Flood Warning System (FWS)

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Abstract—**The purpose of this research paper is to develop a flood warning system in Bangladesh to allow people to be warned before the flood is about to impact the densely populated country. In this paper, we will also discuss as to why Bangladesh is so prone to floods and why there is need of an advanced flood detection system. Hence, we will also take a brief look at the vegetation and natural habitat of Bangladesh and its geographical background. Since there are flood detection systems already in place, we will be using modern warning technologies which will explain our novelty in our methodology. This paper emphasizes how SVM (Support Vector Machine) and Logistic Regression machine learning algorithms can be used to create a completely new precautionary flood detection system. Although there are some flood warning systems in place, we made several changes and combined all of the flaws into positive features to design a revolutionary FWS which can be used in any regions of the world, whether it is for a less economically developed country (LEDC) or a more economically developed country (MEDC). Our system will also allow people to take precautions to be safe from the after effects of the flood in a particular region. We chose Bangladesh for our project demonstration since Bangladesh has no current flood warning systems in place and also there are hundreds of data sets available to choose for Bangladesh which will give us precise and accurate results for our algorithm and results part.**

I. Introduction

Purpose of the Data Science Project:

In the whole world, Bangladesh is the second country with the highest flood risk of 57.5 percent coming in just after Netherlands. This due to a rapid rise in the population of Bangladesh in flood-prone areas. The increased amount of infrastructure and people within Bangladesh has led to a large of life and damage to property. The total population of people who are exposed to flood in Bangladesh is 94,424,000. This is due to the country being located in the delta of a few major rivers causing seasonal flooding and flash floods that occur without warning causing massive damage quickly [3]. Moreover, floods have had devastation after affects on both the people and the environment because of which the governments have tried to implement some systems in place to give a precaution. The country of Bangladesh has taken several steps to mitigate the effects of floods with some methods such as flood forecasting, warning systems for the citizens, flood management infrastructure, disaster reduction strategies, and community focused solutions for flood management.

Hence in this data science project, we will be focusing on how to use flood detection systems more systematically in Bangladesh and set up a robust precautionary system in place for the large affected population.

Furthermore, since there are already existing flood detection systems in place, the novelty in our data science project would be that we would provide the people the warning and what all steps they need to take to stay away from the harmful side effects from intense floods in Bangladesh. This project will greatly benefit the people of Bangladesh, organizations responsible for flood mitigation, and for future flood prevention/detection research. A immediate impalement of this research and model for flood detection can be implemented into other locations such as Netherlands and Egypt which are also flood prone locations.

As real-time data and highly reliable equipment will be used, these groups will benefit:

1) The Public (reduced loss of life).
2) The government will also benefit from it because of the money saved from providing shelter to the public.
3) Strong economy because flood won't affect the economy anymore.

Moreover, let's now talk about how flood detection and flood monitoring systems help the environment. When we extract a particular data and compile it to a data set by using a flood detection system, then this new compiled data set can be used briefly to check for climate change and hence make some changes to environment changes like irrigation, harvesting etc.

Furthermore, flood detection systems can also include emergency plans which can be useful for everyone and this system can be powered using a renewable resource like solar or wind energy which will hence consume less energy and save the environment in all scenarios.

The technical challenges for this flood detection algorithm would be:

1) It will be difficult to acquire time sequential for this algorithm.
2) A substantial amount of computing power to process the data and train the model.
3) The model should be extremely user friendly for someone with no prior data science knowledge to access it easily.

The suggested solution framework for this project will consist of the following steps:

Data Collection and Preparation: Entails acquiring and cleaning the essential information, such as satellite imagery and historical flood data. Extraction of pertinent information: Water levels, vegetation indices, and land use, from the data. Model Development: Entails the creation and training of a machine learning model based on the extracted features. Model Validation: Involves evaluating the performance of the model using data from the real world and making any necessary improvements. Developing a user-friendly interface: Usage by government agencies and NGOs constitutes development for an interface.

