Report: electronics integration and wheelchair mounting for the Robogami arm

ROBOGAMI. Design and integration of the electronics enclosure, the pump enclosure and the wheelchair mount

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Abstract

This report documents the electronics integration and mechanical mounting work carried out for the Robogami assistive arm during an internship at the BIOROB laboratory (EPFL). It covers the electronics enclosure that houses the control boards and the battery, a separate pump enclosure for the vacuum gripper, and the interface that mounts the assembly on the wheelchair. For each sub-system the report explains, in broad strokes, what was designed, why the main decisions were taken, and what remains to be done. Mass minimisation and modularity (reusing the electronics block across gripper changes) were the two guiding criteria throughout. The current prototype is functional at the sub-system level; the main open items are the final assembly validation, a safe battery-charging interface, and a future migration to a custom PCB with battery management.

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Nomenclature and abbreviations

Symbol / Acronym	Designation
LiPo	Lithium-polymer
PCB	Printed Circuit Board

1 Introduction

1.1 The Robogami project

Imagine not being able to pick a dropped set of keys off the floor, reach a shelf, or carry a bag across the room on your own. For people who use a wheelchair, these everyday tasks that most of us take for granted can be genuinely difficult, and they often depend on someone else's help. That dependence affects people's autonomy in their own homes. This is exactly where Robogami comes in. First developed at the Reconfigurable Robotics Lab (RRL) of EPFL, then lent at the BIOROB laboratory in order to finalise the project, it is an assistive robotic arm designed to give wheelchair users back that independence, helping with these tasks while staying light, affordable and easy to carry.

Robogami is a *foldable, reconfigurable* robotic arm built from repeated modules, inspired by origami. Each module adds three independently actuated joints, and modules can be stacked to tune the arm to the user: fewer modules give a shorter but stronger arm, more modules give a longer reach for lighter loads. Two reference builds frame the project :

- a two-module arm that reaches about 240 mm and lifts up to 1 kg,
- and a three-module arm that reaches about 420 mm for lighter objects.

This ability to reconfigure the same system is the core idea of Robogami: one design that adapts to very different users and situations.

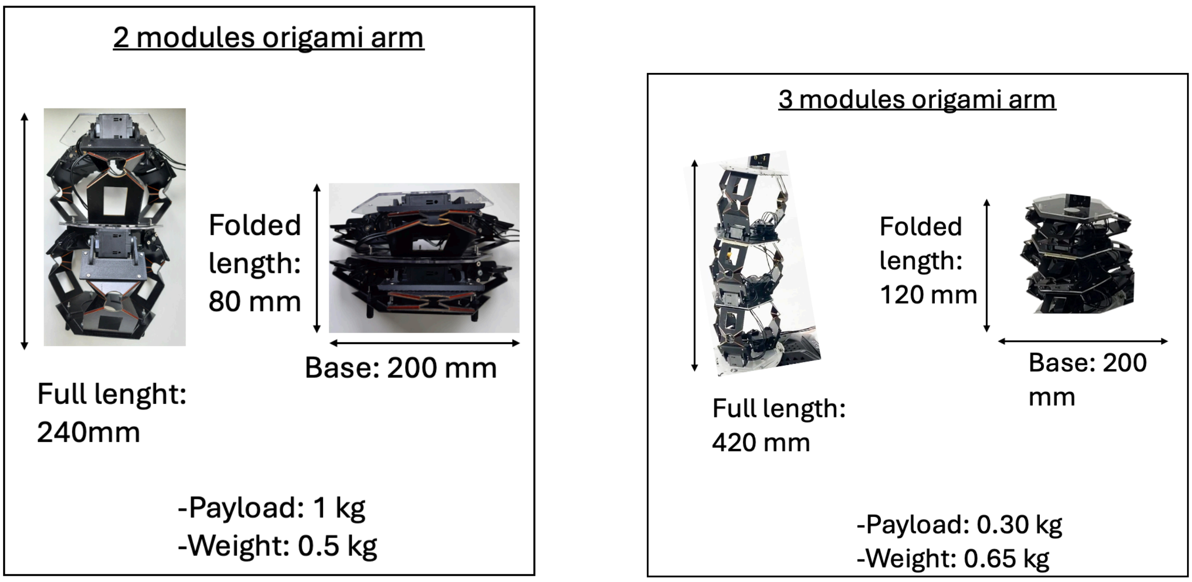


Figure 1. The two reference configurations of the Robogami arm. Adding or removing modules trades reach against the load the arm can lift.

