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MODELING AND ANALYSIS OF SEMI-AUTOMATIC DEPLOYABLE CANOPY

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Abstract
The unique "Portable Semi-Automatic Deployable Canopy" changes weather protection for farmers, delivery workers, office staff, and students. Unlike regular umbrellas, this special canopy opens itself, allowing farmers to work in any weather and delivery workers to continue their jobs regardless of conditions. It's also convenient for office workers and students, as it attaches to bags and transforms into a small backpack for easy carrying. The project uses an Arduino board and stepper motor to control and optimize the canopy deployment process. It includes a rain sensor that acts as an early detection system, triggering a light or sound signal to alert users to changing weather. This innovative canopy combines advanced technology with practical benefits, setting a new standard for modern weather protection.

Keywords:
Portable canopy, semi-automatic mechanics, wearable design, user-friendly innovation, versatile functionality.

I. Introduction

In response to the unique challenges faced by individuals working in varied weather conditions, our project endeavors to introduce a groundbreaking solution—the Portable Semi-Automatic Umbrella Opener. This innovative device is not just an ordinary umbrella; it is a versatile, hands-free protective tool designed to address the specific needs of farmers, delivery personnel, office workers, and even children.

1.1 Existing Models

Traditional fixed canopy systems have played a significant role in diverse applications, offering reliable shelter over extended periods. However, their inherent drawback lies in the realm of portability. These structures, firmly anchored to a fixed location, excel in providing enduring protection but encounter challenges in situations demanding swift relocation. While they prove effective for long-term use, the inability to easily transport them hampers their applicability in dynamic environments where rapid deployment and mobility are essential. In scenarios requiring quick adaptability to changing conditions or relocation, the limitations of traditional fixed canopy systems become evident, necessitating innovative solutions to bridge this gap in functionality.

So, in simpler terms, regular umbrellas can be a bit hard to carry around comfortably, and they may not open and close as quickly as we might need them to. The goal of improving this in the project is to create an umbrella that is easy to carry and quick to use, especially in situations where time and convenience are crucial.

1.2 Proposed Model

In our quest to create an innovative and user-friendly canopy, we focused on making it effortlessly portable. The canopy is designed to be carried like a compact backpack, easily attachable to any bag

for convenience. The standout feature is the integration of an Arduino board, essentially a smart assistant embedded in the canopy. This addition transforms the canopy into a semi-automatic marvel, enhancing its functionality.
To further elevate its practicality, we incorporated a rain sensor. This nifty sensor is capable of predicting rain, giving users a timely heads-up. This project isn't just about keeping individuals dry and comfortable; it's about simplifying life for farmers, delivery personnel, office workers, students, and even kids. The goal is to provide a solution that is not only easy to carry but also smartly adaptive to weather conditions, ensuring a seamless experience for users.

1.3 Scope Of The Project

The scope of the Portable Semi-Automatic Umbrella Opener project encompasses a comprehensive approach to designing and implementing a versatile weather protection device. The primary goal is to address the specific needs of farmers, delivery personnel, office workers, and children, providing a portable solution that offers protection against both rain and intense sunlight. The key elements of the project scope include:

1. Design and Engineering : Develop a compact and lightweight umbrella structure that is easily portable. Integrate a semi-automatic mechanism for quick and effortless deployment. Design adjustable straps, resembling a backpack, for convenient wear by farmers and easy attachment to bags for office workers and delivery personnel.
2. Weather Responsive Technology : Incorporate a rain sensor to enable automatic deployment during rainfall. Implement a sun sensor for proactive shade provision during intense sunlight. Integrate a smart system for timely weather alerts and user notifications.
3. Versatility of various user groups : Design the device to cater specifically to the needs of farmers, ensuring it can be comfortably worn as a backpack. Ensure the device is easily attachable to bags for office workers and delivery personnel, providing hands-free protection during commutes. Consider user-friendly adjustments and sizing for children, making the device suitable for their use.
4. Simulation and Testing : Utilize simulation tools and methodologies to validate the design's structural integrity, performance, and reliability in varying weather conditions. Conduct extensive testing to ensure the device's durability, ease of use, and effectiveness in real-world scenarios.
5. User Interface experience : Develop an intuitive user interface for easy activation and adjustment of the umbrella. Focus on creating a positive user experience, ensuring the device is simple, quick, and efficient to use.
6. Integration with daily activities : Explore seamless integration of the portable umbrella into the daily routines of farmers, delivery personnel, office workers, and children. Assess practical aspects such as ease of attachment to bags, wearability, and overall convenience.
7. Safety considerations : Implement safety features to prevent accidents or malfunctions during usage. Ensure that the materials used are safe for various user groups, including children.
8. Scalability and Accessibility : Consider scalability for potential mass production and distribution. Ensure that the device is affordable and accessible to the target user groups.

