IC 201P – Design Practicum

Computer vision-based non-contact flow measurement system for flood early warning

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Abstract

The project aims to develop a cost-effective solution for flood detection using the volumetric flow of a river. The project will involve using the surface velocities of the river, which will be captured through live video streaming from a camera module integrated with a programmed Raspberry pi.

The detection of a flood using the volumetric flow of water is an innovative approach that can potentially have a significant impact on reducing the negative consequences of floods. By accurately measuring the volumetric flow of a river, it becomes possible to detect changes in flow rate that may indicate an impending flood. This information can be used to alert the local authorities and residents, giving them time to prepare and evacuate if necessary.

The proposed solution is not only cost-effective but also highly efficient. By using live video streaming, the system can provide real-time information on the flow rate of the river, making it possible to detect flood events quickly and accurately.

Overall, the proposed flood detection solution has the potential to significantly reduce the negative impacts of floods in India and other regions around the world. By providing accurate and timely information on river flow rates, the system can help communities and local authorities to prepare for and respond to flood events more effectively.

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Chapter 1
Introduction

Disaster warning systems play a critical role in protecting communities from the devastating effects of natural calamities. In recent years, the Himalayan region has seen an increase in extreme weather events, leading to severe flooding and landslides. Detecting these events before they occur can mean the difference between life and death for those in their path. Traditional methods of monitoring water levels and flow rates in rivers are time-consuming and often rely on manual measurements, which can be prone to errors. Computer vision, powered by artificial intelligence, offers a promising solution to this challenge. By analyzing video footage of a river's surface, AI algorithms can accurately estimate the flow rate and detect changes that may indicate an impending flood. In this chapter, we give an introduction to how we can detect the discharge rate (volume/time) of a flowing river using computer vision and AI to improve disaster warning systems and protect communities from the devastating effects of flooding and other natural disasters.

1.1 Background and Scope of the Problem

Stream gauging is a widely used method for measuring the discharge of a river, which refers to the volume of water flowing through a given point in the river per unit of time. Here's an overview of how the stream-gauging method works:

- A section of the river is chosen where the flow is relatively uniform and stable, usually a straight section with a constant width and depth.
- A stream gauge is installed in the river to measure the water level continuously. This gauge may be a simple staff gauge, a float gauge, or a pressure transducer.
- Measurements are taken of the river's cross-section at various points along the chosen section. This involves measuring the width and depth of the river at regular intervals, typically every 5-10% of the channel width.
- A current meter is used to measure the velocity of the water at various points along the section. This is done by suspending the meter in the water and measuring the speed and direction of the current.
- The data collected from the measurements of water depth, width, and velocity are used to calculate the discharge of the river using the following formula:

$$Discharge\ (Q)\ =\ Area\ x\ Velocity$$

where Area is the cross-sectional area of the river and Velocity is the average velocity of the water in the cross-section.

In this chapter,

1.1 Background and Scope of the Problem
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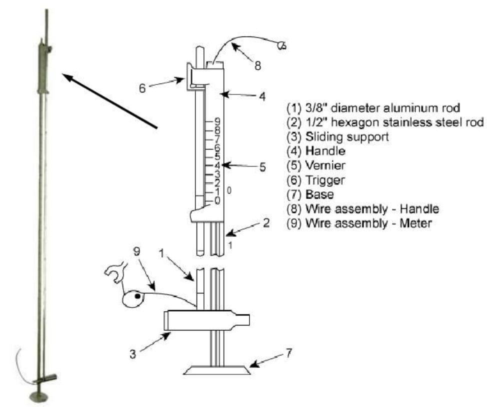
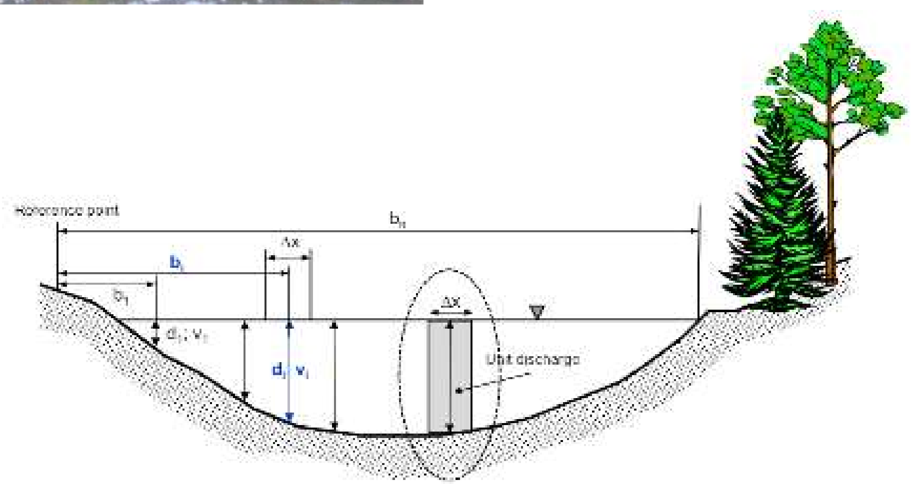
Overall, stream gauging is a labor-intensive and time-consuming process, but it is an essential method for measuring the discharge of a river accurately. The data obtained from stream gauging is critical for managing water resources, predicting floods, and designing infrastructure such as bridges, dams, and levees. If the flow of the stream is too strong, this is a safe method of measuring discharge.





(Clockwise from top-right) (i) The Traditional method of measuring the discharge of a river, (ii) the velocity-area method for calculating discharge, (iii) A Wading rod used for velocity measurements *(Source: [1], [2])*

1.2 Design Philosophy Used in this Report

The design philosophy of this report is focused on enhancing the reader's experience by creating a visually appealing and informative document. The report is organized into five chapters, with sub-sections within each to ensure a clear and logical flow of information. The contents page provides an overview of each chapter and its subsections, making it easier for the reader to navigate through the report. The report also includes both footnotes and endnotes, ensuring that the sources of information are documented. In addition, certain diagrams have been created by hand and included as photos to enhance the visual representation of the information. The report has been designed to

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[1][1] “Watershed 201: Measuring Stream Discharge and Suspended Sediment,” Stroud Water Research Center. https://stroudcenter.org/event/watershed-201/

[2][2] D. Caissie, “Discharge measurement by the velocity-area method and calculating rating curves,” Jul. 2021, doi: https://doi.org/10.13140/RG.2.2.29395.71208.

be as visually engaging as possible, with a clear and consistent layout, typography, and color scheme. Overall, the design philosophy of this report is centered around making the information accessible, engaging, and informative for the reader.

1.3 Problem statement

The problem addressed in this project is to accurately measure the discharge rate of a stream using cameras, to develop a reliable and cost-effective system.

1.4 Beneficiaries

The development of a computer vision-based non-contact flow measurement system for flood early warning has the potential to benefit a wide range of stakeholders. First and foremost, the system could improve the accuracy and efficiency of flood warning systems, helping to mitigate the risk of property damage and loss of life in flood-prone areas. Additionally, the system could be of significant value to government agencies responsible for monitoring and managing water resources, providing them with a more reliable and cost-effective method of measuring water flow rates. Finally, the system could also be of benefit to researchers and academics studying hydrology and related fields, providing them with new insights and data on water flow rates and patterns. Ultimately, the development of this system could have significant positive impacts on communities, businesses, and individuals in flood-prone areas, as well as on broader efforts to understand and manage water resources.

1.5 Organization of the Report

This report is organized into five chapters, each of which serves a specific purpose in presenting the project.

Chapter 1 provides an introduction to the project, including the background, scope, problem statement, intended beneficiaries, design philosophy, and organization of the report.

Chapter 2 presents a market research analysis, comparing existing products in the market.

