REMODEL - Robotic tEchnologies for the Manipulation of cOmplex DeformablE Linear objects

Deliverable 6.3 – Mechatronic tools for grasping and manipulation

Version 2019-10-14

Project acronym: REMODEL
Project title: Robotic tEchnologies for the Manipulation of cOmplex DeformablE Linear objects
Grant Agreement No.: 870133
ObjectsTopic: DT-FOF-12-2019
Call Identifier: H2020-NMBP-TR-IND-2018-2020
Type of Action: RIA
Project duration: 48 months
Project start date: 01/11/2019
Work Package: WP6
Lead Beneficiary: UNIBO
Authors: All
Dissemination level: Confidential
Contractual delivery date: 30/06/2021
Actual delivery date: 30/06/2021
Project website address: https://remodel-project.eu

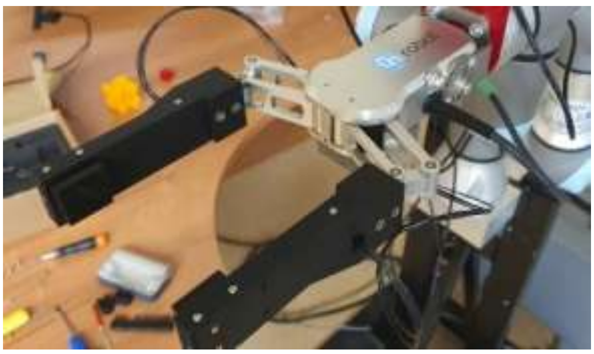
1 Scope

This deliverable includes the documentation about the tools developed in Task 6.3.

On the basis of the experience gained during the WIRES experiment, several grasping and manipulation tools have been developed for the different use cases in order to perform preliminary tests and implement the rootic platforms in T6.1. Moreover, both tactile sensors build in T6.2, 2D low-cost cameras as well as endoscopic cameras for close view on target objects have been integrated into the manipulation tools in order to evaluate the benefits for tasks like the cable insertion and connection or cabel shape detection. Also small-size 3D vision sensors like the Intel RealSense have been evaluated and integrated into the grasping tools.

(a)

(b)



(c)

(d)

Figure 1. Tactile sensors integrated into partners' grippers: WSG-50 @TECNALIA (a), Panda gripper @UNIBO (b), WSG-50 @TAU (c), RG2 @PUT (d).

The grasping tools are based on commercial parallel grippers, while the tactile sensors developed in T6.2 have been integrated in the gripper fingers. These tools are also used to investigate the wire manipulation problems in WP5.

The developed tools will be further refined and adapted data to optimize the final end effectors for REMODEL use cases along the integration and validation phases carried out in WP7. Open source ROS packages have been developed where needed for the implementation of the communication interface between the grasping tool and the other parts of the robotic platforms.

2 Results

2.1 Grasping tools

A couple of fingers sensorized with the tactile sensors developed in T6.2 have been designed and integrated into different kind of commercial parallel gripper. Integration in different grippers available in REMODEL partners' laboratories has been completed by using an additional PCB boards allocated on the gripper for the acquisition of the sensing data. The selected grippers are WSG-50 available at UCLV, TECNALIA and TAU, Panda gripper available at UCLV and UNIBO, OnRobot RG2 available at PUT. A ROS package to control the WSG-50 gripper has been released at it is available in the REMODEL gitlab repository[1]. All the tactile sensors have been tested in UCLV laboratory in T6.1. ROS packages for the data acquisition has been developed and released for partners. The tactile sensors have been characterized in terms of sensitivity, linearity, hysteresis, Signal-to-Noise Ratio and time response. A couple of fingers have been sent to UNIBO, TECNALIA, PUT and TAU for the integration in robotic platforms. Figure 1 reports pictures of tactile sensors integrated in robotic platforms at partners' laboratories. The data have been used in T5.2 to start the implementation of grasping algorithms.