II. Literature Review

1. **Wang and Liu et.al** Their work showcases advancements in weather protection, a direction that our project actively aligns with. Specifically, our project integrates smart sensors for rain and sunlight, demonstrating a commitment to incorporating cutting-edge technologies for proactive weather protection.
2. **Li and Chen et.al** In their paper explains the realm of wearable canopy concepts, emphasizing the significance of hands-free operation for individuals engaged in various activities. Their work systematically explores the practical aspects and user-centric design principles behind these concepts, shedding light on the potential transformative impact on users' daily experiences.
3. **Choi and colleagues et.al** They performed research on adaptable deployment mechanisms, uncovering their potential to significantly enhance user experience and convenience in weather

protection devices. Through their meticulous investigation, they delved into the intricacies of how adaptable deployment mechanisms can be harnessed to address challenges and improve the overall usability of weather protection devices.

III. Problem Statement

In various industries and daily life, people face challenges with conventional weather protection tools like umbrellas, especially when it comes to portability, efficiency, and adaptability. The "Portable Semi-Automatic Deployable Canopy" project responds to these limitations, offering a solution for individuals like farmers, delivery personnel, office workers, and students who encounter disruptions due to unpredictable weather. The identified problem centers around the need for a sophisticated canopy system with semi-automated deployment, drawing inspiration from car convertible roofs. Wearability, portability, and the integration of rain sensors for early detection amplify the complexity of the challenge. The project aspires to revolutionize weather protection by combining advanced technology with user-friendly design, aiming to provide a transformative solution for unpredictable weather conditions.

3.1 Key Challenges

1. Inconvenience in Traditional Solutions: Traditional umbrellas and canopies are often cumbersome and inconvenient to carry, hindering the ease of mobility for individuals who need to move quickly.
2. Delayed Deployment: Manual deployment processes of conventional umbrellas and canopies can be time-consuming, causing delays in obtaining immediate protection when weather conditions change suddenly.
3. Limited Adaptability: Existing solutions lack the adaptability required for dynamic environments, making them less effective for users who work in diverse weather conditions or need quick deployment in various settings.
4. Safety Concerns: Conventional umbrellas may pose safety risks, especially when individuals, such as farmers or delivery personnel, need both hands for their tasks, leading to compromised safety during adverse weather.
5. Lack of Smart Features: Current weather protection devices often lack smart features that could enhance user experience, such as automatic deployment based on weather conditions or real-time weather alerts.

3.2 Solution Overview

Our innovative solution introduces a groundbreaking concept—a smart umbrella with a unique twist. Unlike conventional umbrellas, our design incorporates a self-opening mechanism, reminiscent of a car's roof that automatically deploys when it starts raining. This smart umbrella serves a dual purpose by providing protection from the rain and offering shade during sunny spells. The beauty of this design is that it doesn't require constant manual holding; it seamlessly attaches to your bag, functioning like a portable backpack. This feature adds to its practicality, catering to the needs of farmers, delivery personnel, office workers, students, and even kids who can benefit from its ease of use. Beyond its fundamental functions, our smart umbrella is equipped with a weather prediction feature, alerting users in advance about impending adverse weather conditions. This comprehensive solution ensures users stay dry, shaded, and well-prepared for varying weather scenarios.

3.3 Key Features

1. Compact and Lightweight Design : The device is engineered to be compact and lightweight, ensuring easy portability. Its design prioritizes user convenience, allowing individuals to carry it effortlessly during their daily activities.
2. Instant Activation : Inspired by the swift deployment of a car's convertible roof, our device enables instant activation. Users can quickly respond to changing weather conditions, deploying the protective

covering with ease.
3. Versatile Protection : The device is equipped to shield users from both rain and intense sunlight. Its versatile design caters to the diverse needs of individuals who may face unpredictable weather while commuting, working outdoors, or engaging in various activities.
4. User-Friendly Operation : The user interface is designed to be intuitive and user-friendly, ensuring that individuals of all ages can activate the weather protection device effortlessly. The emphasis is on simplicity and quick response.