Chapter 3 details the origin and evolution of the project idea within the group.

Chapter 4 presents a detailed design of the project, including a block diagram of the product functionality, component interactions, and design configuration.

Chapter 5 discusses the assembly of the project components, limitations from a functional perspective, a Gantt chart of the schedule plan, the contribution of each member, and the overall conclusions of the project.

The subsections within each chapter provide a clear and logical flow of information, ensuring the reader can easily follow the project's development and implementation.

References

[1] “Watershed 201: Measuring Stream Discharge and Suspended Sediment,” Stroud Water Research Center. https://stroudcenter.org/event/watershed-201/

[2] D. Caissie, “Discharge measurement by the velocity-area method and calculating rating curves,” Jul. 2021, doi: https://doi.org/10.13140/RG.2.2.29395.71208.

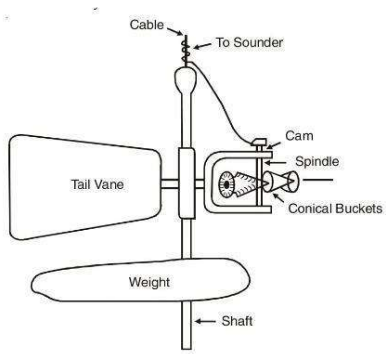
Chapter 2

Market research

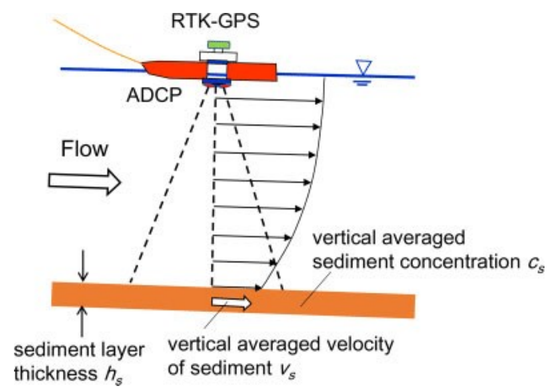
2.1 An Introduction to the existing products and Techniques

2.1.1 Existing Instruments

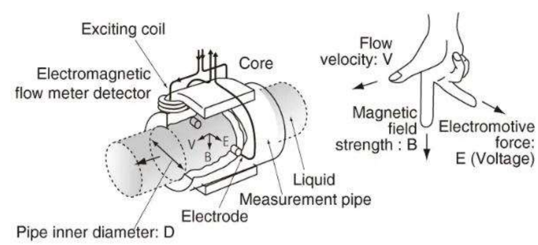
Current meters: Current meters are the most common devices used to measure river water velocity. These instruments are designed to measure the speed of water flow by directly measuring the speed of the water passing by. They consist of a propeller or a vane that rotates with the flow of water and sends signals to a recorder or display unit [1].



Acoustic Doppler Current Profiler (ADCP): ADCP is a device that uses sound waves to measure the velocity of the water. The ADCP sends out sound waves into the water, which reflect off the particles in the water, and the device calculates the velocity of the water based on the Doppler effect [2].



Electromagnetic current meter: An electromagnetic current meter measures the velocity of water by using a magnetic field. As the water passes through the magnetic field, a voltage is induced in the water, which is proportional to the velocity of the water [3].



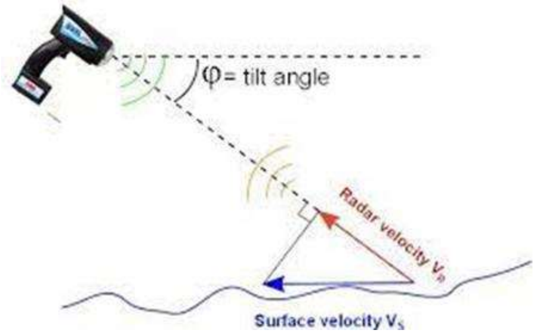
In this chapter,

2.1 An Introduction to the existing products and Techniques

2.2 Problems Associated with existing alternatives

2.3 How the intended product stands out

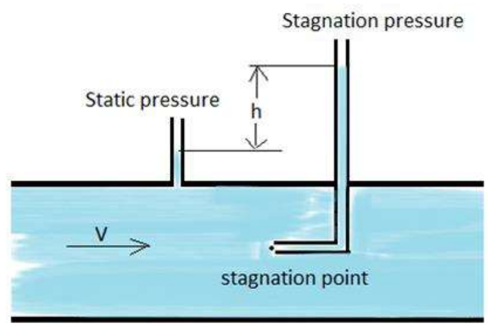
Surface velocity radar: A surface velocity radar measures the velocity of water by bouncing microwaves off the water's surface. The device measures the Doppler shift of the reflected microwaves to calculate the velocity of the water.



Pitot tubes: A pitot tube is a device that measures the velocity of water by measuring the pressure difference between a stagnation point and a point downstream. The pressure difference is proportional to the velocity of the water [4].

2.1.2 Existing Techniques

The flow in rivers is typically measured using the Velocity Area method, which involves determining the velocity of the stream at specific depths and calculating the flow using the corresponding area. Alternatively, structures like weirs and channel controls are often utilized for measurement purposes. However, these methods encounter common challenges such as maintenance issues, labor-intensive processes, place-specific limitations and time-consuming operations.



2.2 Problems Associated with existing alternatives

I. Calibration issues: Water velocity measurement devices must be calibrated regularly to ensure accurate readings. If not properly calibrated, these devices can provide incorrect or inconsistent results.

II. Sensor placement: Incorrect sensor placement can affect the accuracy of measurements. Sensors placed too close to the riverbed or near the water's surface may not accurately measure the velocity of the water in the middle of the river.
III. Environmental factors: Water velocity measurement devices can be affected by environmental factors, such as turbulence or debris in the water, which can lead to incorrect measurements.
IV. Power source: Some water velocity measurement devices require a power source to operate, which can be a problem in remote or hard-to-reach locations where access to power may be limited.
V. Interference: Water velocity measurement devices can be affected by electromagnetic or acoustic interference, which can lead to inaccurate readings.
VI. Instrument failure: Water velocity measurement devices can fail due to mechanical or electronic issues, resulting in inaccurate or unreliable readings.
VII. Human error: Improper use of water velocity measurement devices or human error can also lead to inaccurate readings.
VIII. Complexity: Some water velocity measurement devices can be complex and require specialized knowledge to operate, which can limit their accessibility.
IX. Cost: Depending on the device and the required accuracy, water velocity measurement devices can be expensive, which can limit their accessibility to researchers or organizations with limited budgets.
X. Maintenance: Regular maintenance is necessary to ensure accurate and reliable readings from water velocity measurement devices, which can be time-consuming and costly.

2.3 How the intended product stands out

Our instrument uses a machine learning algorithm to measure water velocity. The algorithm analyses data from the video to determine the velocity of the water. By using a machine learning algorithm, our instrument provides real-time, accurate, and cost-effective measurements of water velocity, which can be used for a range of applications, including flood warning systems, hydroelectric power plant operations, and water resource management.

I. Increased accuracy: Machine learning algorithms can analyze large amounts of data and identify patterns that may not be easily detectable by human analysts. This can result in more accurate velocity measurements and a better understanding of water flow dynamics.
II. Real-time monitoring: Machine learning algorithms can process data in real time, enabling continuous monitoring of water velocity. This can be particularly useful for detecting sudden changes in water flow or identifying potential hazards.
III. Reduced cost: Traditional water velocity measurement systems can be expensive to install and maintain. Machine learning algorithms can be developed using existing data sources and require minimal hardware, reducing the cost of implementing a water velocity measurement system.
IV. Flexibility: Machine learning algorithms can be adapted to different types of water flow environments, including rivers, streams, and estuaries. This flexibility makes them suitable for a range of applications, from flood warning systems to hydroelectric power plant operations.
V. Improved data analysis: Machine learning algorithms can help identify trends and patterns in water velocity data that can be used to improve water resource management. For example, they can be used to identify areas of low flow that may require additional water management interventions.

