**Brief Installation Guide**

**Step 1: Electronics Assembly**

1. Mount Arduino in waterproof enclosure
2. Connect L298D motor driver to breadboard
3. Wire rain sensor and status components
4. Install XT60 power connectors
5. Test all electrical connections

**Step 2: Mechanical Setup**

1. Construct aluminum shelter frame
2. Install pulleys at strategic points
3. Mount motors with proper alignment
4. Thread cable through pulley system
5. Attach clothesline to moving cable

**Step 3: System Integration**

1. Connect motor cables using XT60 connectors
2. Position rain sensor in optimal location
3. Secure all wiring and connections
4. Perform calibration and testing
5. Weather-seal all connections

**Elaborated Installation Guide**

**🔌 Phase 1: Electronics Assembly**

**Step 1.1: Prepare the Breadboard**

Time: 15 minutes

Difficulty: Easy

Actions:

1. Place breadboard on clean, static-free surface

2. Identify power rails (red/blue strips on sides)

3. Plan component layout before placing anything

4. Keep L298D away from Arduino (heat separation)

**Step 1.2: Mount Arduino Uno**

Time: 10 minutes

Actions:

1. Position Arduino next to breadboard

2. Connect USB cable to Arduino

3. Upload a simple LED blink sketch to test

4. Verify 5V and GND pins are accessible

5. Do NOT power Arduino while making connections

**Step 1.3: Install L298D Motor Driver**

Time: 20 minutes

CRITICAL: Double-check all connections

Pin Mapping (L298D → Arduino):

- IN1 → Digital Pin 7

- IN2 → Digital Pin 6

- IN3 → Digital Pin 5

- IN4 → Digital Pin 4

- ENA → Digital Pin 9 (PWM)

- ENB → Digital Pin 10 (PWM)

- VCC → Leave unconnected (will connect to Li-ion)

- GND → Arduino GND (CRITICAL common ground)

- 5V → Arduino 5V (logic power)

Connection Process:

1. Insert L298D into breadboard (straddle center gap)

2. Use male-male jumper wires for connections

3. Make connections in order listed above

4. Double-check each connection with multimeter continuity

5. Verify no short circuits between adjacent pins

**Step 1.4: Connect Rain Sensor**

Time: 15 minutes

Connections (Rain Sensor → Arduino):

- VCC → Arduino 5V

- GND → Arduino GND

- Signal → Digital Pin 2

Testing:

1. Connect Arduino to USB power

2. Upload test sketch to read sensor

3. Test with water drops - should read HIGH when wet

4. Verify 5V supply at sensor VCC pin

**Step 1.5: Add Status Components**

Time: 20 minutes

LED Circuit:

- LED Anode → 330Ω resistor → Arduino Pin 13

- LED Cathode → Arduino GND

Buzzer Circuit (Optional):

- Buzzer (+) → Arduino Pin 8

- Buzzer (-) → Arduino GND

Testing:

1. Upload blink sketch for LED test

2. Test buzzer with tone() function

3. Verify no excessive current draw

**Step 1.6: Prepare XT60 Power Connection**

Time: 30 minutes

CRITICAL: This step requires precision

Materials:

- XT60 Male connector with 14AWG silicone wire (10cm)

- Heat shrink tubing (5mm diameter)

- Solder and soldering iron

Process:

1. Strip 8mm insulation from both red and black wires

2. Tin wire ends with solder

3. Insert red wire into L298D VCC screw terminal

4. Insert black wire into L298D GND screw terminal

5. Tighten terminal screws until wires cannot be pulled out

6. Cover terminals with heat shrink for safety

7. Test connection: XT60 should fit snugly into battery pack

VERIFICATION CRITICAL:

- Measure resistance between XT60 and terminals (<0.1Ω)

- Ensure no short circuit between red and black

- Physical pull test - wires should not come loose

**🏗️ Phase 2: Mechanical Assembly**

**Step 2.1: Construct Shelter Frame**

Time: 2 hours

Skill Level: Intermediate

Materials:

- Aluminum extrusion 20x20mm

- Corner brackets (8 pieces)

- M6 bolts and nuts

Frame Dimensions:

- Width: 2.0m

- Depth: 1.5m

- Height: 2.2m (sloped for rain runoff)

Assembly Sequence:

1. Cut aluminum extrusion to required lengths:

- 2 pieces × 2.0m (front/back horizontal)

- 2 pieces × 1.5m (side horizontals)

- 4 pieces × 2.2m (vertical posts)

- 2 pieces × 1.8m (roof supports)

2. Assemble base frame (ground level):

- Connect 2.0m and 1.5m pieces with corner brackets

- Ensure frame is perfectly square (measure diagonals)

- All diagonal measurements should be equal

3. Install vertical posts:

- Attach 4 vertical posts to base corners

- Use level to ensure posts are plumb

- Temporarily brace with diagonal supports

4. Complete roof frame:

- Install top horizontal members

- Add sloped roof supports for water drainage

- Double-check all connections are tight

Quality Check:

- Frame must be rigid (no wobbling)

- All joints properly aligned

- Ready to support motor loads and weather forces

**Step 2.2: Install Pulley System**

Time: 1.5 hours

Precision Required: High

Components per Pulley Point:

- 1× Ball bearing pulley (50mm diameter)

- 1× Eye bolt M6×50mm with nut and washers

- 1× Mounting bracket

Installation Points (4 total):

- Top front corner (motor 1 side)

- Top back corner (motor 1 side)

- Top front corner (motor 2 side)

- Top back corner (motor 2 side)

Process for Each Pulley:

1. Mark mounting hole 50mm from corner intersection

2. Drill 6mm hole through aluminum frame

3. Insert eye bolt with washer

4. Secure with nut and lock washer on back side

5. Attach pulley to eye bolt with pin

6. Test rotation - should spin freely without binding

7. Apply light machine oil to bearing

Cable Routing Plan:

Motor 1 → Front Pulley → Back Pulley → Clothesline Attachment Point

Motor 2 → Front Pulley → Back Pulley → Clothesline Attachment Point

(Both motors work together to move single cable system)

**Step 2.3: Mount DC Motors**

Time: 1 hour

Critical: Proper alignment essential

Motor Mounting Requirements:

- Position motors at frame base level

- Align output shafts with pulley system

- Secure mounting to prevent movement under load

- Weatherproof motor connections

Mounting Process:

1. Mark motor positions on frame base

- Motor 1: Left side, 30cm from front

- Motor 2: Right side, 30cm from front

- Both motors parallel to frame sides

2. Attach motor mount brackets to frame:

- Use M6 bolts through frame slots

- Position brackets for perfect motor alignment

- Double-check measurements before drilling

3. Secure motors to brackets:

- Use motor mounting bolts (usually M4)

- Ensure motor shafts are horizontal

- Test that motors don't interfere with each other

4. Install cable connection system:

- Attach cable drum or coupling to motor shaft

- Connect steel cable to motor drive system

- Ensure smooth cable feed to pulleys

Motor Wiring (Temporary):

- Leave motor wires long enough to reach electronics

- Protect connections from weather

- Label Motor 1 and Motor 2 clearly

**Step 2.4: Install Steel Cable System**

Time: 45 minutes

Safety: Wear gloves (cable can cut)

Cable Specifications:

- 3mm diameter stainless steel cable

- Total length: 8-10 meters

- Breaking strength: >200kg

Routing Path:

Start → Motor 1 → Front Pulley 1 → Back Pulley 1 →

Cross Point → Front Pulley 2 → Back Pulley 2 → Motor 2

Installation Process:

1. Begin at Motor 1 attachment point

2. Route cable through first pulley pair

3. Create cross-connection at center (clothesline attachment)

4. Continue routing through second pulley pair

5. Terminate at Motor 2 attachment point

6. Secure all terminations with cable clamps (2 clamps per end)

Tension Adjustment:

- Cable should be taught but not over-tensioned

- Allow slight sag for thermal expansion

- Test motor operation - cable should move smoothly

- No binding or interference at any pulley point

Clothesline Attachment:

- Attach actual clothesline at cable cross-point

- Use strong carabiner or shackle connection

- Clothesline should hang 1.5-2.0m below cable level

- Test weight capacity with wet clothes load

**🏠 Phase 3: Enclosure & Weather Protection (2-3 hours)**

**Step 3.1: Prepare Electronics Enclosure**

Time: 1 hour

Enclosure Requirements:

- Waterproof rating: IP65 minimum

- Size: 200×120×100mm minimum

- Material: ABS plastic or aluminum

- Mounting: Secure to frame structure

Enclosure Preparation:

1. Plan component layout inside enclosure:

- Arduino Uno: Left side

- Breadboard with L298D: Center

- 4S Li-ion battery: Right side (ventilation area)

- Leave space for airflow around battery

2. Mark and drill cable entry points:

- USB cable entry (Arduino power)

- Motor cable entries (2× holes for motor wires)

- Rain sensor cable entry

- Status LED mounting hole

3. Install cable glands in all holes:

- Use PG7 waterproof cable glands

- Apply silicone sealant around glands

- Test waterproofing with spray bottle

4. Create component mounting points:

- Use foam padding for shock absorption

- Secure Arduino with spacers and screws

- Mount breadboard with adhesive base

- Create battery compartment with vent holes

**Step 3.2: Final Electronics Integration**

Time: 1.5 hours

CRITICAL: Test each connection before sealing

Integration Process:

1. Install all electronics in prepared enclosure

2. Route cables through cable glands

3. Make final electrical connections

4. Perform comprehensive system test

Connection Checklist:

□ Arduino USB cable to power source

□ XT60 connector to 4S Li-ion battery

□ Motor 1 wires to L298D OUT1/OUT2

□ Motor 2 wires to L298D OUT3/OUT4

□ Rain sensor cable to Arduino Pin 2

□ Status LED visible outside enclosure

□ All grounds connected together

System Test Protocol:

1. Connect Arduino USB power (do NOT connect battery yet)

2. Upload final code to Arduino

3. Test rain sensor with water drops

4. Verify LED patterns work correctly

5. Check serial monitor output

6. Connect 4S battery and test motor operation

7. Verify emergency rain detection during extension

8. Test complete retraction/extension cycle

Final Sealing:

- Apply silicone sealant around all penetrations

- Close enclosure with gasket properly seated

- Mount enclosure to frame in accessible location

- Test waterproofing with garden hose

**Step 3.3: Install Weather Protection**

Time: 30 minutes

Tarpaulin Installation:

1. Measure and cut tarpaulin to fit frame + 20cm overhang

2. Install grommets at attachment points (every 50cm)

3. Secure tarpaulin to frame with bungee cords

4. Ensure proper slope for water drainage

5. Create drainage gutters if needed

Rain Sensor Positioning:

1. Mount rain sensor outside shelter area

2. Position to catch rain but avoid false triggers

3. Protect sensor electronics but expose sensing pad

4. Use long cable to reach Arduino in enclosure

5. Test sensor response with water spray

Final Weather Sealing:

- Seal all electrical penetrations

- Protect motor connections with weatherproof housings

- Apply cable strain relief at all entry points

- Install drainage for any water accumulation points

**🔋 Phase 4: Power System Integration (1 hour)**

**Step 4.1: Battery Installation**

Time: 30 minutes

SAFETY CRITICAL: Li-ion handling procedures

4S Battery Safety Check:

□ Voltage reads 14.8V ±0.5V

□ No physical damage to cells or BMS

□ XT60 connector clean and tight

□ Balance lead properly connected

□ No overheating during initial test

Installation Process:

1. Create secure battery mounting in enclosure

- Use foam padding to prevent movement

- Ensure adequate ventilation around battery

- Position for easy access to XT60 connector

2. Install battery monitoring (optional):

- Connect voltage divider to Arduino A1

- 30kΩ resistor from battery + to A1

- 10kΩ resistor from A1 to ground

- Test voltage reading: should show ~14.8V

3. Power system test:

- Connect XT60 connector to battery

- Verify L298D receives 14.8V

- Test motor operation with multimeter current measurement

- Should draw ~3.1A during motor operation

**Step 4.2: Charging System Setup**

Time: 30 minutes

Charger Configuration:

1. Set charger to 4S Li-ion mode

2. Set charge current to 1-2A

3. Connect balance lead first, then main power

4. Verify all cell voltages are balanced (±0.1V)

Charging Location:

- Remove battery from weather enclosure for charging

- Charge in well-ventilated area away from flammables

- Never charge unattended

- Use timer to prevent overcharging

Charging Schedule:

- Charge after every 2-3 days of operation

- Don't let battery discharge below 12.8V

- Store at 40-60% charge if not using system

**✅ Phase 5: System Commissioning & Testing (1-2 hours)**

**Step 5.1: Calibration**

Time: 45 minutes

Rain Sensor Calibration:

1. Measure dry sensor reading (should be ~1000-1023)

2. Apply water drops and measure wet reading (should be <300)

3. Set threshold in code: const int RAIN\_THRESHOLD = 300;

4. Test multiple water amounts for consistent triggering

5. Verify no false positives from vibration or wind

Motor Timing Calibration:

1. Manually measure clothesline travel distance

2. Time complete retraction with stopwatch

3. Time complete extension with stopwatch

4. Adjust MOTOR\_RUN\_TIME in code if needed

5. Ensure complete travel in both directions

System Response Testing:

1. Test immediate rain response (should be <2 seconds)

2. Verify 30-second safety delay after rain stops

3. Test emergency override during extension

4. Confirm motor speeds are appropriate (not too loud)

**Step 5.2: Load Testing**

Time: 30 minutes

Mechanical Load Test:

1. Hang representative clothing load on clothesline

2. Add weight equivalent to wet clothes (2-3kg)

3. Test retraction under load - should complete smoothly

4. Test extension under load - should not bind or stall

5. Check cable tension and pulley operation

Electrical Load Test:

1. Measure actual current draw during loaded operation

2. Should not exceed 4A total current

3. Monitor battery voltage under load

4. Verify no voltage drops affecting Arduino operation

5. Check all connections remain secure under load

**Step 5.3: Weather Simulation Testing**

Time: 45 minutes

Rain Simulation:

1. Use garden hose with spray nozzle to simulate rain

2. Test sensor detection from various angles

3. Verify water doesn't affect electronics enclosure

4. Test system operation during simulated storm

5. Check drainage and water management

Temperature Testing:

1. Test operation in available temperature range

2. Check battery performance in cold conditions

3. Verify electronics don't overheat in enclosure

4. Test cable flexibility in temperature extremes

Final Integration Test:

1. Run complete 24-hour test cycle

2. Monitor battery life and performance

3. Check for any mechanical wear or loosening

4. Verify consistent operation over multiple cycles

5. Document any adjustments needed

**Final Assembly Checklist**

**Electrical Systems**

* All connections secure and tested
* No short circuits or ground faults
* Current draw within specifications (<4A)
* Battery charging system operational
* Serial debugging output functional

**Mechanical Systems**

* Frame rigid and weather-resistant
* Pulley system operates smoothly
* Motors properly aligned and secured
* Cable routing optimized and protected
* Clothesline attachment points secure

**Software Systems**

* Code uploaded and functional
* Rain sensor calibrated correctly
* Motor timing optimized for setup
* Emergency overrides tested
* Status indicators working

**Weather Protection**

* Electronics enclosure waterproof
* All cable entries sealed
* Shelter provides adequate coverage
* Drainage systems functional
* Long-term weather durability verified