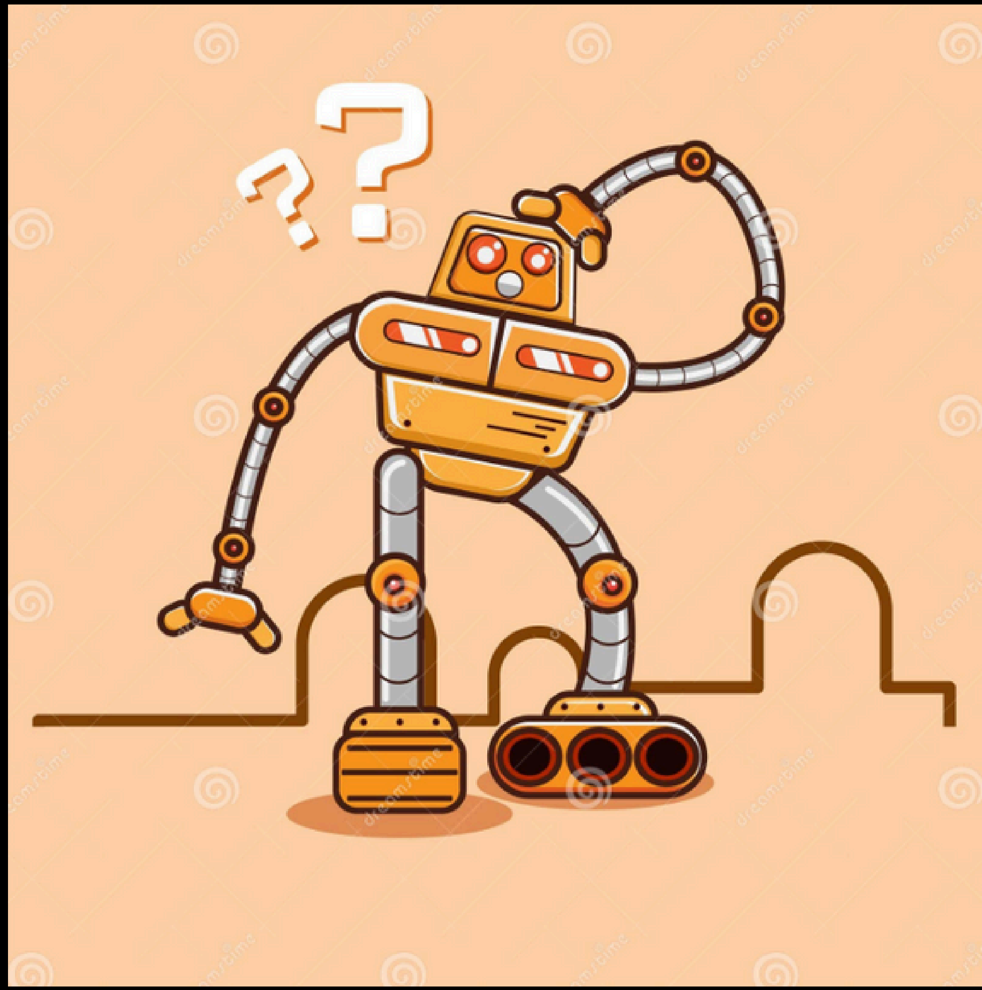
WHAT MAKES UP A ROBOT?



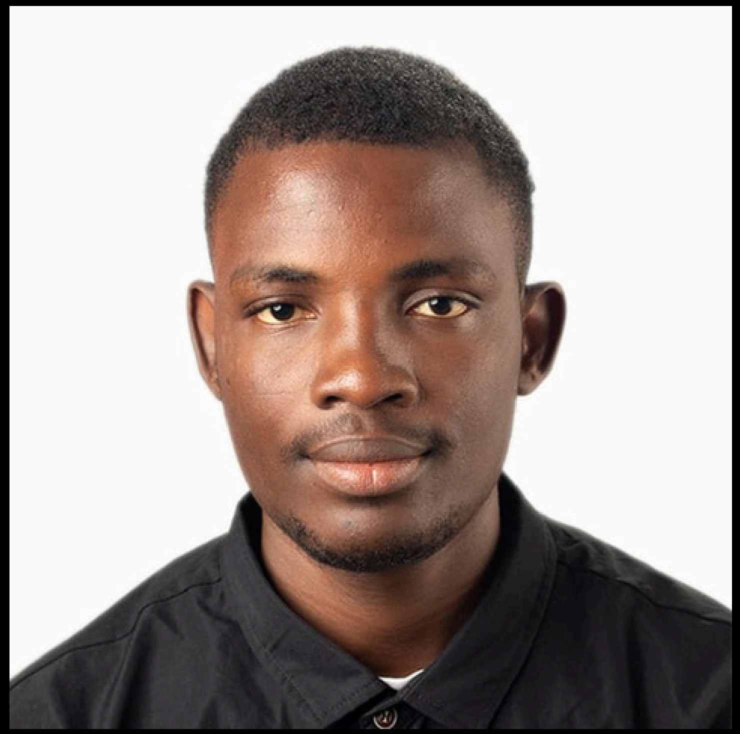
By Bakel Bakel Begededum

GENERAL RULES

- All mics should be muted
- I am always looking at the chat box so feel free drop questions anytime
- Feel free to use the “raise your hand” option anytime
- I recommend you have a note (could be digital), I tend to drop random knowledge casually

SHOUT OUT TO SAKA

- Mechanical Engineering graduate, LAUTECH, focus on robotics & autonomous systems
- Lead, Robotics & AI Innovator Network (RAIN-IN) | Former President, SPE LAUTECH Chapter
- Awards:
  - 1st – Hack4Livestock Hackathon
  - 1st – 234 AI Hackathon (UI)
  - Runner-Up – UNILAG Energy Challenge & Nigerian Genius Competition
  - Gold Medal – LAUTECH Research & Discovery Exhibition
  - 3rd – UI Design Studio Competition
- Expertise: Embedded AI, real-time systems, digital twins, simulation
- Passion: Building safe, intelligent robots for agriculture, manufacturing & service industries



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ABOUT AURORA ROBOTICS

“Aurora Robotics is an indigenous Nigerian company, built by a team of highly skilled and talented roboticists who are passionate about advancing robotics innovation locally and globally.”

- Education
- Robotics Software development
- Hardware design and prototyping
- Full-scale production

ABOUT AURORA INTERSTELLAR

Aurora Interstellar is building Africa’s largest robotics, AI and Industry 4.0/5.0 network, connecting talents across Nigeria and beyond to global opportunities.

- Training and Mentorship
- Open-source projects
- Competitions, Internships and Scholarships

WHY ARE WE DOING THIS?

- To bridge the gap between theory and practical
- To build a community of indigenous talent
- To prepare students and young engineers for Masters, PhD, and career opportunities.
- To showcase that Nigeria and Africa can lead in robotics innovation, not just consume technology.
- To inspire consistency, passion, and collaboration

ABOUT ME

Well,
I am a lot of things,
but for today I am a speaker at **RAIN LAUTECH!, I appreciate the honour.**

https://www.linkedin.com/in/bakel-bakel-6341a7150/

https://www.upwork.com/freelancers/bakel

All slides, code and materials will be shared in the training repo. Feel free to use and share but do not modify

(I am very good with lawsuits)

WHAT MAKES UP A ROBOT?
THE CORE BUILDING BLOCKS

- Structure (Body)
  - The physical frame that holds everything together, made from metal, plastic, or soft materials. Robot arm, chassis, hull
- Actuators (Muscles)
  - Convert energy into motion. These are motors, servos, hydraulics, or pneumatics that move parts. Motors moving robot joints
- Sensors (Eyes, Ears, Tongues, Skin, Nose)
  - Collect data from the environment: detect light, distance, force, sound, temperature, etc. Camera, LiDAR, IMU, pressure sensor

WHAT MAKES UP A ROBOT?
THE CORE BUILDING BLOCKS

- Control System (Brain)
  - The computer or microcontroller that processes sensor data and makes decisions. Raspberry Pi, Arduino, Jetson or other onboard computers/controller

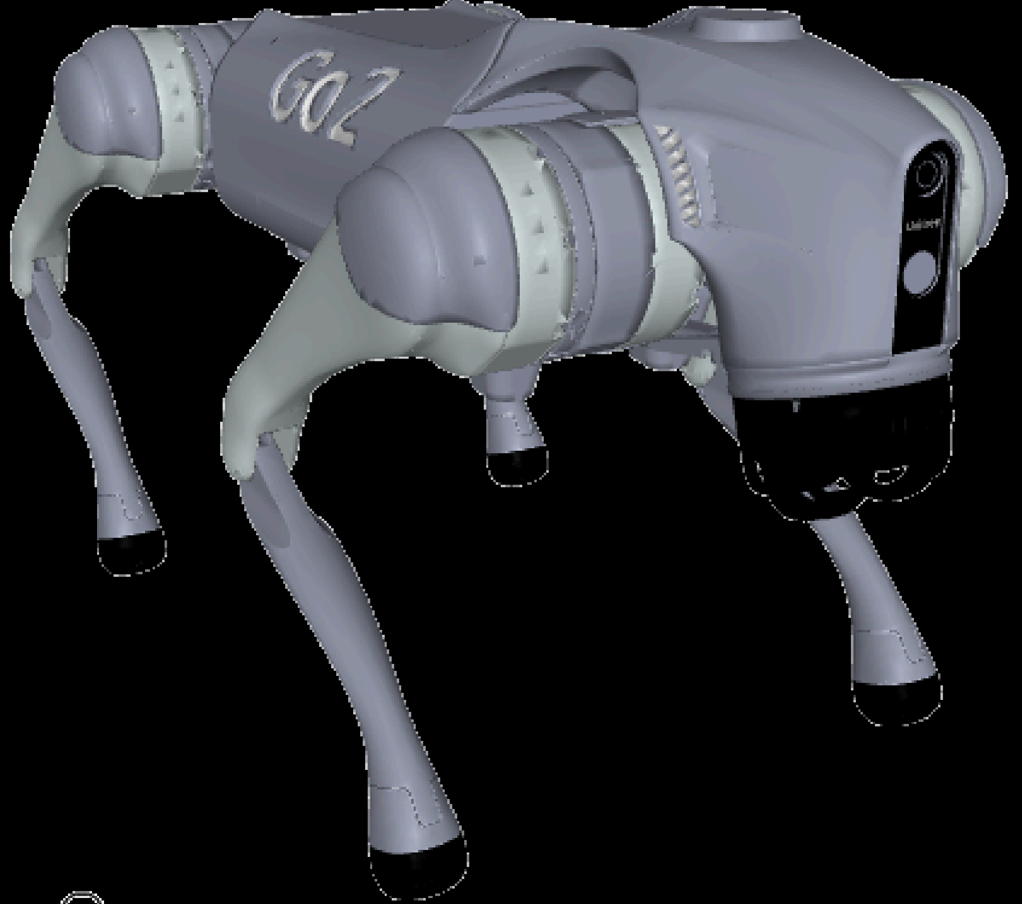
- Power Source (Heart, maybe stomach): Provides energy for all systems, electrical, battery, or external supply. Battery pack, solar cell

- End Effector / Tool The “hand” or tool that interacts with the environment. Gripper, drill, surgical scalpel
- Communication / Interface: Allows data exchange between robot, operator, or other robots. Wi-Fi, radio, Bluetooth

Alright, lets understand what makes up part of each field of robotics
Get ready for a short burst of information overload
Brace for impact,