1.2 Understanding the need: the user study

The project did not start from technology but from people. A prior user study combined three complementary sources: a questionnaire answered by 40 participants, in-home visits with 4 volunteers, and a review of the research literature. The picture that emerged was consistent across all three: wheelchair users, most of them using manual wheelchairs, struggle above all with *reaching, grasping and carrying* objects, and these tasks are most often handed off to a relative or carer. When asked what mattered in an assistive device, participants pointed first to it being lightweight, efficient, affordable and easy to carry.

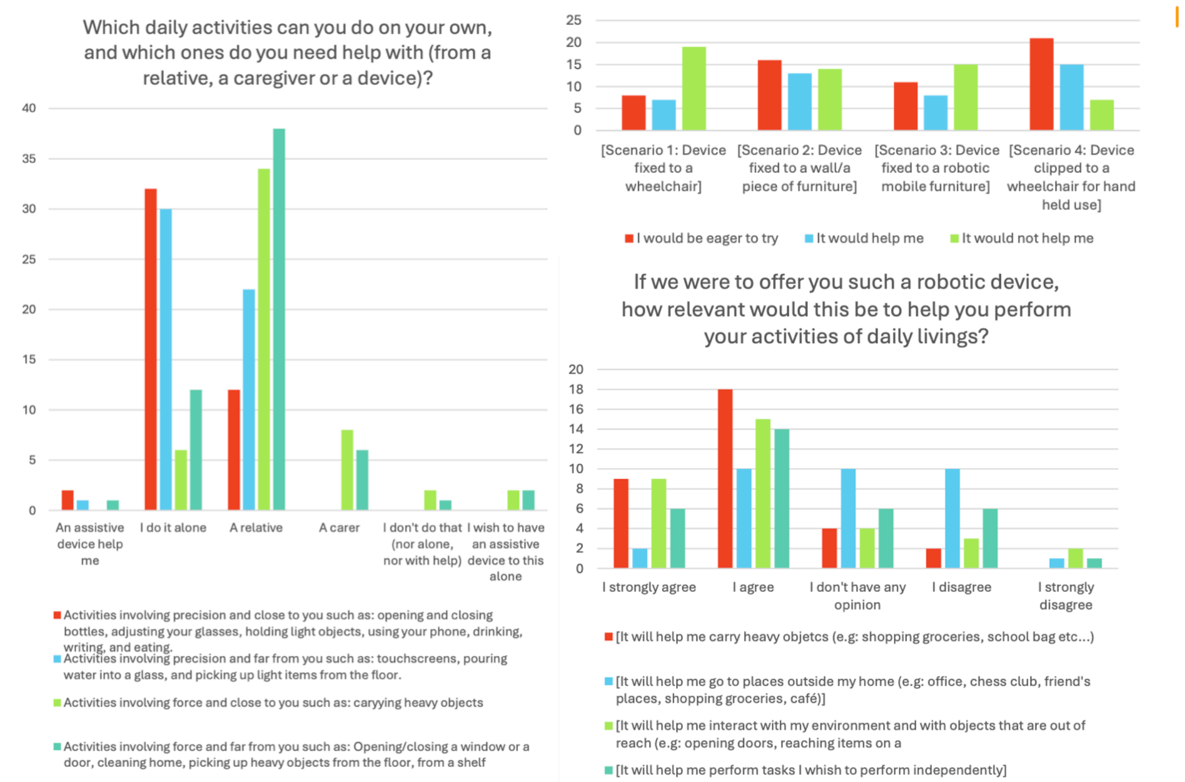


Figure 2. Key findings of the user study (40 questionnaires, 4 in-home visits). Lightness, efficiency, portability and cost were the users' main expectations, the same priorities that guide the design work in this report.

The study also compared several ways the arm could be used : fixed permanently to the wheelchair, attached to furniture, mounted on a mobile stand, or clipped to the wheelchair for handheld use. The handheld option, where the user picks up the arm to guide it and clips it back afterwards, was the best received. This matters for the present work because it means the supporting electronics must be compact and transportable, and must travel with the wheelchair rather than weigh down the arm.

