Engineering Book – Robot Design

GENIUS Robotics — Genie Firefighter (2026)

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GitHub: https://github.com/Kushal-Sachdeva78/K.A.D-Ballers-Genius-Olympiad-Robot

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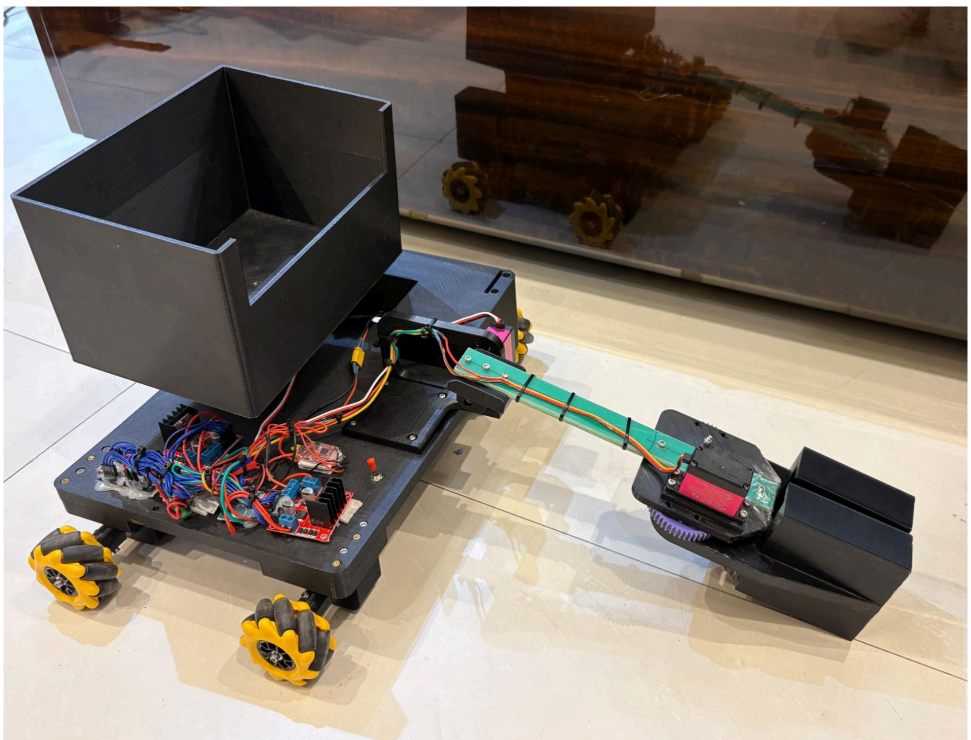

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1. Executive Summary

Our Genie Firefighter robot is a **tele-operated 4-mecanum drive** platform designed to:

1. **Clear debris** (tennis balls) from the safe zone and deposit into the **elevated debris bin**
2. **Collect water gel cubes** from the shared warehouse and place them into the **fire zone**

The robot uses:

- **4× 12V 50 RPM DC motors** for mecanum drive
- **3× metal gear 35 kg servos** for arm lift, gripper open/close, and basket flip
- **Arduino Nano** as the main controller
- **HC-05 Bluetooth module** + phone app for wireless tele-op
- **2× L298N motor drivers** to control the DC motors
- **12V battery** + **buck converter** to power logic + servos

Manufacturing note: The **entire robot chassis and mechanisms are 3D-printed in PETG** (with metal fasteners/electronics installed).

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2. Mission Breakdown & Constraints

2.1 Tasks

Task 1 (Debris):

- Collect **10 tennis balls** from the safe zone
- Deposit them into the **debris bin** outside the field perimeter
- Safe zone must be cleared before Task 2 begins

Task 2 (Fire):

- Collect gel cubes (2.2”) from the shared warehouse
- Place/throw them into the **fire zone**
- Carry limit: **max 5 cubes at a time**
- Must not enter smoked damaged area; avoid touching buckets/houses

2.2 Constraints That Shaped Our Design

- Start size ≤ **20” × 20” × 20”**
- **Tele-op only**, wireless communication only
- Onboard power only; **≤ 12V** per power item
- Up to 8 DC motors allowed (we use 4)
- Accurate navigation near tape boundaries is essential (penalty avoidance)

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3. Design Choices (Why this design)

3.1 Why Mecanum Drive

- Items are randomly placed → alignment speed matters
- Mecanum allows **strafe + diagonal** movement without turning
- Helps the driver make micro-adjustments near taped borders and around obstacles