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[1] sanjay sharma, “Measuring the average velocity of flow,” *civilengineering.blog*, Nov. 03, 2020. [Online]. Available: https://civilengineering.blog/2020/11/03/measuring-the-average-velocity-of-flow/

[2] S. Okada, Atsuhiro Yorozuya, Haruhiko Koseki, S. Kudo, and K. Muraoka, “Comprehensive measurement techniques of water flow, bedload and suspended sediment in large river using Acoustic Doppler Current Profiler,” Nov. 2016, doi: https://doi.org/10.1201/9781315623207-230.

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[4] *Study.com*, 2023. [Online]. Available: https://study.com/academy/answer/an-airplane-is-flying-at-an-altitude-of-12-000-m-determine-the-gauge-pressure-at-the-stagnation-point-on-the-nose-of-the-plane-if-the-speed-of-the-plane-is-200-frac-km-h.html.
[Accessed: May 17, 2023]

[5] E. P. Agency, “How we measure water level and flow of rivers,” *www.epa.ie*. [Online]. Available: https://www.epa.ie/our-services/monitoring--assessment/freshwater--marine/rivers/water-level-and-flow/how-we-measure-water-level-and-flow-of-rivers/#:~:text=The%20principal%20methods%20of%20flow%20measurement%20we%20use

Chapter 3

Conceptual design

This chapter provides a detailed account of the origin and evolution of the project idea within the group. This section gives the first problem statement, and the evolution of that statement to make the project practically feasible for the duration of the semester. From this, readers can gain a deeper understanding of the design process and the rationale behind the final product. Additionally, this information can be valuable for future work, as it can inform the development of similar projects or inspire new ideas for innovation.

3.1 Origin of the first problem statement

During the initial stages of the project, the group considered several ideas for the problem statement, but they were either unrefined or exceeded the time frame of the semester. The current problem statement of calculating the discharge rate of a stream using computer vision was suggested to the group by our mentor, Dr. Vivek Gupta. This problem statement was selected because it was both feasible within the project timeline and had practical implications for flood early warning systems.

3.2 The conceptual idea of the project, and the approach toward refinement

The idea for a discharge measurement system consists of three main components:

(i) obtaining a video of the stream's surface,
(ii) processing the video to extract velocity vectors,
(iii) using these vectors in an algorithm to calculate the stream's discharge.

During the initial stages of the project, the group conducted a comprehensive analysis to identify potential challenges associated with each component and develop strategies for addressing them. Certain parts of the project were eliminated to ensure its feasibility within the project timeline. An overall mind map of the conceptual part of the project is given on the next page.

The following sections of the chapter discuss the aspects of the project that were analyzed and highlight which ones were ultimately deemed unfeasible for implementation.

In this chapter,

3.1 Origin of the first problem statement
3.2 The conceptual idea of the project, and the approach toward refinement
3.3 Taking videos of the stream surface
3.4 Processing videos to get the discharge of the stream
3.5 Experimentation of concepts

3.3 Taking videos of the stream surface

3.3.1 How do we attach the cameras?

The method of attaching the camera to the system depends on its type and dimensions. Originally, the group had considered using a large camera connected to a Raspberry Pi. Raspberry pi can also work as an operating system giving us a highly interactive interface to work upon and it is also highly reliable.

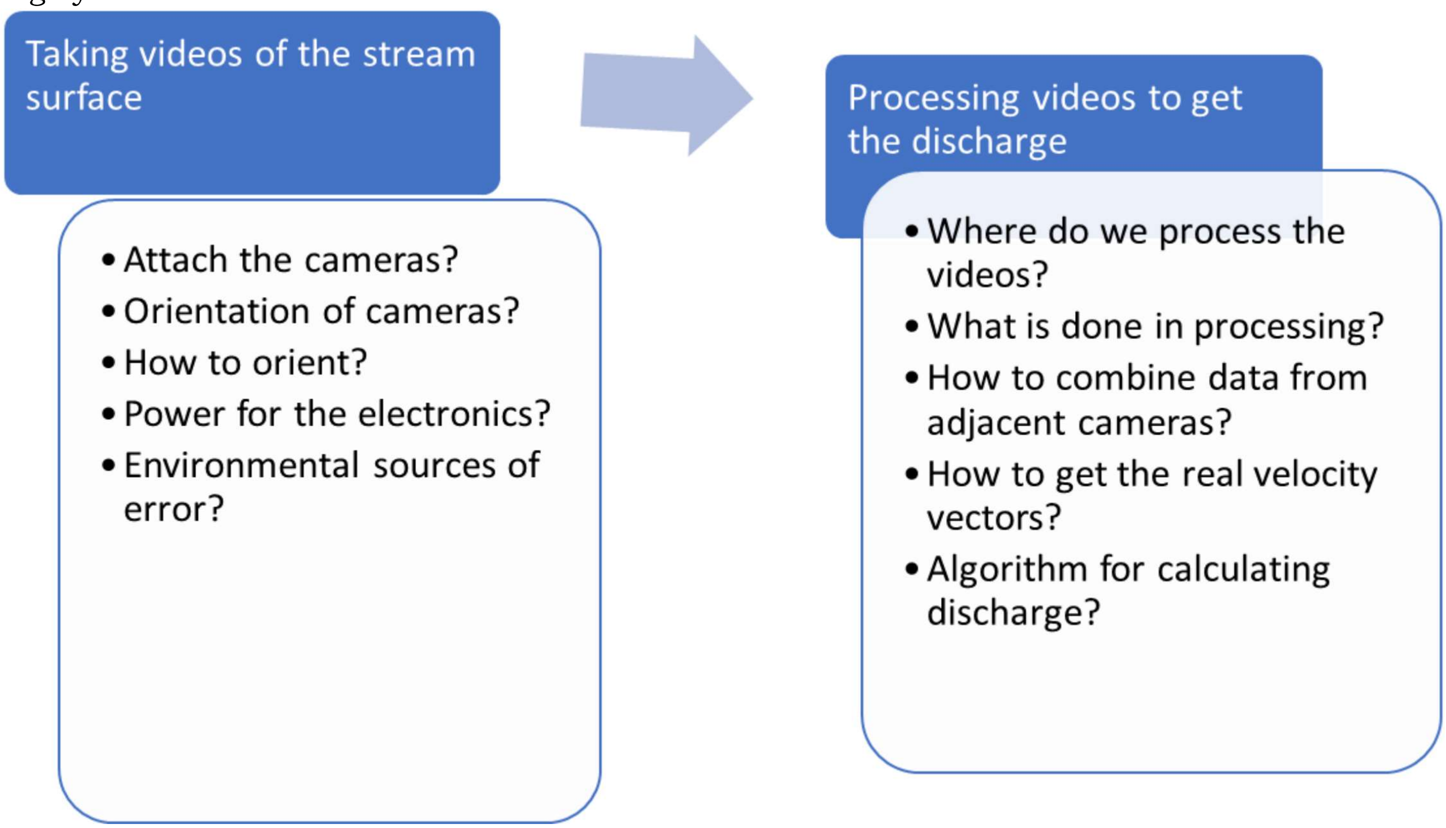


figure 3.1 An overall mind map of the concepts involved, and the parts which were considered

3.3.2 What orientation should the camera have?

Initially, the group had considered attaching the cameras on poles along the bank of the stream. However, this option would have required more complex image processing to calculate the distances between the cameras and points on the stream. Additionally, integrating videos from different cameras would have been challenging. To simplify the problem, the group decided to assume that the cameras would be mounted under a bridge, with their direction of vision perpendicular to the stream surface. They also assumed that the banks of the stream were parallel.

