WORLD ROBOT OLYMPIAD™

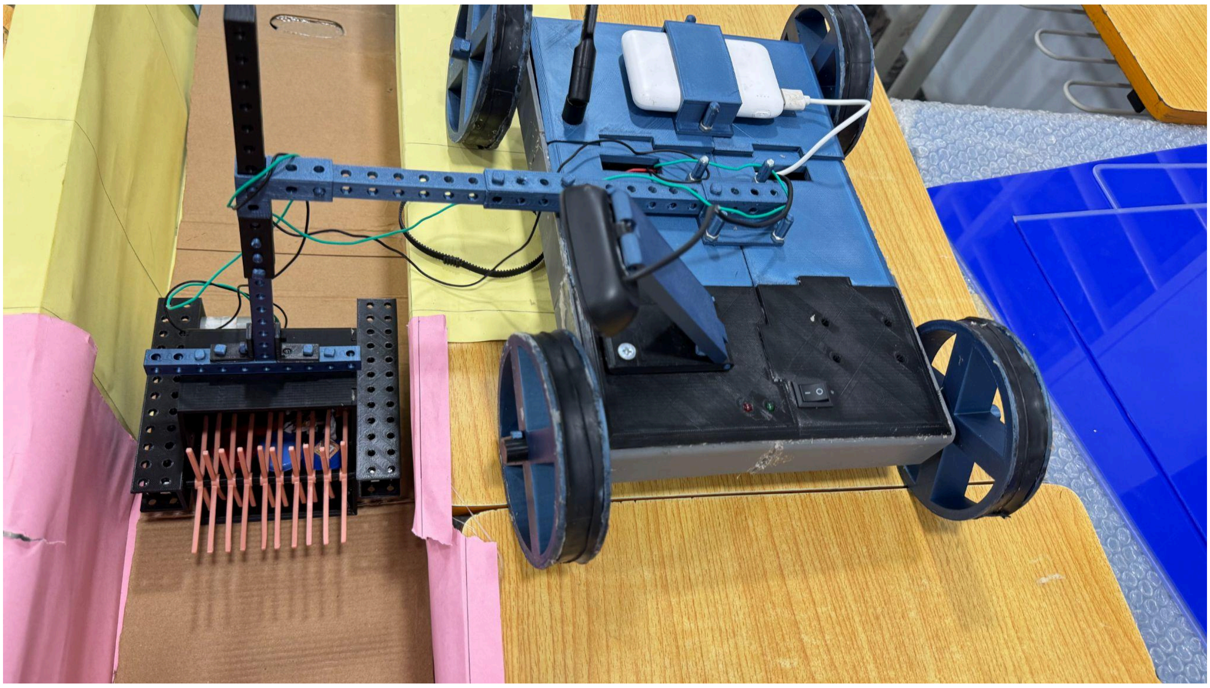
FUTURE INNOVATORS

SENIOR

TEAM NAME

TEAM CLEANSWEEP

GHANA



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PRESENTATION OF TEAM

Our team is made up of six dedicated students from Presbyterian Boys' Secondary School, Ghana, each bringing unique skills and talents to the table:

- **Aforo Emmanuel Amoh**
  Emmanuel, 18, is a final-year student and an executive member of the PRESEC Robotics and Programming Club. He led the development and engineering of the robot's software, playing a critical role in programming and systems integration.
- **Anum Ryan Nii-Akwei**
  Ryan, 17, is a final-year student and serves as an executive member of the PRESEC Robotics and Programming Club. He was responsible for the robot's hardware design, overseeing its construction and mechanical assembly.
- **Asare Kofi Brako Junior**
  Kofi, 18, is a final-year student and a member of the PRESEC Robotics and Programming Club. He was the team's lead in design and modeling, crafting the structure and appearance of the robotic system.
- **Oblitey Josiah Nii Oblitey**
  Josiah, 16, is a first-year student and a member of the PRESEC Robotics and Programming Club. He contributed to various aspects of the team's efforts, including support tasks during the robot's development and testing phases.
- **Okuntade Emmanuel George**
  Emmanuel, 16, is a first-year student and a member of the PRESEC Robotics and Programming Club. He played a key role in testing the robot and provided consistent support to ensure its performance remained engaging and reliable.
- **Quarcoo Stesha Tettey Buadjorm**
  Stesha, 16, is a final-year student and an executive member of the PRESEC Robotics and Programming Club. With a strong sense of creativity, he served as the lead graphic designer, making significant contributions to the visual presentation of the booth and the robot's aesthetics.