3.2 Why Arm + Gripper + Basket Dump

- Tennis balls and gel cubes are different textures and shapes; a controlled grab is more reliable than pushing
- Arm + gripper gives repeatable pickup, basket provides storage, dump makes unloading faster

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4. System Layout (Architecture)

4.1 Control Flow

Driver Phone (Bluetooth Serial App)
→ sends single character commands
→ **HC-05 Bluetooth**
→ **Arduino Nano**
→ outputs to:

- **Motor Drivers (2× L298N)** → 4 DC motors → mecanum wheels
- **Servos** → arm servo / gripper servo / basket servo

4.2 Power Distribution

- **12V battery → L298N boards → DC motors**
- **12V battery → buck converter → regulated 5V rail → Arduino + HC-05 + servos**
- **Common ground shared across all modules** for stability

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5. Mechanical Design (Detailed)

5.1 Chassis & Packaging (PETG 3D Print)

Material: PETG (full robot printed)
Why PETG:

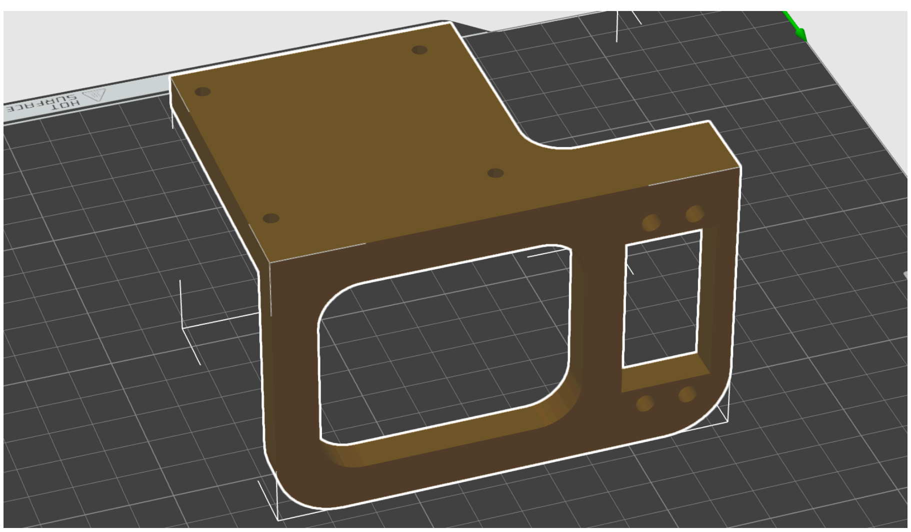
- Stronger and less brittle than PLA
- Better temperature resistance than PLA (helpful for motors/servo heat zones)
- Good layer adhesion for load-bearing parts

Chassis goals:

- Fit within starting size limits
- Keep center of gravity low (battery low, central)
- Protect electronics and wiring
- Provide rigid mounts for motors and servos (reduce flex)

Design features we included (recommended to mention during judging):

- Reinforced motor mounts (thicker walls + ribbing)
- Cable channels / tie points to prevent snagging
- Standoffs for electronics and buck converter
- Mount points that can be reprinted quickly if broken



5.2 Drivetrain (4-Mecanum)

Components:

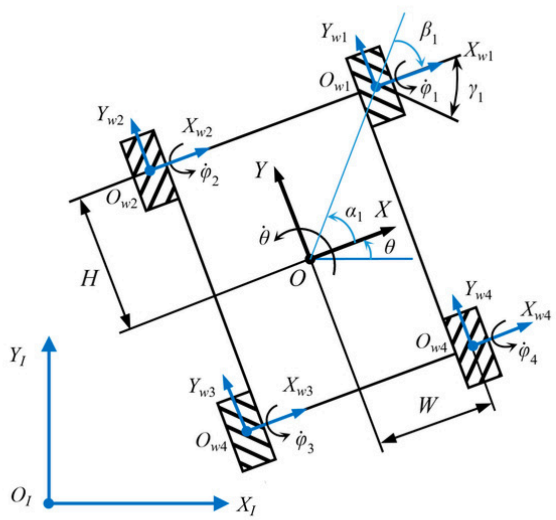
- 4 mecanum wheels
- 4× 12V 50 RPM DC motors
- 2× L298N drivers

Why it works for this game:

- Strafing reduces time spent turning
- Diagonals speed up alignment to scattered objects
- Rotation in place helps quick reorientation without overshooting taped boundaries

Build notes (PETG-specific):

- Wheel mounts printed with extra wall thickness
- Use washers/spacers to reduce wobble
- Ensure correct roller orientation (front-left/front-right must be mirrored)



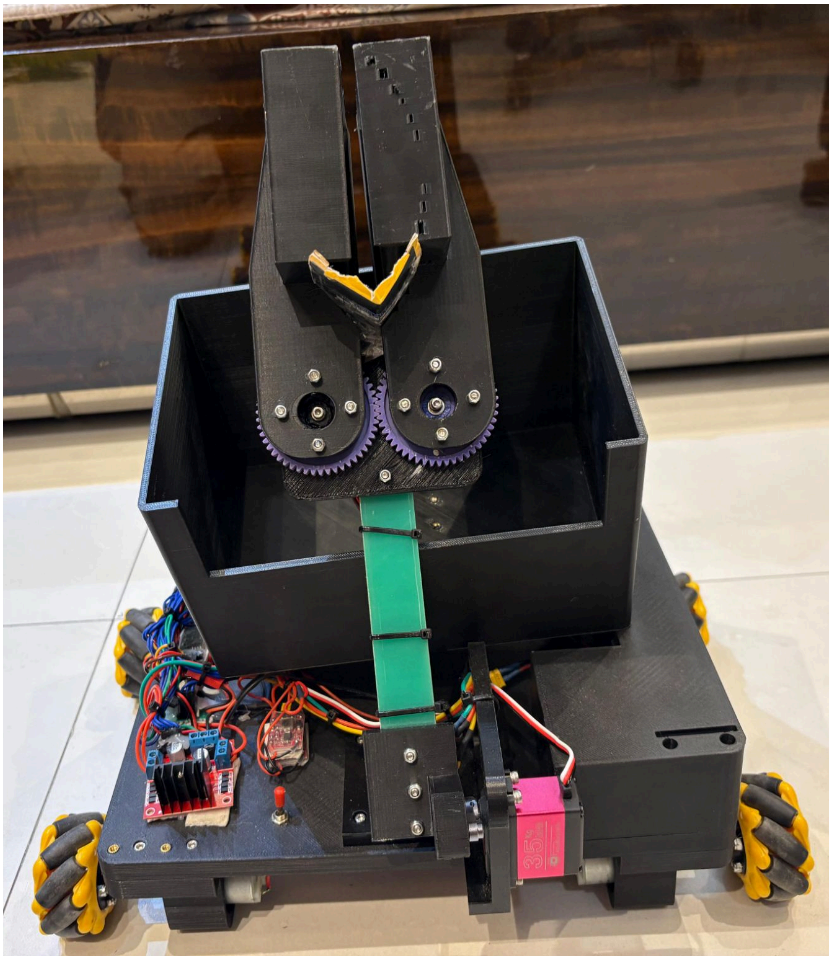
5.3 Arm Mechanism (Servo Lift)

Function: reach floor → lift to basket height
Servo: 35 kg metal gear servo
Design requirements:

- Reach ground without pushing objects away
- Lift high enough to drop into basket
- Minimize flex (PETG parts reinforced)

Mechanical notes:

- Arm pivot printed thick + supported with ribs
- Servo horn mounting holes reinforced
- Endpoints tuned to avoid servo stalling at hard stops