3.3.3 How do we orient the cameras?

The cameras need to be oriented in two specific ways:

i. They must be positioned to face directly downward, perpendicular to the surface of the river water.

ii. They should be adjusted so that the banks of the river appear vertically aligned in the captured images.

To achieve this, the group explored the possibility of using gyroscopes, which measure changes in orientation relative to a reference point. The algorithm designed for this purpose consisted of the following steps:

i. Calibration of the gyroscope along two of its axes using a spirit level.
ii. Utilizing images of the river banks captured by the same camera, along with readings from the gyroscope at different time points, to deduce the calibrated value for the third axis of the gyroscope.

However, an additional challenge arises during the installation process, as it is practically impossible to guarantee the absence of deviations from the ideal orientation. To address this issue, image correction techniques could be employed to obtain a more accurate representation of the scene. However, due to scope limitations, this approach was not pursued.

3.3.4 From where do we get the power supply?

In the initial stages of the project, the group considered three potential sources of power for the components, namely,

(i) solar energy,
(ii) turbine energy, and
(iii) vibration energy from the bridge

However, due to the complexity of implementing these power sources and to simplify the demonstration of the concept, the group ultimately decided to use lipo batteries instead. Through this, the group was able to focus their efforts on refining the core functionality of the system and presenting a clear proof-of-concept for their design.

3.3.5 Sources of error due to environmental factors

When considering the approach of using computer vision for calculating the discharge of a stream, the following potential sources of error in the recorded videos were identified:

(i) If the video is recorded at night, visibility might be an issue. To overcome this problem, lights could be used to illuminate the stream surface.
(ii) In case of rain, a shed could be used to cover the portion of the stream being recorded. However, since only the area under the bridge was being recorded, this issue was not pursued further.
(iii) The effect of vibrations in the bridge on the video recordings was neglected.

3.4 Processing videos to get the discharge of the stream

3.4.1 Where do we process the videos?

Three options were considered for video processing:

(i) Processing the videos directly on the Raspberry Pi. However, due to the unavailability of Raspberry Pi, this option was dropped.

(ii) Sending the videos to a server for processing. However, this option was also deemed too complex and was also dropped.

(iii) Sending the videos to a laptop using a wireless connection, and then processing them on the laptop. This option was ultimately chosen for the sake of simplicity during the implementation.

3.4.2 What is done in the processing?

The group considered the following flow for processing the videos:

(i) Capture videos from the cameras.

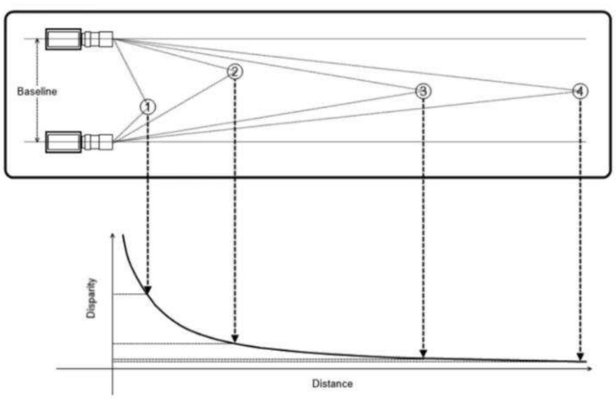
(ii) Determine the image velocity vectors, i.e., the velocity of points with respect to the camera's vision.

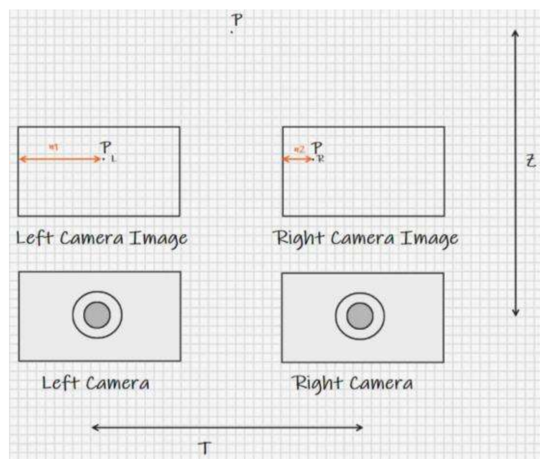
(iii) Compute real velocity vectors by multiplying the image velocity by the distance of the point on the stream's surface from the camera.

(iv) Calculate the stream's discharge based on the velocity vectors obtained.

3.4.3 How to determine the real velocity vectors?

To determine the distance of a point on the stream to the camera, the group explored several methods. Since the distance from the camera to each point on the surface of the stream directly below the bridge is assumed to be unchanging, because of its large value, only the height of the bridge from the water surface may be measured. The group considered the following approaches for this purpose:





Figures 3.2 and 3.3 – On stereovision, Source [3]

(i) Stereovision: This involves using two cameras to find the distance by analyzing the difference in the appearance of a point in each of them. However, this method may have limitations when finding common points in the images from two cameras due to changes in light reflection on the surface of the stream.

(ii) Hard-coding the distance: The distance from the bridge to the stream surface could be directly coded into the program.

(iii) Depth sensor: A depth sensor could be used to measure the distance from the bridge to the stream surface.

[3][1] A. Garg, "Stereo Vision: Depth Estimation between object and camera," Analytics Vidhya, Feb. 25, 2022. https://medium.com/analytics-vidhya/distance-estimation-cf2f2fd709d8

(iv) Scale on the bridge: Certain bridges have a scale drawn on their sides to indicate the level of the water. A camera could be set up to read the value from this scale, but for the sake of simplicity, this was not included in the project.

3.4.4 The algorithm for calculating discharge?

One of the group members was assigned to write the algorithm for the project. As the required algorithm is not available as open-source code, it needs to be written from scratch by understanding the algorithm from a research paper.

In addition to the main algorithm, it is essential to perform pre-processing when dealing with multiple camera systems. In such cases, the videos captured by all the cameras need to be integrated to encompass the entire breadth of the river.

3.5 Experimentation of concepts

To test the concepts used in this project, the group planned several experiments:

(i) An experiment to verify the functionality of the complete algorithm. For this, we will record videos of the surface of the water flow in a flume and process them using our algorithm.

(ii) An experiment to manually align the camera using images captured from the camera, as discussed earlier in the chapter.

(iii) An experiment to validate the accuracy of distance measurement using stereovision.

Figure 3.4 – A Flume, Source [4]

References

[1] A. Garg, "Stereo Vision: Depth Estimation between object and camera," Analytics Vidhya, Feb. 25, 2022. https://medium.com/analytics-vidhya/distance-estimation-cf2f2fd709d8

[2] "Flumes Equipment Fluid Machinery Retailer from Roorkee, Uttarakhand," www.exportersindia.com. https://www.exportersindia.com/m-s-engineering-models-equipment/other-products.htm (accessed Apr. 18, 2023).

[4] [2] "Flumes Equipment Fluid Machinery Retailer from Roorkee, Uttarakhand," www.exportersindia.com. https://www.exportersindia.com/m-s-engineering-models-equipment/other-products.htm (accessed Apr. 18, 2023).

Chapter 4

Embodiment and Detailed Design

This chapter provides a comprehensive overview of each component of the system, including its functionality and selection process.