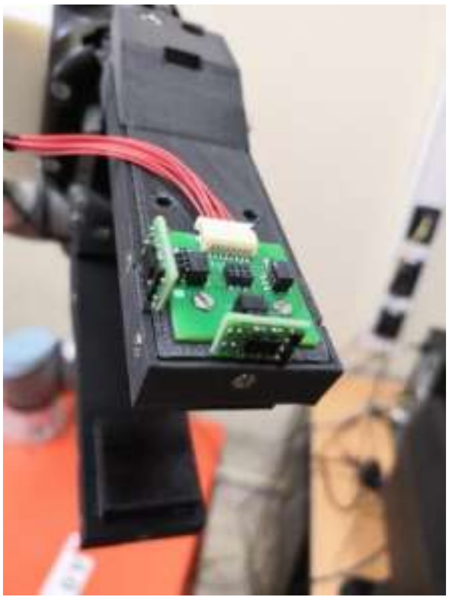


Figure 2. Realized prototype of the proximity sensors mounted on the sensorized finger used for testing.

A proximity sensor module has been designed to be integrated around the fingers already sensorized with the tactile sensors. Up to 4 proximity sensing points based on Time-of-Flight devices can be added to a finger. A microcontroller-based additional board has been designed to drive the proximity modules and to interface them with the same acquisition board available on gripper. Firmware for the on-board microcontroller has been developed and tested. All components have been produced, in order to test the proximity sensor capabilities. A ROS driver for the acquisition of proximity data has been developed and tested. Figure 2 shows some pictures of proximity sensor development.

Due to the specific requirements of the switch-gear cabling use case, specific very thin fingers

[1] https://dei-gitlab.dei.unibo.it/palli_group/wsg50-ros-pkg-remodel

have been designed to executed the cable grasping and connection. The Schunk MEG 40 electric gripper has been preliminarly selected for this use case due to its reduced size and opening compatible with the application requirements. A ROS package to control the Schunk MEG 40 gripper has been released at it is available in the REMODEL gitlab repository[2]. Figure 3 reports some CAD drawing of the developed finger prototypes. In particular, Figure 3(a) and Figure 3(b) show the gripper in open and closed configuration respectively. Figure 3(c) shows a detail of the finger pad, in which suitable grooves have been included to hold the wire orientation during the insertion task. These grooves allow to hold the cable in horizontal and vertical position and at ±45 degrees of rotation.

