9 User Guide

Contents

9.1 Constructing the Manipulator 65
9.1.1 BOM and Printing 65
9.1.2 Electronics Guide 67
9.1.3 Finger Tip Assembly 67
9.1.4 Finger Assembly 70
9.1.5 Palm and Manipulator assembly 71
9.2 Firmware Start Guide 71

This User Guide refers to parts and files found in the VF3-Manipulator Repository.

9.1 Constructing the Manipulator

9.1.1 BOM and Printing

All parts can be FDM printed in standard PLA. SLA printing is not recommended, due to the weaker results. It is better to use smaller layer heights, such that slopes and holes are of suitable resolution. With a 0.16mm layer height the arrangement in 9.1 takes 2 hours and 20 minutes to print.

Each finger requires 40.36 grams of filament, while the palm parts require 38.19 grams all together. The total amount of filament used is 159.27 grams.

Two parts (the top plate and base plate of the manipulator) may be laser cut instead of 3D printed. 5mm acrylic is a suitable material for this, and the svg file is included in the CAD file

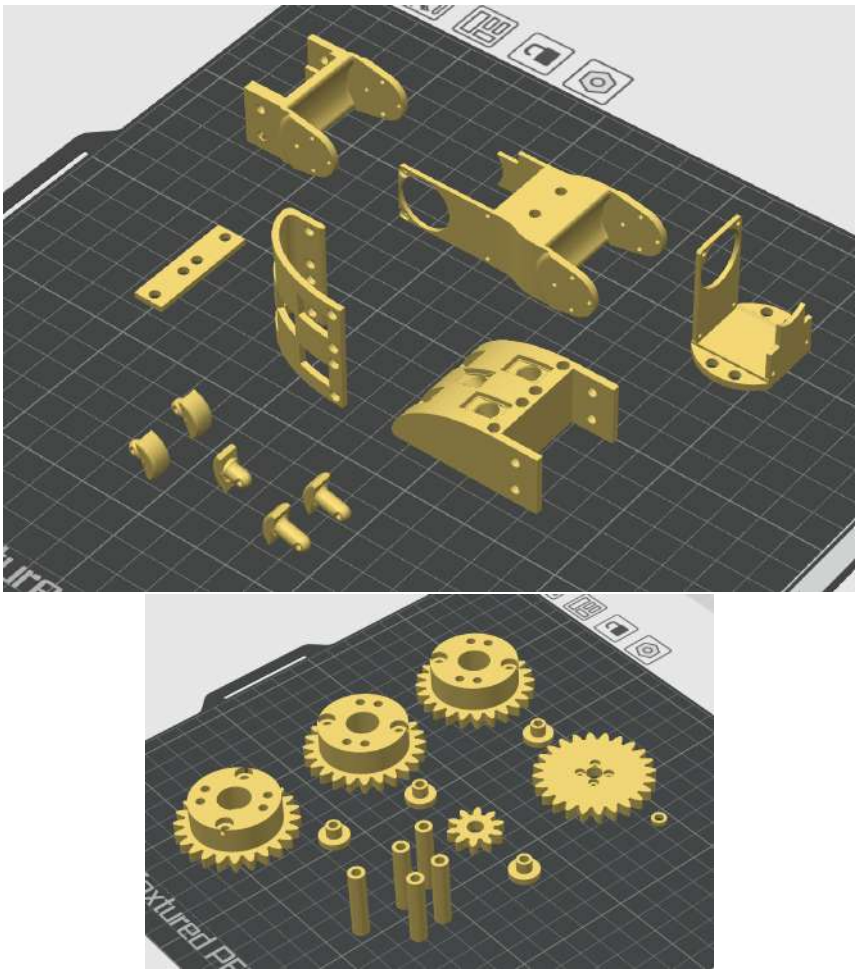

Figure 9.1: All parts necessary for a single finger (left) and the 3-finger palm (right), in their recommended printing orientation

