of 8 mNm. Due to integrated motor control electronics, joint torque, position, and impedance can be directly regulated without any additional components. The corresponding command values are sent over a CANopen network. The maximum bit rate is 1 Mbit/s. With a nominal 48-V voltage, the joint reaches a speed of 12 rad/s and a maximal torque of 40 Nm. The joint housing is IP66-rated. Integration into ROS (robot operating system) middleware is supported. *hz*

CANopen-based robot arm


(Source: Servosila)

Servosila located in Dubai (UAE) has developed a CANopen-connectable robot arm. It is designed for mobile service robots. The product is usually mounted on a chassis or a torso of a mobile robot and powered by the host robotic platform. The robotic arms can be used outdoors and indoors. They are water-tight, dust-proof, and function in rain and snow. They are controlled via a CANopen network. The robot host controller sends commands to the servo actuators of the robotic arm and receives execution reports from them. For convenience, an external USB-to-CAN adapter (dongle) is supplied with robotic arms.

The robot host controller runs either Linux or Windows or no operating system at all as long as it provides a CANopen interface. A software package for ROS, an open-source robotic operating system, is available online for those programmers or researchers, who prefer using ROS. The robotic arms come with a package of software tools for configuring, testing, health-checking, and fine-tuning the arms. The software shall normally be installed on a laptop computer or a PC that gets connected to the arm via a USB-to-CAN adapter, whenever the arm needs to be serviced.

The robot arm is equipped with either a rotating or a non-rotating gripper optimized for grabbing objects from the ground or from various heights. Opening doors by rotating the door handles is a key design use case. The grippers might have provisions for installing additional instruments such as dirt digging claws or drills.

The fingers of the gripper come with hardpoints for connecting external tools. The hardpoints on the fingers and on the chassis come handy when the robot needs to be adapted for a specific remote engineering operation. For example, special claws at the tips of the gripper fingers enable the robot to drag suspicious objects such as left bags, cut open holes, or gently open the bags. According to the supplier, the claws also enable the robot to dig dirt or pick objects hidden under piles of rubbish. The claws are optional and field-installable. *hz*