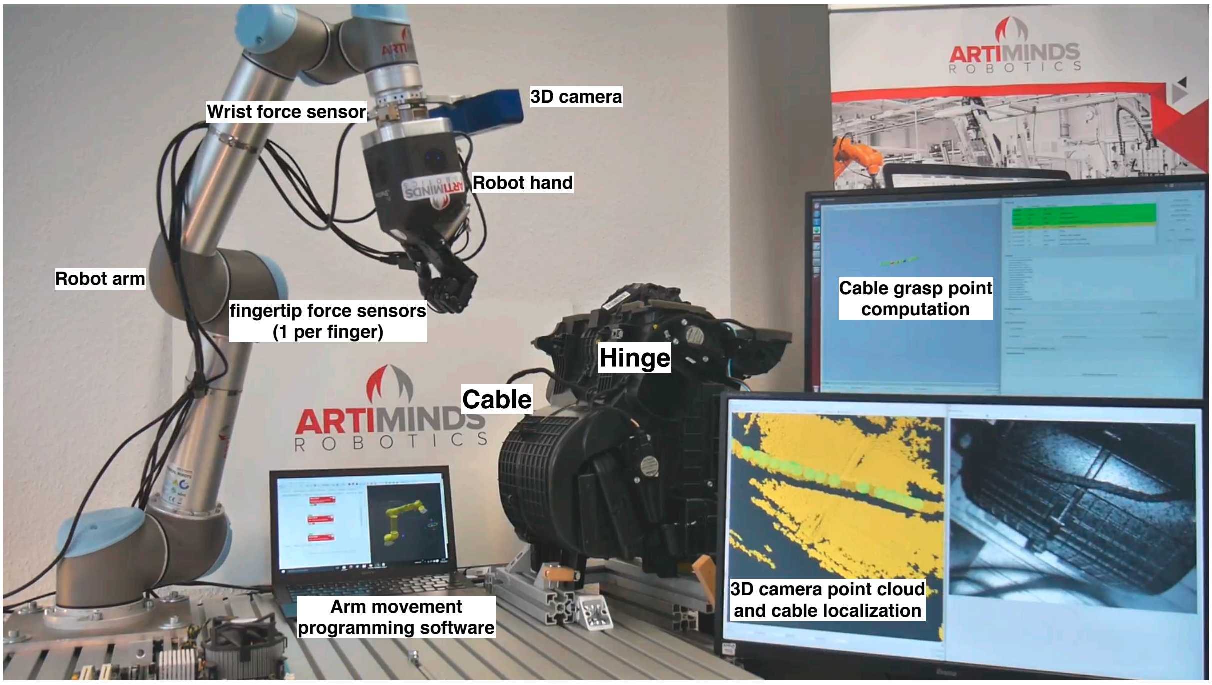
Storyboard Experiment DexBuddy

I) Overview



In the task the robot has to grasp a **cable** of a vehicle air conditioning system (HVAC) and clip it into a **hinge** at the HVAC.
The robot consists of a **robot arm** and dexterous **robot hand** with four fingers. It has three main external sensor types: a **3D camera** mounted at its wrist for close range depth vision, a **6D force-torque sensor** at its wrist and a 3D **force sensor** in each **fingertip**.

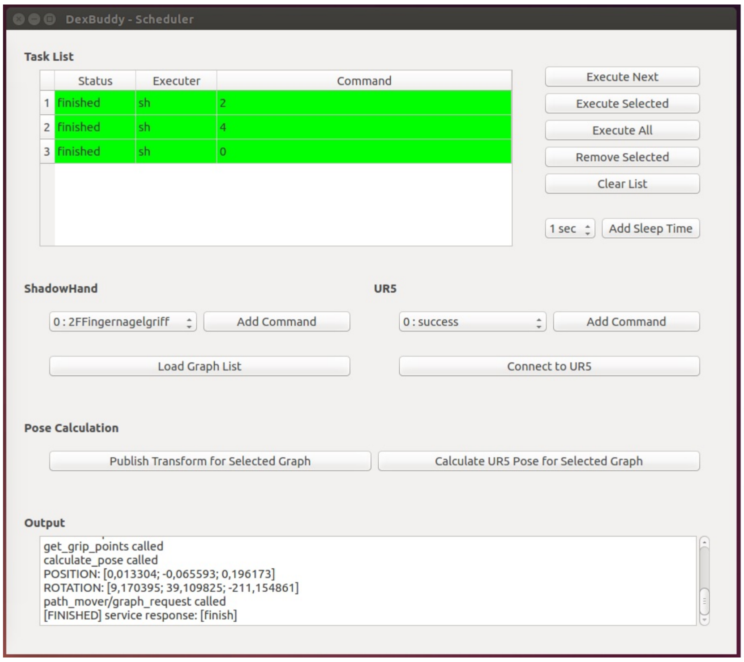
The experiment has to combine 3D-vision for cable pose estimation and respective grasp planning with force-control-based execution of both dexterous finger as well as arm movements. This leads to highly sensor-based autonomous execution of the complex task.