May the force be with us💚

QUADRUPED ROBOTS



go2

anymal b

spot

QUADRUPED ROBOTS

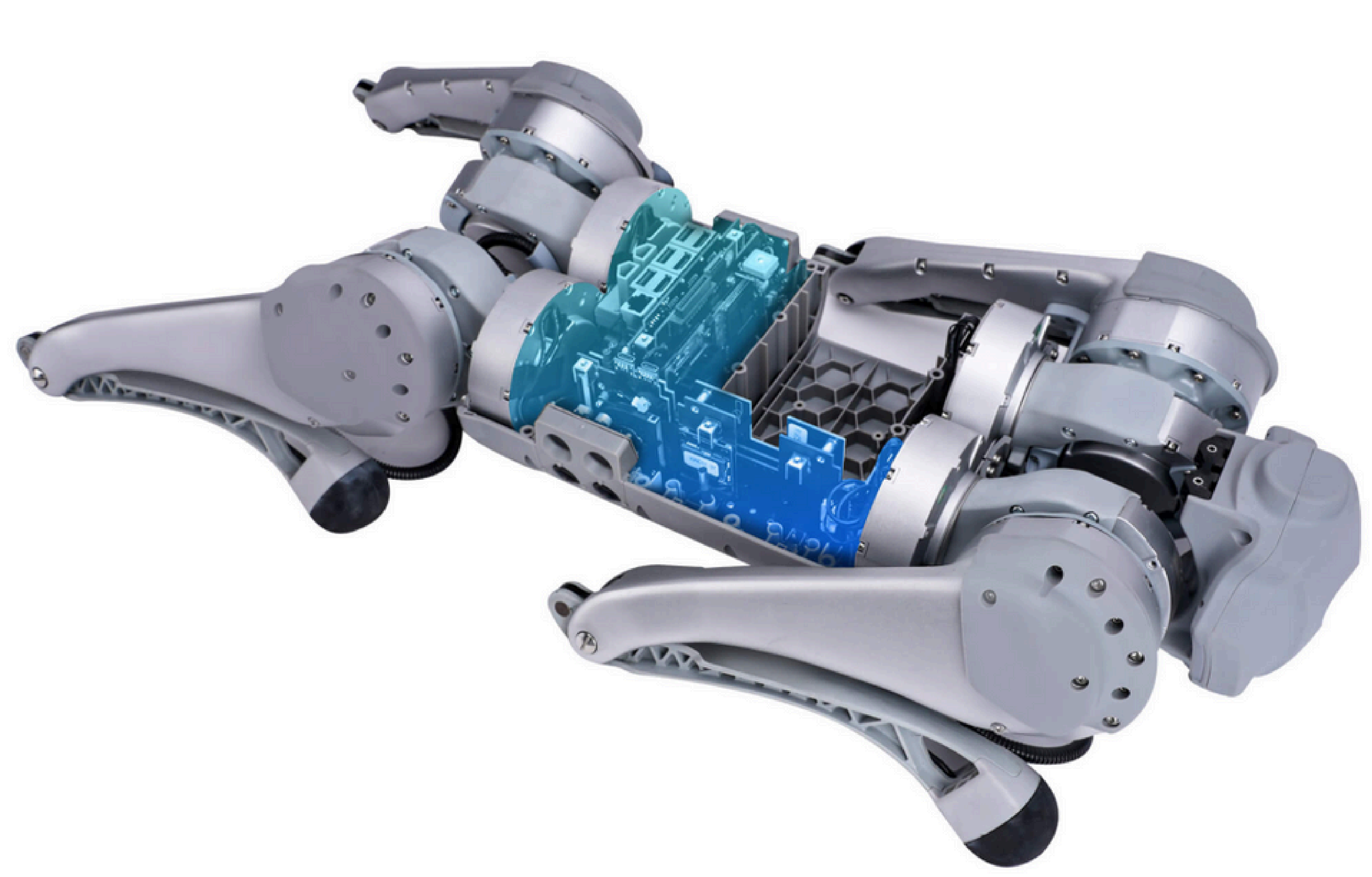
- Legged Mechanism:
  - Four articulated legs attached to a central body frame
  - 2-3 joints per leg allowing complex movements.
- Actuators & Power:
  - Electric motors (with gear reduction for high torque)
  - Hydraulics in larger models.
  - A rechargeable battery pack for power

QUADRUPED ROBOTS

- Sensors:
  - IMU to sense orientation and balance
  - Joint encoders in each leg track angles for precise motion control.
  - Foot contact & force sensors to detect ground contact.
  - Vision sensors (cameras, ultrasound, LiDAR) for terrain mapping.

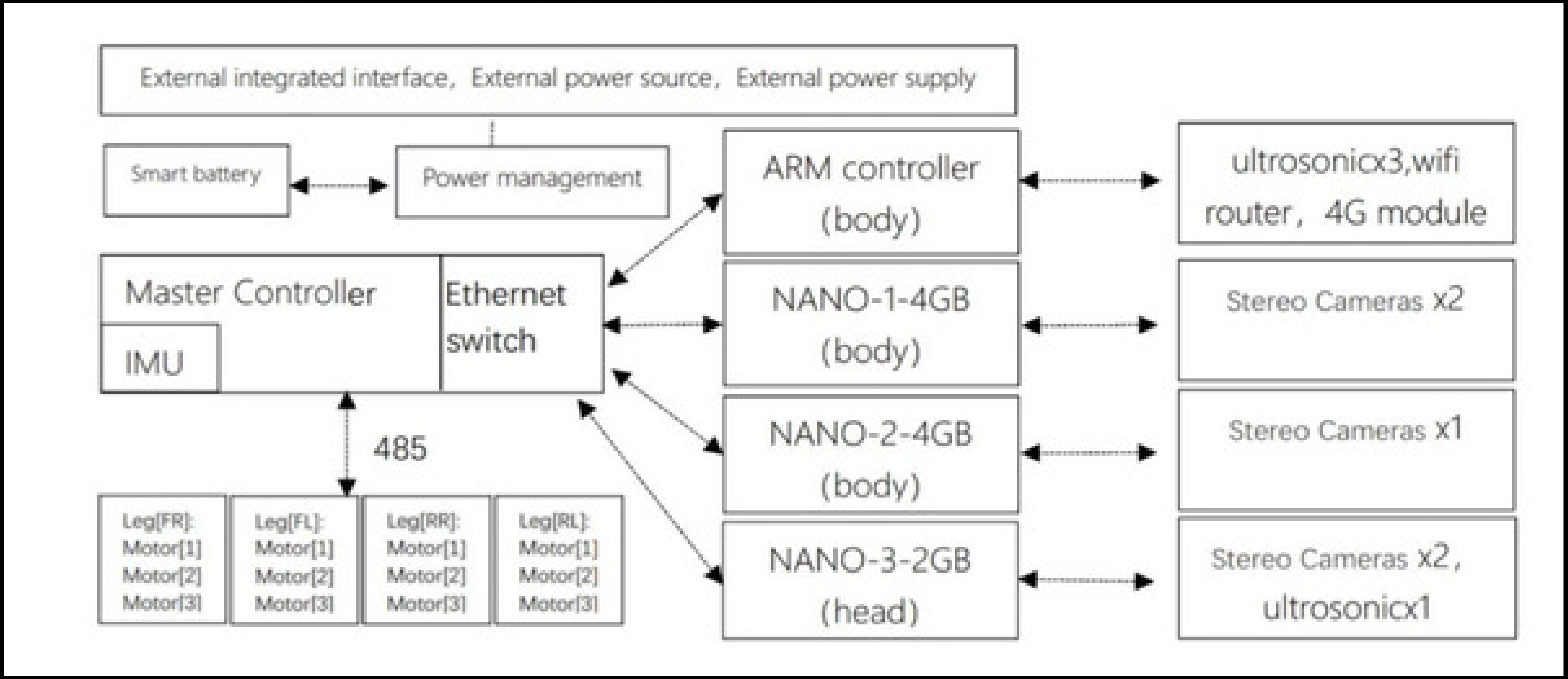
QUADRUPED ROBOTS

- Frame & Mobility Aids:
  - The body frame of aluminum or carbon fiber
  - Houses electronics and compliant elements to absorb.
  - Might have a tail or other appendages for additional balance or maneuverability.

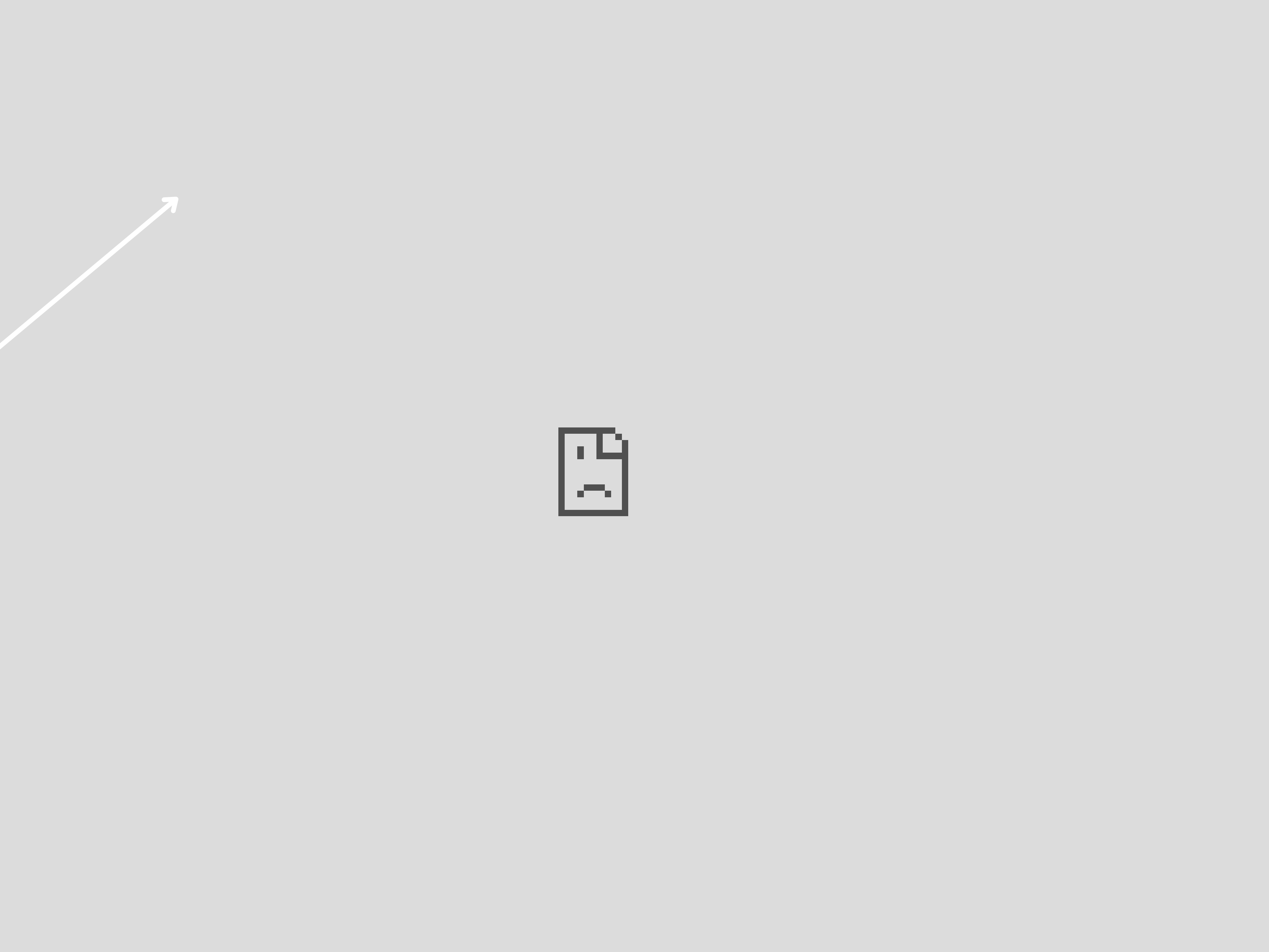


QUADRUPED ROBOTS

- Control System:
  - Onboard computer or microcontroller network runs the locomotion algorithms.
  - Inverse kinematics and balance control to coordinate the legs
  - Algorithms that adjust posture based on IMU feedback.
  - The control system manages different gaits such as walking, trotting, jumping (I worked on one and its a crazy control system!) and can react to disturbances in real time.



