SAPHARI

SAFE AND AUTONOMOUS PHYSICAL HUMAN-AWARE ROBOT INTERACTION

SEVENTH FRAMEWORK PROGRAMME

COGNITIVE SYSTEMS & ROBOTICS

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D.2.2.1 - Low-cost modular VSA platform

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Nature: P	**Dissemination Level:** PU
R = Report P = Prototype D = Demonstrator O = Other	PU = Public PP = Restricted to other programme participants (including the Commission Services) RE = Restricted to a group specified by the consortium (including the Commission Services) CO = Confidential, only for members of the consortium (including the Commission Services)

WP Leader: UNIPI

Partners Contributed: UNIPI, UNIROMA, IIT, DLR

Executive Summary

This deliverable presents the level of readiness in the development of the “Exploratory Platform for Variable Stiffness Actuation”, Task 2.2. According to the DOW specifications, in the description of T2.2 and D.2.2.1, the new platform, *qbmate*, is defined and the actuation units together with the mechanical, electrical and software interfaces are ready (see Section: Introduction). The delivery of the platform to the others consortium partners has already starded, together with a preliminary distribution to new users and members of the Natural Machine Motion Initiative community, NMMI, (see Section: Introduction).

As described in the following report, the platform is currently composed of two main actuation units, the *qbmove maker* and *maker pro*, see Section 1.1, and will be completed by a third unit, the *qbmove advanced* (see MS33 for details). Each of these units presents the carachteristics of a variable stiffness servo actuator. Thanks to the embedded electronics (Section 1.3) and a complete set of libraries and tools (sections 1.4 and 1.6) it is possible manage the actuators in order to make an easy and profitable control of their position and stiffness preset. The platform is completed by a set of standard mechanical interconnection components (Section 1.2) for the realization of different kinds of robots, as shown in Figure 1, and a set of customizable ancillaries (Section 1.5) that expand the standard capabilities of the platform, e.g. grippers, stereo cameras etc. Finally, according to the open SW and open HW paradigm of the platform, all the information (3D CAD, electronic schematics, manuals etc etc) regarding the platform is available on the NMMI website, under a Creative Commons Attribution 4.0 International License.

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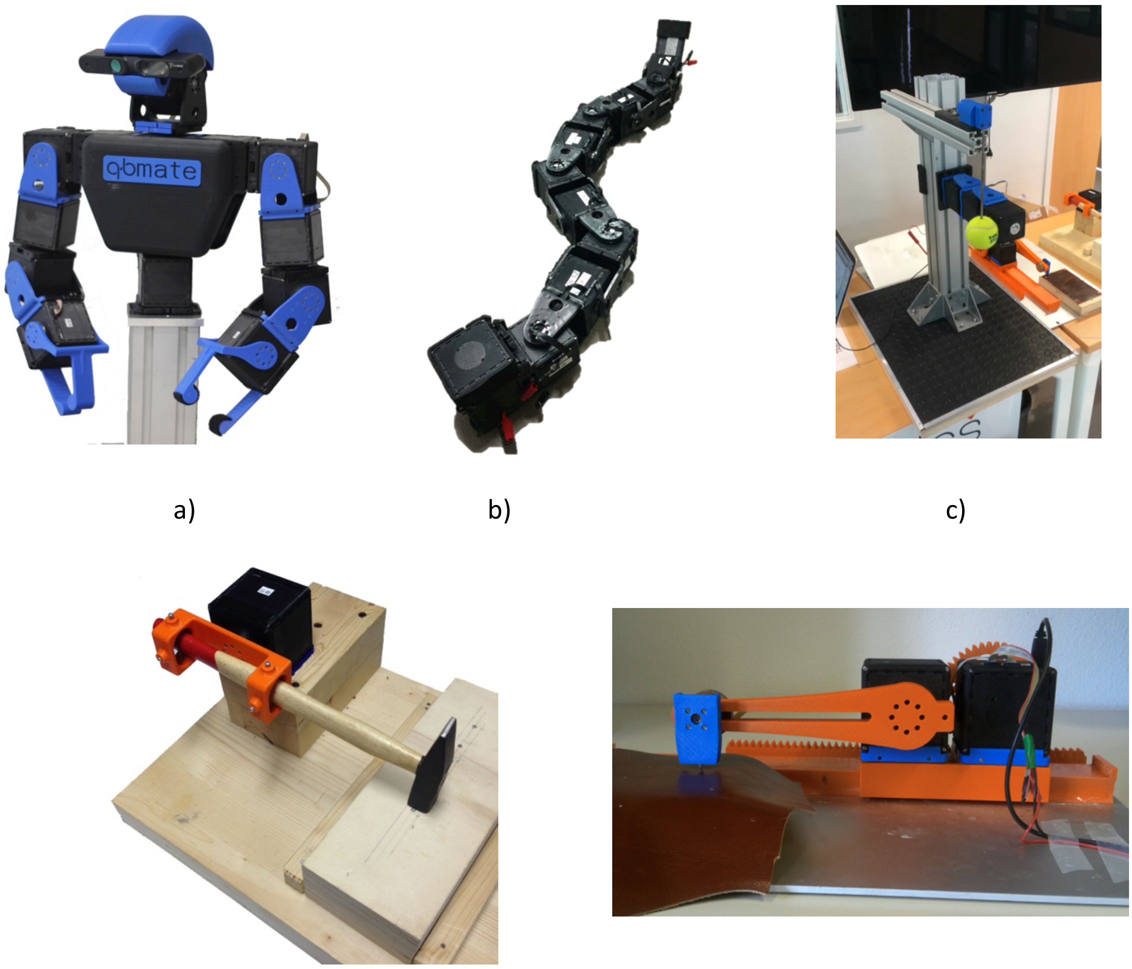
Introduction