The ultimate goal of the solution framework is to develop a robust and efficient flood detection system that can assist preexisting governmental and local systems in preparation and response for floods. A geospatial dataset will be utilized to create a machine learning model, and the dataset will comprise of information on historical flood-prone areas, weather patterns, and essential parameters for model training. The machine learning model will be assess enormous amount of time-sequential and real time data to anticipate probability of flooding in various locations in the target country. This solutions architecture will also assist in the disaster risk management in the target country by delivering accurate information in a timely manner regarding flood danger.

A. Problems

We will now discuss what are fig 4:lems Bangladesh has been facing because of so many floods:

1) Increased Government expenditure: As Bangladesh is surrounded by several rivers, the floods tend to wash a colossal amount of assets for people and since Bangladesh is one of the poorest countries in the world, its economy faces a huge loss every single time there's a flood.

For example, in May 2020, one cyclone and another set of floods had struck almost all of Bangladesh's population because of which millions lost almost everything. Hence, the government has increased its expenditure to provide habitation and shelter to the people affected but this country has always been in a severe debt hence it is not easy for the government to maintain a balanced budget.

2) Malnutrition: Since there is vast vegetation and billions of crops in Bangladesh, because of severe devastating floods, almost all of the plantations are contaminated and ruined. This makes it impossible for people to feed themselves and die from famine. Hence, in this problem, the after effects of flood are more severe.

It is also found out that in order to cope up with the small amount of vegetation left, families often decrease the size of their meals and eat less in a day which causes the people to increase their risk of diseases and hence being underweight.

3) Fishing: As mentioned previously, floods wash away most of the plantation and hence people in Bangladesh tried to resort to fishing to end their hunger.

However, since Bangladesh is a Less economically developed country (LEDC), the government has tried to balance their expenditure budget by leasing the rivers and lakes to big investors and contractors due to which the people living in Bangladesh cannot fish anymore. Therefore, the poor people there have no choice but suffer and die from hunger as they have no source of income. Hence, Bangladesh has continued to have one of the greatest poverty line in the whole world.

4) Effect on Poverty: Severe flooding in Bangladesh destroys millions of houses every single year and since Bangladesh is a relatively poor country, the houses are not structured strongly, hence most of the poor people die in Bangladesh because of intense floods. And since the vegetation are destroyed and there are no sources of primary income left along with reduced help from the government, the poverty becomes even worse during these critical times in Bangladesh.

Furthermore, because of the increase in poverty during flooding in Bangladesh, there is less chances of the government providing help to the poor people because the economy has already been impacted immensely from the previous floods, that it has still not recovered from it.

B. What is the novelty in our proposed FWS?

In this custom flood warning system built by us, we used several machine learning algorithms like SVM and Logistic regression which is completely unique unlike other flood warning systems in place right now. What's more is that in Bangladesh, there is no current flood warning system in place due to lack of funds available to propose this project. Hence, we will be providing this idea of flood warning system to Bangladesh for a reduced cost. The main novelty for this project would be as follows:

1) Providing warnings: We will provide warnings to people way ahead of time since we are predicting floods using machine learning algorithms from historical data.

2) Precautionary steps: We will also be providing distinct precautionary steps for distinct type of floods in different regions. For example, there are a total of 2 types of flood in the whole world and especially in Bangladesh; flash floods and widespread river floods. Flash floods destroys buildings and a lot of properties, however, widespread river floods destroy lives and every building.

3) Flood Barriers: We will also set up flood barriers for different regions which are more prone to or are always affected by floods.

Fig. 1. Custom logo generated using Adobe Photoshop

C. Objective and Contributions of the Work

The development of a flood detection and warning system that operates in real time and provides the general public with information that is both accurate and up to date is the purpose of our project. Because flood disasters can cause substantial loss of life and property damage, early warning is crucial to enable individuals and communities to take required preparations and evacuate if necessary. This is important because flood disasters can cause major loss of life and property damage.