IEEE, GREECEEEEEEE🇬🇷



THE BOY
NEARLY SPOIL
SOMETHING

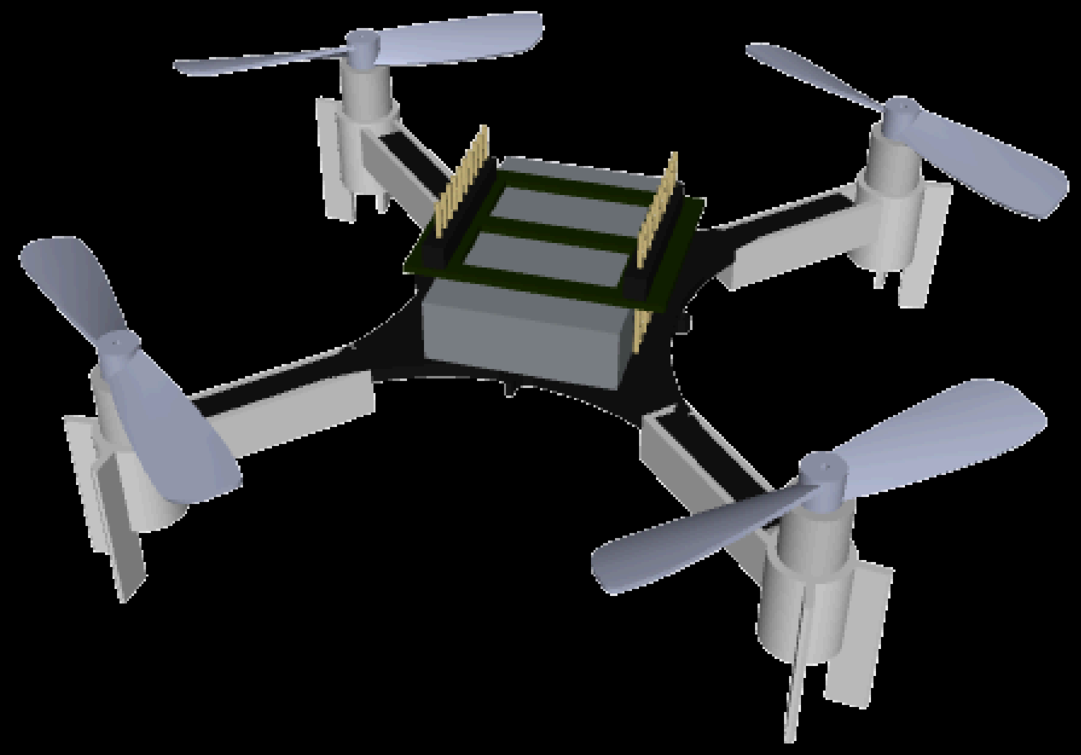
https://www.linkedin.com/posts/bakel-bakel-6341a7150_optrob25-robotics-ugcPost-7350974820215308288-eJcQ

QUADRUPED ROBOTS DEMO

Creep on all four!

AERIAL ROBOTS (AUTONOMOUS DRONES)

skydio x2



crazyflie 2

Aerial Robots (Autonomous Drones)

Airframe:

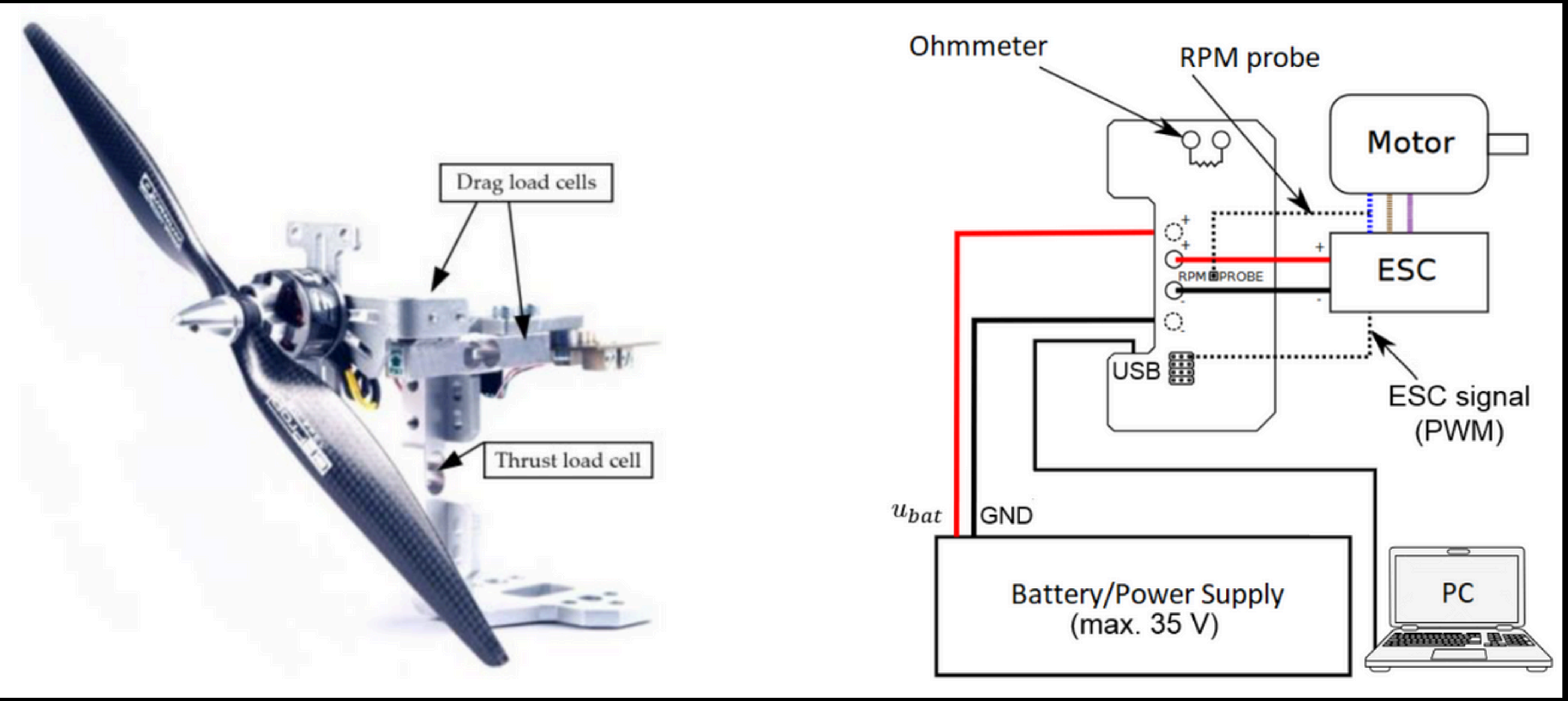
A lightweight frame holding all components.

In multi-rotor drones (e.g. quadcopters), a central body with extending arms (usually 4 arms in an X or + configuration for quadrotors) supports the motors. It also provides mounting points for the flight controller, GPS antenna, payload (like a camera), and battery.

Aerial Robots (Autonomous Drones)

Propulsion:

- Rotors and Motors generate lift and control.
- A quadcopter has four brushless DC motors, the speed of each motor is independently controlled to achieve desired thrust and torque: adjusting the relative speeds allows the drone to pitch, roll, yaw, or maintain hover.
- The motors are driven by electronic speed controllers (ESCs) which take throttle commands from the flight controller and modulate power from the battery to the motors rapidly.



Aerial Robots (Autonomous Drones)

Power:

- High-energy Lithium-Polymer (Li-Po) batteries to supply the significant current required by the motors.
- Power distribution wiring connects the battery to all ESCs and the flight controller (often through a power management board that provides regulated lower voltages for electronics).

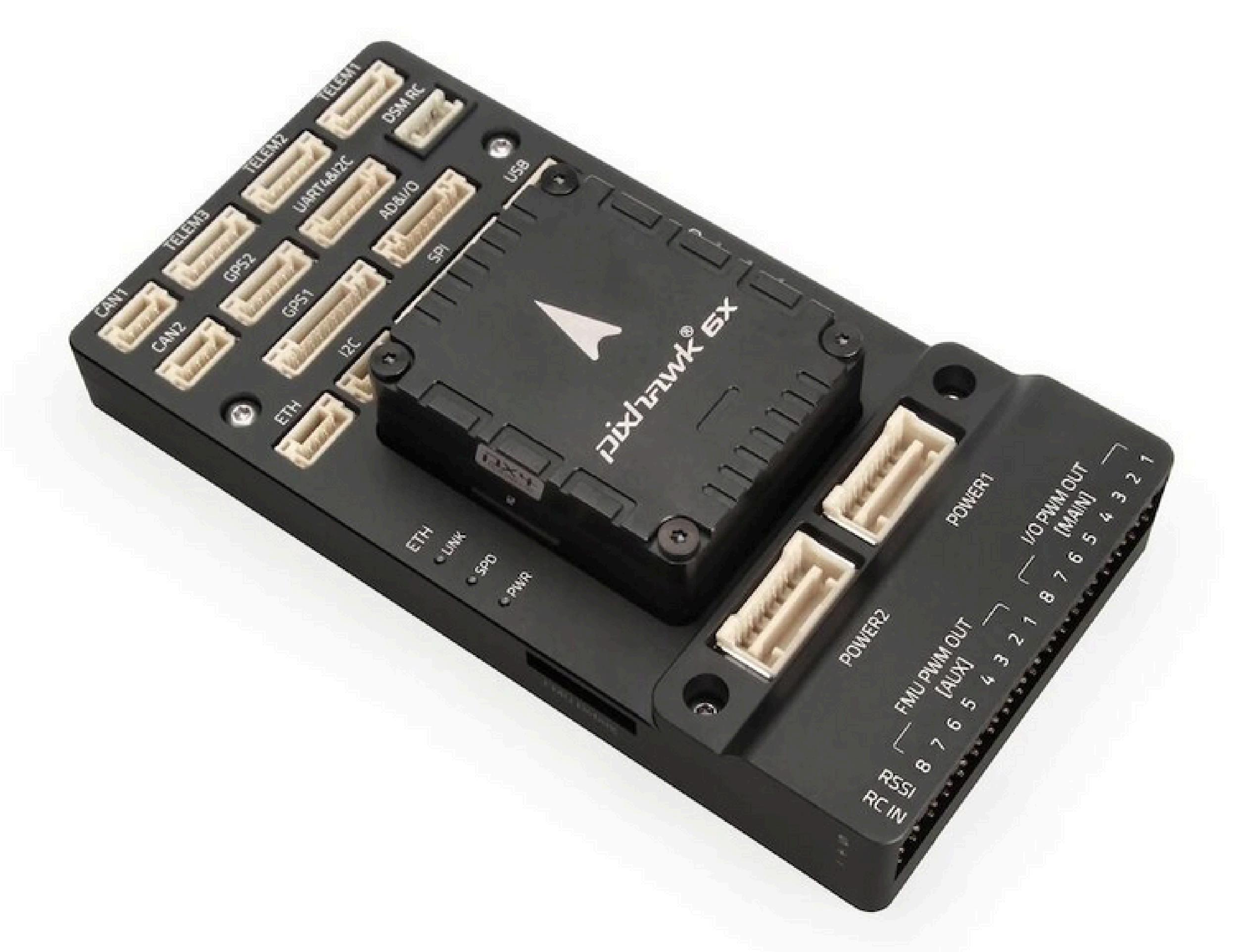
Aerial Robots (Autonomous Drones)

Flight Controller & IMU:

For stabilizing the drone.

It includes an IMU and often a magnetometer (compass) and barometer (altitude sensor).

The flight controller runs a real-time stabilization loop (hundreds of times per second) to keep the drone level and execute pilot or autonomous commands.



Aerial Robots (Autonomous Drones)

Navigation & Autonomy Sensors:

For autonomous flight, drones add sensors like GPS for global positioning outdoors, which enables waypoint navigation and return-to-home functionality. In GPS-denied environments (indoors), drones may use optical flow cameras or laser rangefinders for position holding. Some advanced drones carry computer vision systems or lidar for obstacle avoidance and mapping, allowing them to sense and react to the environment. A downward-facing altimeter (sonar or lidar) can help with precise landing.