IIV. Components

4.1 Mechanical Components

- Canopy
- Base structure
- Links and Joints

4.2 Electrical Components

- Battery
- Servo motor
- Rain sensor
- LED Indicator
- Arduino board

V. Design and Development

All the sketches, parts and assembly is done in shapr3D. The "Portable Semi-Automatic Deployable Canopy" project navigates the intersection of innovative design and practical functionality, aiming to redefine conventional approaches to weather protection. In this section, we delve into the intricate process of translating conceptual ideas into tangible solutions, exploring the dimensions, mechanisms, and features that characterize the project's design and development.

5.1 Base Design

The base of our "Portable Semi-Automatic Deployable Canopy" is cleverly shaped like a 'C', and you can check out how it looks in the figure below. The star of the show is the top plate—it's like the command center, connecting all the important parts like motors, links, canopies, the microcontroller (Arduino), and even the rain sensor. Everything important sits on this top plate. Now, on the bottom plate, we've got the battery. That's the power hub for the microcontroller and other electrical bits. It's like the heart of the whole operation, making sure everything runs smoothly.

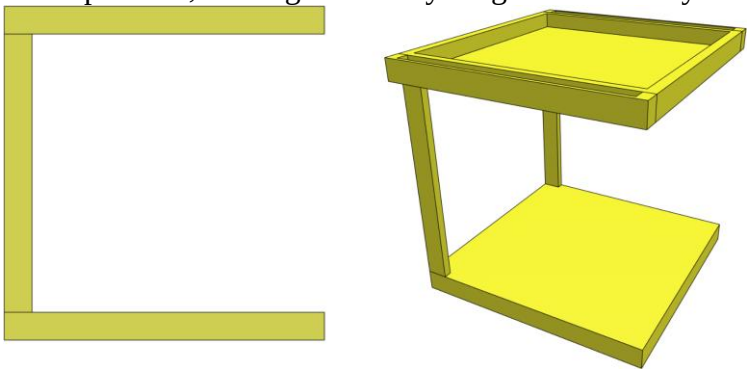

Fig 1: Base design

5.2 Canopy Design and Aerodynamics

The aero-centric design strategically manipulates air flow dynamics. Notably, the bottom surface experiences compression at the initial point (depicted in green), resulting in accelerated air velocity in comparison to the top airflow. This variance in velocity induces a pressure disparity, with lower

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pressure at the bottom and higher pressure at the top. Leveraging the fundamental principle that fluids move from areas of high pressure to low pressure, this aerodynamic configuration prompts the upward movement of air from the top to the bottom. The consequential effect manifests as a downward force, contributing to enhanced stability and performance of the canopy system.

In the pursuit of optimizing aerodynamic efficiency, a deliberate gap has been strategically introduced between each canopy in the design of the "Portable Semi-Automatic Deployable Canopy" project. This intentional spacing serves the purpose , to facilitate air flow and mitigate drag, thereby enhancing overall performance, and secondly, to enable users to navigate at improved speeds.

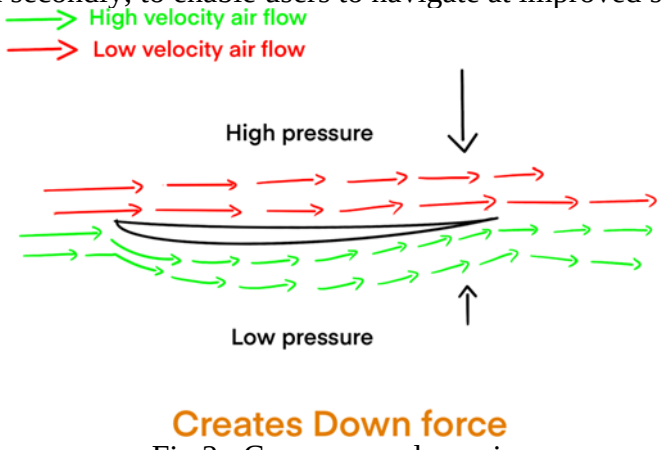

Fig 2 : Canopy aerodynamics

5.3 Tri-Fold Canopy Integration

At the heart of our design lies the ingenious incorporation of three canopies—the top, middle, and bottom canopies—each serving a distinct purpose. This trifold configuration isn't just about aesthetics; it's a strategic move with a host of advantages.