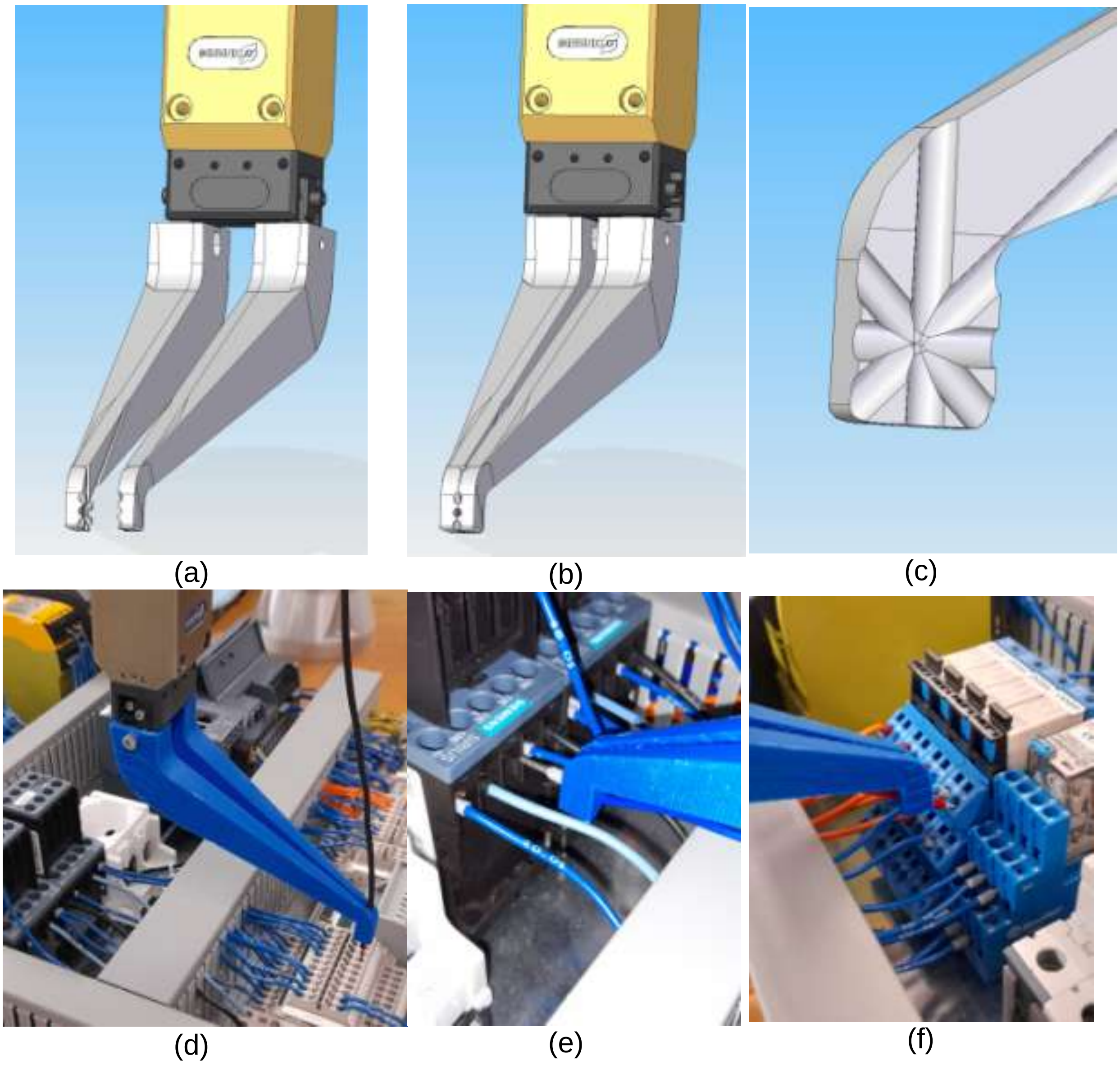


Figure 3. CAD design of the fingers for cable connection in UC1 in open position (a), and in closed position (b), detailed view oft he finger pad with grooves for cable holding (c), the finger prototypes inserting a cable in vertical direction (d), horizontal direction (e) and at 45 degrees (f).

[2] https://dei-gitlab.dei.unibo.it/lar/gripper_meg_40_ec_control_package.

These fingers have been used to evaluated the cable insertion on different types of components. In particular, Figure 3(d) shows the insertion of a cable into a vertical terminal block, while shows the insertion of a cable into a vertical terminal block, while Figure 3(e) shows the insertion on a horizontal screw terminal. Finally, Figure 3(f) show the insertion of a cable in relay blocks at 45 degrees.

Figure 4 shows the design of the so called crocked fingers that have particularly conceived to deal with the grasping of the cables directly from the Komax machine. The shape of these fingers will couple with the ones used in the Komax machine for the final cable preparation stage. The crooked fingers will approach Komax grasping point from bottom have been designed to be integrated into Robotiq Hand-e gripper. The collected cables are then arranged on a suitable warehouse than can be then moved to the assembly station for both manual and automatic assembly. Suitable clips to be integrated inside the warehouse for cable collections have been designed and mechanically simulated (via FEM) to evaluate its functionality with cables ranging from 0.5mm to 6mm. In T6.2, the design of tactile sensors for the crocked fingers has started.

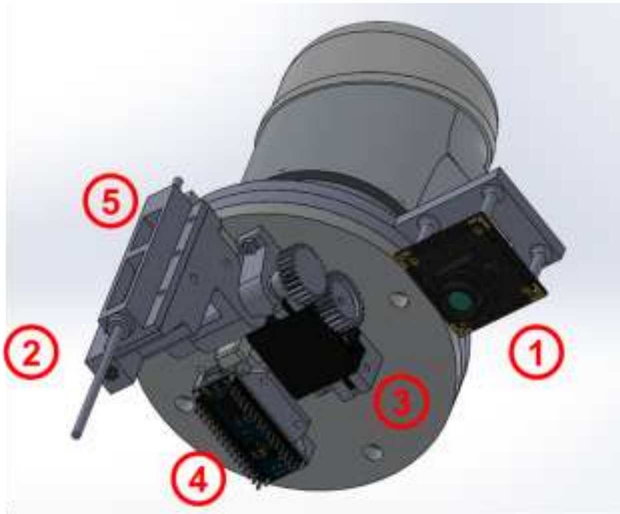
(a) (b)

Figure 4. CAD design of the fingers for cable production management (a), detailed view of the integration in the hand-e gripper (b).