Aerial Robots (Autonomous Drones)

Communication:

- Radio receiver to get control signals from a remote pilot.
- Autonomous drones also use telemetry radios (or Wi-Fi links) to communicate with a ground station, sending live data like battery status, GPS location, and video feed if a camera is onboard.

Control Software:

- The drone’s software (e.g ArduPilot or PX4) integrates sensor data and high-level commands.
- It manages flight modes (manual, altitude hold, GPS hold, autonomous mission waypoints, etc.) and can stabilize the vehicle even in moderate wind.

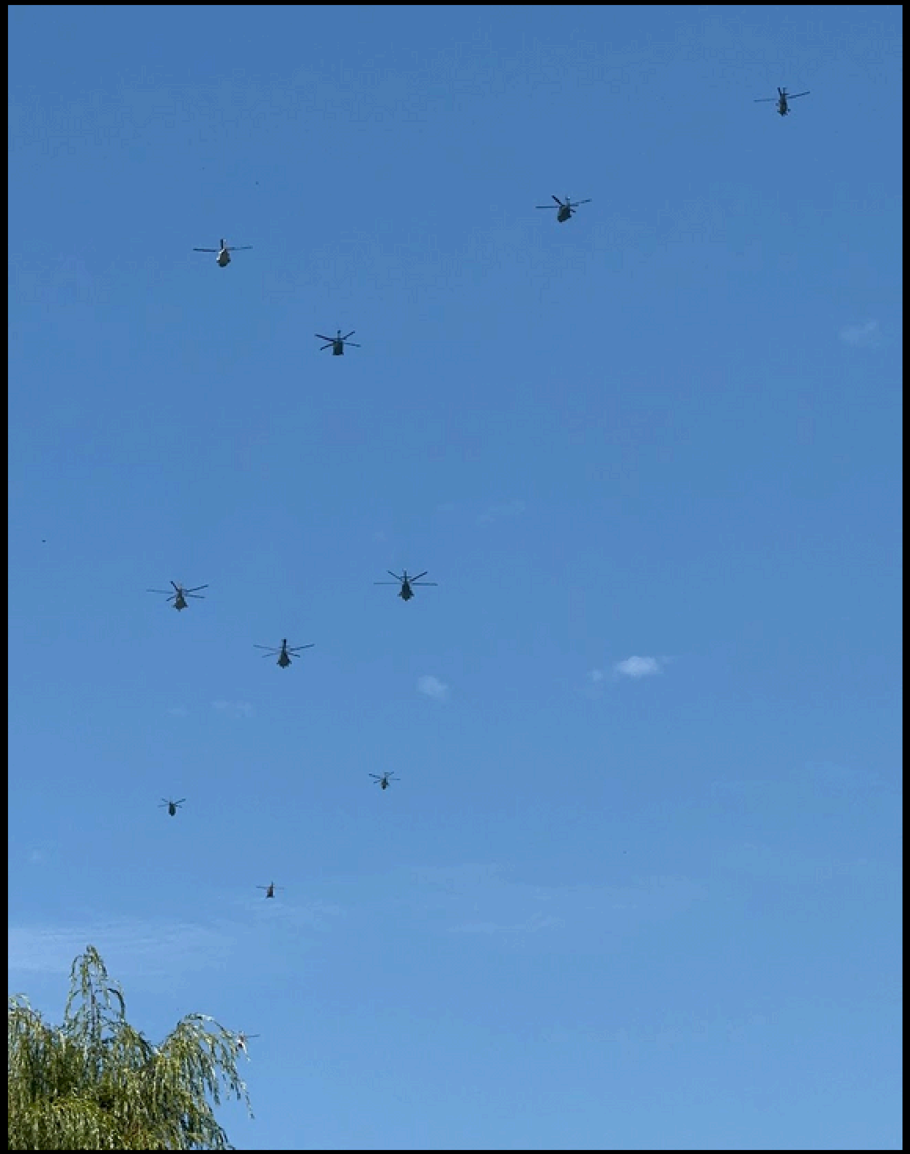
Swarm Robotics (Aerial)

'In swarm robotics, intelligence isn't centralized, it's distributed, but somehow, they are one
A hundred simple drones can act smarter together than one powerful one alone.'

IEEE RAS, PRAGUEEE🇨🇿

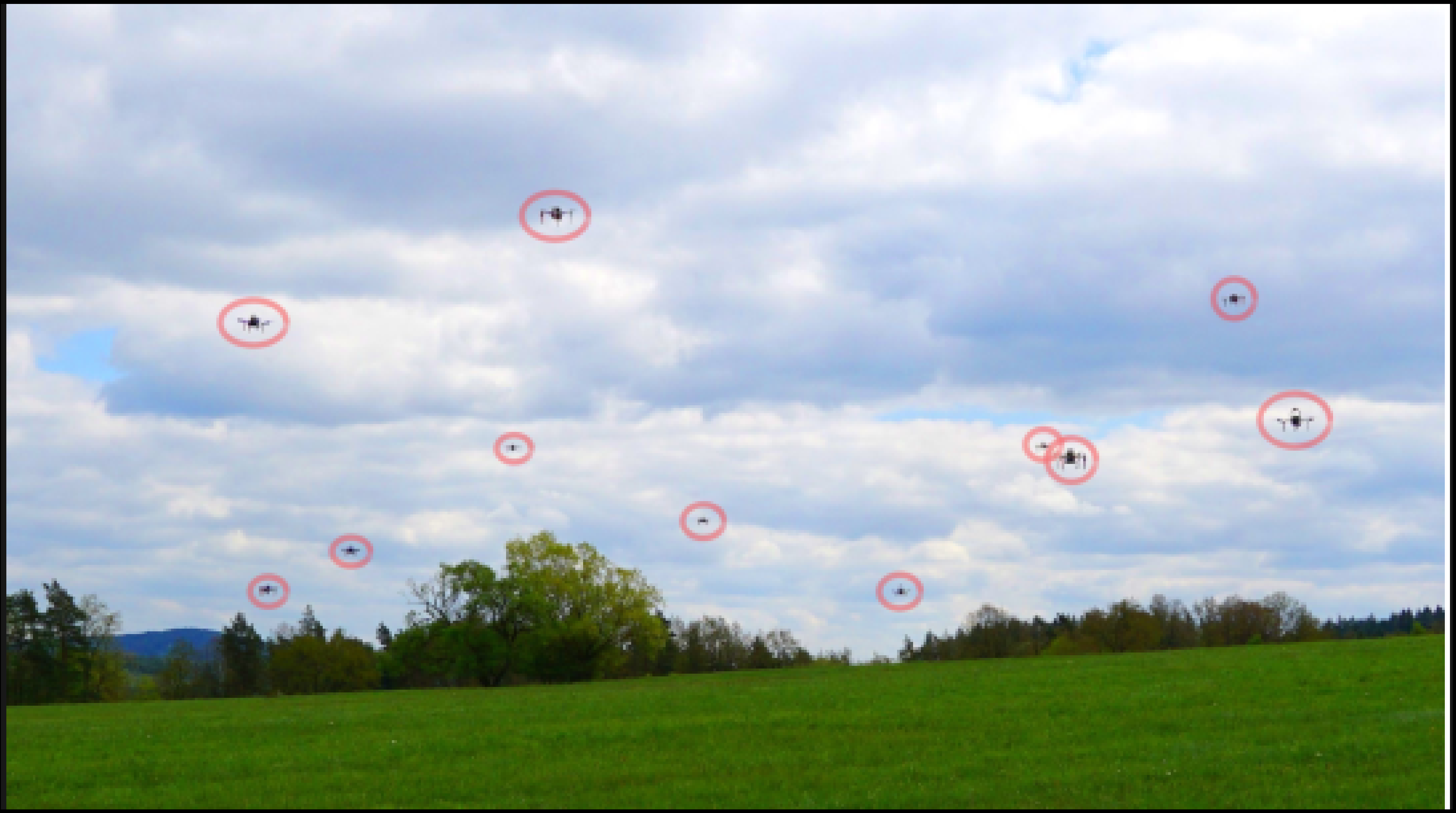
(where my ancestors told me to start up Aurora)

I'm somewhere in the crowd, i got better pictures, trust me🙂



IEEE RAS, PRAGUEEE🇨🇿 (The City was vibes)

Cooperative Motion Planning for Multi-Robot Teams



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Swarm Robotics (Aerial)

- Structure (The Modular Airframe)
- Each drone in a swarm is a modular, lightweight aerial robot, optimized for endurance and simplicity.

- Frame Design: The structure is typically a quadrotor frame, four arms extending from a central hub, each holding a motor and propeller.
  - The body is made of carbon fiber or reinforced polymer to ensure high strength-to-weight ratio and vibration damping.

- Embedded Components: Inside the frame lies the flight controller, power distribution board, IMU, and radio modules.
  - Mounting points allow the addition of sensors (cameras, LiDAR, GPS modules) or small payloads.

Swarm Robotics (Aerial)

- Swarm-Ready Architecture:
  - Every drone in a swarm is identical or modularly similar, this standardization allows them to replace or synchronize with one another seamlessly.
  - It also simplifies maintenance and programming since one design works across the fleet.

- Mechanical Protection:
  - Propeller guards and dampers are added to protect the structure and nearby drones during close-proximity flight.

Swarm Robotics (Aerial)

Collective Actuation:

- In a swarm, these micro-adjustments happen not only per drone but synchronously across the network, giving the illusion of a coordinated “flock.”

Actuator Synchrony:

- Although each propeller’s speed is controlled locally, the patterns of motion (e.g., tilt or climb) propagate across the swarm at network speed, causing the entire group to move fluidly as a single organism.

- The synchronization emerges naturally, as each drone reacts to its neighbors, all drones adjust together.

Swarm Robotics (Aerial)

- Each drone in the swarm executes tiny, rapid control loops that adjust motor thrust thousands of times per second.

- Sharing info is key here.
  - Local Sensing: Each drone measures its position, velocity, and orientation via onboard sensors
  - Neighborhood Awareness: Using wireless links (Wi-Fi, UWB, or ZigBee), each drone exchanges its current state (position, speed, heading) with nearby drones in the network, its “neighbors.”

Swarm Robotics (Aerial)

- Consensus Rules (The rule that governs the motion):
  - Each drone then updates its control targets based on simple shared rules:
    - Alignment: match direction and velocity with neighbors.
    - Cohesion: move toward the average position of nearby drones.
    - Separation: avoid getting too close to prevent collision.
    - Distributed Control: These rules are computed locally, so every drone decides its own thrust vector.

Sensors make swarm drones aware of their environment and each other.

To move as a group safely, each drone needs to perceive position, motion, and proximity with high accuracy.

- IMU (Inertial Measurement Unit): Measures acceleration and angular velocity for real-time stabilization.
- GPS (Global Positioning System): Provides global coordinates, allowing drones to maintain formation and navigate pre-defined waypoints.
- Optical Flow Sensors / Cameras: Estimate ground velocity and visual odometry, especially useful indoors or in GPS-denied environments.
- Ultrasonic / IR / ToF Sensors: Measure altitude and detect nearby drones or obstacles within a few meters.
- LiDAR (Optional): Provides 3D awareness for high-precision mapping and collision avoidance.
- Communication-based Sensing: Many swarm behaviors rely on wireless signal strength, relative distance, and position broadcasting (e.g., Wi-Fi, UWB, or ZigBee) for inter-drone awareness.

Swarm Robotics (Aerial)

Control System (The Swarm Brain)
The intelligence of a swarm lies not in any single drone, but in the collective algorithmic behavior that connects them.

Control Layers:

- Low-Level Control:
  - Runs inside each drone’s flight controller (e.g., Pixhawk or Crazyflie).
  - Handles attitude stabilization, motor speed regulation, and PID loops at millisecond speeds.

- Mid-Level Control: Coordinates movement, executing commands like “move to point X” or “maintain altitude 5 m.”