As proof of the effectivness of the platform and its implementation Figure 1 show some different kinds of employment of the qbmoves: a 12 DOFs humanoid upper body, a 10 DOFs snake, a 3 DOFs arm, a 1 DOF hammer and a 2 DOFs cutter.



a) b) c)

d) e)

Figure 1 The picture shows some of the emplyment and rahilazations made with the qbmove variable stiffness units. Picture a) shows a 12 DOFs upper body completed by two simple 1 DOF grippers and a stereo camera, b) show the implementation of a 10 DOFs snake, c) show a 3 DOFs arm adopted to evaluate dymanic performance of the units, d) show a single DOF arm platform used to evaluate the power performance of the units and finally e) show a 2 DOFs leather cutter platform.

Table I report some of the related dissemination activities (lives demos and oral presentations) performed to show and promote the platform in some of the most important robotics conferences, fears and events.

EVENT	KIND of CONTRIBUTION	ACTIVITIES
Human Friendly Robotics, Rome, 2013	Conference presentation	Live Demos and booth
TechFest, Mumbay, 2014	Fear Booth	Live Demos and booth
International Conference on Robotics and Automation, Hong Kong, 2014	- Workshop on snake Robotics - Workshop on Matlab for robotics	Live demos
International Conference in Intelligent Robot and System, Chicago, 2014	- Workshop on VIA - Conference Booth - Plenary session on NMMI - Paper presentation	Live Demos and booth
Human Friendly Robotics, Pontedera, 2014	Conference presentation	Live Demos

Table 1 The Table show some of the main robotic events where the qbmoves and qbmate platform were showed and presented in the 2014.

Table II report the current distribution and diffusion of the produced units.

CUSTOMER	UNITS AND KITS	STATUS
UNIPI	3 full kit + upper body accessories 4 full kit + accessories	delivered delivered
University of TUM	1 Advanced KIT + upper body accessories	delivered
DLR	3 qbmove units + accessories	delivered
UNIROMA	1 qbmove unit 1 full kit + upper body accessories	delivered in delivery
UNINAPOLI	1 qbmove unit 1 full kit + upper body accessories	delivered in delivery
Beihang Univerisity	1 qbmove unit + accessories	delivered
Fraunhofer IPK	1 qbmove unit + accessories	delivered
King's college London	1 qbmove unit + accessories	in delivery
The University of Tokyo	2 qbmove unit + accessories	delivered
LAAS-CNRS, Robotics and InteractionS group	1 qbmove unit + accessories	In delivery
Note: the remaining qbmoves are currently assembled or ready to be assembled at the qbrobotics facility		

Table 2 this table shows the stage of the current production activity together with the diffusion of the units between project partners and new users.