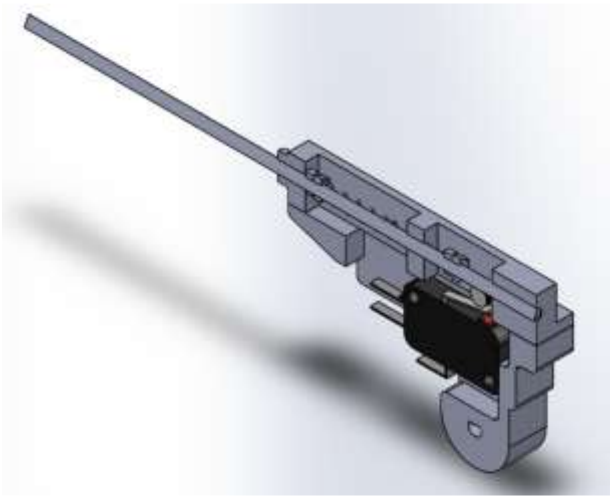
2.2 Tool for connection on terminal blocks and connection checking

A specific tool have been designed to open the elastic clips for the connection on terminal blocks and for the execution of connection check. Figure 5 shows the design details and the prototype of this tool implemented for the system validation.
In particular, with reference to Figure 5(a), this tool is composed by:

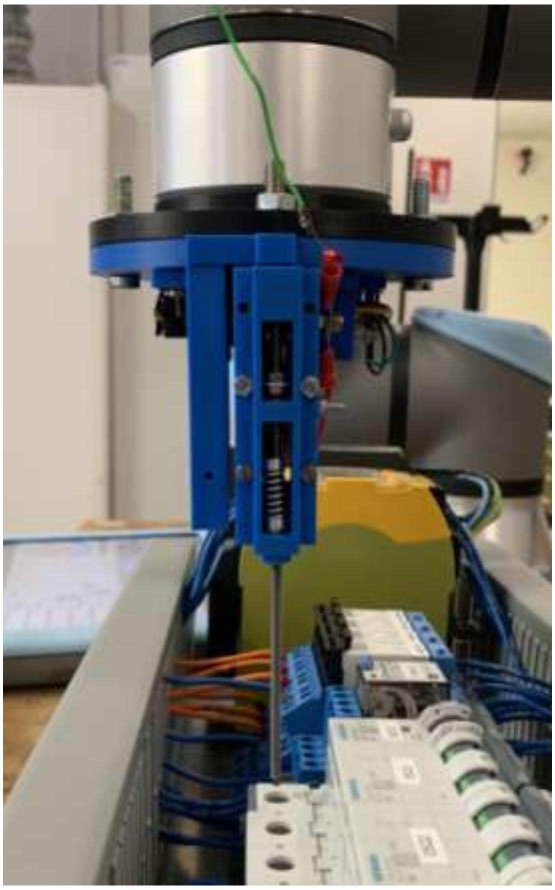
1. 2D USB Camera for component detection;
2. Endoscopic Camera for precise insertion control;
3. Micro-Servo Driver to retract the tool when not needed;
4. An Arduino Nano board to control the tool;
5. A Sliding tester to sense the contact and check the connection.



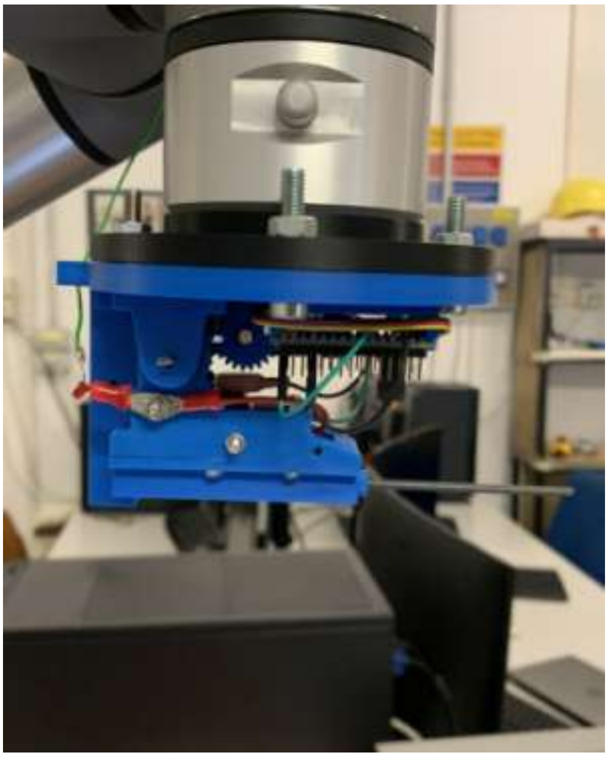
(a)



(b)



(c)



(d)

Figure 5. CAD design clip opening and testing tool (a), detail of the tool suspension and contact detection mechanism (b), a picture of the developed prototype with extended probe (c) and with retracted probe (d).