- High-Level Swarm Coordination:
- Implemented in a central ground station or distributed across all drones.
- Algorithms here manage:
  - Formation control (e.g., V-shape, grid, ring)
  - Collision avoidance
  - Flocking behaviors (based on Reynolds’ 3 rules: alignment, cohesion, separation)
  - Task allocation (who maps which zone or searches which region)

Swarm Robotics (Aerial)

Communication Backbone:

- Each drone broadcasts its position and velocity to neighbors via wireless mesh networking (Wi-Fi, ZigBee, or UWB).
- Communication delay and packet loss are mitigated through predictive modeling — drones estimate neighbor motion even when signals drop.

Swarm Intelligence Algorithms:

Common approaches include:

- Flocking algorithms (Reynolds, 1987)
- Potential fields (repulsion and attraction forces)
- Consensus-based distributed control
- Bio-inspired neural models

Functionality (Emergent Behaviors and Applications)

The real power of swarm drones lies not in one machine, but in the emergence of collective intelligence.

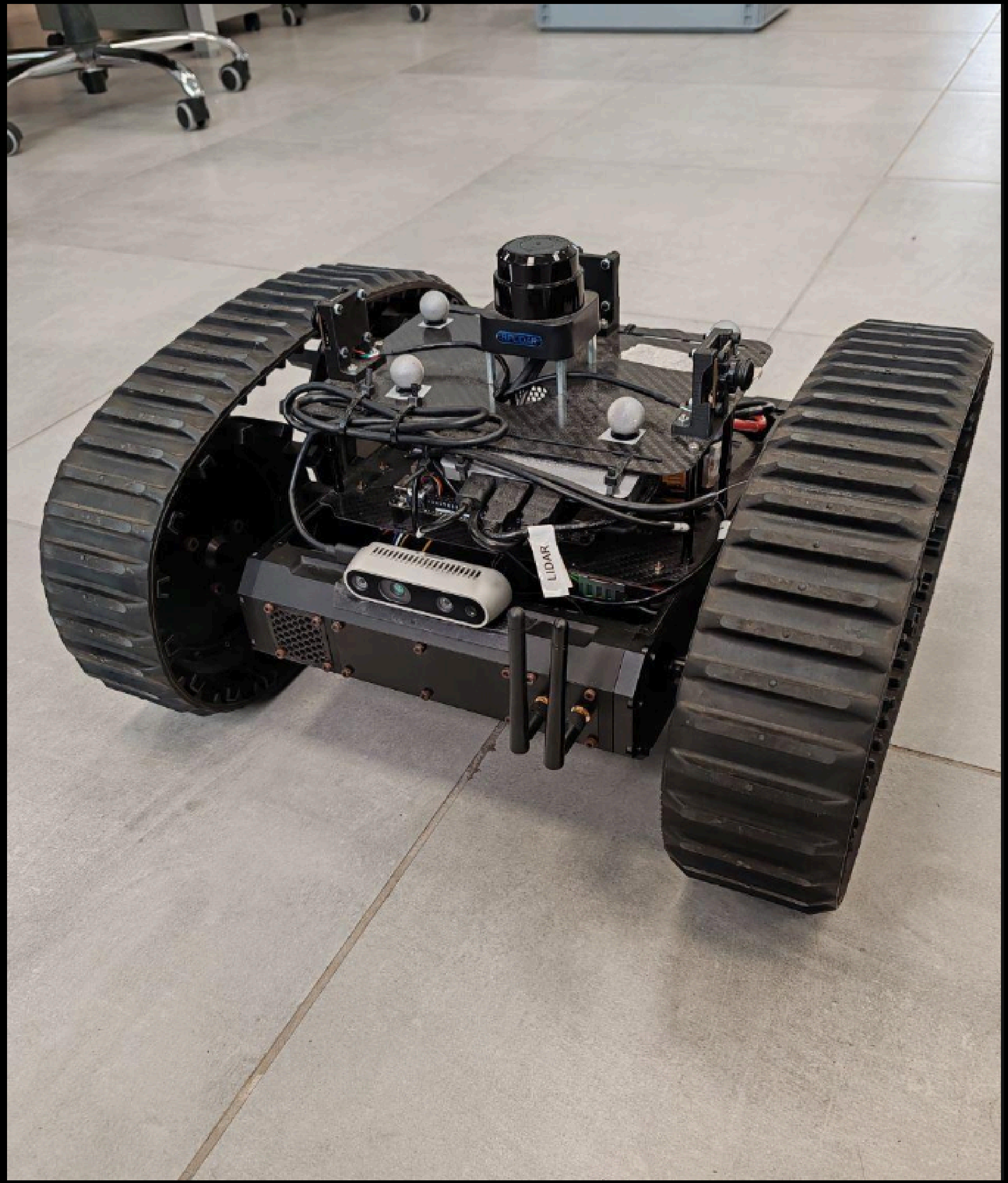
Emergent Behaviors:

- Self-organization: Drones automatically form stable formations or patterns without a leader.
- Fault tolerance: If one drone fails, others redistribute its task – the swarm remains functional.
- Scalability: Whether 5 drones or 500, the same principles allow expansion without redesigning control logic.
- Environmental adaptability: The swarm can spread out for exploration or cluster together to pass through narrow spaces.

SWARM ROBOTICS DEMO

'Just hang with me, this'll only take a moment, OK ?'
~ NF, The Search (July, 2019)

AUTONOMOUS MOBILE ROBOT



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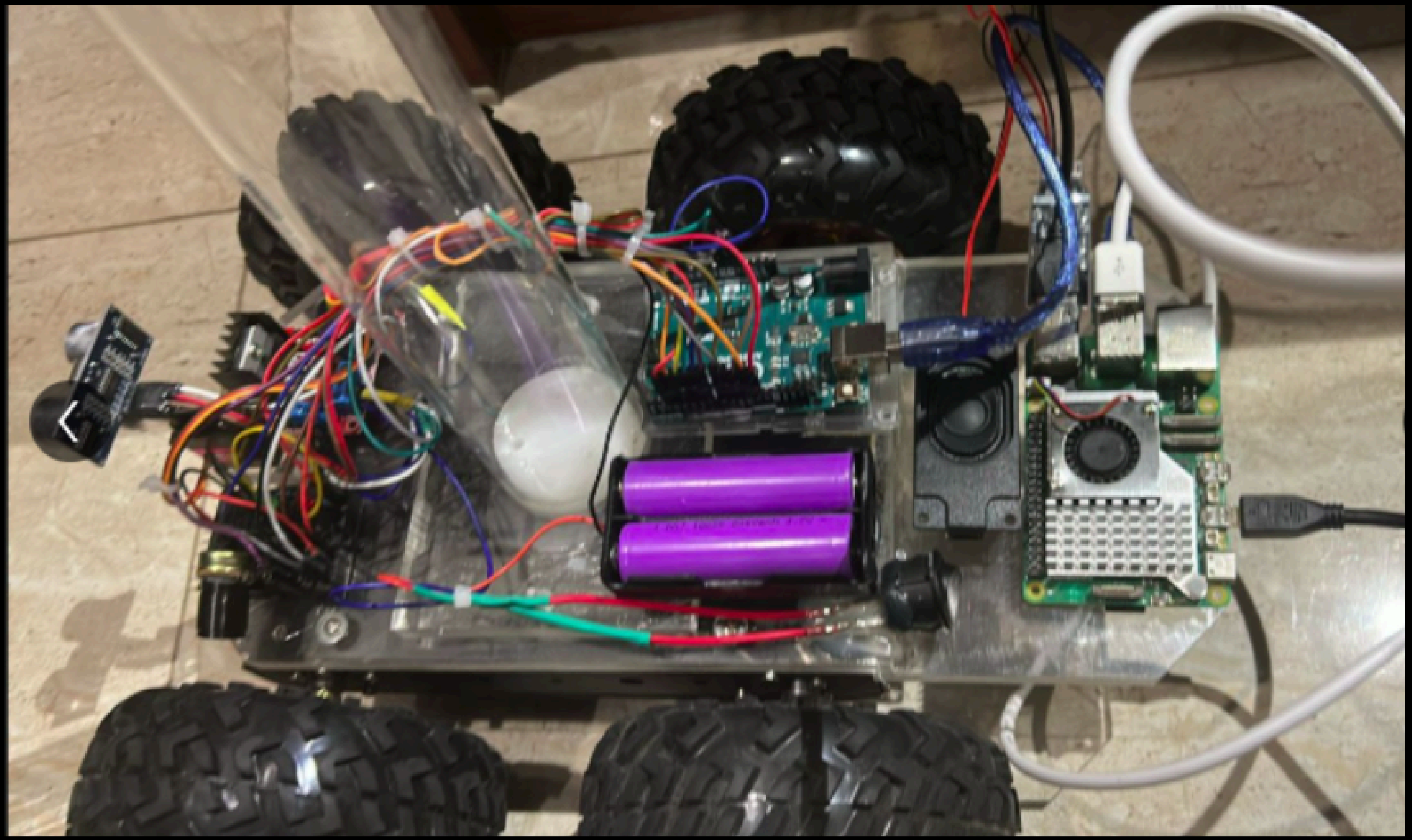
A VERY SIMPLE MOBILE ROBOT



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AUTONOMOUS MOBILE ROBOT

- Chassis & Locomotion:
  - Wheels or tracks for movement:
    - Differential drive often with caster wheels for balance
    - Four/six-wheeled configurations for stability
    - Chassis is a rigid frame, metal or high-strength plastic
    - Wheel motors (electric DC or brushless motors) with gearboxes provide the torque to drive and steer the robot.

AUTONOMOUS MOBILE ROBOT

- Power System:
  - Onboard battery pack typically lithium-ion.
  - Power management circuits regulate voltage.
  - Safety features (fuses, monitoring ICs) protect against over-current.
  - Support battery hot-swap or automatic recharging (like docking to a charging station) to enable long-term autonomy.

AUTONOMOUS MOBILE ROBOT

- Sensors for Navigation: Autonomous mobile bases are equipped with a variety of sensors for perception and localization. A LIDAR scanner is often mounted on top to create 2D/3D maps of the surroundings for SLAM (Simultaneous Localization and Mapping).
- Cameras provide vision input for object recognition or visual SLAM.
- Ultrasonic or infrared rangefinders might be placed around the base for near-distance obstacle detection.
- Wheel encoders measure wheel rotations for odometry, and an IMU gives inertial data.
- High-end units may include GPS if outdoor navigation over large areas is needed.

AUTONOMOUS MOBILE ROBOT

- Onboard Computer & Control:
  - A small computer (Raspberry Pi, NVIDIA Jetson,etc)
  - Runs the robot's software (often ROS),control algorithms, sensor fusion and decision-making software.
  - Handles path planning, obstacle avoidance, and high-level autonomy
  - A separate motor controller board or microcontroller handles low-level motor drivers (speed control, PID loops for wheel velocity).

- Communication & Interfaces:
  - Wireless communication to receive commands or send back telemetry.
  - Status LEDs or a user interface for battery levels and errors.

MOBILE ROBOTICS DEMO

WHAT HUMAN PROCESS BRINGS ABOUT THE ROBOT

Concepts/Theory ⇒ Maths ⇒ Codes/ Simulation ⇒ Application

HUMANOID ROBOTS THE CLOSEST MACHINES TO US

Humanoid robots are designed to replicate the human body, not just in appearance but also in movement, perception, and behavior. Their purpose is often to work in human environments, interact naturally with people, or perform tasks that require a human-like form.

HUMANOID ROBOTS

Body (Structure)

The body of a humanoid robot mirrors the human skeleton, head, torso, arms, hands, legs, and feet.