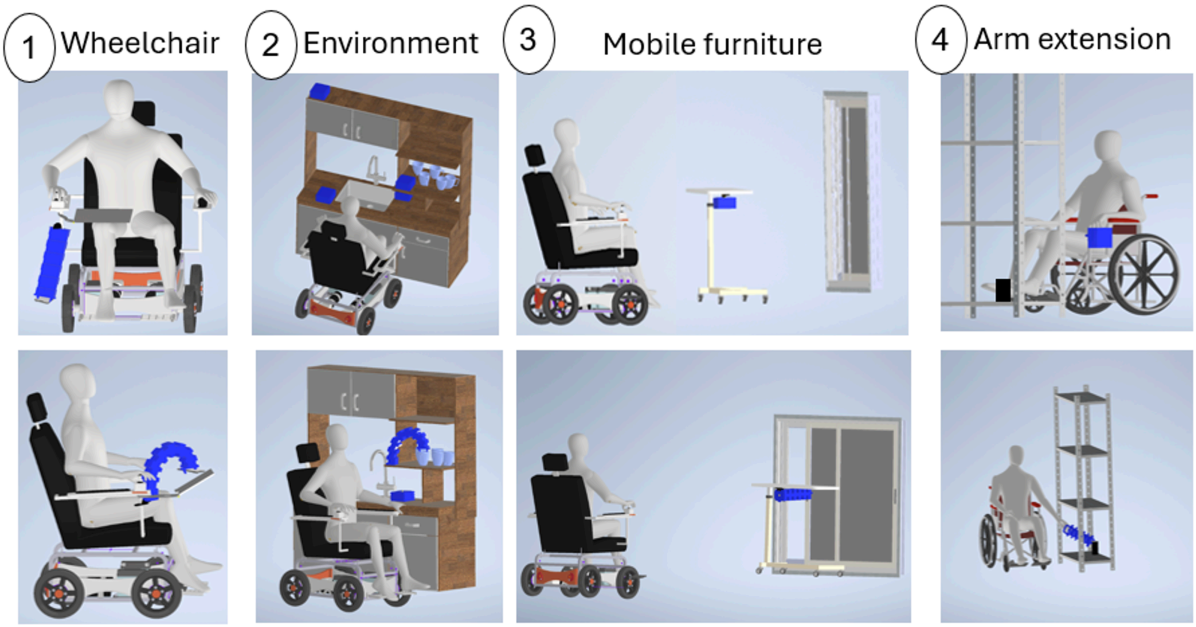


Figure 3. The use scenarios considered for Robogami. The handheld scenario (4), preferred by users, calls for compact and transportable onboard electronics.

1.3 The chosen activity

Guided by these findings, the project targets one concrete activity: *picking up and holding objects from the floor*, for users who keep some upper-body mobility. In practice, the user switches the arm and the pump on from the buttons on the Robogami's handle, positions themselves near the object, guides the arm with the handheld controller until it reaches the object, activates the grip, then moves or holds the object before releasing it and switching off. Two features of this scenario shape the work presented here: the whole electronics assembly is carried by the wheelchair, not by the arm, so that no extra mass is added at the arm since users might not have the same arm force and dexterity as a healthy human being.

1.4 What this report covers

The overall Robogami solution is built by a team, with sub-systems developed in parallel: a control handle, a gripper, the control software, an electronics storage box, and a wheelchair mounting system. This report focuses on the **electronics and mechanical integration** : the electronics enclosure, the pump enclosure, the interface that mounts everything on the wheelchair, and the cable that links the moving arm to the fixed enclosure. The arm structure, the servomotors, the control software and the gripper itself are the work of other team members and appear here only as constraints on the design.

The rest of the report follows the sub-systems in turn. Section 2 sets out the requirements that drive the design; Section 3 places the other team members' sub-systems around this work; Sections 4 to 7 present, one by one, the electronics enclosure, the pump enclosure, the power integration and the wheelchair mount, explaining in each case what was done and why; Section 8 shows how it all fits together; and Sections 9 and 10 give the current status and what remains to be done.

2 Requirements specification

The requirements below are inherited from the shared project specification and are reproduced here only where they drive the electronics and mounting design. The full specification table is a common project artefact.

Key user requirements : The device must be lightweight and easy to carry, operate at low actuation force, run fast and quietly (cycle time below about one minute), and provide simple visual feedback. The target cost is 0 CHF to 2000 CHF for the whole device.