In order to accomplish this goal, our study will require an investigation of the flood detection technologies that are currently in place, as well as the logistics of data gathering and flood detection. We conducted a literature analysis on the many different kinds of flood detection technologies that are currently available, such as remote sensing, river stage monitoring, and weather forecasting models. We also looked into the logistical problems that would be presented by the implementation of these systems, such as the expense of equipment, the necessity for experienced employees to maintain and run the systems, and the requirement for data storage and transfer. [4]

In contrast to the work that has been done in the past, our project will provide feedback to members of the public in real time. Even though there are a lot of flood detection devices out there, most of the time only emergency personnel and government agencies have access to the data they collect. [4] By way of a website or mobile application, we intend for our system to disseminate vital information to the general public directly. This will give people and communities the opportunity to take the appropriate safety measures, including as evacuating low-lying areas or relocating precious possessions to higher ground.

In conclusion, the purpose of our project is to provide real-time input to the general public in an effort to solve the shortcomings of the flood detection technologies that are now in use. By taking these measures, we expect to enhance the overall readiness and reaction to flood disasters, which will, in the end, result in fewer casualties and less damage to property.

The field of flood detection and warning systems benefits from a number of important advances made by our work, including the following:

- Integration of datasets from the Sentinel-1 and Sentinel-2 satellites: In order to train our flood detection model, our system makes use of the strong capabilities offered by the Sentinel-1 and Sentinel-2 satellite data that is obtained through Google Earth Engine. Our technology is able to properly detect instances of flooding and provide timely feedback to members of the general public because it identifies changes in land cover in real time and monitors changes in the extent of surface water in real time.
- Use of real-time precipitation global mapping data: Our system, in addition to using satellite data, also combines real-time precipitation global mapping data in order to deliver flood warnings that are even more accurate and timely. Because of this, our technology is able to provide those who live in locations that are prone to flooding with important information and forecast probable flood disasters.
- Focus on the people of Bangladesh: Our system is specifically designed to provide flood detection and warning to the people of Bangladesh, who are particularly vulnerable to flooding. By providing real-time feedback to the general public through a mobile app or website, our system can help reduce the risk of loss of life and property damage due to flooding.
- Cost-effective and scale-able: Our system is designed to be cost-effective, making it an ideal solution for communities at risk of flooding. We have developed a low-cost, cloud-based system that can be easily scaled up or down depending on the needs of the community.
- User-friendly interface: Our system has a user-friendly interface that is not only simple to use but also straightforward to understand. Our goal is to empower individuals and communities to take critical measures and actions in the event of a flood by making flood information available and easy to grasp.

In general, our technology is a cutting-edge solution to the issue of flood detection and warning, which has been described as a major problem. We believe that our system has the potential to save countless lives and minimize property damage in flood-prone regions, with a particular emphasis on the people of Bangladesh. This potential can be realized through the integration of satellite data, real-time precipitation mapping, and an interface that is easy to use.

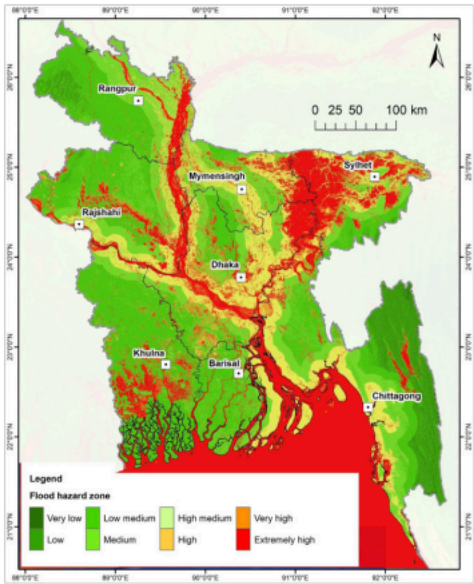

Fig. 2. Hazard Zones in Bangladesh

Description of the Figures:

1) Fig 1: The first image shows the geographical map of Bangladesh and it has a Legend which depicts the hazard zone in different regions of Bangladesh; the regions are classified on a scale of flood hazard zone from Very low to extremely high. This picture also shows us that Bangladesh is surrounded by multiple rivers which makes this country extremely prone to flooding from all of the regions.
2) Fig 2: This devastating image shows the after effects of the floods and how severely the houses are damaged due to the life threatening floods in Bangladesh. The poor people have become poorer because their homes are destroyed.