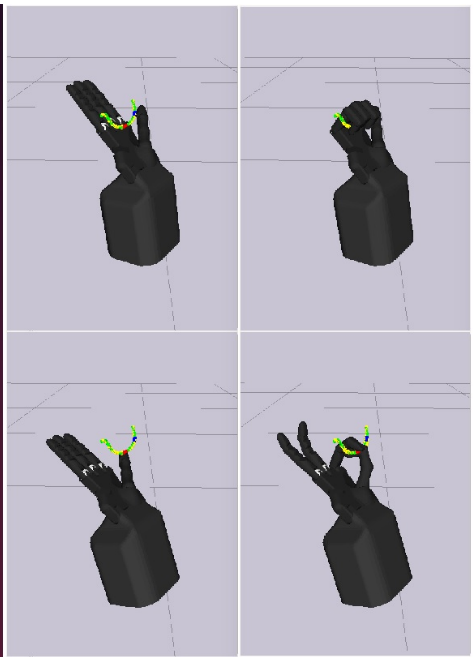
There are 4 main groups of software components for handling the execution:

1) Vision for cable localization
2) Force-controlled and trajectory-based arm movement
3) Force-controlled and trajectory-based hand movement
4) Coordination/scheduling

The coordination/scheduling group is outlined as follows:


rviz
hand_gui
/sh_JOINT_position_controller/command
/sh_JOINT_position_controller/pid/set_parameters
/get_cable_points
visualize_cable_raw
/get_cable_points
/visualization_marker
visualize_cable
/get_grip_points
/visualization_marker
visualize_grip_points
/visualization_marker
Legende
A
Service
B
A calls service of B
A
Topic
B
A publishes message on topic
transform_broadcaster
/set_transform
cable_handler_server
/calculate_pose
/get_grip_points
scheduler
/path_mover/graph_info
/path_mover/graph_request
path_mover
/cable_detection_3d/cable_detection/cables
vision
ur5
shadowhand


DexBuddy - Scheduler
Task List
Status
Executer
Command
1 finished sh 2
2 finished sh 4
3 finished sh 0
Execute Next
Execute Selected
Execute All
Remove Selected
Clear List
1 sec
Add Sleep Time
ShadowHand
UR5
0 : 2FFingernagelgriff
Add Command
0 : success
Add Command
Load Graph List
Connect to UR5
Pose Calculation
Publish Transform for Selected Graph
Calculate UR5 Pose for Selected Graph
Output
get_grip_points called
calculate_pose called
POSITION: [0,013304; -0,065593; 0,196173]
ROTATION: [9,170395; 39,109825; -211,154861]
path_mover/graph_request called
[FINISHED] service response: [finish]