SUMMARY PROJECT IDEA

The issue of solid waste blocking Accra's gutters has been an open secret for as long as anyone can remember. The persistent issue continues to cause perennial problems such as flooding, property damage, and grave health consequences through the breeding of disease vectors and propagation of waterborne diseases. Fixing this issue, therefore, is not a case of solving a single issue; it is a case of solving a multitude of connected problems that plague the country regularly.

We picked this problem as it impacts many lives each day in Ghana's capital and other expanding cities in Africa. Even though people know about the issue, it remains unsolved. This happens because human labour and waste systems are both ineffective.

To deal with this, we built Cleanover - a semi-autonomous robotic system - it cleans solid waste from gutters on streets. By concentrating on only solid waste, we offer a practical, focused answer.

Cleanover moves along the edges of street drains using visual data from an onboard camera for navigation. A robotic arm equipped with a rotating intake mechanism collects solid waste and deposits it into an onboard bin. When full, the onboard bin can then be emptied. This design allows Cleanover to clean long sections of drainage infrastructure in a single pass with minimal human intervention.

When deployed, **Cleanover** will assist in the reduction of flooding, improve sanitation, and lower the spread of disease in urban areas. It will also ease the burden on municipal sanitation workers and provide a scalable, green technology for cities struggling with similar issues worldwide.

Our project is important because it targets a real, everyday problem with a practical and scalable solution. By automating a critical part of urban sanitation, Cleanover will help create cleaner, healthier, and more resilient cities, starting with Accra.

PRESENTATION OF ROBOTIC SOLUTION

The idea for Cleanover was born out of a real-world problem we observed right in our immediate environment, Presbyterian Boys' Secondary School, Legon. Like many areas in Accra, our school community struggles with improper waste disposal, especially in the open street-side gutters along key paths. Over time, litter like plastic bottles and food wrappers builds up, blocking the flow of water.

In one notable incident, heavy rainfall caused such a blockage that the gutters overflowed, flooding our walkways. This made it clear to us that clogged drains aren't just a national problem; they directly waste resources, disrupt school life, and create serious health and safety risks in our own community.

We asked ourselves: *How can we solve this problem in a way that protects people, saves time and resources, and prepares our cities for the future*?

That question led to **Cleanover**, a **semi-autonomous robot** designed to clear solid waste from gutters. It reduces the need for manual labour, eliminates water waste compared to high-pressure cleaning methods, and operates efficiently with minimal supervision. By using vision-based navigation and an onboard collection system, Cleanover helps cities manage sanitation more intelligently.

While we started with our school, the issue and the solution apply across Accra and many urban areas facing the same challenge. Cleanover supports the vision of **future cities** where robots don't just replace human effort, they help us **use our limited resources more wisely**, protect public health, and build more resilient communities.

We began by researching various methods for collecting garbage in drains. Some of these ways were:

1. Use of robot grabber arms. This idea was scrapped due to slow operation, limited maneuverability, and visibility issues.
2. Hydro-jetting. This is the use of high-pressure water streams to blast away debris in drains. We decided not to use this because it uses a considerable amount of water, which is a concern in areas with scarce water supply, and it technically does not fully eradicate solid waste.
3. Drone-assisted system. This involves the use of drones to identify blocked and choked drains to deploy cleaning crews, but this was too complex and involved a high cost to implement.

Finally, we settled on using a surgical intake system which is cost-effective, easy to implement and removes rubbish efficiently.

For the Cleanover prototype, the chassis was designed and 3D printed in multiple parts that could be assembled to form the full body of the robot. This approach allowed for easier assembly and testing. The primary cleaning mechanism consists of an L-shaped surgical intake system, which extends laterally from the body of the robot. Its purpose is to collect solid waste from the gutter and deposit it into an integrated waste bin located within the cleaning system.

Internally, the main chassis houses several key electronic components. A Raspberry Pi 4B functions as the brain of Cleanover and is also responsible for high-level control. An Arduino Nano is used to manage lower-level hardware control tasks, such as operating the sensors and motors. The JGA25-370 motors are controlled by two L298N motor driver boards which are powered by a set of batteries that power both the Nano and the motors, along with a dedicated power bank that supplies electricity to the Raspberry Pi.