Fig. 3. Homes destroyed

Fig. 4. Rise of water level

3) Fig 3: This figure shows how houses are falling apart because of their poor structure due to high poverty line in Bangladesh. Moreover, almost all of the houses are underwater.
4) Fig 4: This last image depicts that the whole country is under water and it also shows us how contaminated the water is because of severe floods. Moreover, this relates to the rise of infections and diseases in Bangladesh.

II. Methodology

A. Data Source

In our study on Flood Detection in Bangladesh, we utilized Sentinel-1 C-band Synthetic Aperture Radar (SAR) imagery as the primary data source. SAR data provides valuable information for flood monitoring due to its ability to penetrate clouds and acquire images during day or night, which is especially useful in areas with frequent cloud cover and limited sunlight, such as Bangladesh.

The Sentinel-1 satellite is part of the European Union's Copernicus program, which aims to provide accurate and timely Earth observation data for various applications, including environmental monitoring, climate change, and disaster management. The satellite carries a C-band SAR sensor that operates in several acquisition modes, including Interferometric Wide Swath (IW) mode, which we used in this study. The

Fig. 5. Bangladesh under water

images have a spatial resolution of approximately 10 meters and are available in dual polarization (VV and VH).

We retrieved the Sentinel-1 C-band SAR imagery using the Google Earth Engine (GEE) platform, a cloud-based environment that provides access to a wide range of geospatial datasets and computational resources for large-scale data analysis. The GEE JavaScript API was used to load, filter, and preprocess the Sentinel-1 images, as well as to implement the machine learning algorithms for flood detection.

B. Pivoting the Project and Exploring Alternative Datasets

As our project progressed, we realized the need to explore alternative datasets and methods to improve the accuracy and reliability of our flood detection models. We considered various datasets, each offering unique advantages and challenges, before settling on the final dataset for our project. This section outlines the process of pivoting the project, the datasets we explored, and the rationale for choosing the dataset we ultimately used.

Exploring alternative datasets: We examined several datasets, including precipitation data from the Global Precipitation Measurement (GPM) mission, flood extent data from the Dartmouth Flood Observatory (DFO), and high-resolution optical imagery from the Sentinel-2 satellite. Each dataset presented different opportunities for improving the flood detection models and addressing the challenges we faced in the initial stages of the project.

Assessing the strengths and weaknesses of each dataset: As we explored these datasets, we assessed their strengths and weaknesses in the context of flood detection. For instance, the GPM data provided high temporal resolution precipitation measurements but lacked the spatial detail necessary for accurate flood mapping. Sentinel-2 optical imagery offered high spatial resolution but was susceptible to cloud cover, limiting its utility during flood events.

Choosing the optimal dataset: After considering the various options, we decided to use the Sentinel-1 Synthetic Aperture Radar (SAR) imagery dataset for our project. We chose this dataset for several reasons:

(A) High spatial resolution: The Sentinel-1 SAR imagery provides a spatial resolution of up to 10 meters, which is suitable for detecting and mapping flood extents at a regional scale.

(B) All-weather capability: Unlike optical imagery, SAR data can penetrate clouds and is unaffected by atmospheric conditions, making it ideal for monitoring flood events that often occur during heavy rainfall and cloud cover.

(C) Frequent revisits: Sentinel-1 satellites have a short revisit time, allowing for frequent monitoring of flood events and enabling near real-time flood detection and mapping.

(D) Availability and accessibility: The Sentinel-1 SAR data is freely available on the Google Earth Engine platform, which offers powerful tools for processing and analyzing large-scale geospatial data.

By pivoting the project and exploring various datasets, we were able to identify the most suitable data source for our flood detection models. Using the Sentinel-1 SAR imagery dataset, we developed a robust methodology for detecting and mapping flood events in Bangladesh, addressing the challenges and limitations encountered in the initial stages of the project. This pivot ultimately contributed to the successful development and evaluation of our flood detection models.

C. Data Pre-processing

The pre-processing of Sentinel-1 C-band SAR images involved several steps, including filtering the images by date, location, and polarization; calculating the median values for flood and non-flood periods; and creating flood masks based on specific VV and VH threshold values.