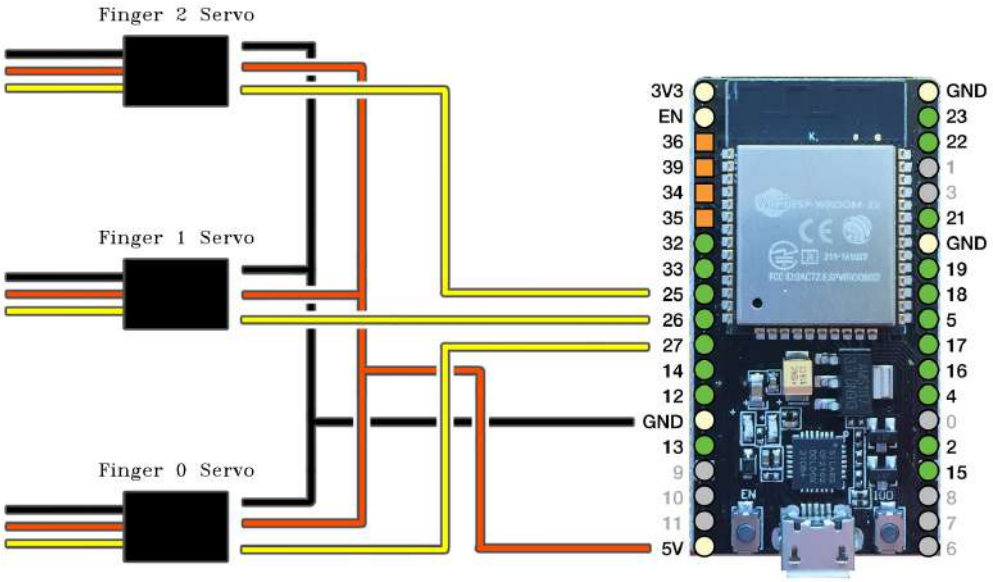

Figure 9.2: Connections for the VF mechanism servos. ESP32 pinout reference sourced from [47]

on the GitHub. The list of components are as follows (note that the Dycem can be changed to another high-friction material; see later in the User Guide for details): The total cost for a single VF3 manipulator (not including the 1-finger and 2-finger mount costs) is £292.96 (including VAT).

9.1.2 Electronics Guide

9.1.3 Finger Tip Assembly

1. First, assemble the electronics as shown on the breadboard/diagram, and flash the ESP32 with the code from the repository
2. Press in all heat set inserts (see Figure 9.3)
3. Install thread guide and MG20S servo
   (a) Connecting the servo with the ESP32, send a command via serial to go to the extended position (see Firmware Start Guide below for more guidance)
   (b) Place the pictured servo horn on the MG90S in the orientation pictured in Figure 9.4
4. Install HF surface
   (a) For sheet materials, cut to size and lay over the printed spacer; for moulded materials, use the provided 3D models and wrap around the base finger-tip

Part	Quantity	Cost (total)	Notes
3D printed parts			
PLA Filament	159.27g	£2.03	Use filament type as appropriate for printer model
Actuators			
XL330-M288-T Dynamixel Servo Motors	7	£190.40	
MG20S TowerPro Servo Motors	3	£10.50	Other models with the same footprint and similar torque acceptable
Friction Mechanism Mechnical Components			
Dycem	> 16.5cm x 3.6cm area	£0.42	
Thread/string	375cm	Negligible	
Spring (0.5 x 6 x 15mm)	9	£5.39	For finger pads of types 2 and 3
Spring (0.5 x 6 x 10mm)	6	£3.59	For finger pads of type 1
Electronics			
ESP32 WROOM-32	1	£9.99	Other Arduino-capable microcontroller with at least 3 PWM pins acceptable
Wires	Variable	£1.00	
Dynamixel Starter Set	1	£65.90	Required for powering servos and connecting to a PC
Fasteners (not including those packaged with the servomotors)			
M2.5x10 screws	30	£0.77	
M2.5 heat-set inserts	30	£1.12	
M3 screws	28	£0.35	2 of these screws need to be 14-17mm long, in order to function as locator pins for finger mounts
M3 heat-set inserts	28	£3.35	
1-finger mount			
20-2020 Aluminium extrusion	>11cm length	£2.05	
M5 screws	2	£0.46	
M5 T-nuts	2	£0.46	
2-finger mount			
M3 nuts	8	£0.10	
3-finger palm			
5mm thick clear acrylic	13cm x 16cm & 8.5cm x 10cm areas	£1.18	For the base plate and top plate respectively