Section 1 report a short summary of the platform structure and ancillaries. Details about mechanics, electrical and software framework are available inside the Natural Machine Motion Initiative community website. Pushing over the basic idea of building a completely open source platform in software and HW, from the NMMI website community it is possible to download source CAD file, source libraries, electronic schematics and codes for applications, under a Creative Commons Attribution 4.0 International License.

qbmate platform

The qbmate platform is intended as a modular system that makes capable a user to build a several number of robotic devices and perform with them a several number of experiments and investigation studies, as shown in Figure 1.

Actuation units

Two actuation units are now available, Fig. 2, the *qb move maker* and the *qb maker pro*, the two systems are fully compatible, one respect to the other, in HW and SW, but differ for different range of performance (in terms of torque, speed and range of stiffness), production requirements and the internal control electronic.

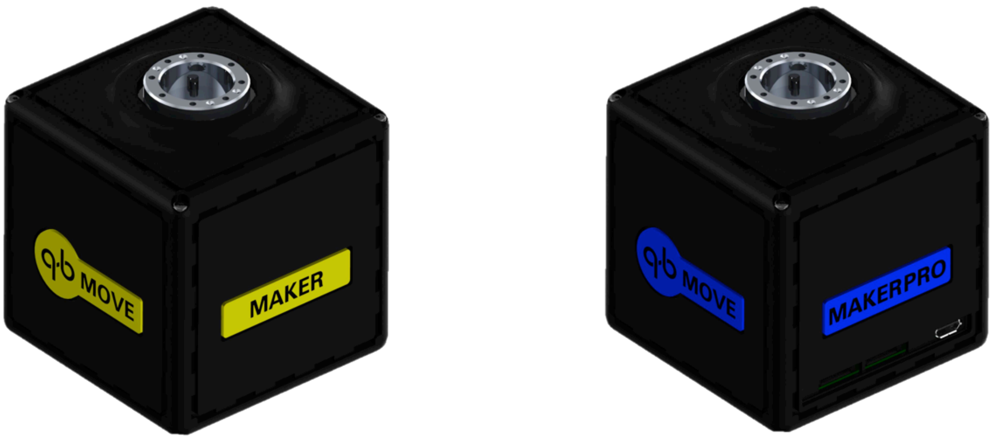


Figure 2 The picture shows the two actuation units that compose the qbmate platform: the qbmove maker, a simple fully 3d printed, 100%arduino compatible units and the qbmove maker pro, an evolution of the previous one, characterized by better performance, customized electronic boards and deasy chain capabilities.

The *qb maker* is thinked to be cheap, easy to build with rapid prototyping machines and fully compatible with Arduino boards. The *qb maker pro* unit have increased performance with respect to *qb maker*, it is builded with much more strong material and present a complete customized electronic board that allows better performance in terms of electrical interconnection capabilities, control and communication capabilities.

A third actuation unit, *qbmove advanced*, is currently in an advanced production definition phase (much more details on the MS33), and will be integrated inside the *qbmate* platform. This unit allow the *qbmate* platform to deal with highest torque and speed ranges together with increased variable stiffness performance.

Mechanical interconnection system

Figure 3 shows the basic mechanical interconnection components that compose the platform. The main component of the mechanical interface is the CORE element that combined with FLAT WINGS or C WINGS, allows the implementation of revolute joints with parallel (Fig. 3b) and perperndicular axes (Fig. 3c). Fig. 3 d shows the implementation of a rigid interconnection between two actuation units and Figure 3 a) shows the snap-on open/close system of the interconnection flanges.