Externally, Cleanover is equipped with peripherals to enhance its functionality. A webcam is mounted 60 degrees to provide vision capabilities for edge detection. A GPS module with an antenna has also been integrated to provide real-time localization. To provide clear visual feedback on the robot's status, Cleanover is also fitted with LED status indicators. The red LED signals GPS and system errors: it blinks while the GPS is searching for satellites and remains solid if an error occurs, such as an invalid command or system fault. The green LED reflects movement status: it stays solid when the robot is idle and ready (with GPS lock, if available), and blinks during movement, including forward, backward, or turning. When both the red and green LEDs are used together, they flash three times at startup to indicate successful system initialization. If both LEDs blink simultaneously during operation, it signifies that the robot is reversing, acting as a visual warning.

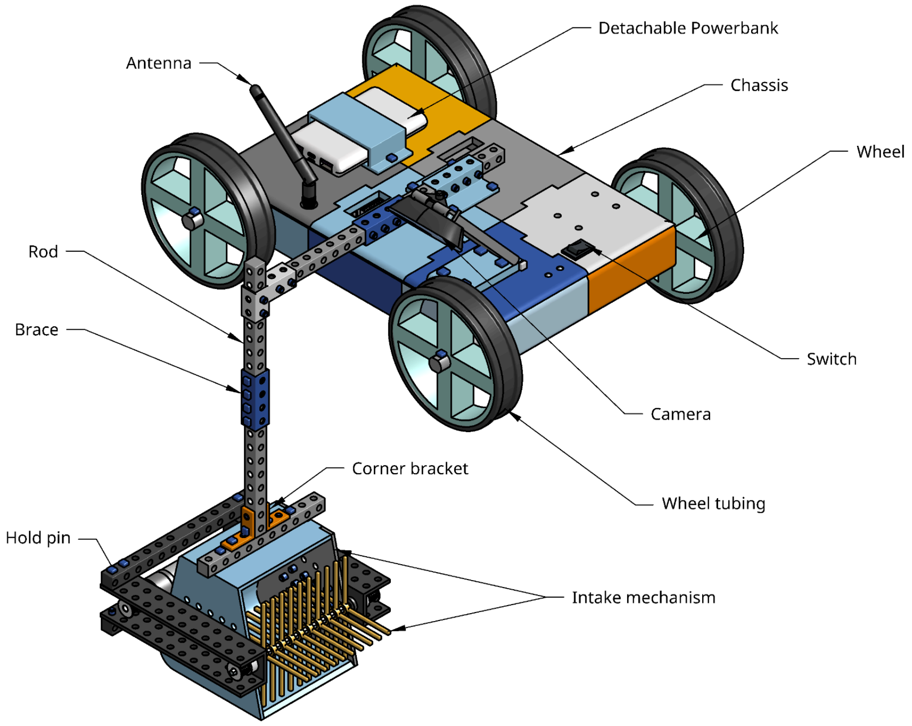

Figure 1: 3D model representation of the Cleanover robot.

Numerous custom parts were also 3D printed, including the wheels of Cleanover designed specifically to effectively operate across a variety of surface types; the intake system; the webcam holder; motor mounts; a protective case for the Raspberry Pi; the cleaning brace and several smaller items such as screw covers and pin lockers. The use of 3D printed parts allowed for fast prototyping and design flexibility.

The software aspect of this robotic system consists of two integrated components: a Python-based edge-following program and a Flask-powered web dashboard for remote control and monitoring.

The main program which is the autonomous operation of the robot, uses OpenCV, a computer vision library, along with Pyserial. It processes the real-time video feed from the camera attached to the robot to detect the edge of the gutter using a multi-stage vision pipeline.

First, the video frames from the real-time feed are converted to grayscale and smoothed using a Gaussian blur to reduce noise. A region of interest (ROI) mask is also applied to focus on the lower portion of the feed, which is normally where the edge of the gutter is located, optimizing the efficiency of processing.

Next, edge detection is performed using the Canny Edge Detection algorithm which works by detecting sharp brightness changes, filters out noise, and carefully picking the most important edge lines, followed by the Hough Line Transform algorithm which detects straight lines by turning points on edges into possible lines and identifying where many of them line up.

After detection, all the edges identified are filtered to isolate the most reliable line of all detected. These lines are extended across the frame for accurate distance calculations, ensuring the robot can assess its range to the edge effectively.

Cleanover's autonomous movement logic is driven by visual inputs and operates through three states: **EDGE_DETECTION**, **FOLLOWING_EDGE**, and **ADJUSTING**. While in the FOLLOWING_EDGE state, the robot moves forward at a fixed speed, continuously monitoring its distance from the edge.