Table 9.1: BOM for one manipulator

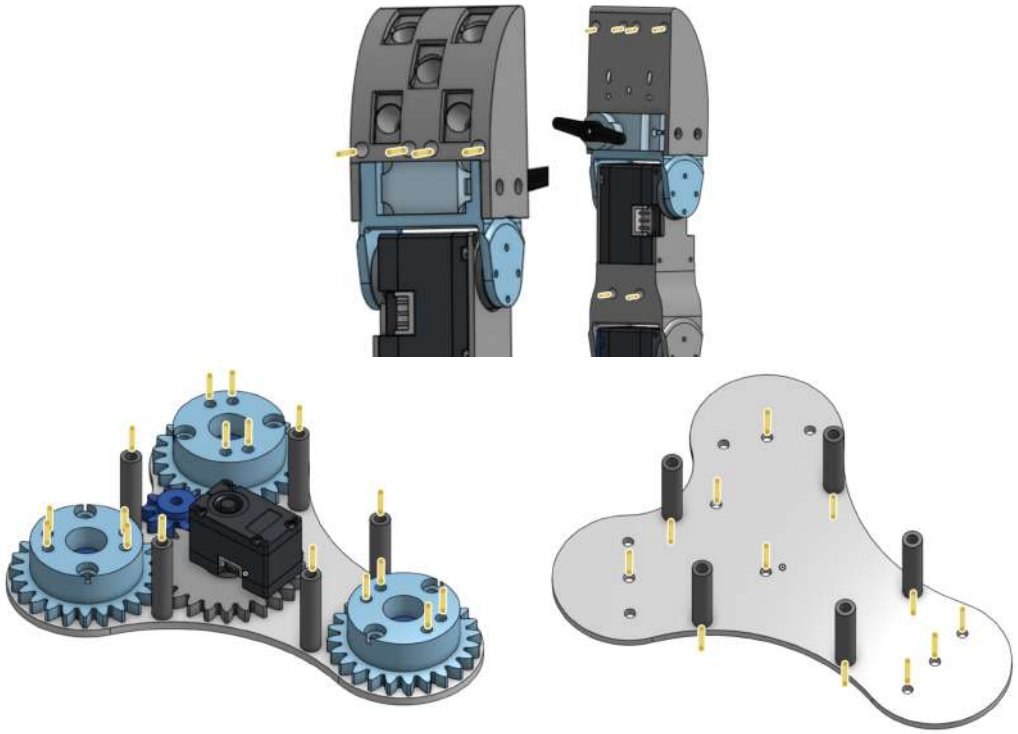

Figure 9.3: Locations for heat set inserts. Top: M2.5, Bottom: M3

Figure 9.4: Orientation of the servo horn during assembly

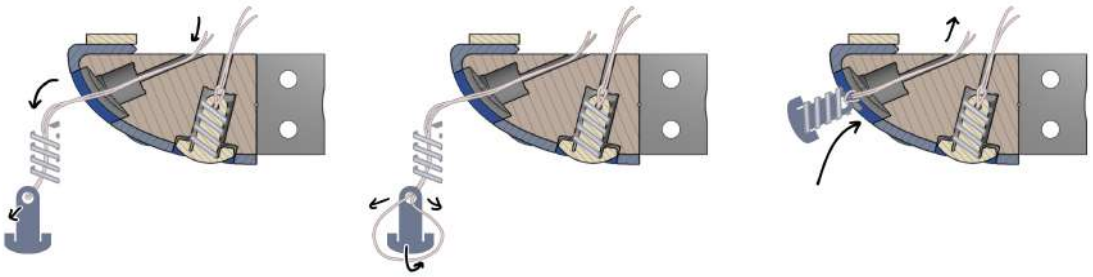

Figure 9.5: Major stages of installing a finger tip, with the arrows indicating direction of the thread