1. Aerodynamics : The three-canopy setup is not just about looks; it's a nod to aerodynamic efficiency. The distribution of canopies optimizes airflow, minimizing resistance and ensuring stability during use.
2. Stability : Stability is key, especially in variable weather conditions. The three-canopy configuration enhances stability, preventing undue strain on the structure and offering a reliable shield against wind and rain.
3. Adjustability : Each canopy plays a unique role, contributing to the overall adjustability of the system. Users can tailor the deployment based on their specific needs, be it shielding from the sun or braving unexpected rain.

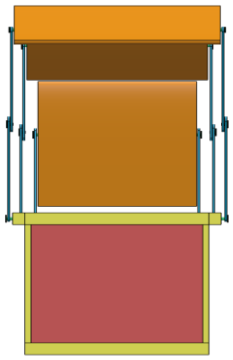

Fig 3 : Front view of prototype model

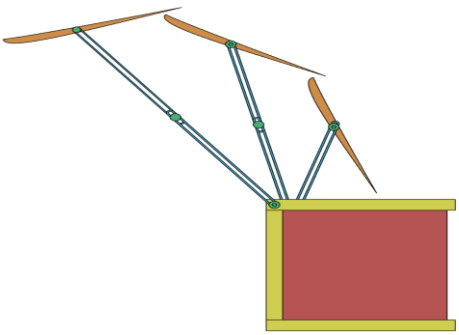

Fig 4 : Side view of prototype model

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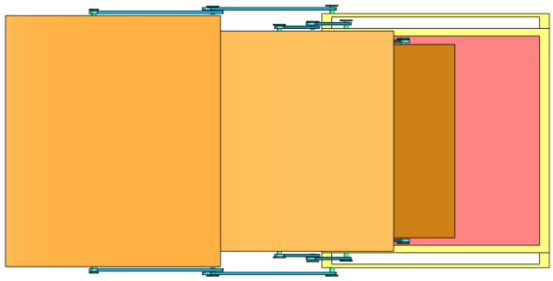

Fig 5 : Top view of prototype model

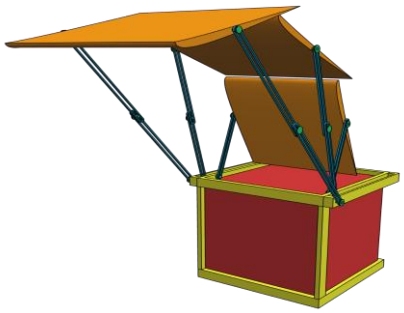

Fig 6 : Isometric view of prototype model

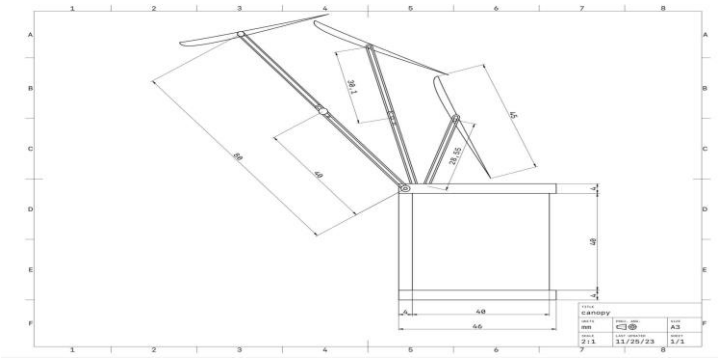

Fig 7 : Front view drawing with dimensions

VI. Mechanism

The following figures represent the steps taken to move the canopy to its final position.