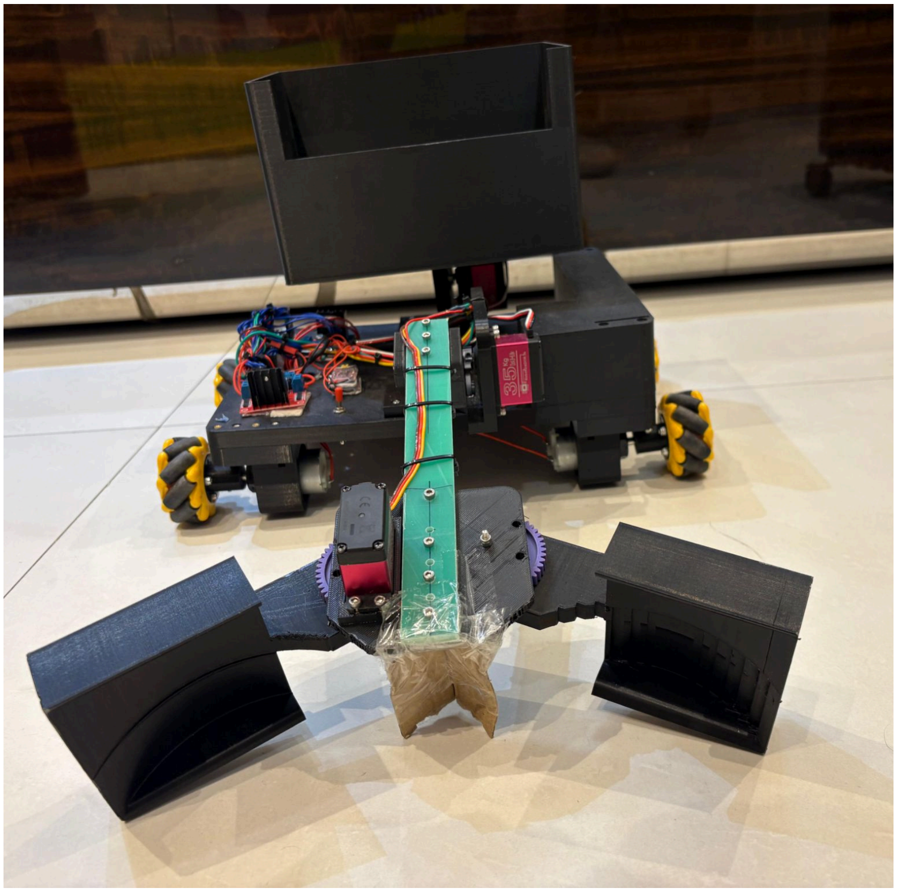
5.4 Gripper (Servo Open/Close)

Function: capture balls/cubes reliably
Servo: 35 kg metal gear servo
Design features:

- Jaw profile shaped to “cup” a tennis ball
- Closing angle tuned so gel cubes are held, not crushed
- Printed jaws reinforced at stress points (fillets/ribs)

Testing outcomes:

- Best grip happens when object is centered before closing
- Slow approach + stop command improves pickup reliability



5.5 Basket / Holder + Flip Dump

Purpose:

- Store collected items (reduce trips)
- Dump quickly into debris bin / release cubes into fire zone

Mechanism:

- Basket mount hinged
- Servo moves between:
    - **LOAD position:** holds items during driving
    - **UNLOAD position:** flips to release

Key design constraint:

- Debris bin is elevated, so dumping angle and approach matter (future lift planned below)

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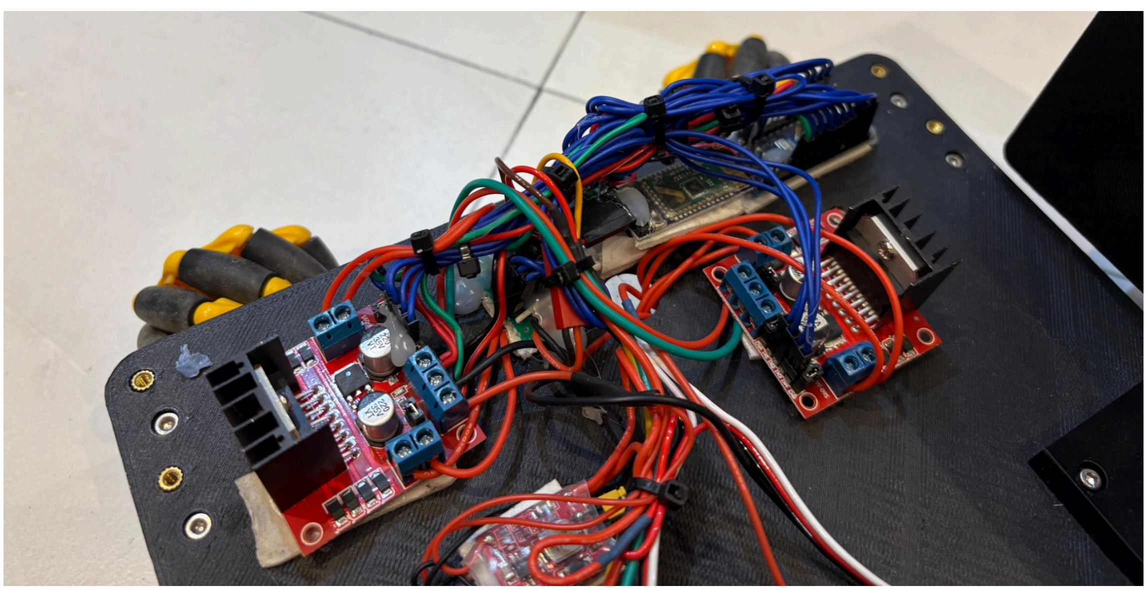
6. Electronics Design