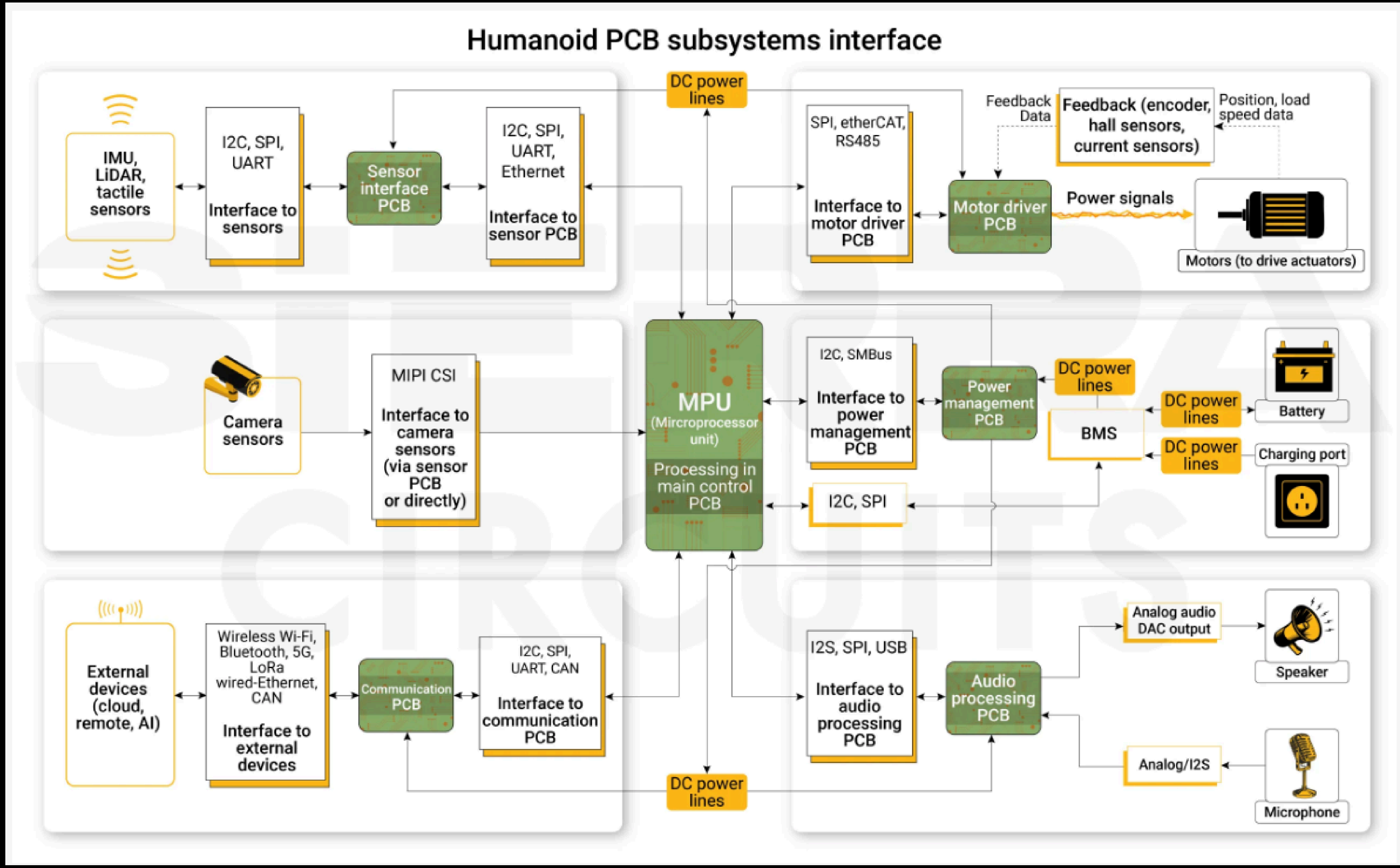
Each part is connected through joints, giving the robot Degrees of Freedom (DoF), which represent the independent ways it can move.

A typical humanoid like ASIMO or Atlas has over 20–30 DoF, allowing complex motions like walking, turning, bending, or grasping.

The frame is built from lightweight but strong materials such as aluminum alloys, carbon fiber, or polymer composites to reduce weight and energy consumption.

HUMANOID ROBOTS

Inside the frame are compartments for batteries, computers, and wiring, while the outer surface may be covered by plastic panels or soft skins for a more human-like appearance.



HUMANOID ROBOTS

- Actuators (Muscles)
- Electric motors (servo or brushless DC): common for precision and control, used in robots like Pepper or NAO.
- Hydraulic actuators: provide high force for dynamic motion, used in robots like Boston Dynamics Atlas.
- Pneumatic actuators: use air pressure for compliant (soft) movement, often seen in research prototypes.
- Each actuator is connected to the robot's joints via gears, belts, or tendons, translating rotational or linear motion into realistic limb movement.

HUMANOID ROBOTS

3. Sensors (Senses and Perception)

Vision sensors: Cameras (stereo or RGB-D) and LiDAR

IMU: Measures acceleration and rotation

Force/Torque sensors: Mounted in joints or feet to detect how much pressure or resistance is being applied, essential for walking and gripping safely.

Tactile sensors: Embedded in fingertips or palms, these allow the robot to “feel” touch, texture, or pressure, much like human skin.

HUMANOID ROBOTS

4. Control System (Brain and Nervous System)
It consists of onboard computers (often multi-core CPUs and GPUs) that run:
Low-level control loops (for real-time joint motion, stability, and safety)
High-level algorithms (for walking, grasping, face tracking, speech, or decision-making)
AI and machine learning modules help the robot adapt to changes, understand speech, or recognize objects.
Control is often hierarchical:
Low-level: microcontrollers handle motor commands.
Mid-level: motion planning, balancing.
High-level: behavior control, communication, or task execution. (I’ve worked on this)

HUMANOID ROBOTS

5. Power System

Humanoids need significant energy to move multiple joints and run onboard computers.

Most use rechargeable lithium-ion battery packs, stored in the torso or back.

Example: ASIMO's battery was a 51.8 V lithium-ion pack lasting about 1 hour per charge.

Some larger robots use external tethers or hybrid power systems for longer operation.

Energy management is critical: walking and balancing consume a lot of power, so humanoids often plan their motions to save energy.

HUMANOID ROBOTS

6. Hands (End Effectors)
A hallmark of humanoid robots is their dexterous hands.
Matter of fact, this is usually put in a group of it’s own.
Each hand may have 5 fingers and up to 20 joints, mimicking the human hand.

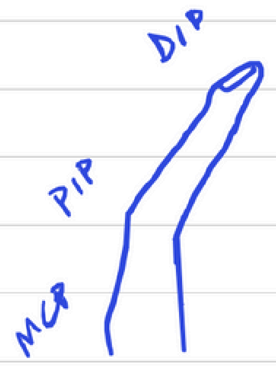
Driven by miniature motors or tendon-like cables (I’m working on this on the moment and na die I dey)

Tactile and force sensors in the fingertips provide feedback for delicate handling.
In advanced models (e.g., Shadow Dexterous Hand, DLR Hand II), hands can even sense temperature or texture.
The design aims for human-like grasp patterns – holding a pen, shaking hands, or turning a doorknob.

Sneak Peep on the maths governing Robotic Hands

(1) Kinematic coupling between PIP and DIP joints. (2)Mapping between joint angles and motor rotation. (3) Dynamic control equations for velocity and actuation. (4) Sensor feedback integration for accurate position control.

System architecture shows how multiple DC motors and servos replicate the full human hand's flexibility.



for a finger joints $q = [\theta_{MCP}, \theta_{PIP}, \theta_{DIP}]^T$

$$\Delta L = r_M \Delta\theta_{MCP} + r_P \Delta\theta_{PIP} + r_D \Delta\theta_{DIP}$$

But if DIP is coupled then
$\theta_{DPP} = k\theta_{PIP}$

$$\Delta L = r_M \Delta\theta_{MCP} + (r_P + k r_D)\Delta\theta_{PIP}$$

Motor command => $\Delta\theta_{Motor} = \Delta L / r_s$

$$\theta_{motor} = \frac{1}{r_s}\left[r_M \theta^{gloves}_{MCP} + (r_P + k r_D)\theta^{glove}_{PIP} \right]$$

System layout → 5 DC motors [finger curl] [one per digit]
11 servo [Posture / Arm]

5 DC motor: where map to PIP flexion

11 servo: 2 per finger + MCP ab/ad & MCP forward flexion

Curl DC motor

$$\Delta L^i = r^i_{PIP} \Delta\theta^i_{PIP} + r^i_{DIP} \Delta\theta^i_{DIP}$$

$$\theta^i_{DIP} = k^i \theta^i_{PIP} \Rightarrow \Delta L^i = (r^i_{PIP} + k^i r^i_{DIP}) \Delta\theta^i_{PIP}$$

$$\Delta\phi^i_{motor} = \frac{\Delta L^i}{r^i_{spool}}$$

$$\phi^i_{motor} = \frac{r^i_{PIP} + k^i r^i_{DPP}}{r^i_{spool}} \theta^i_{PIP} + \phi^i_0$$

$$u^i_{DC} = \alpha^i \phi^i_{motor} + B^i$$

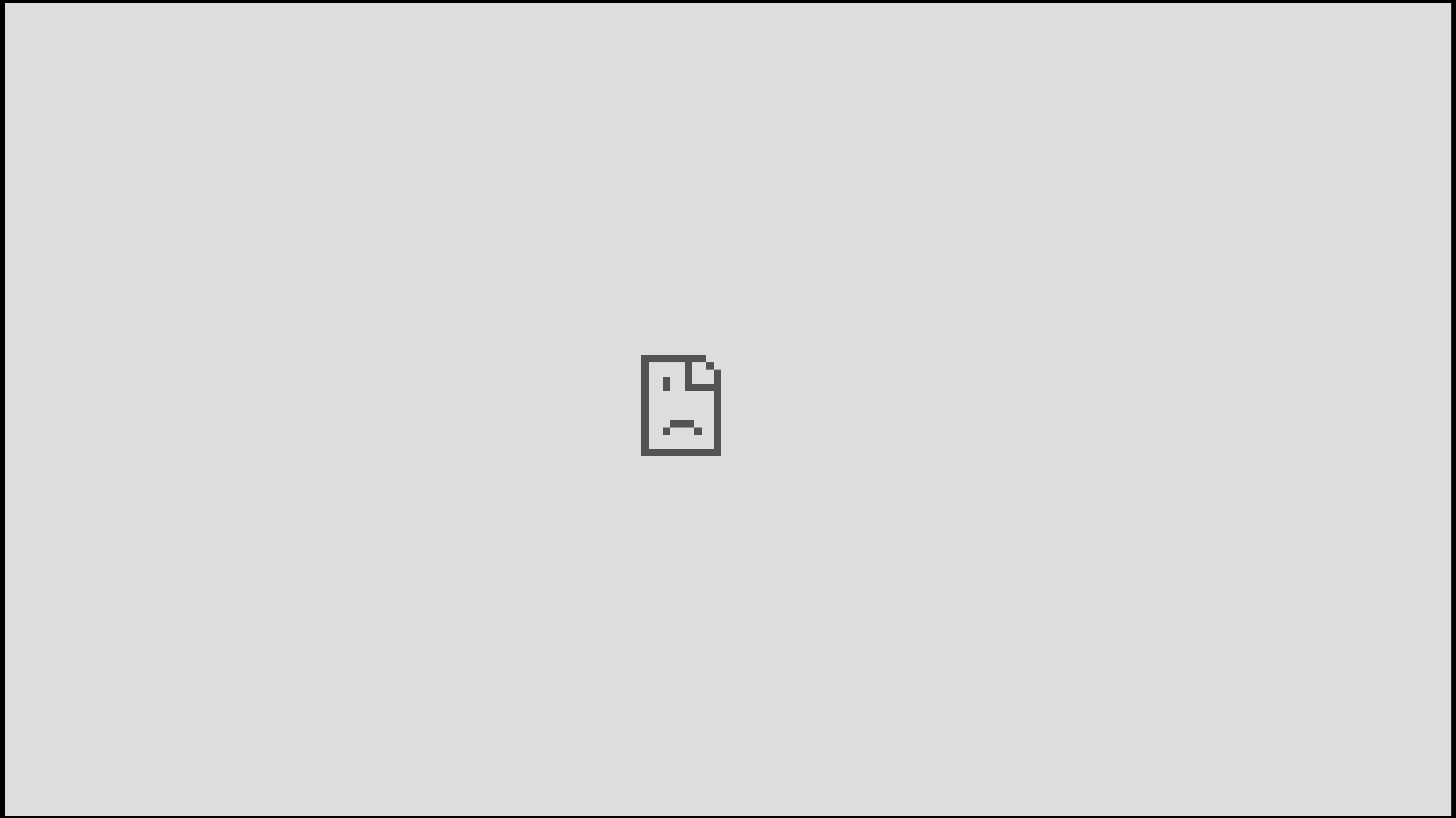
Base servos

$$\begin{bmatrix} s^i_R \\ s^i_L \end{bmatrix} = \begin{bmatrix} b^i_R \\ b^i_L \end{bmatrix} + \begin{bmatrix} g^i_{11} & g^i_{12} \\ g^i_{21} & g^i_{22} \end{bmatrix} \begin{bmatrix} \theta^i_{MCP,flex} \\ \theta^i_{MCP,abd} \end{bmatrix} \quad \{[0°, 180°]$$

final forms:

$$u^i_{DC} = \text{clip}_{[0,300]}\left(\alpha^i \left(\frac{r^i_{PIP} + k^i r^i_{DIP}}{r^i_{spool}} \theta^i_{PIP} + \phi^i_0 \right) + \beta^i \right)$$