Figure 5(a) reports also a detail of the mechanism to retract the probe, while Figure 5(b) reports details of the tool suspension and probing mechanism, together with a view of the switch that can be used by the robot to improve the interaction with the terminals. The retractable tool will be combined with the screwdriver in order to be able to operate with both screw and clip terminals with the same tool. A picture of the developed prototype with extended probe can be seen in Figure 5(c), while a picture in which the probe is retracted is reported in Figure 5(d).

(a) (b)

Figure 6. Grippers with integrated vision: Panda gripper with 2D and 3D cameras @UNIBO (a), WSG-50 with 3D camera @TECNALIA.

2.3 Vision system integration

Figure 6 reports a couple of samples of how the vision system has been integrated into the tools for cable grasping. In particular, Figure 6(a) shows the Panda gripper with integrated 2D camera and 3D vision sensor (Intel RealSense D435) for comparison on the capabilities to reconstruct the cable shape and localize the components. Figure 6(a) shows the WSG-50 gripper with integrated 3D vision sensor (Intel RealSense D435) for the detection of the components during wiring harness assembly.

2.4 Rolling Fingers

The rolling fingers have been designed for the grasping and manipulation of cables during the routing to control the cable sliding without slipping. The rolling fingers have integrated actuation, position and inertial sensing through IMU, and a local microcontroller manages the coordinated motion of the finger with the desired trajectory of the cable. Figure 7(a) shows the CAD design of the rolling fingers and their integration with the Schunk MEG 40. A couple of rolling fingers prototype have been realized by using the 3D printing technology, as shown in Figure 7(b), and experimentally tested to control the sliding of the cable, as reported in Figure 7(c). A ROS package have been created for the interface with the rolling fingers[3].

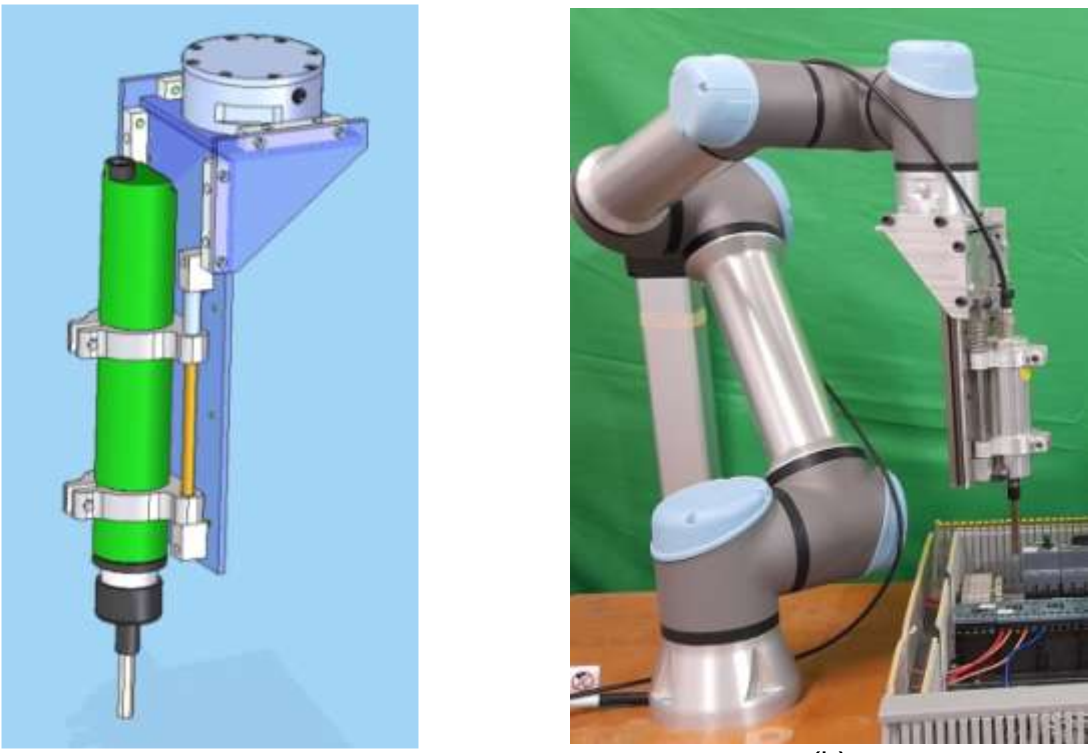
[3] https://dei-gitlab.dei.unibo.it/palli_group/rolling_fingers

(a) (b) (c)

Figure 7. CAD design of the rotary finger (a), rotary finger prototype (b) and rotary fingers during the manipulation of a cable (c).