6.1 Parts Used

- Arduino Nano (main controller)
- HC-05 Bluetooth module
- 2× L298N motor driver boards
- 4× DC motors (12V, 50 RPM)
- 3× 35 kg metal gear servos
- 12V battery
- Buck converter (12V → 5V)
- Wiring, connectors, switch (recommended)

6.2 Electronics Layout Notes

- Keep buck converter close to Arduino/servo power distribution
- Route motor wires away from Bluetooth wires where possible
- Secure all connectors to withstand vibrations and arm motion



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7. Coding Scheme

7.1 Control Method

A phone app sends single-character commands over Bluetooth to HC-05. Arduino Nano reads the character and triggers:

- mecanum movement patterns (forward/back/strafe/diagonal/rotate)
- servo position actions (arm, gripper, basket)

7.2 Driver Command Map (Summary)

Movement: F B L R S G H I J X Y
Servos: U/D arm, O/C gripper, M/N basket load/unload

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8. Testing & Experiments (Development Evidence)

8.1 Drive Testing

- Straight driving (check drift)
- Strafing along tape line (precision)
- Rotation in place (control near boundaries)

Result: mecanum improved alignment speed significantly compared to turning-based drive.

8.2 Pickup Testing

- Tested tennis balls and cubes at different angles
- Tuned arm down position to prevent pushing objects away
- Tuned gripper close angle for secure hold without crushing cubes

8.3 Basket Testing

- Verified load position prevents spills while moving
- Verified unload position releases consistently into a target container

8.4 Power & Bluetooth Stability

- Tested simultaneous driving + servo movement for resets

- Verified stable control when phone is kept within close range
- Buck converter + common ground improved stability

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9. Build Log (Recommended for Judges)

- Stage 1: CAD + first PETG chassis print (date, issues, fixes)
- Stage 2: drivetrain assembly and wheel orientation verification
- Stage 3: arm/gripper print iterations (strength improvements)
- Stage 4: electronics mounting + wiring organization
- Stage 5: integrated testing + driver training

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10. Match Strategy

Task 1: strafe/diagonal align → arm down → grip → arm up → store → repeat → dump
Task 2: warehouse entry → collect cubes (≤5) → return → place/throw into fire zone (avoid smoked zone)

Penalty prevention:

- slow down near buckets/tape
- stop before gripping
- avoid risky turns—use strafing instead

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11. Future Implementations (Planned Upgrades)

11.1 Scissor Lift for Basket (Raise to Bin Height)

Problem: debris bin is elevated; dumping from low height can be inconsistent.
Upgrade: add a **scissor lift under the basket** to raise it before unloading.

- Actuation options: lead screw + motor, linear actuator, or gear-driven lift
- Adds controlled vertical reach for consistent bin dumping

Expected benefit: faster scoring + fewer missed deposits.

11.2 Rubber-Band Rotating Intake (Fast Automatic Intake)

Problem: arm+gripper is reliable but slower for many items.
Upgrade: add a front **rubber-band roller intake**:

- two inward-spinning rollers pull balls/cubes automatically
- guides items into basket with less driver precision needed

Expected benefit: faster debris clear + faster cube collection + reduced driver workload.

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12. Bill of Materials (BOM)

Mechanical (3D Printed PETG)

- PETG filament (chassis, mounts, arm, gripper, basket, brackets)
- 4× mecanum wheels
- Fasteners: screws/nuts/washers (assorted)
- Hinges/pins for arm and basket pivots (printed or metal)

Electrical

- Arduino Nano
- HC-05 Bluetooth module
- 2× L298N motor drivers

- 4× 12V 50 RPM DC motors
- 3× 35 kg metal gear servos
- 12V battery pack
- Buck converter (12V → 5V)
- Wiring/connectors/switch/zip ties

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13. GitHub Repository (Code + 3D Models + Photos)

All design files, code, and documentation are stored in our GitHub repository.

GitHub Repo Link:
https://github.com/Kushal-Sachdeva78/K.A.D-Ballers-Genius-Olympiad-Robot