If it gets too close determined by a configurable safe-distance threshold, it switches to the ADJUSTING state. In this state, the robot shifts either left or right to reposition itself, depending on where the edge is detected relative to its current location. Once a safe distance is re-established, it returns to forward motion.

Directional commands are sent to the Arduino via a rate-limited serial connection to avoid overwhelming the microcontroller. Visual feedback is provided on a web dashboard, displaying both the detected edge and real-time distance measurements.

```python
def start_robot(self, run_time_minutes=5):
    """Start the robot operation"""
    if not self.connect_arduino():
        logging.error("Cannot start robot without Arduino connection")
        return False

    self.running = True
    self.state = RobotState.EDGE_DETECTION
    start_time = time.time()
    end_time = start_time + (run_time_minutes * 60) # Convert minutes to seconds

    cap = cv2.VideoCapture(0)
    if not cap.isOpened():
        logging.error("Error: Could not open camera")
        return False

    logging.info(f"Robot started! Detecting edge for {self.detection_time} seconds...")
    logging.info("Press 'q' to quit, 's' to save frame, 'SPACE' to emergency stop")

    try:
        while self.running and time.time() < end_time:
            ret, frame = cap.read()
            if not ret:
                print("Error: Could not read frame")
                break

            edge_line, edges = self.process_frame(frame)

            distance = None
            if edge_line:
                distance = self.calculate_distance_to_edge(edge_line, frame.shape[1], frame.shape[0])

            # Add runtime display
            elapsed = time.time() - start_time
            remaining = max(0, end_time - time.time())
            runtime_text = f"Runtime: {int(elapsed)}s (Remaining: {int(remaining)}s)"

            self.update_robot_state(edge_line, frame.shape[1], frame.shape[0])

            result = self.draw_visualization(frame, edge_line, distance)
            cv2.putText(result, runtime_text, (10, 90), cv2.FONT_HERSHEY_SIMPLEX, 0.7, (255, 255, 255), 2)


            cv2.imshow('Robot View', result)
            cv2.imshow('Edge Detection', edges)

            key = cv2.waitKey(1) & 0xFF
            if key == ord('q'):
                break
            elif key == ord('s'):
                cv2.imwrite('robot_view.jpg', result)
                print("Frame saved!")
            elif key == ord(' '):
                self.send_command("stop", 0)
                self.state = RobotState.STOPPED
                logging.warning("EMERGENCY STOP!")
                break

    except KeyboardInterrupt:
        logging.info("Interrupted by user")

    finally:
        self.send_command("stop", 0)
        logging.info(f"Session completed after {run_time_minutes} minutes")
        cap.release()
        cv2.destroyAllWindows()
        if self.arduino:
            self.arduino.close()
        logging.info("Robot stopped and cleaned up")

    return True
```

Figure 2: Code snippet illustrating robot initialization during edge-following.

To enhance functionality, a Flask-based web dashboard was developed, providing a user-friendly interface with two control modes: **Autonomous Navigation** and **Manual Override**. The Autonomous Navigation mode initiates the edge detection program and includes an interface for monitoring the live feed of the edge processing, while the Manual Override mode features a toggleable joystick and D-pad control for more direct movement.

A local map which is saved on the server and sourced from Google Maps is also used by Cleanover for real-time GPS tracking via a Neo-7M module. It relays the robot's live location to the local map using **WebSockets** for low-latency updates. The dashboard also includes calibration utilities such as motor speed tests, camera feed diagnostics and an emergency stop button for immediate system halting.

Throughout development, we encountered several technical and design challenges. One of the first major issues involved our motor drivers. We discovered that each of our L298N driver boards had one faulty output channel, which restricted motor movement to only one direction. After diagnosing the problem, we rewired the system so that each motor was assigned to a working channel on a separate board, an approach that required careful rerouting and testing to maintain control consistency.

Also, when transmitting rapid commands specifically with the manual joystick control the Arduino occasionally missed instructions due to serial buffer overflows. This sometimes caused unresponsive behaviour with the robot. We then had to introduce rate limiting where we enforced a minimum delay between serial transmissions.

Concurrency issues were also identified, where running the Flask server and OpenCV's video processing in parallel caused crashes and lags occasionally. To resolve these issues, we implemented thread isolation which involved separating video processing from the Flask server to reduce overload.

Another significant challenge was designing an effective intake mechanism. Our initial ideas lacked the precision and reliability needed to collect waste efficiently from the gutter. After several prototypes, we improvised using lightweight, modular materials and incorporated angled scoops and flexible components to improve debris capture while minimizing drag and resistance.