Environmental constraints : Wheelchair widths and heights vary, so the mounting must be adaptable; the added mass must not compromise the wheelchair's stability; and the stowed assembly must not obstruct the wheelchair's pivoting space.

Requirements driving this work : From the above, the electronics and mounting sub-systems inherit the following targets:

- **Mass** : the electronics box is targeted at about 100 g (with its components below 1 kg), and mass minimisation is the primary criterion for every decision.
- **Modularity** : because the arm is reconfigurable and its gripper may change, the electronics block needs to be built to be reused as is, so that the work done on this project is not wasted.
- **Power** : enough to drive the six servomotors and the vacuum pump of the gripper, from a single onboard battery.
- **Mounting** : that adapts to different wheelchair tubes while holding the offset weight steady
- **Serviceability** : that the battery can be charged and the system switched on without too many manipulations on the electronics box.

3 System overview

Four elements travel with the wheelchair and make up the complete system: the Robogami arm with its gripper and handheld controller used to guide it, an electronics box that powers and controls everything, a separate box for the gripper's pump and the mounting of these boxes to the wheelchair.

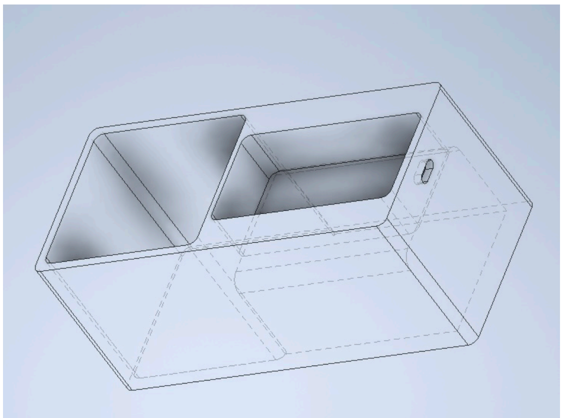
Three sub-systems are the work of other team members and set the boundary of what follows. The **gripper** is a granular-jamming vacuum gripper driven by an electric pump, which is the reason a pump has to be powered and housed. The **handheld controller** carries a joystick to move the arm and a button to activate the grip. The **control software** runs on an Arduino DUE and turns those inputs into commands for the six servomotors and the pump. For the work presented here, these three define what the electronics must supply, which connectors it must route, and the on/off logic it must accommodate.

4 Electronics enclosure

The electronics enclosure went through a clear change of direction before settling on its current form. Rather than present only the final design, this section follows that path, since the reasons for abandoning the first idea are what justify the final one.

4.1 First attempts: one box for everything

The very first design tried to house every component inside a single box. It could not be 3D-printed: the deep internal cavity created overhangs that the printer could not build without excessive support, and the result was unusable. The design was then reorganised into a single box split into **three compartments**, one each for the control boards, the battery, and the pump, closed by a sliding snap-fit lid. The first prints of the board compartment failed and needed several rounds of adjustments before a clean, correctly fitting part came out.



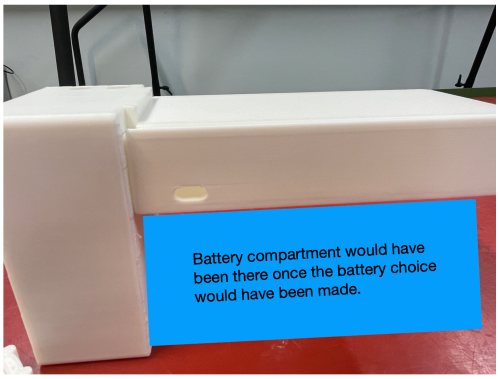


Figure 4. Early enclosure prototypes: the first single-cavity box, which could not be printed, and the three-compartment version with its first print.

4.2 The turning point: two separate boxes

During a weekly review at the start of August, the three-compartment layout was found to be impractical. Splitting the components into separate compartments multiplied the wired links between them, in particular between the battery and the boards, and these cables had to cross the planes along which the sections were meant to slide and snap together. Cables crossing those planes make a clean assembly impossible.

The design therefore moved to **two independent boxes**: one grouping the electronics and the battery, and one for the pump alone. Beyond solving the wiring problem, this split has a lasting benefit: if the gripper (and therefore its pump) is later replaced, the electronics box can be reused unchanged, so the work invested in it is not lost.