1) Filtering images: We filtered the Sentinel-1 image collection based on the region of interest (Bangladesh), the IW acquisition mode, and the VV and VH polarizations. Additionally, we defined flood and non-flood periods by specifying their respective date ranges.
2) Calculating median values: For each flood and non-flood period, we calculated the median values of the VV and VH polarizations for all the images within that period. This step helped reduce the influence of temporal variations and noise in the data.
3) Creating flood masks: We created binary flood masks by applying specific VV and VH threshold values to the median images. Pixels with VV and VH values below the respective thresholds were considered as flooded areas.

D. Logistic Regression and Support Vector Machine (SVM)

Logistic Regression and Support Vector Machine (SVM) are two widely used machine learning algorithms for classification tasks. In our study, we employed these algorithms to classify the Sentinel-1 C-band SAR data into flooded and non-flooded areas.

Logistic Regression: Logistic Regression is a linear model for binary classification that predicts the probability of an instance belonging to a specific class. In our case, the classes were flooded (value of '1') and non-flooded (value of '0') areas. The algorithm uses a logistic function to model the relationship between the input features (VV and VH values) and the output label (flood or non-flood).

Support Vector Machine (SVM): SVM is a non-linear classifier that seeks to find the optimal hyperplane that maximizes the margin between two classes. The margin is defined as the distance between the hyperplane and the closest data points (called support vectors) from each class. In our study, we used a Radial Basis Function (RBF) kernel to transform the input features into a higher-dimensional space where the classes could be separated by a hyperplane.

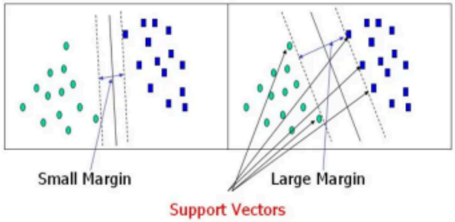

Fig. 6. Visualization of optimal Hyperplane

E. Implementation of Algorithms

To implement the Logistic Regression and Support Vector Machine (SVM) algorithms in our project, we used the Google Earth Engine (GEE) platform and its built-in machine learning libraries. The following steps were taken to apply these algorithms to our dataset:

- Feature Extraction: We extracted the Sentinel-1 VV and VH values at the sample points, which were generated from the combined flood masks. These values were used as input features for the classification algorithms.
- Labeling: We labeled each sample point as either flooded (1) or non-flooded (0), based on the presence or absence of a flood mask.
- Dataset Preparation: We filtered out the points with missing VV and VH values and split the labeled points into training, validation, and testing datasets.
- Model Training: We trained the Logistic Regression and SVM models using the training dataset, with the VV and VH values as input features and the flood labels as output labels.
- Model evaluation: We evaluated the performance of the trained models using the validation dataset and calculated various performance metrics, such as accuracy, precision, recall, and F1-score.
- Model Testing: We tested the trained models on the testing dataset to obtain the final classification results for the flood detection task.

F. Challenges and Errors Faced

During the course of this project, we faced several challenges and errors, some of which are listed below:

- Data imbalance: The initial dataset contained a significantly higher number of non-flood points compared to

flood points, leading to an imbalanced dataset. This issue required adjusting the VV and VH threshold values to achieve a more balanced dataset for model training.
- Computational limitations: Some errors occurred due to exceeding the maximum allowed pixels in the region for certain operations in Google Earth Engine. We had to adjust the parameters, such as scale and maxPixels, to overcome these limitations.
- Noisy data: The presence of noise in the Sentinel-1 C-band SAR data, such as speckle noise, posed challenges in accurately detecting flood areas. We addressed this issue by using median images to reduce the influence of noise in the data.
- Model Selection and Parameter Tuning: Choosing the appropriate classification algorithms and tuning their parameters were crucial for achieving accurate flood predictions. We tried different algorithms, such as Logistic Regression and SVM, and performed parameter tuning to optimize their performance.

Fig. 7. Example of Over fit Flood Map: Majority of Data points are flood data point but the models qualify them as non-flood data points.