4.1 Product Architecture

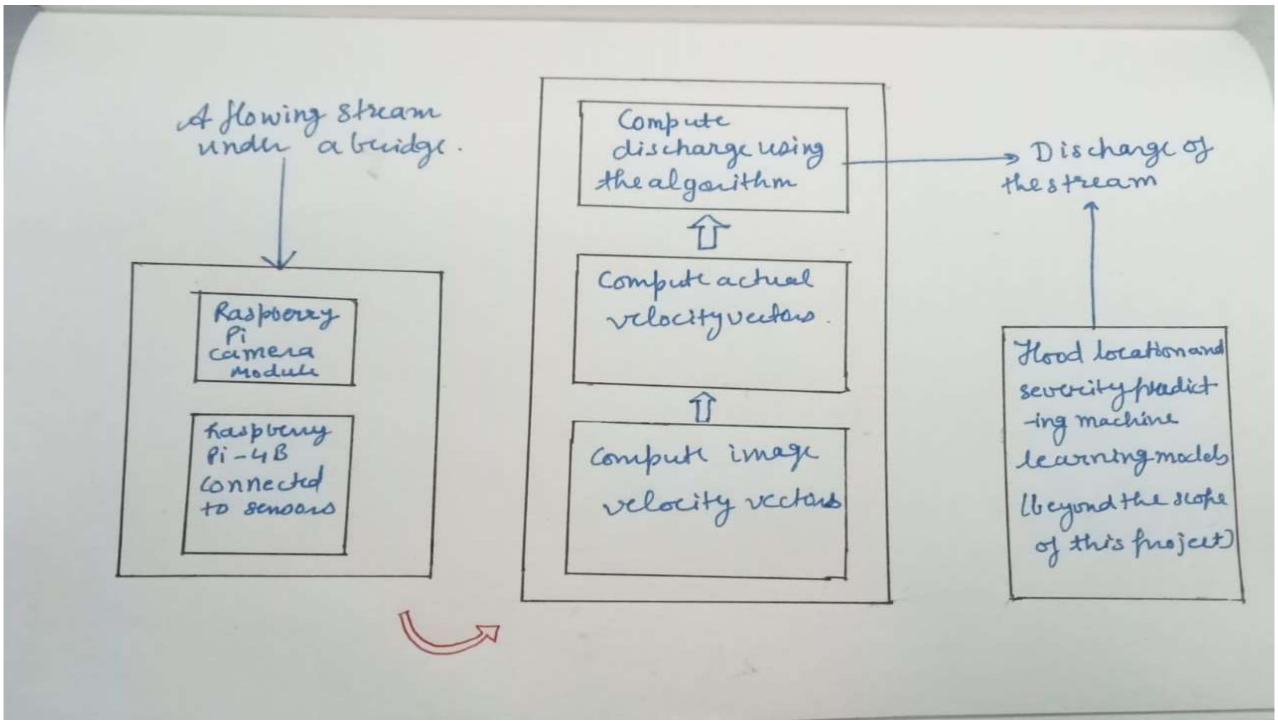


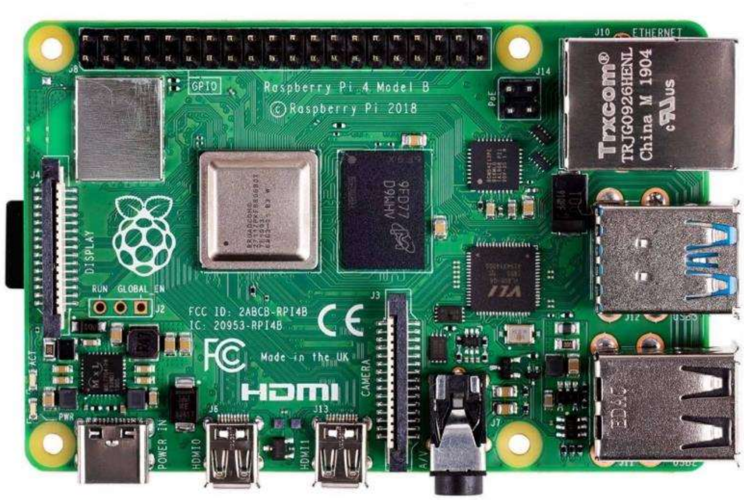
Figure 4.1 – Gives a mind map of the product architecture

The working principle and the feasibility of the design concept were thoroughly discussed in the third chapter.

4.2 System-level design

4.2.1 The components

Raspberry pi 4B(8gb) - Raspberry Pi 4 Model B is the latest product in the popular Raspberry Pi range of computers. It offers ground-breaking increases in processor speed, multimedia performance, memory, and connectivity compared to the prior-generation Raspberry Pi 3 Model B+, while retaining backwards compatibility and similar power consumption. For the end user, Raspberry Pi 4 Model B provides desktop performance comparable to entry-level x86 PC systems

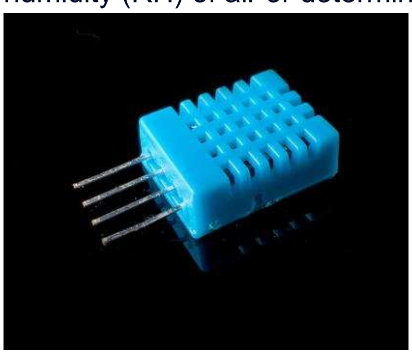


Raspberry pi Camera module - The Raspberry Pi Camera Board is a custom designed add-on module for Raspberry Pi hardware. It attaches to Raspberry Pi hardware through a custom CSI interface. The sensor has a 5 megapixel native resolution in still capture mode. In video mode it supports capture resolutions up to 1080p at 30 frames per second.

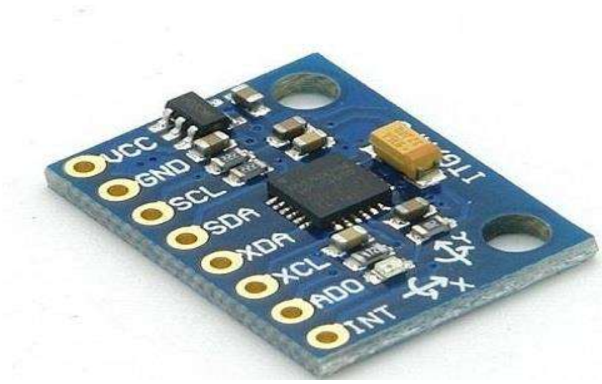
Raspberry pi Heat sink - The Raspberry Pi's processor has a built-in temperature sensor that can detect when it gets too hot. This happens when it's working hard-to-run complex software, for example. To prevent further increases in temperature, it lowers the CPU clock speed. This "throttling" action slows down the whole processor and can significantly impact the performance of whatever program is running.To avoid this we use a heat sink.

Temperature Sensor-A temperature sensor is an electronic device that measures the temperature of its environment and converts the input data into electronic data to record, monitor, or signal temperature changes.

Humidity Sensor- The humidity sensor is a device that senses, measures, and reports the relative humidity (RH) of air or determines the amount of water vapor present in gas mixture (air) or pure gas.



3 - axis Gyroscope Sensor - A gyroscope is a device that uses Earth's gravity to help determine orientation. Gyro sensors are devices that sense angular velocity which is the change in rotational angle per unit of time. Angular velocity is generally expressed in deg/s (degrees per second). This is used to align our camera and is placed on the ball and socket joint.



4.2.2 How components interact with each other

1. Raspberry Pi Boot Process:
   - Raspberry Pi is booted to the Raspberry Pi Operating System (32-bit) using a pendrive.
   - The operating system starts up.
2. VNC Viewer Connection:
   - Connect to the Raspberry Pi using a VNC viewer for remote access.
3. Installation of Libraries:
   - Install the numpy and OpenCV libraries on the Raspberry Pi to enable code execution for surface velocity and discharge calculations.
4. Sensor and Camera Connection:
   - Connect all the sensors required to collect data to the Raspberry Pi.
   - Connect the camera module to the Raspberry Pi for video capture.
5. Data Collection:
   - The camera starts collecting video data.
   - The code processes the video to calculate surface velocity and discharge.
6. Sensor Data Collection:
   - Collect data from the temperature and humidity sensors.
7. Data Storage:
   - Store the collected data in a CSV file.
8. Data Transfer to Server:
   - Transfer the CSV file containing the collected data to your server for further processing or analysis.