2.5 Screwdriver

The tool is composed by an integrated torque/controlled screwdriver with remote PLC control and process data recording capabilities (Kolver PLUTO3CA electric screw-driver + EDU2AE/TOP/E control unit) an by a support for the integration of the screwdriver into the robot. Figure 8(a) reports the CAD model of the tool, while Figure 8(b) show its integration with the robotic manipulator in the UC1 robotic platform.



(a) (b)

Figure 8. CAD model of the screwdriver with robot support (a), picture of the tool mounted on the robot (b).

The screwdriver controller is programmable in terms of rotation speed and maximum torque, and a ROS interface has been developed to in order to select the different program to run depending on the different type of connections to be performed. The software package to control the screwdriver is available at the REMODEL repository[4].

2.6 Surface preparation tool

A devoted automatic tool for the preparation of the medical hose surface for quality analysis has been designed. After the evaluation of several alternative solutions, the design is now focused on multiple comb-type wheels that maintain the alignment for the hose during the execution of the cut. Figure 9 reports some CAD examples of developed tools. The surface preparation tool will be controlled by a local board and will be provided with a user interface to enable its usage by human operators.

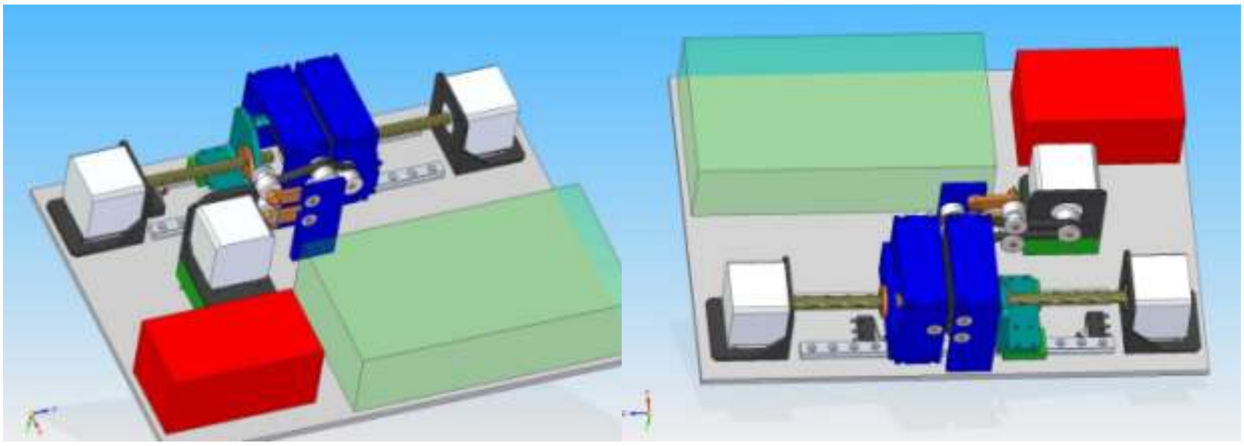


Figure 9. CAD model of the surface preparation tool for UC4: back view (a) and front view (b).

3 Conclusions

This document reports an overview of the mechatronic tools developed in REMODEL to manage cables and medical hoses acoording to the application requirements. Most of the proposed devices have been tested to TRL 4. The capabilities in terms of workspace, max gripping force, accuracy in positioning and velocity are evaluated in laboratory, taking into account all use cases tackled in this project. During the integration of the different use cases, if needed, an optimized version of the tools will be released. ROS packages are released for the different tools and tested in a PC-based ROS network. All HW/SW characteristics are compared with the system requirements defined in WP2.

Durign the implementation of REMODEL at TRL 5, the tools will be integrated into a robotic platform both from hardware and software point of view. All communication features with the industrial interfaces will be tested and verified.

[4] https://dei-gitlab.dei.unibo.it/palli_group/screwdriver_interface