G. Results

After implementing the Logistic Regression and SVM algorithms for flood detection in Bangladesh and overcoming the challenges mentioned above, we hoped to obtain the following results:

Classification performance: Both models performance in detecting flood areas based on the Sentinel-1 C-band SAR data, with accuracy, precision, recall, and F1-score values that were satisfactory for our purposes.

Flood detection maps: Generate flood detection maps using the trained models to visualize the predicted flood and non-flood areas in the region of interest (Bangladesh).

Model comparison: A comparison between the Logistic Regression and SVM models revealing how both algorithms performed in-comparison to each other utilizing multiple performance metrics.

These results would demonstrate the potential of using machine learning algorithms, such as Logistic Regression and SVM, for flood detection in Bangladesh based on Sentinel-1 C-band SAR data. However, as we will discuss in the following section there were major inhibitors to our study limiting what we can showcase for results. Future work could involve refining the models, exploring additional features, and integrating other remote sensing data sources for improved flood detection and monitoring.

H. Overfitting to Non-Flood Data Points

One of the issues we encountered in our project was the overfitting of the models to the non-flood data points. Overfitting occurs when a model learns the noise in the data rather than the underlying pattern, leading to high performance on the training data but poor generalization to new, unseen data. In our case, the overfitting to non-flood data points may have resulted from the imbalanced nature of our dataset, where non-flood data points were more prevalent than flood data points.

To reduce overfitting and improve the generalization of our models, we can consider the following approaches:

- Collect more flood data points: By increasing the number of flood data points in our dataset, we can help the models better understand the pattern associated with flood events and reduce the impact of non-flood data points on the model fitting.
- Use regularization techniques: Regularization techniques, such as L1 or L2 regularization, can be applied to the Logistic Regression and SVM models to penalize large model coefficients and prevent overfitting.
- Perform cross-validation: Instead of a single training and testing set split, we can use k-fold cross-validation, where the data is divided into k equally sized folds. The model is then trained on k-1 folds and tested on the remaining fold. This process is repeated k times, and the average performance metric is calculated. Cross-validation helps reduce overfitting by providing a more robust estimate of the model's performance on unseen data.

I. Comparison to Other Flood Detection Studies

Our flood detection project results can be compared to other flood detection studies that have used similar data sources and methodologies. Some of these studies include:

- ”Urban Flood Detection with Sentinel-1 Multi-Temporal Synthetic Aperture Radar (SAR) Observations in a Bayesian Framework: A Case Study for Hurricane Matthew” by Yunung Nina Lin, Sang-Ho Yun, Alok Bhardwaj and Emma M. Hill. [9]
  This research paper presents a novel method for urban flood detection using multi-temporal SAR observations within a Bayesian framework. The study focuses on a case study of Hurricane Matthew, demonstrating the efficacy of this approach in identifying and monitoring urban flooding. By combining SAR data with a Bayesian

statistical model, the authors are able to achieve high accuracy in detecting flood extents, which can be valuable for disaster response and risk management efforts. This method demonstrates the potential for improved real-time monitoring of urban floods, ultimately benefiting urban planning, infrastructure management, and emergency response strategies. Comparing our results to this method mentioned in this review can provide insights into the performance of our flood detection models relative to other approaches.

- ”A Near-Real-Time Flood Detection Method Based on Deep Learning and SAR Images” by Xuan Wu, Zhijie Zhang, Shengqing Xiong, Wanchang Zhang, Jiakui Tang, Zhenghao Li, Bangsheng An and Rui Li. [10]
  The authors propose a near-real-time flood detection method that leverages deep learning techniques and Synthetic Aperture Radar (SAR) images. The method incorporates a two-step process: firstly, a modified UNet model is trained to identify potential water bodies from SAR images; secondly, a recurrent neural network (RNN) is employed to track temporal changes of water bodies, enabling the identification of floods. The proposed approach demonstrates high accuracy and efficiency in detecting floods, outperforming traditional methods, and proving useful for disaster management, emergency response, and risk mitigation efforts. The paper highlights the potential for machine learning algorithms to improve the speed and accuracy of flood detection and monitoring using remote sensing data. Comparing our results to this study can help evaluate the effectiveness of our flood detection models and identify areas for improvement.