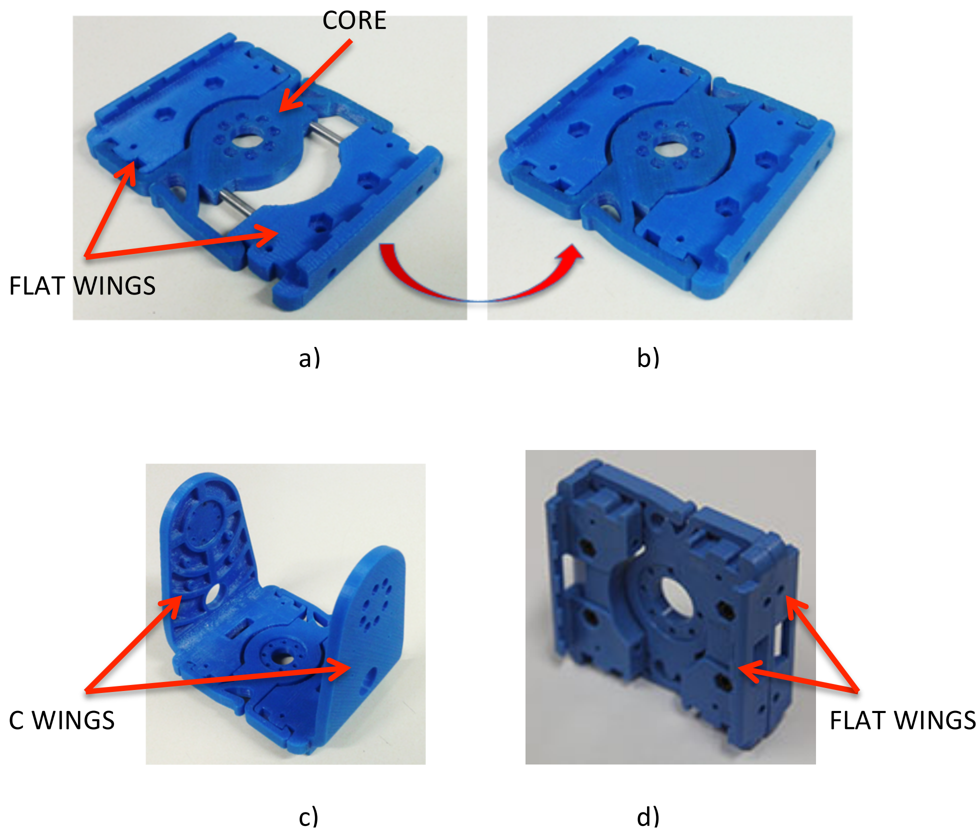
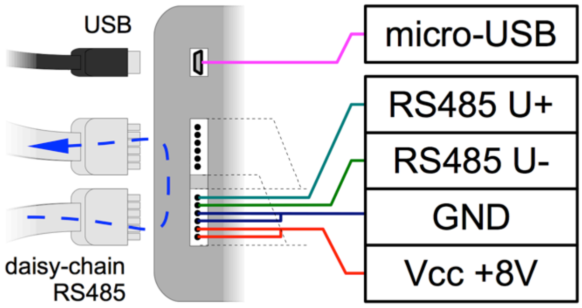


Figure 3 The pictures show the three basic typology of interconnections that is possible to realize with the platform: parallel (b), perpendicular (c) and rigid (d). Picture a) shows the open/close mechanisms.

Electrical interconnection system

Figure 4 a) shows the electrical and communication interface of the *qbmove maker pro* unit, together with a picture of the electronic boards (Fig. 4 b).



a)

b)

Figure 4 The figure shows the electrical and communication interface of *the qbmove maker pro* unit a) and the electronic board that is installed inside each single unit b).

As shown in the picture each unit have a USB port, that allow the simple connection to a computer or external control units and two I/O power and communication ports, these ports allow the implementing of the daisy chain connection.

The RS485 communication bus allows the realization of a daisy chain interconnection up to 15 units. A single power chain between the actuators is capable to support up to 5 units.

Some special electronic interfaces, *qbally*^{2} and *qbally*^{4} are developed to allow the rehalization of chains up to 20 units in a single robotic device. An example is shown in Figure 5.