4.3 Detailed design

4.4.1 Electronics aspect

1. Raspberry pi Processor: The Raspberry Pi 4B is powered by a Broadcom BCM2711 quad-core ARM Cortex-A72 CPU, running at 1.5GHz. This processor provides improved speed and performance compared to earlier Raspberry Pi models.

2. Power: Power is being provided by the laptop through the usb cable.

3. Wifi Connectivity: Configuring the manual wifi by editing wpa_supplicant.

Replacing

```
network={

    ssid="YOUR_SSID"

    psk="YOUR_PASSWORD"

}
```

With our network details.

4. Resolution rate: 2592 x 1944 is the resolution of the camera module of raspberry pi 4B.

5. Field of View:The Raspberry Pi camera module V2 has a field of view(FOV) of approximately 62.2 degrees horizontally, 48.8 degrees, and 73.5 degrees diagonally.

6. Frame rate: There are different frame rate for different resolutions:

1. 1080p(1920*1080):- 30 frames per second
2. 720p(1280*720):- 60 frames per second
3. Lower resolutions:- frames can exceed upto 90 per second

7. 3-axis gyroscope sensor: Calibrates the cameras at the right location and this is mount on the ball and socket joint.

8. Other sensors: Connected to raspberry pi and used to collected data in different environmental conditions so we have good data according to different climatic and environmental conditions.

4.4.2 Software aspect

Getting the surface velocity of the flowing river,

We are using OpyFlow, an open-source python package for Optical Flow measurements. It is based on OpenCV and vtk libraries to detect Good Features to Track (GFT), calculate their displacements by the Lukas Kanade method, and interpolate them on a mesh. This method is called Feature Image Velocimetry or Feature Tracking.

Good Features to Track (built-in functionality in OpenCV)

- First, it calculates the corner quality score at every pixel using either Shi-Tomasi or Harris Corner
- Then this function performs a non-maximum suppression (the local maximums in 3 x 3 neighborhoods are retained).
- After this, all the corners with a quality score less than qualityLevel*maxx, yqualityScore(x,y) are rejected. This maxx, yqualityScore(x,y) is the best corner score. For instance, if the best corner has a quality score = 1500, and qualityLevel=0.01, then all the corners with a quality score of less than 15 are rejected.
- Now, all the remaining corners are sorted by the quality score in the descending order.
- Function throws away each corner for which there is a stronger corner at a distance less than maxDistance.

Lukas Kanade method to find Displacements

It is developed by Bruce D. Lucas and Takeo Kanade. It has 3 assumptions:

I. brightness constancy:

   the value of pixel is same for a point I(x,y,t) and I(x',y',t+1)

II. small motion:

   the motion vector for a point is small

III. small region move together:

   The pixel's neighbors have the same (u,v)

Algorithm steps:

Input: I1, I2, assuming image size = 128×128

(I1 is the image at time t, I2 is the image at time t+1)

Output: motion vector V = (Vx, Vy)

I. Calculate the partial derivatives of the image I1 (Ix, Iy, It) with respect to position x, y and time t. At the edge of the image I1, Ix, Iy and It can be set as 0, because I1(i-1, j), I1(i+1, j), I1(i, j-1), I2(i, j+1) might not exist.

$$Ix(i, j) = I1(i+1, j) - I1(i-1, j)$$

$$Iy(i, j) = I1(i, j+1) - I2(i, j-1)$$

$$It(i, j) = I2(i, j) - I1(i, j)$$

II. For every pixel in I1, take location (i, j) as an example, within a window centered at I1(i, j), assuming the window size is 5×5, We have the corresponding 5×5 windows in Ix, Iy, It matrixes. For pixel q1=I1(i-2,j-2), q2= I1(i-2,j-1), ..., q25= I1(i+2,j+2) in the 5×5 window, we have the equation:

$$\begin{aligned} I_x(q_1)V_x + I_y(q_1)V_y &= -I_t(q_1) \\ I_x(q_2)V_x + I_y(q_2)V_y &= -I_t(q_2) \\ &\vdots \\ I_x(q_n)V_x + I_y(q_n)V_y &= -I_t(q_n) \end{aligned}$$

These equations can be written in matrix form Av = b where,

$$A = \begin{bmatrix} I_x(q_1) & I_y(q_1) \\ I_x(q_2) & I_y(q_2) \\ \vdots & \vdots \\ I_x(q_n) & I_y(q_n) \end{bmatrix}, \quad v = \begin{bmatrix} V_x \\ V_y \end{bmatrix}, \quad \text{and} \quad b = \begin{bmatrix} -I_t(q_1) \\ -I_t(q_2) \\ \vdots \\ -I_t(q_n) \end{bmatrix}$$

III. The motion vector $V = (V_x, V_y) = (A^T A)-1\ A^T b$

Getting the Volumetric Flow from surface velocities

For this, we implemented the method in [5] and wrote our own code. We used NumPy and pandas libraries.

The article provides a methodology for estimating the discharge starting from the monitoring of surface flow velocity, u_{surf}. The approach is based on the entropy theory and involves the actual location of maximum flow velocity, u_{max}, which may occur below the water surface (dip phenomena), affecting the shape of velocity profile. The method identifies the two-dimensional velocity distribution in the cross-sectional flow area, just sampling u_{surf} and applying an iterative procedure to estimate both the dip and u_{max}.

4.4.3 Mechanical Aspects

Manufacturing of Flume

Material Used: Acrylic Sheets and Resins (Adhesive and Hardener)

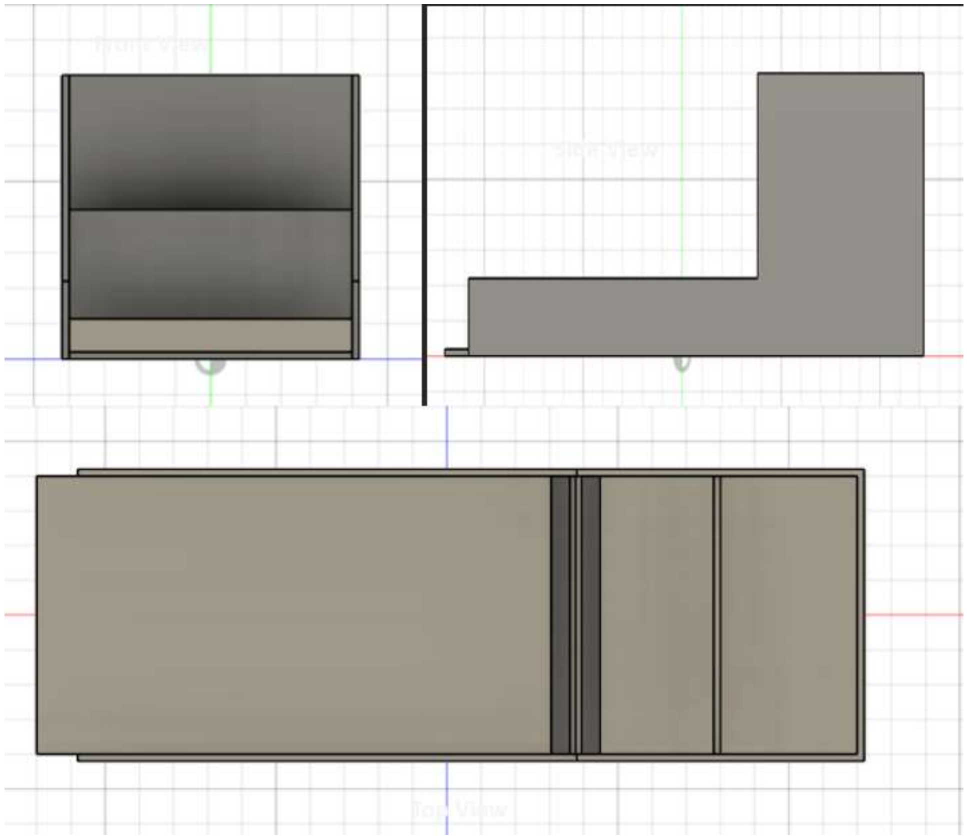
Process of Manufacturing:

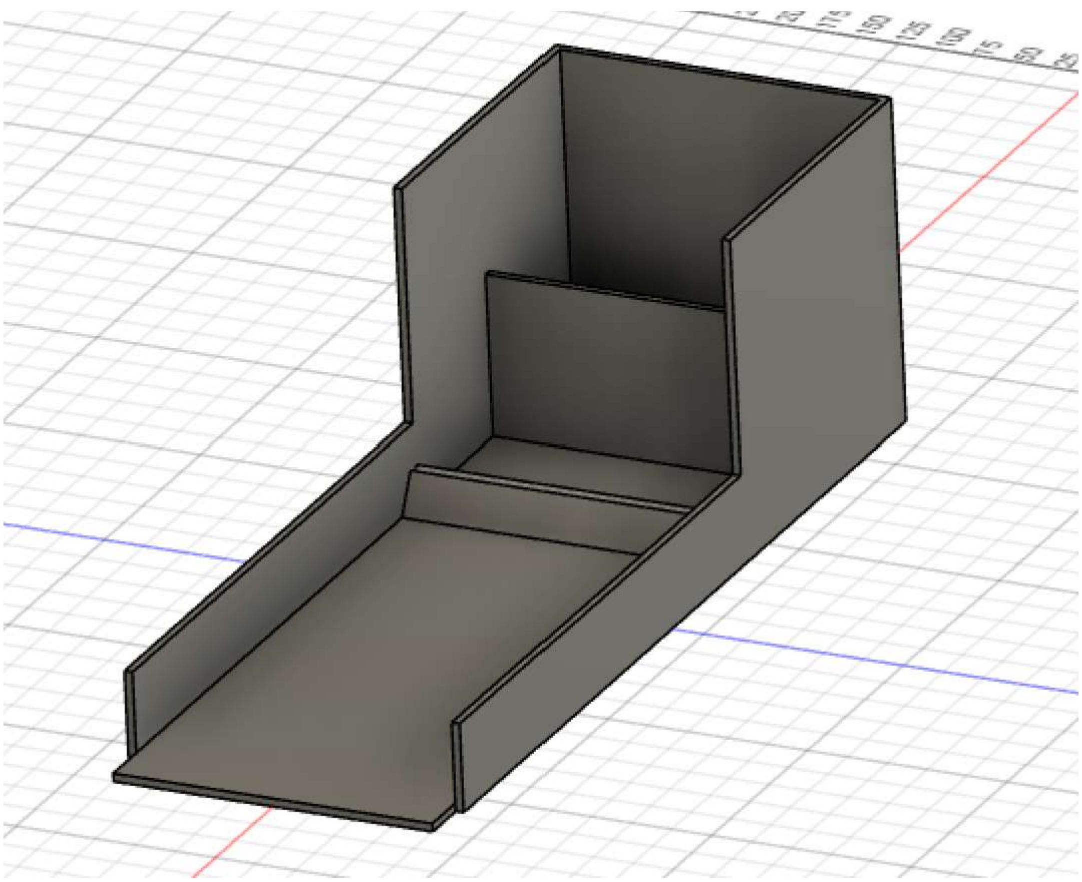
There are overall 9 parts of the of the acrylic sheet cuts which have been assembled to make the flume ready.

i. Base: For the flow of water
ii. Side walls: It's made up of two parts, one rectangular bottom and one upper part which have been sticked using the adhesive. As two side walls are there, so 4 parts of acrylic cuts.
iii. Middle sloped walls: Its 2 acrylic cuts (sticked together) which have been sloped at around 60 degrees for smooth and uniform flow of water.
iv. Storage Walls: It has been made for collecting the water and maintaining some potential for flow.
v. Back Wall: This has been provided so that water is stored properly and do not flow outside.

Diagrams:

[5][1] T. Moramarco, S. Barbetta, and A. Tarpanelli, "From Surface Flow Velocity Measurements to Discharge Assessment by the Entropy Theory," Water, vol. 9, no. 2, p. 120, Feb. 2017, doi: https://doi.org/10.3390/w9020120.





Working of the flume:

Water is filled in a bucket. From the bucket the motor pump is driving the water to the flume storage through the pipe. When the storage of flume is filled, water flows down to the bucket through the base of flume. This cycle gets repeated until the power is supplied to the motor pump. This basically demonstrates the river flow of water.

References

[1] T. Moramarco, S. Barbetta, and A. Tarpanelli, “From Surface Flow Velocity Measurements to Discharge Assessment by the Entropy Theory,” Water, vol. 9, no. 2, p. 120, Feb. 2017, doi: https://doi.org/10.3390/w9020120.

Chapter 5

Fabrication and Assembly

5.1 Bill of materials

	Components	Qnt.	Price each	Amount
1.	Submersible pump	1	1300	1300
2.	Pipe and Adhesive	2	-	576
3.	Mini Spirit level	1	240	240
4.	SD card	1	370	370
5.	Raspberry Pi, 8GB	1	20060	20060
6.	Night Stereo Camera	2	1829	3658
7.	3-axis Gyroscope	2	177	354
8.	Heat-Sink	1	885	885
9.	Sensors	3	167	501
10.	Miscellaneous	-	-	2167
	Grand Total			30,111

5.2 Component Descriptions

The project does not have a lot of mechanical and electrical components. A description of two electronic components is given.

ESP 32 CAM kit, source: [1]

Technical Details

Brand	RoboThings
Manufacturer	TZT
Product Dimensions	4 x 2.7 x 2 cm
Hard Drive Interface	USB
Hardware Interface	Bluetooth, USB
Compatible Devices	Desktop
Mounting Hardware	USB to TTL, CAM, ESP Board
Number of items	3
Wireless Type	Bluetooth
Data Link Protocol	Bluetooth, USB
Manufacturer	TZT
Country of Origin	China

In this chapter,

5.1 Bill of materials
5.2 Component Descriptions
5.3 Limitations and challenges
5.4 Scheduling plan
5.5 Final conclusions

Battery details, source [2]