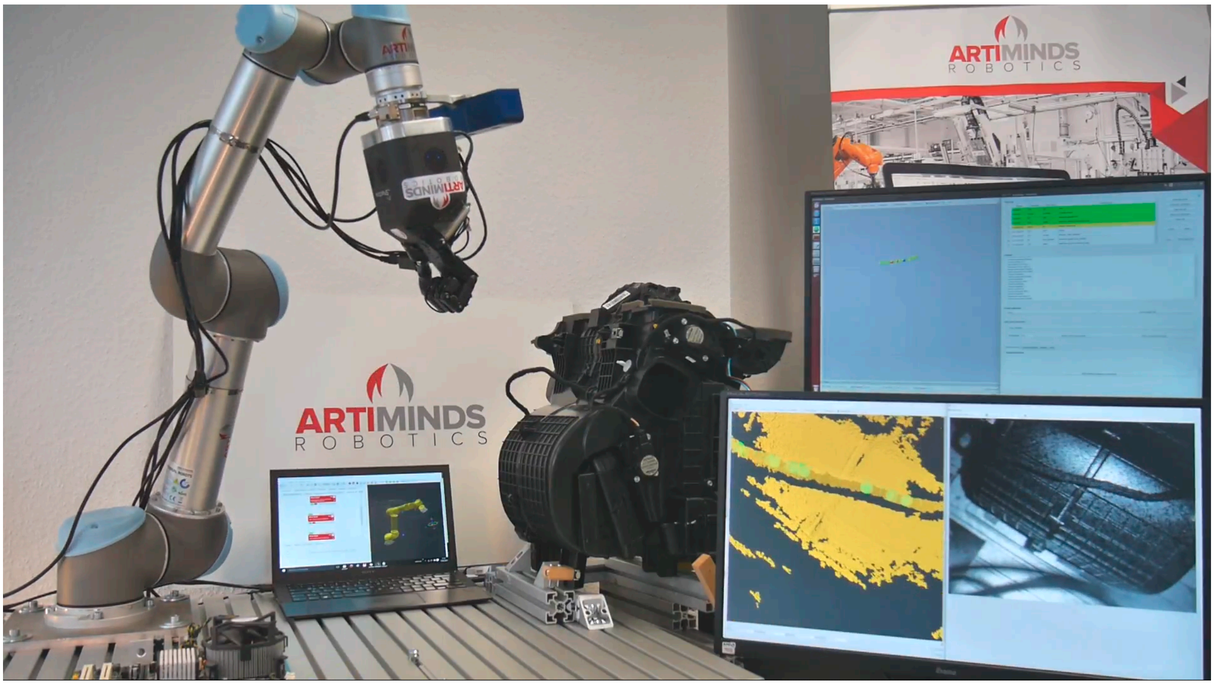


II) Execution of the task

Step 1: Localization of pose and shape of the cable

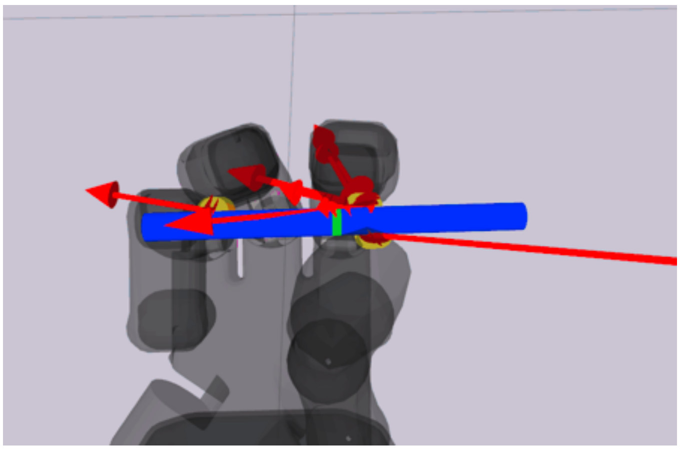
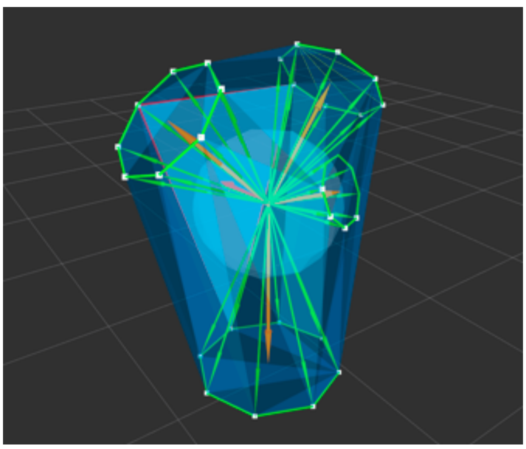
In the first step, the robot arm moves its wrist into a suitable pose for the 3D camera to localize the cable within a designated area. Here, the camera has approximately a distance of 40cm to the cable. The cable is without any natural or artificial markers.

Cable localization is performed over several frames to get robust results. This procedure takes under 5 seconds for robust results. A single recognition instance takes less than 1 second. The result is a sequence of spheres, modeling the cable pose and shape in space in the frame of reference of the robot. This is in turn used for the next step.