4.3 Internal architecture

The electronics box is organised as **stacked sections** closed by a sliding snap-fit lid. The control boards sit on an upper sub-plate, while the battery, which is mechanically less demanding, sits underneath; placing the heavier battery low also lowers the centre of gravity of the whole assembly. **Snap-fit connections** were chosen to hold the sections together because the box itself carries very little mechanical load: once mounted, the only real force it sees is the vibration of the wheelchair, so a light interlocking fit is enough and avoids the added weight and part count of screwing every section together.

The box also carries a few functional openings. One face carries the bayonet interface, used to attach the pump box with a simple twist-and-lock motion, together with a port for the cable that runs to the arm and a **magnetic pogo-pin connector** to ensure the electrical connection between the pump and the control boards. Finally, a hole fitted for the rivet of a magnetic **Fidlock** connector, which is how the whole box attaches to, and quickly detaches from, the bracket that clamps to the wheelchair.

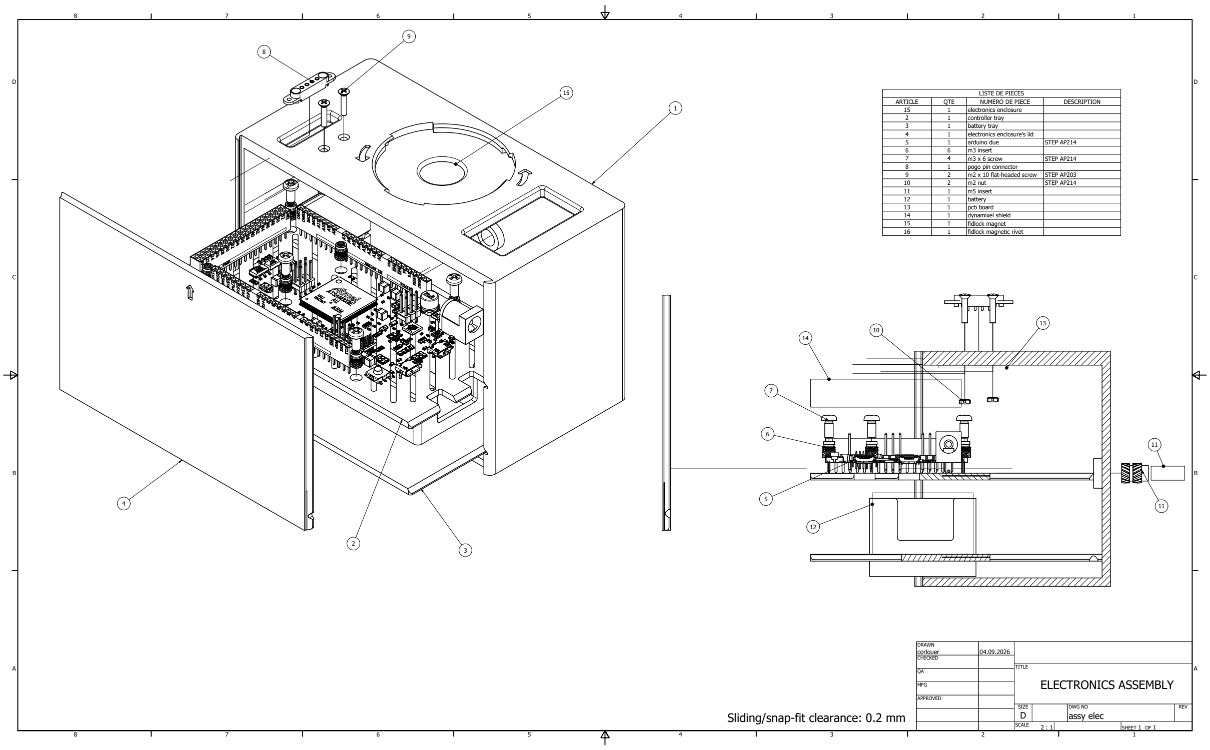


Figure 5. Internal architecture of the electronics box: stacked sections with the boards above and the battery below, closed by a sliding snap-fit lid.

The battery is kept in place by low retention walls with an opening for its cables, which stop it moving under vibration while still letting it be removed.

4.4 Charging

Charging is not yet integrated. For now the battery has to be taken out of the box and recharged in a dedicated balance charger. For an end user this would mean returning the whole electronics box so that it can be recharged for them, which is clearly not convenient. Making the battery rechargeable directly on the box, without removing it, is therefore an explicit goal for future work (Section 10).