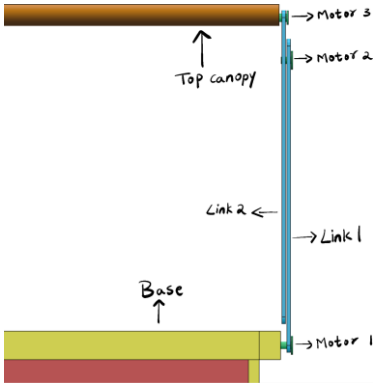

Fig 8 : Base , links and canopy connection

1. **STEP 1** : In the initial step of our operational sequence, activation of the system is initiated by the user pressing the ON button. Subsequently, the microcontroller orchestrates the transmission of signals to the foundational motor, commonly referred to as the base motor. This strategic interaction sets into motion a coordinated movement involving Link 1, Link 2, and the top canopy , seamlessly transitioning to their predetermined positions, as visually elucidated in the figure below.

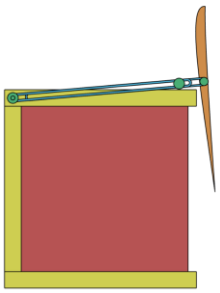

Fig 9 : Initial position

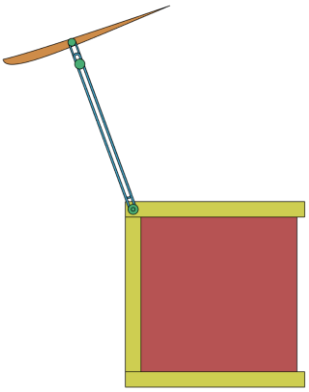

Fig 10 : Step 1 - Activation and Canopy Movement

2. **STEP 2** : In the subsequent phase, denoted as the second step in our operational sequence, the focus shifts to the secondary motor positioned between Link 1 and Link 2. Following the directives communicated by the microcontroller, this motor executes a precise rotational movement to a predetermined angle. This strategic maneuver sets in motion the linear motion mechanism embedded in Link 2, facilitating its upward movement to a specified height. This orchestrated interplay, meticulously calibrated by the microcontroller, is represented in the figure below.

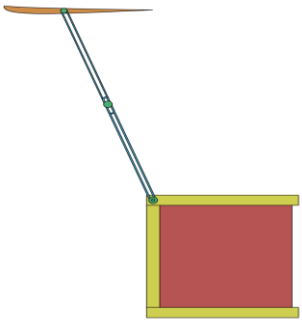

Fig 11 : Step 2 - Motorized Elevation of Link 2 to Predetermined Height

3. **STEP 3** : In the culminating step, the third and final phase of our operational sequence, the spotlight falls on the tertiary motor strategically positioned between Link 2 and the canopy. Upon receiving precise directives from the microcontroller, this motor embarks on a calculated rotational movement to achieve a predetermined angle.

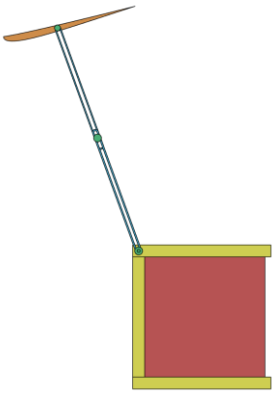

Fig 12 : Step 3 - Precision Canopy Adjustment

This intricate maneuver ensures the optimal positioning of the canopy, aligning it to provide the user

with the perfect shade. Simultaneously, this rotation shields the user from rainfall, embodying the seamless convergence of user-centric design and technological precision in the "Portable Semi-Automatic Deployable Canopy" system.

6.1 User Controlled Adjustment

Crucially, this entire mechanism is activated when the user presses the ON button, facilitated through IoT integration. The first and second motors move to their predetermined positions, with the second motor adjusting at a specific angle, elevating Link 2 to the desired height. Subsequently, the third motor imparts the finishing touch, rotating the canopy to its final position. This user-controlled adjustment mechanism empowers individuals to tailor the height of the canopy according to their specific preferences.