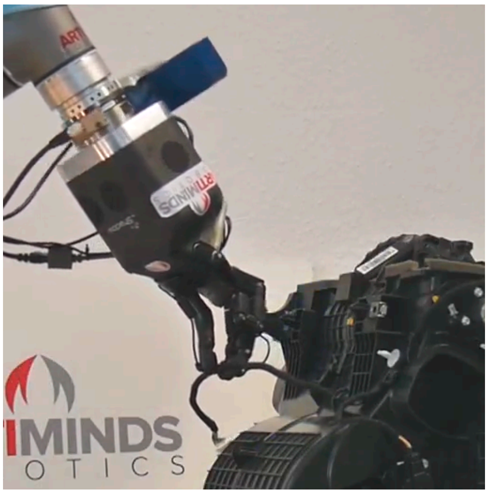
Step 2: Planning the grasp for the cable

Given a model of the current shape and pose of the cable, a previously computed grasp type is selected from a database. These grasps are computed using grasp wrench space analyses on common cable shape configurations. Arm and position control finger movements are computed to match the localized pose of the cable in space.

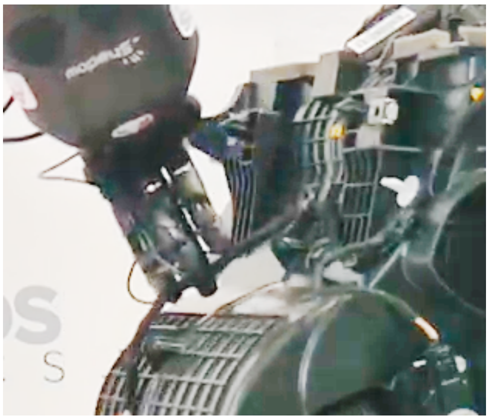



Step 3: Execution of the grasp using position and force-feedback control
The initial part of a grasp is executed by simultaneous position-controlled arm and finger movements. The final part, however, needs force-feedback control of the finger motions to robustly reach a stable grasp. Therefore, a switch from position control to force control is performed for the finger motions near the end of the planned grasp. The final force-control segment uses predefined control strategies and the 3D fingertip force sensors to achieve stable grasps of the cable.

Step 4: Stretching the cable
After the cable has been grasped robustly, the cable has to be stretched to achieve a defined state of the cable. This is realized by moving the robot arm in force-feedback control mode, which uses the force-torque sensor mounted at the wrist. The robot will thus feel when the cable is stretched.



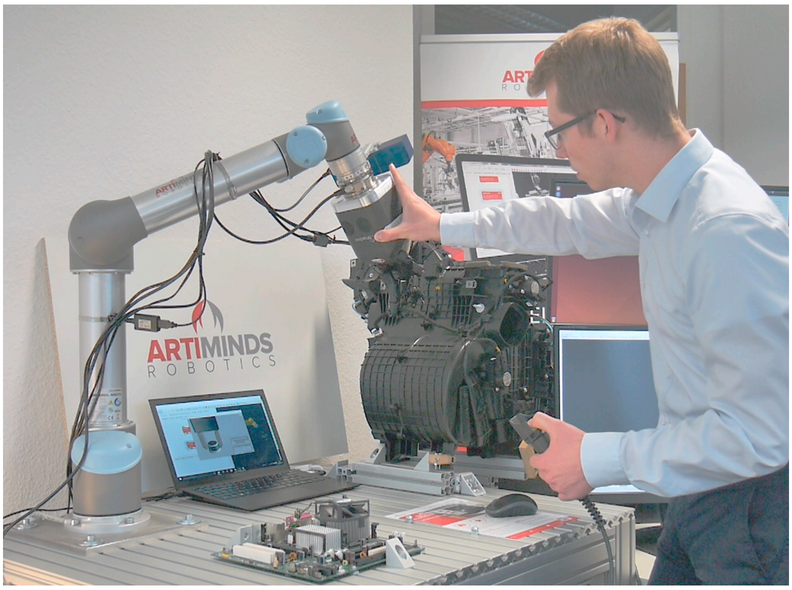
Step 5: Clipping the cable into the hinge
Next, the robot executes several motions to form a strap, which can be inserted robustly into the hinge. The robot uses its 4th finger in a dexterous manipulation movement to support the force-controlled insertion.



Step 6: Release of the cable
Finally, the cable, which is inserted into the clip, is released.

III) Teach-in of the task

Teaching arm movement key poses:
Key poses of the arm movement are set by intuitively guiding the robot in combination with the graphical user interface of the ArtiMinds Robot Programming Suite.



Teaching finger poses for parameterization of grasp planning:
Finger poses for parameterization of grasps and dexterous manipulation are set in a similar fashion as the arm poses, but in a distinct software environment, managing the grasp database.