5 Pump enclosure and interface

The pump has its own box, separated from the electronics for the vibration, heat and noise reasons above and to keep the electronics reusable across gripper changes. Inside, the pump is **laid on its side** rather than standing upright, which cuts the height it takes up and further lowers the centre of gravity of the assembly. The pump's noise, which is significant, is damped by lining the enclosure with an insulating foam; a further optimisation of the noise and vibration reduction remains possible and is left as future work.

The pump box docks onto the electronics box through the bayonet and magnetic pogo-pin interfaces described earlier, so it can be connected or removed by hand, without tools, which fits the modular philosophy of the design. The circuit that switches the pump was soldered onto a small board together with the magnetic connector.

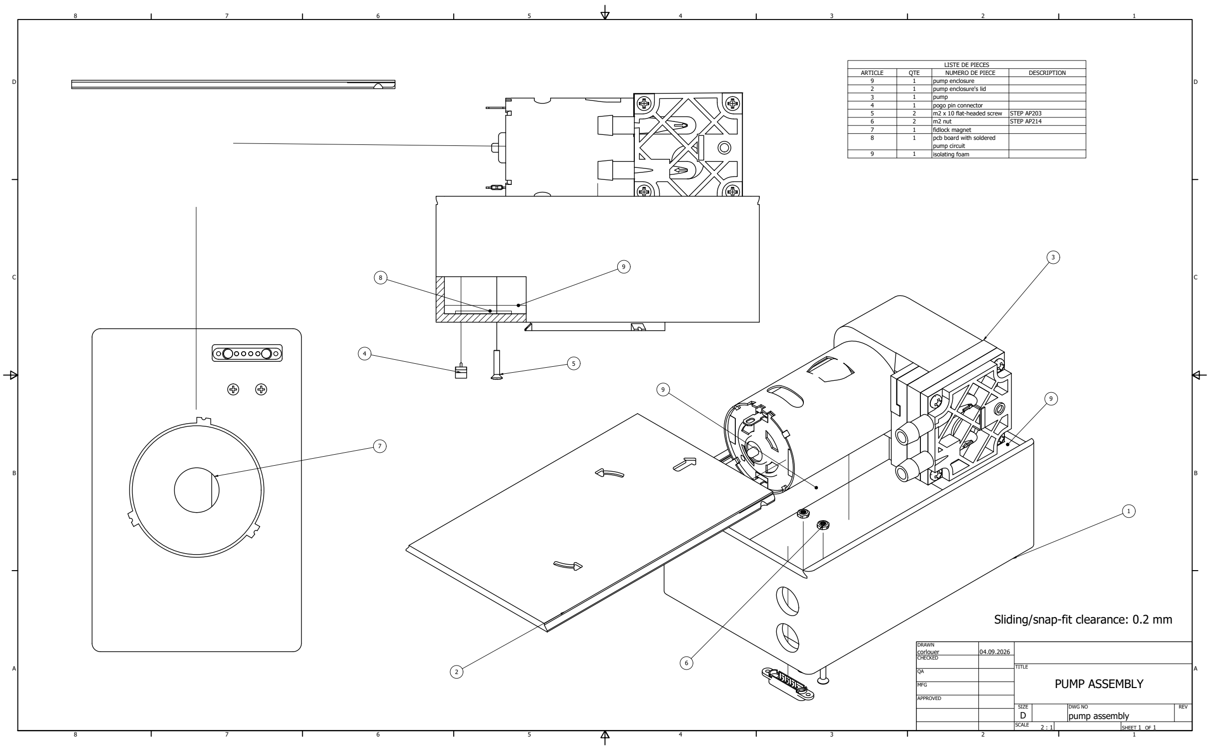


Figure 6. The pump assembly

6 Power integration and distribution

6.1 From 12 V to 11.1 V: letting the measurements decide

The battery choice is a good example of a decision that changed once it was put to the test. The servomotors are happiest on a 12 V supply, so the search began there, but a 12 V nominal pack proved hard to source from a Swiss supplier. Rather than force the point, the current actually drawn by the arm was measured under several load cases, up to a grasped weight of 800 g. The measurements showed a steady draw of about 1.3 A, roughly half the initial estimate, with brief peaks near 2.4 A. This lower, measured demand made a standard 11.1 V three-cell pack perfectly adequate and removed the need for the hard-to-find 12 V option.