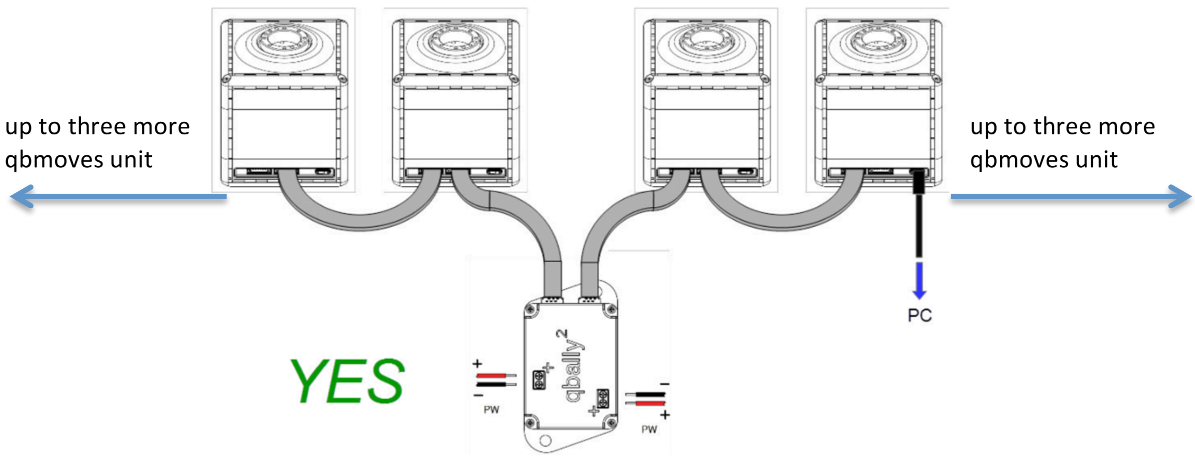


Figure 5** the Figure show how it is possible, adopting the qbally*^{2} *interface, rehalize a daisy chain (power and communication) connection between ten qbmove maker pro units.

Software

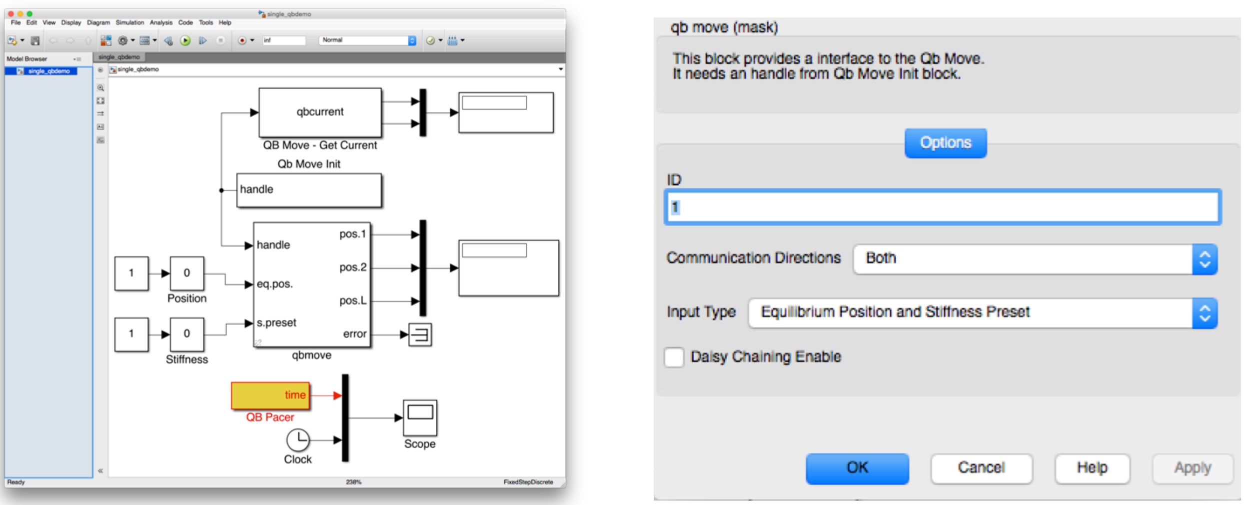
The platform is supported by a complete set of software utilities and libraries available on the NMMI website:

- C++ libraries
- MATLAB\Simulink control and simulation toolbox (as shown in Figure 6 a)
- A graphics interface is available for the managing of control parameters and electronic board
- a ROS node is currently under development and test.

The software platform is currently fully compatible with Windows, Mac OSX and Linux Operating Systems.

Each *qbmaker pro* unit have inside a set of different control modalities that allows different kinds of control strategies ("Input Type" in Figure 6 b):

- Sitffness and position control: the most simple and standard, this is the modality that allow the user to use the actuator as a variable stiffness servo motor.
- Current control: this is a much more sofistacated control modality that allow the user to go deeply inside the system and have, for example, a direct current control on the prime movers.
- Advanced modality: in this modality it is possible for the user to modify and changes all the parameters that are inside the system (e.g. ranges of motion, PID parameters, current limit, gains etc).



a) b)

Figure 6 Figure a) shows and example of MATLAB\Simulink schema, the main qbmove command block and the qbpacer, a soft real time tool, are highlighted. Figure b) show a detail of some parameters that the user can manage inside the qbmove command block, e.g. the input modality.