In spite of these obstacles, developing Cleanover has shown us the value of designing with our community in mind. What began as a response to an everyday issue in our school has grown into a scalable idea with the potential to improve sanitation across Accra and other cities. By focusing the robot on solid waste only, we've created a solution that is realistic, implementable, and impactful, one that addresses a real need without overcomplicating the technology.

SOCIAL IMPACT & INNOVATION

Cleanover is not just a robotic project; it is a response to a widespread social and environmental issue that affects urban communities across Ghana and beyond. By addressing the problem of solid waste accumulation in street gutters, Cleanover aims to improve public health, reduce the frequency of flooding, and promote responsible sanitation practices. The potential social impact of this solution is substantial, especially in areas where municipal waste management is limited, and clogged drainage systems pose a daily threat to health and safety.

One of the most immediate and measurable impacts of Cleanover is its contribution to reducing flooding in urban areas. In Accra, and particularly in communities like ours at Presbyterian Boys' Secondary School, floods occur frequently when waste blocks the drainage systems during rain. These floods can damage homes, disrupt transportation, and even result in loss of life. By keeping gutters clear of solid waste, Cleanover helps ensure water can flow freely, significantly lowering the risk of such disasters. This impact alone has the potential to benefit thousands of people in densely populated communities where proper drainage is critical for daily life.

Another significant social impact lies in public health. Open drains filled with waste are breeding grounds for mosquitoes, flies, and other disease vectors. These conditions are directly linked to the spread of illnesses such as malaria, cholera, and typhoid. By automating the process of clearing solid waste from gutters, Cleanover reduces the buildup of debris and stagnant water that contribute to these health risks. Over time, this could lead to improved health outcomes, fewer hospital visits, and a lower burden on local healthcare systems.

Cleanover also brings value to the sanitation workforce. Currently, gutter cleaning is done manually, often under hazardous and unhygienic conditions. Workers are exposed to harmful waste, pathogens, and even physical injuries. With Cleanover, much of this dangerous work can be supplemented or reduced. The robot does not replace human workers entirely, but it reduces their exposure to the most dangerous tasks while allowing them to focus on supervision, maintenance, and logistics. This creates an opportunity for safer working conditions and retraining for technical roles, contributing to skills development in robotics and maintenance.

From a broader perspective, Cleanover encourages innovation and environmental responsibility. It shows how technology can be adapted to solve everyday problems in a practical, localized way. In communities where high-tech solutions are often seen as irrelevant or inaccessible, Cleanover is an example of a low-cost, scalable innovation that addresses a real need. It also contributes to the larger conversation around sustainability and the role of youth in solving national issues. This project can inspire students, schools, and local innovators to think critically about their environment and develop solutions rooted in their communities.

A concrete example of where Cleanover could be deployed effectively is **within the Presbyterian Boys' Secondary School (PRESEC) community itself**. The school's network of street gutters experiences frequent clogging due to litter from students and residents alike, as well as natural debris like leaves. This clogging has led to instances of water overflow during rains, making walkways slippery and unsafe, disrupting daily activities, and raising health concerns.

By deploying Cleanover units along the school's gutters, waste could be collected systematically and regularly without interrupting school activities. The robot's semi-autonomous operation means it can patrol these gutters during off-peak hours, such as evenings or weekends, ensuring continuous cleaning with minimal supervision. This would help prevent flooding, reduce breeding grounds for disease vectors like mosquitoes, and maintain a cleaner, healthier environment.

Another real-world example that underscores the importance of gutter cleaning solutions is the work of **BuzStopBoys**, a grassroots NGO based in Accra. They have gained recognition for voluntarily cleaning clogged street gutters and promoting environmental hygiene through community engagement. Their efforts demonstrate the urgency and scale of the problem, as well as the dedication of individuals willing to tackle it manually. Cleanover is designed not to replace such efforts, but to **complement and amplify them**. By automating parts of the cleaning process, Cleanover can support initiatives like BuzStopBoys by handling repetitive or hazardous tasks, allowing human volunteers to focus on education, outreach, and deeper cleaning efforts. This synergy between community action and technology creates a more sustainable and scalable approach to urban sanitation.

Moreover, the presence of Cleanover within the school environment can serve as a **living classroom**, inspiring students to engage with robotics, environmental responsibility, and community health issues. It creates a practical example of how innovation can be applied locally to solve everyday problems.

This focused and manageable deployment within PRESEC is a concrete first step. It provides a controlled environment to refine the system, demonstrate impact, and build a model that can be scaled to similar schools and communities across Accra and Ghana.