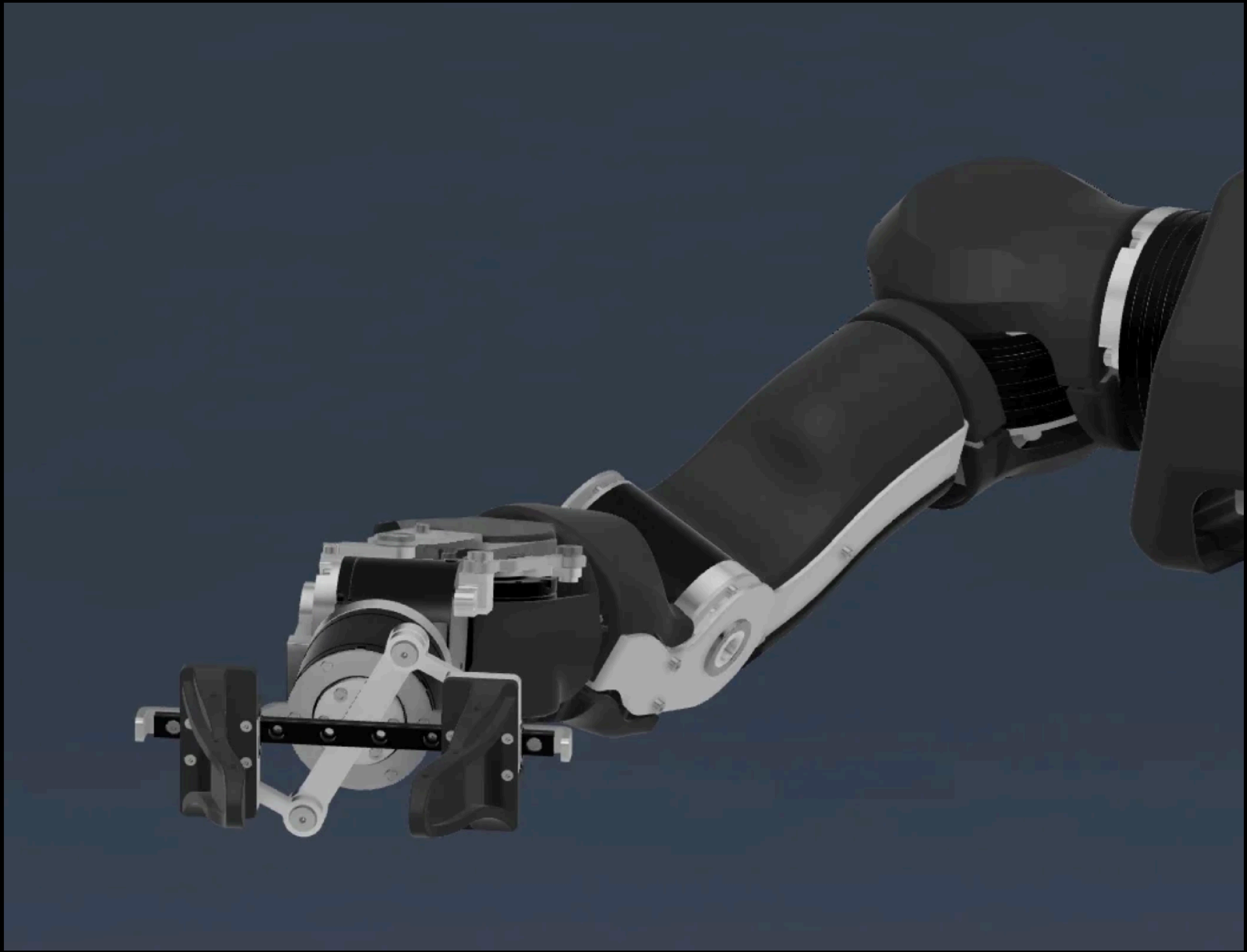
$$\begin{bmatrix} s^i_R \\ s^i_L \end{bmatrix} = \text{clip}_{[0°,180°]}\left(\begin{bmatrix} b^i_R \\ b^i_L \end{bmatrix} + M \cdot \begin{bmatrix} \theta^i_{MCP,flex} \\ \theta^i_{MCP,abd} \end{bmatrix} \right)$$



https://www.linkedin.com/posts/bakel-bakel-6341a7150_robotics-humanoidrobots-nao-activity-7328617673435594753-jQEK

ROBOTIC ARMS

- Structure: Rigid metal frame with arm segments (links) and joints, anchored to a base.
- Actuators: Servo motors at each joint (typically electric, sometimes hydraulic/pneumatic) provide movement.
- Sensors: Encoders at joints (for position feedback), current sensors, and optional force/torque sensors (for collision or load sensing).
- Power: Usually AC electrical power from mains (or compressed air/hydraulics for some systems).
- Control system: Built-in controller (robot “brain”) with digital I/O, running pre-programmed motion instructions.
- End effector: Tool at the arm’s wrist (e.g. gripper, welder, screwdriver) selected for the specific task.



7 DOF

Bimanual Arms

6.0 kg

Peak Payload per Arm

633 mm

Arm Reach

1 kHz

CAN-FD Control

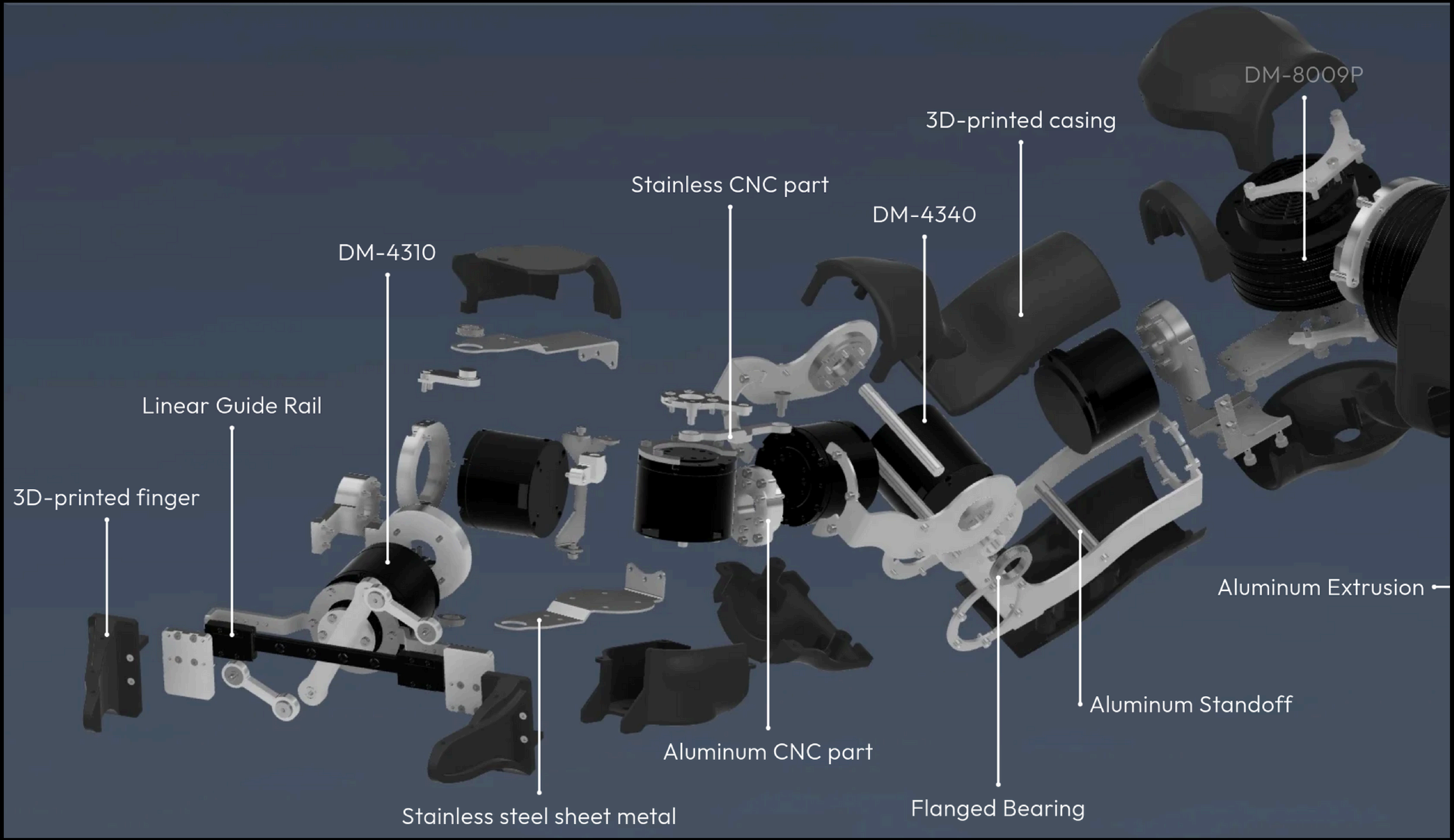
5.5 kg

Weight per Arm

$ 6,500

Bill of Materials Cost

EXPLANATIONS OF THESE PARTS IN THE FOLLOWING SLIDES



1. 3D-Printed Finger
Function: This is the end-effector.
Material & Design: Made from lightweight, durable polymer using 3D printing for custom geometry and human-like shape.

2. Linear Guide Rail
Function: Provides a smooth linear motion path.
Purpose: It ensures precise and constrained movement of the finger mechanism or actuator carriage.
Mechanism: Bearings inside the rail reduce friction, guiding mechanical components (like sliders or linkages) along a straight line.

3. Stainless Steel Sheet Metal
Function: Structural reinforcement and protection.
Material Role: Stainless steel offers high stiffness, corrosion resistance, and hygienic finish, especially for lab or medical robots.
Purpose: Used for brackets, covers, and connector plates that hold mechanical and electronic parts together.

4. Aluminum CNC Parts
Precision-machined, forms the main joints, linkages, and arm housings.
Material Benefit: Aluminum is light, strong, and thermally conductive, which helps in dissipating heat from motors.
Purpose: These parts connect actuators and bearings to the moving segments of the robotic arm.

5. Flanged Bearings
Function: Allow smooth rotational motion between moving parts.
Bearings are crucial in translating actuator torque into smooth, precise, and efficient movement.

6. Aluminum Standoff
Used to separate and support structural layers or circuit boards.
Keeps mechanical assemblies aligned and provides rigid spacing between them
Light, strong, and corrosion-resistant; ensures that vibration and heat are not transmitted directly between parts.

8. Stainless CNC Part
Precision link or connector with high wear resistance.
Used in load-bearing or high-stress zones where torque or pressure is significant.
Handles higher stress and torque loads than aluminum components, ensuring long service life.