Ancillaries

In order to expand the capabilities of the platform and adapt each kinematics to a specific task or to a specific robot behaviour a set of complementary components have been developed. Figure 7 show some examples of customized mechanical components, a two DOFs head (7a) and a 1 DOFs gripper. Some details about these components are reported on MS34.

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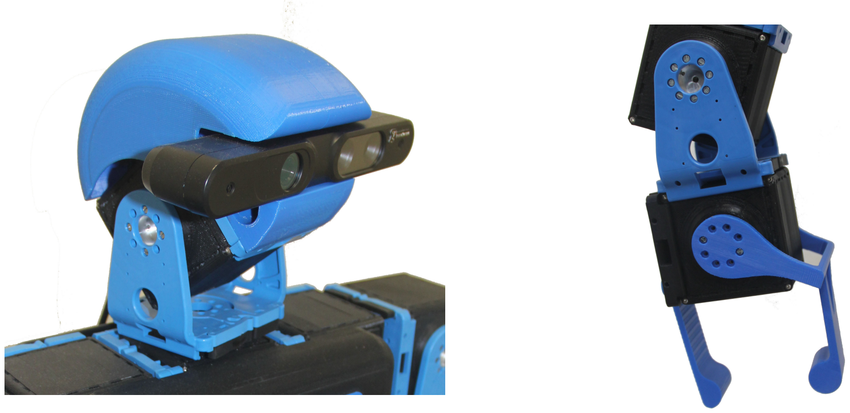


a) b)

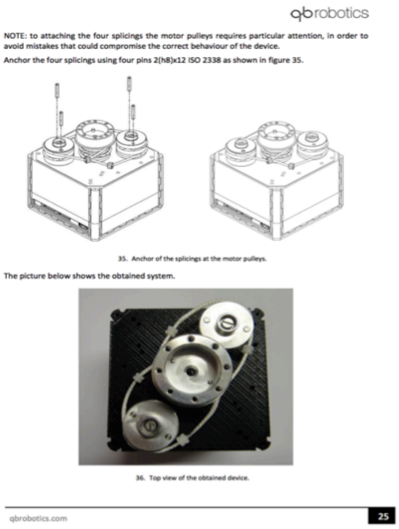
Figure 7: Examples of ancillaries developed to complete the capabilities of the qbmove platform. A two-DOF head (a) and a 1-DOF compliant gripper (b)

Documentation, support and community

Libraries, CAD data, electronic schematics, together with datasheets, assembly and construction manuals are available and continuously updated on the NMMI community website, under a Creative Commons Attribution 4.0 International License.

a) b)

Figure 8 shows a) an example of the *qbmove maker pro* NMMI page (under the menu Explore\ Devices) and b) an example of project developed inside the community, the Arduino interface for the *qbmove maker*. Figure 9 shows some extracts of the manual assembly of the *qbmove maker pro (9a)* and of the *qbmate upper body (9b).*



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NOTE: to attaching the four splicings the motor pulleys requires particular attention, in order to avoid mistakes that could compromise the correct behaviour of the device.

Anchor the four splicings using four pins 2(h8)x12 ISO 2338 as shown in figure 35.

35. Anchor of the splicings at the motor pulleys.

The picture below shows the obtained system.

36. Top view of the obtained device.

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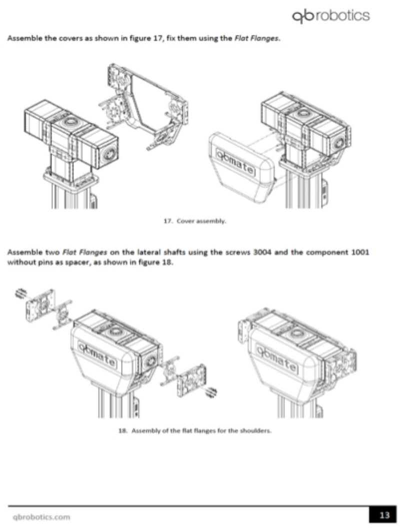

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Assemble the covers as shown in figure 17, fix them using the *Flat Flanges*.

17. Cover assembly.

Assemble two *Flat Flanges* on the lateral shafts using the screws 3004 and the component 1001 without pins as spacer, as shown in figure 18.

18. Assembly of the flat flanges for the shoulders.

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a) b)