6.2 Advantages of this mechanism

1. User-Friendly Control : The mechanism prioritizes user convenience with a straightforward ON button initiation, ensuring an intuitive and user-friendly experience
2. Adjustability at Your Fingertips : Users can effortlessly tailor the canopy's position to their specific needs, providing a customizable and adaptable solution for varying weather conditions.
3. Simplicity in Programming : The microcontroller's programming is designed for simplicity, streamlining the operational sequence and enhancing overall user accessibility.
4. Open-Loop Precision : The open-loop system ensures precision in motor movements, allowing for accurate and predictable adjustments, contributing to the reliability of the entire mechanism.
5. Energy-Efficient Operation : The mechanism's design minimizes the energy requirements, utilizing power-efficient motors without compromising on performance.
6. Cost-Effective Implementation : The reliance on accessible and moderate-powered motors contributes to a cost-effective implementation, making the technology within reach for a broader user base.
7. Low Maintenance Requirements : With a focus on simplicity and durability, the mechanism reduces the need for intricate maintenance, ensuring prolonged and trouble-free usage.
8. Modular Repair Approach : The design allows for a modular repair approach, where damage to a specific part doesn't necessitate the replacement of the entire system, contributing to sustainability and cost-effectiveness.

In essence, the Precision Canopy Adjustment Mechanism not only enhances user control and adaptability but does so in a manner that is energy-efficient, cost-effective, and designed for long-term durability.

VII. Simulation

In the pursuit of enhancing the design and functionality of the "Portable Semi-Automatic Deployable Canopy," comprehensive simulations were conducted using cutting-edge tools, including motion simulation in Autodesk Fusion 360 and air flow simulation in Autodesk CFD.

7.1 Motion Simulation in Fusion 360

The motion simulation aimed to validate the seamless deployment mechanism inspired by car convertible roof systems. Using Autodesk Fusion 360's robust simulation capabilities, we meticulously examined the dynamic motion of the canopy components during deployment and retraction. This process allowed us to optimize the design for efficiency, ensuring smooth and controlled movements. The simulation provided invaluable insights into potential stress points, interference, and overall system behavior, guiding iterative improvements for a reliable and user-friendly deployment experience.

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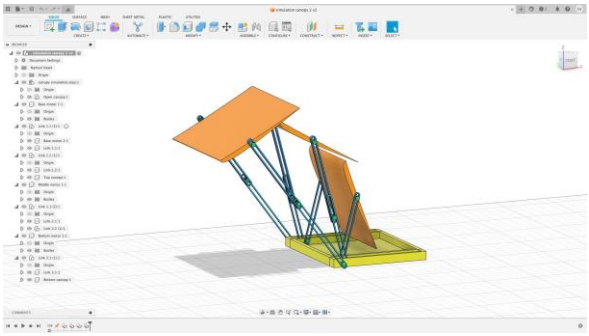

Fig 13 : Prototype model in Autodesk Fusion 360

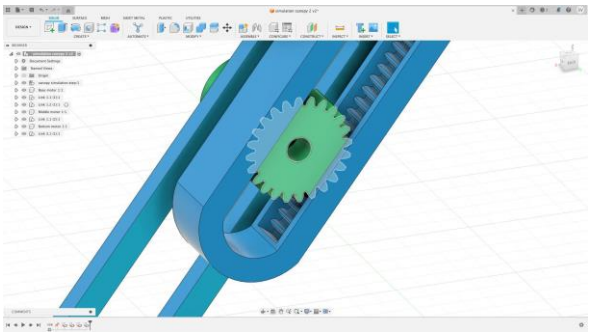

Fig 14 : Link 2 - Rack and Pinion model

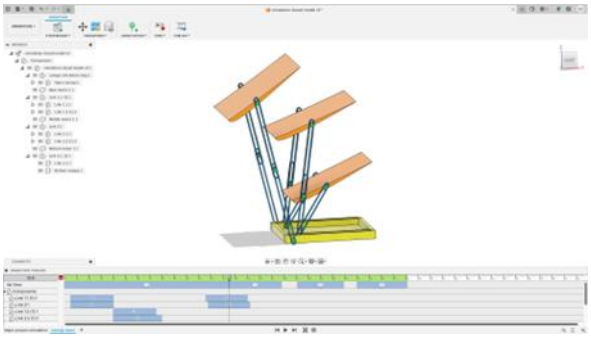

Fig 15 : Prototype motion simulation

7.2 Air Flow Simulation in Autodesk CFD

To assess the canopy's performance in diverse weather conditions, Autodesk CFD was employed to simulate air flow around the deployed canopy. This advanced Computational Fluid Dynamics tool enabled a thorough analysis of how the canopy interacts with wind forces, ensuring stability and aerodynamic efficiency. By visualizing air flow patterns, velocities, and pressures, we could refine the canopy's shape and structure to minimize resistance and enhance overall performance. The incorporation of rain sensors was also simulated to gauge their responsiveness under varying wind conditions, ensuring the early detection system's reliability in real-world scenarios.