The retained pack is a compact **3S LiPo** (Swaytronic 2500 mA h, about 147 g). The Arduino DUE is fed at 12 V through its own internal regulator, so a single pack powers both the controller and the servomotors.

6.2 Connectors and charging

A single battery pack powers both the control board and the motors. It connects to the system through a **JST** connector, comfortably sized for the current the system actually draws. A dedicated battery-management system was deliberately left out of this prototype and deferred to a future custom board; for now the pack's own factory protection serves only as a safety backstop.

7 Wheelchair mounting interface

7.1 Choosing where to put it

Where to attach the assembly on the wheelchair was studied on its own, because each option trades comfort against accessibility. Four locations were compared: inside the armrest, outside the armrest, under the seat, and in the pocket behind the backrest. Mounting **under the seat** was retained: an inside mount would get in the user's way, an outside mount would catch on the surroundings, and the rear pocket is hard to reach, whereas under the seat is both unobtrusive and accessible.

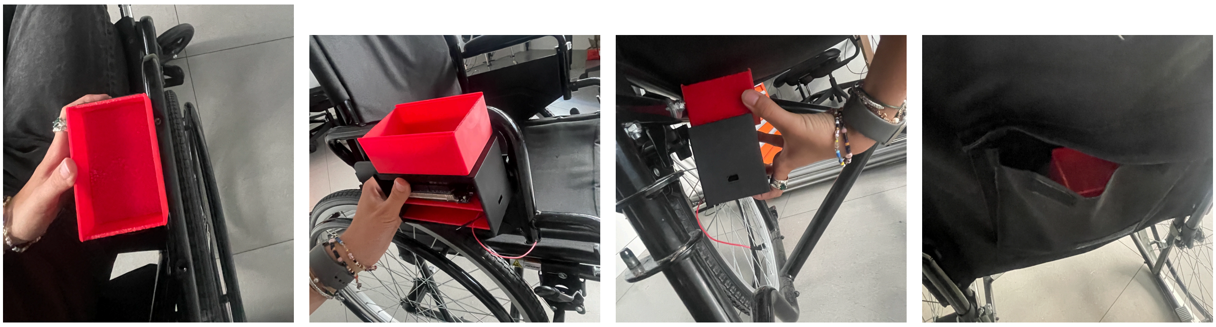


Figure 7. The four mounting positions tested: inside the armrest, outside the armrest, under the seat (retained), and in the rear pocket.

7.2 Designing the bracket

The bracket clamps around a tube of the wheelchair frame with a ring whose diameter can be adjusted, tightened by screws and nuts. Getting this right took several attempts. A first version, a half-circle clamp bolted onto a flat bracket, did not wrap far enough around the tube and left a large gap that would have needed an impractically long screw to close. Simply copying the shape of an off-the-shelf metal bracket did not work either: a metal bracket is tapped so the screw bites directly into the material, but a 3D-printed part needs a captive nut, and that nut protruded straight into the arm meant to clamp the tube. The solution was to place the **nut inside** the part, with the pocket cut so that one side stays integral with the bracket. To resist the tipping moment created by the weight hanging off to one side, the mount uses **two clamps spaced apart** along the tube, and the clamping screw was lengthened by about 4 mm to guarantee enough thread engagement.

Figure 8. The bracket went through several iterations before the nut-inside design, which fits a 3D-printed part and leaves room for the clamp arm.

8 Assembly

Assembly is deliberately simple, because almost everything holds together by sliding snap-fits. Inside the electronics box, the stages that carry the battery and the Arduino slide into place, and only the Arduino itself is screwed down onto its stage. Before the box is closed, the battery is connected to the Arduino through its JST connector, so the system is powered. The sliding snap-fit lid then closes the box.

The pump box closes the same way, with its own sliding snap-fit lid. The two boxes are then joined through the bayonet interface, with a simple twist-and-lock motion. As long as the two boxes are correctly aligned, the magnetic connection between them is made on its own, so there is no separate wiring step. Finally, the whole assembly is held under the wheelchair seat by the bracket.