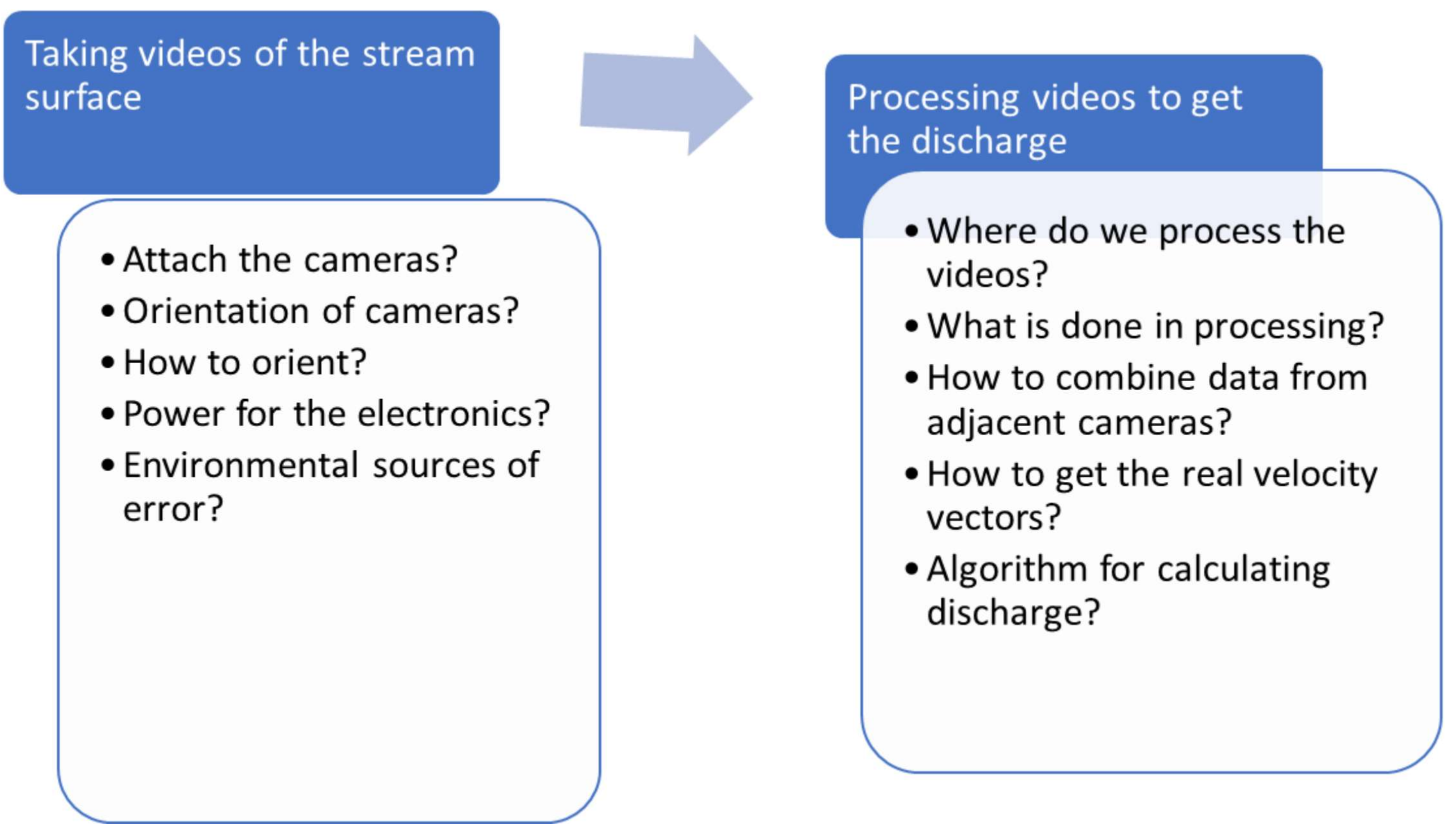
Model	5*AA 4.8V 3500mAh Rechargeable Battery
Type	AA
Material	Nickel-Cadmium
Pin	02
Diameter	14.1mm
Length	50mm
Current Capacity	3500mAh
Voltage	6V

The project does not require manufacturing processes for any of the components. Hence, this section is excluded from this chapter.

Similarly, the project does not require much assembly. It only requires calibration of the cameras, which was discussed in detail in the third chapter.

5.3 Limitations and Challenges

In the third chapter of the report, the group outlined how they attempted to create an overview of the project and then removed parts of it to make it feasible. As a result, the challenges and limitations associated with the project can be divided into two categories. The mind map from the third chapter may be used for reference.



I. Challenges and limitations of the "ideal" project.

a. Issues related to taking videos of the stream surface, such as:

i. The resolution of the camera, which is attached to the bridge and far from the stream, could greatly affect the video quality and consequently result in inaccurate calculations.

ii. Difficulty in accessing the cameras under the bridge for installation and maintenance.

iii. Dependence on manual effort for orientation of the cameras, or the need for complex image processing and additional mechanical components and microcontroller if an automatic alignment method is used.

iv. Regular maintenance requirements for power sources such as small turbines or vibration energy from the bridge. The use of solar panels may be troublesome as they may be damaged by children throwing stones at them.

v. Possible unreliable videos of the cameras during actual floods due to the errors caused by the vibration of the bridge.

b. Challenges related to processing videos to obtain discharge values:

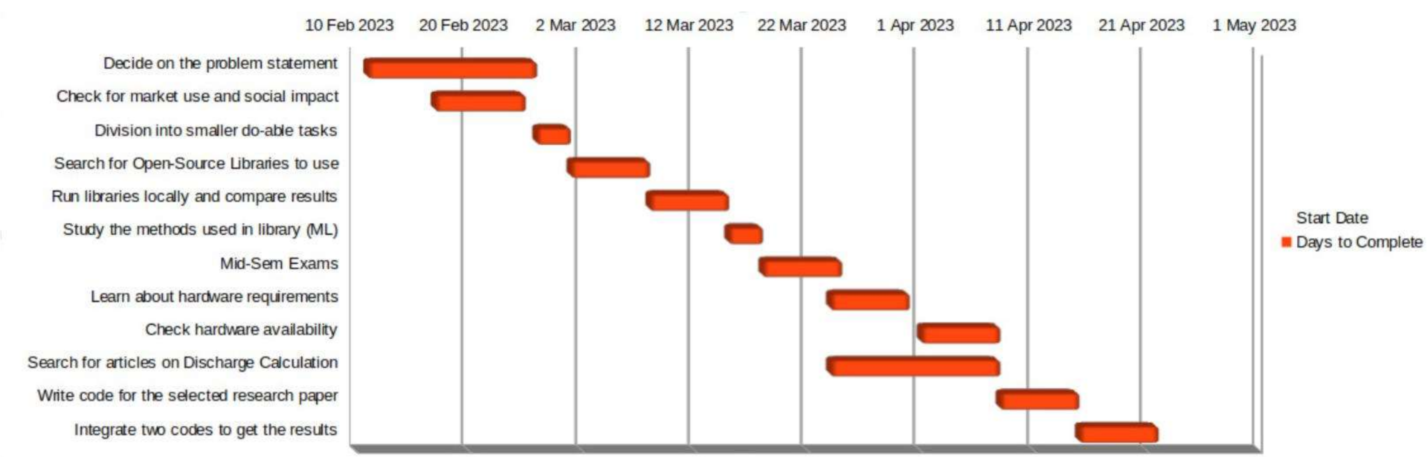
i. The computational expense of the entire process.

ii. Errors in calculating the distance of the camera from the stream when using distance sensors, or when using stereovision due to inaccuracies caused by differences in light reflection from the surface of the stream in images from different cameras.

iii. The algorithm used to calculate the discharge also has its own errors.

II. The challenges and limitations of the group's project were discussed in detail in Chapter 3. The major limitation of our project is the exclusion of the error associated with calculating image velocity vectors when using lights on the stream surface to improve visibility, except for those decisions that were taken by choice.

5.4 Scheduling plan



5.5 Final Conclusions

The main purpose of the project was to demonstrate, that it was possible to calculate the discharge of a stream from videos of the stream surface using computer vision techniques. When it is scaled down to the lab level, the mechanical and electronic aspects of the project are straightforward. The three most crucial issues are (i) how the cameras come to a correct alignment, (ii) how we measure the distance from the camera to the stream surface, and (iii) how we determine the velocity vectors on the surface of the stream.

This project attempts to address these issues by making a lab-scale prototype.

References

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2. https://linuxhint.com/boot-raspberry-pi-from-usb/
3. https://linuxhint.com/install-numpy-raspberry-pi/
4. https://www.realvnc.com/en/blog/how-to-setup-vnc-connect-raspberry-pi/