These simulations, conducted with precision and attention to detail, have been instrumental in refining the Portable Semi-Automatic Deployable Canopy. By leveraging the capabilities of Fusion 360 and Autodesk CFD, we have not only validated the design but also ensured that the final product meets the highest standards of functionality and resilience in the face of unpredictable weather conditions.

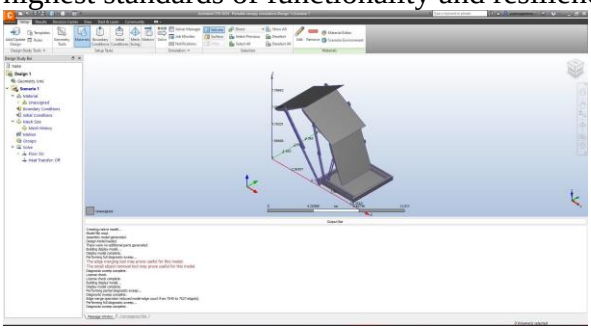

Fig 16 : Autodesk CFD

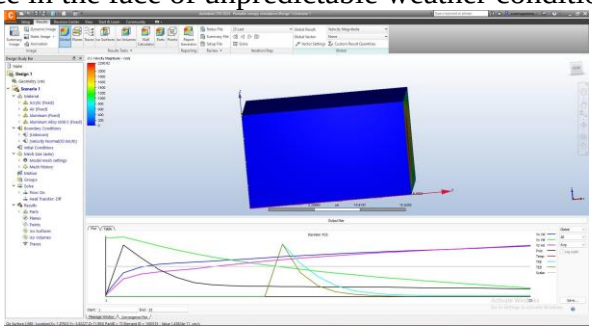

Fig 17 : Navigating for Flow Analysis

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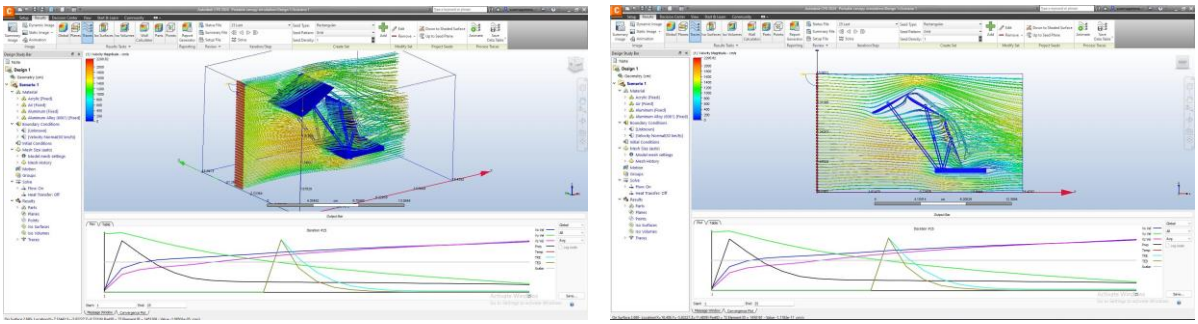

Fig 18 : Final air flow solution in Autodesk CFD

V1II. Conclusion

The "Portable Semi-Automatic Deployable Canopy" project represents a significant advancement in weather protection solutions, addressing the shortcomings of traditional umbrellas. Drawing inspiration from convertible car roofs, the canopy introduces a hands-free and adaptable design, catering to diverse user needs. Its versatility extends beyond rain, providing relief from the sun, making it applicable to various scenarios for individuals like farmers, office workers, delivery personnel, and students. The user-friendly features, such as transforming into a small backpack or attaching to bags, ensure accessibility for everyone.

8.1 Credit authorship contribution statement

Shreyas Varma : Research coordination, project conceptualization, designing.
Raghavendhar Reddy: Data collection, literature review,documentation integrity.
Aravind Musuku: Simulation, Process optimization.
Ashwin Rajeev Kumar: Materials sourcing, documentation assistance.
G.Ashok: Guidance, mentorship, composite materials expertise.

8.2 Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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