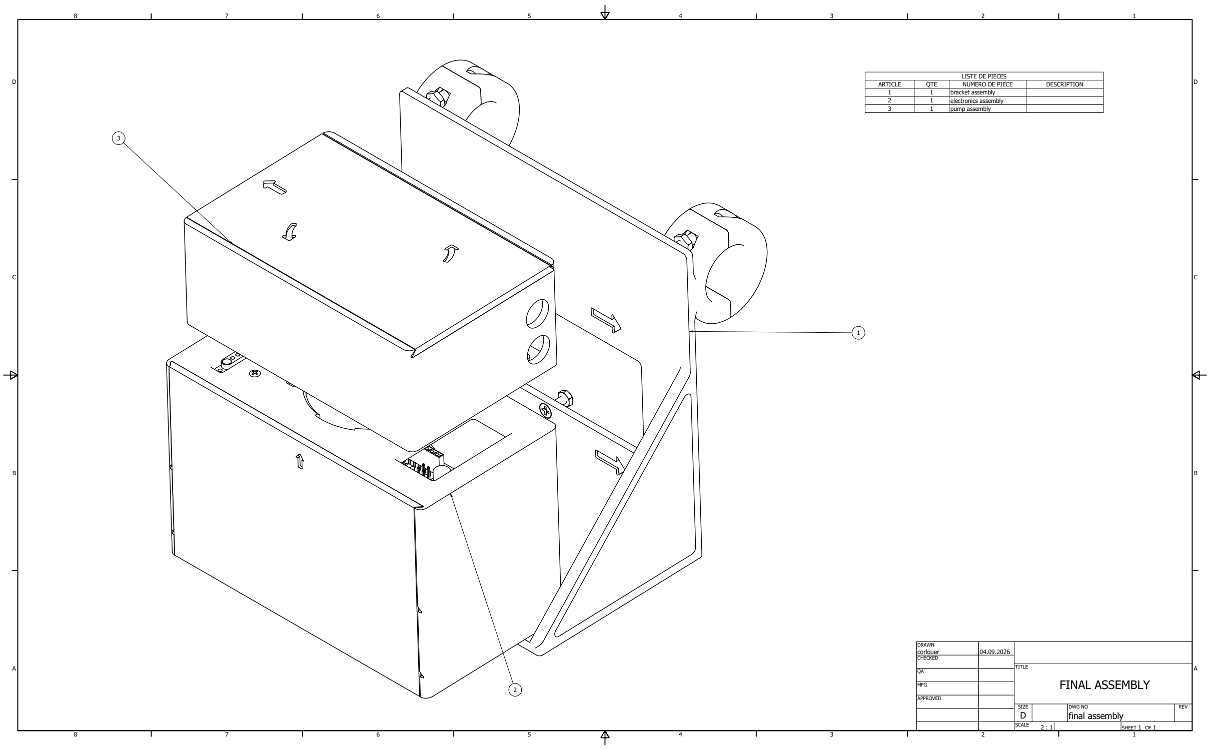


Figure 9. The assembled electronics and pump boxes, mounted under the wheelchair seat.

9 Conclusion and current status

The electronics integration and wheelchair mounting for the Robogami arm were brought to a working prototype. The decisions that shaped it were reached by trying, testing and, when needed, changing course: splitting the electronics and pump into two boxes once the single-box layout proved unworkable, letting current measurements settle the battery choice, and arriving at the nut-inside bracket after two earlier clamp designs failed. Throughout, keeping the assembly light and reusable guided the trade-offs. The result is a compact two-box system that snaps together with almost no tools, attaches to and detaches from the wheelchair through a magnetic connector, and keeps the electronics reusable if the gripper is ever changed.

At the time of writing, the boxes and the mount are designed and printed, the battery and its connectors are chosen, and the pump interface works through its magnetic connection. What remains is mostly integration and convenience: validating the full assembly on the wheelchair, routing the cable between the arm and the box, and above all giving the battery a way to be recharged on the box rather than removed.

10 Future work

- **On-board recharging** : give the battery a way to be recharged directly on the box, so the user no longer has to remove it, or return the whole box, to charge it.
- **Cable management** : design and route the cable that links the moving arm to the fixed box, so it follows the arm without snagging or pulling as it moves.
- **Custom control board with battery management** : replace the prototype wiring with a custom board that also monitors and protects each cell of the battery.
- **Further noise and vibration reduction** : build on the current foam lining to make the pump quieter, which is still in tension with the silent-operation goal.
- **On-wheelchair validation** : test the mount and the system over the full range of arm mo-

tion, and check that the wheelchair stays stable under load.

- **Easier release of the electronics box from the wheelchair** : add a small hook or tab at the pull point to detach the box from the bracket more comfortably; the current release is not very practical.