In terms of numbers, if Cleanover were implemented across just 10 major neighborhoods in Accra, each serving approximately 5,000–10,000 residents, the solution could directly benefit up to 100,000 people. This does not include the indirect impact on municipal workers, healthcare systems, and traffic systems that benefit from reduced flooding and waste.

In conclusion, Cleanover is more than a technical project; it's a tool for social transformation. It addresses critical challenges of waste management, urban flooding, and public health through a solution that is accessible, scalable, and locally driven. Its impact spans individuals, institutions, and cities, making it a socially relevant innovation with real potential to improve lives.

Innovation and Entrepreneurship Aspects of Cleanover

We explored how Cleanover could go beyond a school project and potentially grow into a social enterprise that addresses solid waste management issues in Ghana and beyond. Using the Business Model Canvas as a framework, we considered the following key aspects:

1. Value Proposition:
Cleanover offers an efficient, low-cost, and eco-friendly way to clean solid waste from street-side gutters. It reduces flooding, improves sanitation, and lowers public health risks. Unlike manual cleaning, it operates with minimal human exposure to waste, making it safer and more consistent.

2. Customer Segments:
Our primary customers would be:

- Local governments and municipal sanitation departments
- Schools and universities with large campuses
- Private facility management companies
- NGOs working in urban health and sanitation

3. Key Partners:

- Schools and community leaders (for pilot deployments)
- Municipal authorities (for permissions and scaling)
- Local engineering firms or maker spaces (for manufacturing and servicing)
- Donors or NGOs focused on urban development and sustainability

4. Key Activities:

- Design and manufacturing of Cleanover robots
- Maintenance and support services
- Pilot testing and data collection
- Training for operators and school staff

5. Potential Revenue Streams (for Startup Development):

- Sale of Cleanover units to institutions
- Rental or subscription-based service for cities or schools
- Maintenance contracts
- Sponsorships or grants from environmental agencies

6. Cost Structure:

- Initial R&D and prototyping
- Manufacturing materials and electronics
- Sensor and camera hardware
- Marketing and outreach for pilot sites
- Operational costs (maintenance, training, etc.)

7. Channels:

- School programs and community outreach
- Demonstrations at tech and innovation expos
- Partnerships with sanitation agencies and educational institutions

8. Social Impact (Our core driver):

Our mission is not purely commercial. Cleanover is designed to be a social innovation; its main goal is improving public health and reducing environmental risks in underserved areas.

LIST OF SOURCES

Websites and Documents:

1. GM0 - Types of Active Intakes – *Used as inspiration for the rotating intake mechanism on Cleanover*
   Types of Intake - Game Manual 0

2. **Creately – Business Model Canvas** (for entrepreneurship framework)
   https://creately.com/guides/business-model-canvas-explained/

3. **Arduino and Raspberry Pi Official Documentation** – *For coding and hardware integration*
   https://www.arduino.cc
   https://www.raspberrypi.com

4. **OpenCV Documentation** – *Used for developing image processing/navigation features*
   https://docs.opencv.org

5. ***MyJoyOnline (2021)*** – *Visual report on plastic waste flooding out of choked storm drains in Nima, underscoring urban environmental and flooding issues*
   https://www.myjoyonline.com/photos-15-minutes-of-rainfall-throws-up-plastic-waste-from-nima-gutter/

6. ***The Guardian – "Diarrhoea kills half a million children globally, shows Lancet study"*** *– Used to support the public health relevance of improving sanitation*
   https://www.theguardian.com/global-development/2017/jun/02/diarrhoea-kills-half-a-million-children-globally-shows-lancet-study

7. ***YouTube – "Ghana - Flooding: Over 3,000 Houses Destroyed"*** *– Provided real-life context on the severe consequences of poor drainage systems and flooding in Ghana.*
   Ghana - Flooding : over 3000 houses destroyed

8. ***BuzStopBoys (Instagram Page)*** *– An Accra-based NGO actively engaged in manually cleaning gutters and promoting environmental hygiene. Their work highlights the need for scalable, safe, and technology-driven approaches like Cleanover to complement grassroots sanitation efforts.*
   https://www.instagram.com/buzstopboys/

People Consulted:

1. Mr. Benedict Amoako – Alumnus, Presbyterian Boys' Secondary School
   Provided feedback on the technical development of the robot.

2. Mr. Benjamin Adjei-Peprah – Organising Secretary, PRESEC Alumni
   Shared insights on real waste and drainage issues within the school.