9. 3D-Printed Casing
Protective shell that covers motors, bearings, and internal wiring.
Protects sensitive components from dust, impact, and contamination while maintaining aesthetics and safety.
Benefit: Customizable and easily replaceable; allows rapid design iterations and integration of wire channels or mounting bosses.
Material: Usually ABS, PLA, or carbon-reinforced polymer.

10. Motors (DM-4310, DM-4340, DM-8009P)

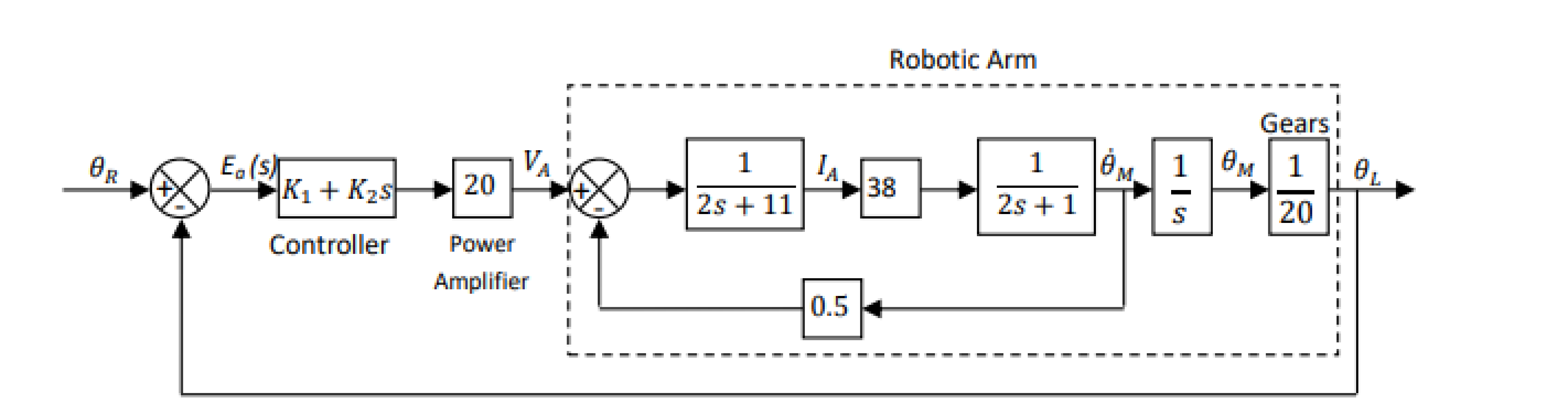
These are actuator units, DAMIAO MIT-Driven Brushless Servo Joint Motor, intelligent servo motors commonly used in high-precision robots.

DM-4310
Type: Compact smart servo motor.
Function: Drives smaller joints (like finger or wrist rotation).
Features: Includes integrated encoder, driver, and microcontroller, allowing precise angle and velocity control.

DM-4340
Type: Medium-sized servo motor.
Function: Provides more torque for intermediate joints (e.g., arm rotation or heavier grasping).
Special Feature: Offers feedback control, torque sensing, and daisy-chain communication for multi-joint synchronization.

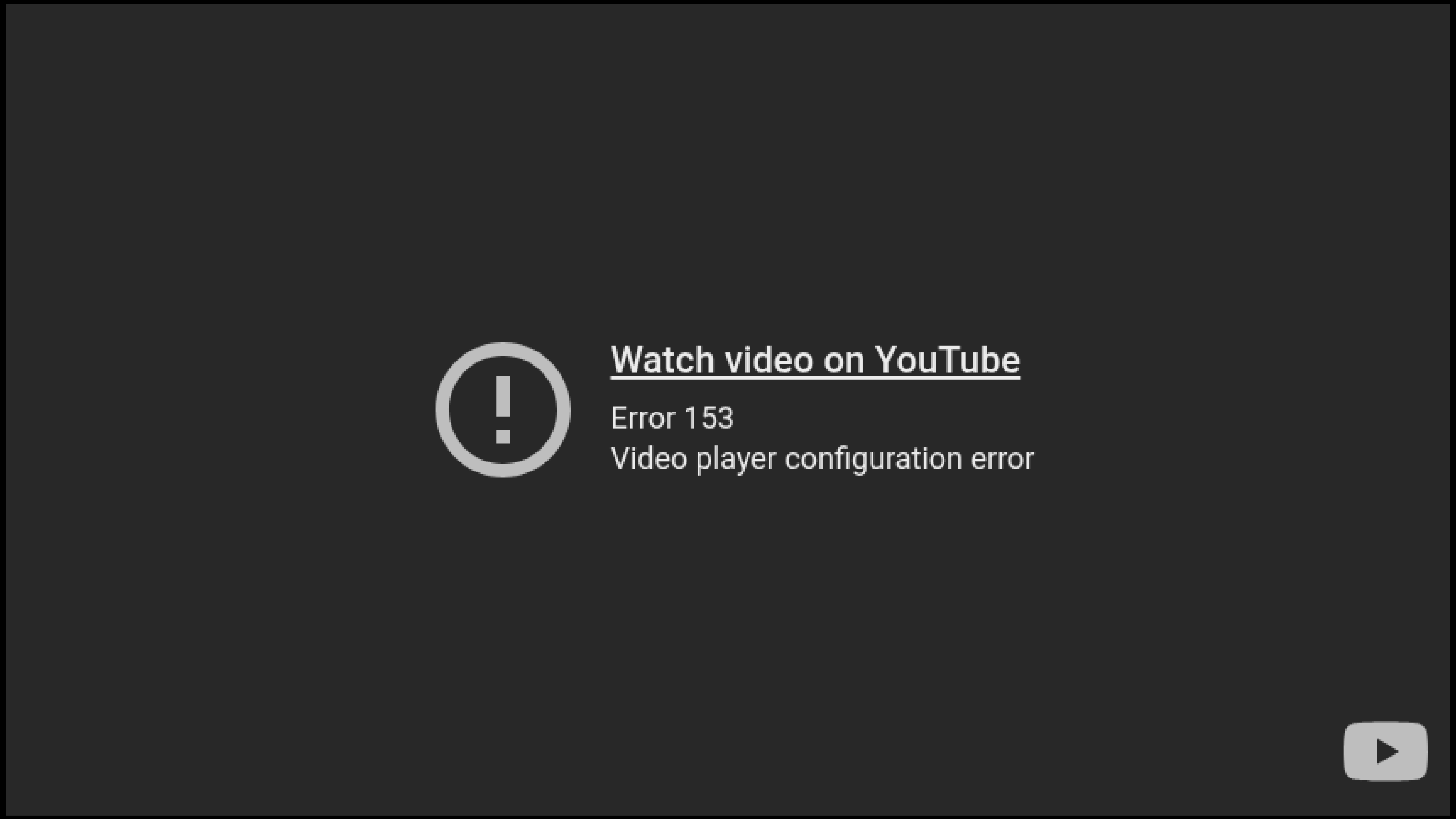
DM-8009P
Type: High-torque actuator or “base joint motor.”
Function: Powers the largest or heaviest joint (like shoulder or base rotation).
Design: Integrated cooling and high-ratio gearbox for sustained operation under load.

WHAT EXACTLY IS THIS CONTROL SYSTEM WE HAVE BEEN SAYING SINCE??



Surface Robots (Autonomous Surface Vessels)

- Hull: Buoyant boat-like body that floats and carries all equipment.
- Propulsion: Electric motor driving propellers for thrust; some use sails or wave-energy
- Power: Onboard batteries (recharged by solar panels on deck).
- Sensors: GPS/compass/IMU for navigation, radar or sonar and cameras
- Control system: Onboard autopilot computer follows waypoints and stabilizes the boat; communicates via radio/satellite to operators.
- Payload: Scientific instruments or sensors (e.g. water samplers, weather sensors) mounted onboard.



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UNDERWATER ROBOTS (AUVS/ROVS)

- Hull: Waterproof, pressure-resistant body (often cylindrical or box-shaped) with buoyancy material for neutral float.
- Thrusters: Multiple electric thrusters (propellers) for 3D movement (forward/back, up/down, rotation)
- Sensors: Sonar (imaging and navigation), depth/pressure sensor, IMU/compass for orientation, and cameras with lights for vision.
- Control: AUVs have onboard navigation computers; ROVs are tethered to a ship for power and remote control.
- Power: AUVs carry batteries (e.g. Li-ion). ROVs often get power through the tether cable.
- Manipulator: ROVs often include a hydraulic manipulator arm for tasks; AUVs usually do surveys without arms.
- Tether (ROV only): Cable from surface supplies power and carries data/video.

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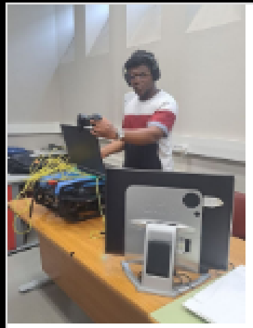

#controlsystems #underwaterrobotics #autonomy #computervision...

I fell in love with control today. Not for the first time. I've always loved control systems. But today felt like falling in love all over again. T...

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Soft and Flexible Robots

- Materials: Made from soft, elastic materials (silicones, rubbers, fabrics) rather than rigid parts.
- Actuators: Soft pneumatic actuators (so-called “PneuNets”) – internal air/fluid channels that inflate to bend the robot.
- Sensors: Flexible stretch or pressure sensors embedded in the robot’s body to sense bending or force.
- Control: Simple valves and pumps regulate internal pressure; the material’s compliance provides smooth, safe motion.
- Power: External air/fluid pumps (sometimes small onboard pumps and batteries) supply the actuation; no rigid drive-trains.
- Examples: Soft grippers or octopus-like tentacle robots that wrap gently around objects.

Snake Robots

Modular Segments: Snake robots consist of a series of linked modules forming a long, flexible body. Each segment is usually identical in structure, containing joints that allow it to bend. The segments are connected serially with 1-2 degrees of freedom at each joint (pitch and/or yaw), enabling the robot to coil and slither in a snake-like manner.

Actuators: Small servo motors or DC motors in each segment drive the joint angles. A large number of actuators (one or two per segment) give the snake robot many degrees of freedom overall, allowing it to execute complex locomotion patterns. The actuators are typically arranged to provide either lateral or dorsal bending (or both) at each joint. Wires or flex-PCBs run through the length of the robot to deliver power and control signals along the chain.

Locomotion & Gait: By coordinating the motion of each segment's joints, snake robots achieve locomotion modes like lateral undulation (slithering), concertina motion (inch-worming), sidewinding, and even climbing (e.g., wrapping around poles or inside pipes). The flexibility and redundancy of many segments let these robots thread through confined spaces and adapt their shape to the environment.

Sensors: Each module may include joint angle sensors (encoders) so the controller knows the shape of the robot at all times. An IMU in the head or distributed along the body can help estimate orientation. Some snake robots also incorporate force sensors or touch sensors on their exterior to detect contact with surfaces. A head-mounted camera or infrared sensor is sometimes used on the leading segment to navigate or inspect environments (especially for search-and-rescue tasks).

Control System: Snake robots often use decentralized or distributed control; each module might have a microcontroller to handle local motor control, while a central controller or lead module coordinates the overall gait. Algorithms for snake robots can involve central pattern generators (bio-inspired rhythmic signals) or predefined gait sequences that synchronize the many joints. The control emphasizes coordinated wave-like motions that propagate down the body, resulting in smooth propulsion or turning.

MICRO AND NANO ROBOTS

Scale: Extremely small.

Actuators: Often powered by external fields (magnetic, acoustic/ultrasound, optical) or chemical reactions (fuel-based micro-engines)

Sensors: Chemical or biological sensors (e.g. for pH or biomarkers) built into the structure; many rely on external imaging (microscopes) to know where they are.

- Control: Mostly through external stimuli or pre-programmed chemical signals

- Micro-robots may also be steered by controlling fields.

- Power: No onboard batteries – they harvest energy from their environment (chemical fuel, light, fields) or are driven directly by external fields.
- Examples: DNA origami nanorobots (folded DNA structures that open in response to a molecule), micro-swimmers propelled by catalytic reactions.

THANK YOU FOR LISTENING