(b) Secure using heat-set inserts and bracket over top

5. For each finger pad (refer to Figure 9.5):

   (a) Take 25cm of thread, and double it up

   (b) Push the ”looped” end through a thread hole in the finger-tip roof, starting with those closest to the thread guide’s base

   (c) Pull the ”looped” end through the other side of the spring cavity, taking care not to pull the thread out of the guide on the other side

   (d) Guide the thread through the the centre of a spring, and through the hole in the appropriate finger-pad

   (e) Open up the loop, and push the finger-pad through it

   (f) Guide the spring into its slot on the finger-pad, and pull into place in the cavity using the other ends of the thread

   (g) Guide the two ends together through their corresponding thread hole towards the servo

6. Repeat step 5 for the remaining finger-pads

7. Once all threads are available:

   (a) Take the ends of a thread protruding from one of the innermost holes

8. Repeat step 6 for the remaining finger pads

9. Tighten the servo screw and cut off any excess thread

Substituting the High-Friction Surface

While Dycem is a suitable material, a mould for cast high-friction surfaces has also been produced (but not tested). If using the casting method, forgo printing the part which the Dycem/sheet material is laid on top of, and wrap the HF surface directly around the finger-tip. Alternatively, if using a sheet material with a different thickness than Dycem, adjust the thickness of the HF surface base as necessary.

9.1.4 Finger Assembly

For each finger:

1. Add dummy horns to each servomotor.
2. Secure base servomotor to the base servo mount.
3. Secure lower phalange servomotor to the upper phalange mount.
4. Secure finger-tip to upper phalange.

9.1.5 Palm and Manipulator assembly

1. Press M3 heat-set inserts into the pictured locations on the acylic base plate, the plate spacer parts, and the finger mounts.
2. Place all the finger mounts, along with the idler gear, and secure. They should be able to spin freely.
3. Secure the plate spacers to the bottom plate.
4. Constrain the finger mounts to mirrored orientations using the long M3 screws.
5. Attach the driver gear to the rotation servo, ensuring it is at angle 0°. Place it (gear facing down, such that it meshes) in position. Connect two cables to it at this point.
6. Attach the top plate, aligning the servo locator holes. Secure it in position. The servo cables should extend out of either side.
7. Remove the M3 locator screws, and use them to constrain the rotation of the thumb mount.
8. Attach all fingers to their respective mounts. The servo ids and finger ids may be changed in the Manipulator class within the command firmware if necessary, but it is recommended to use the following tested scheme:
9. Connect up all cables.

9.2 Firmware Start Guide

1. Connect (via USB cable) to the U2D2 controller, and then to the ESP32. If using WSL, attach the USB ports in this order instead.
   (a) This is also a good point to define position limits ($+90°$ and $-90°$) for each finger servomotor.

Figure 9.6: Major stages of construction the manipulator palm

2. Git clone the VF3-Manipulator repository.

3. Using the Platform.io extension in VS Code, push the FRICTION_CONTROL code to the ESP32 (or other microcontroller).

   (a) At this point, if the ESP32 is sent the serial message <PING:0>, a <PONG:0> message should be sent in response.

4. Ensure ROS2 (Humble) is installed. Copy the ROS2 packages to a new workspace; see the official ROS2 tutorial if this is a new process.

   (a) Ensure the 'colcon build' and 'source install/setup.bash' commands have been run.

5. At this stage, running "ros2 launch vf3_manipulator_bringup demo.launch.py" should result in the fingers returning to their home position of standing straight upward, with VF mode engaged.