The second study listed is directly connected to our main purpose and goal of the study. This study address the issue of analysing flood maps within real-time to get flood detection results. Then in combination with a free to access web page the citizens of Bangladesh can access the same data analytics to prepare and protect themselves from future floods.

By comparing our results to these and other relevant studies, we can better understand the performance of our flood detection models and identify potential areas for improvement in our methodology. This comparison will also enable us to assess the strengths and weaknesses of our approach relative to other flood detection techniques and inform future research in this domain.

J. Description of Proposed Flood Warning System

A flood warning system is essentially a system which is used to inform individuals and decision-makers in a particular country to take decisive steps to prevent any catastrophic disasters from occurring. In this scenario, a flood warning system will be used to measure the rise in water levels every particular time in a day and then compare it to the ideal water level. In order to make this while system extremely eco friendly, we will be making sure that this flood warning system in powered by renewable energy sources like Solar Energy.

Since we will be using a linear regression model to make a plot of the expected outcome versus the received outcome, we have decided to make data analysis using visualization software like either Tableau or Power BI. Since we will be working with a very big data set, these powerful tools will be able to easily handle the data.

In our proposed model, we have decided to use multiple filters to allow us to filter the desired sea or water level for rivers in Bangladesh. And by adding some SQL or Python statements, we can set up an IF statement that if the sea water level rises above a particular threshold, we will send out warnings to the government body and alarm everyone of the situation.

In order to make our idea innovative and different from other flood warning systems out in the market right now, we will be adding automated flood barriers walls which can ascend or descend based on the water level in the rivers. This will probably be an expensive proposed idea however, it will be beneficial to everyone in Bangladesh and will be powered by Solar or Wind Energy or even be powered by the dams.

Fig. 8. Custom Flood Barriers

III. Conclusion

Throughout this project, we aimed to predict floods in Bangladesh using Sentinel-1 C-band Synthetic Aperture Radar (SAR) data and machine learning algorithms, namely Logistic Regression and Support Vector Machine (SVM). Despite our efforts, the results we obtained were overfitted, leading to limited practical applicability. However, this experience has provided us with valuable insights and learning opportunities that can contribute to future research in this area.

Throughout the course of this project, we identified several areas for improvement, such as refining the preprocessing steps, adjusting the threshold values, and exploring alternative machine learning algorithms. By comparing our study with other research projects in flood detection, we have gained a broader understanding of the challenges and nuances associated with this task.

One of the main takeaways from this project is the importance of selecting the appropriate dataset and machine learning model for the task at hand. The choice of data and model can significantly impact the accuracy and reliability of the results. Furthermore, this project highlights the need for rigorous evaluation of machine learning models to ensure their robustness and applicability in real-world situations.

In conclusion, although our initial results were not as successful as we had hoped, this project has enriched our understanding of the complexities involved in flood detection and prediction. We believe that the lessons learned and the areas of improvement identified throughout this study can serve as a valuable foundation for future research. By building upon these findings and further refining the methodologies, we hope to contribute to the ongoing efforts in the development of more accurate and reliable flood detection systems, ultimately benefiting communities affected by flooding in Bangladesh and around the world.

Appendix A
Proof of the First Zonklar Equation

Appendix one text goes here.

Appendix B

Appendix two text goes here.

Acknowledgment

The authors would like to thank...

References

[1] "NASA Flood Extent Detection," mlhub.earth. https://mlhub.earth/data/ (accessed Jan. 28, 2023).

[2] N. Conte, "Mapped: Countries With the Highest Flood Risk," Visual Capitalist, Sep. 14, 2022. https://www.visualcapitalist.com/countries-highest-flood-risk/

[3] "Rising Flood Risks in Bangladesh," earthobservatory.nasa.gov, Aug. 31, 2022. https://earthobservatory.nasa.gov/images/150274/rising-flood-risks-in-bangladesh

[4] "Bangladesh: Flooding and Impacts," FloodWorld. https://water104website.weebly.com/bangladesh-flooding-and-impacts.html

[5] E. Basha and D. Rus, "Design of early warning flood detection systems for developing countries," 2007 International Conference on Information and Communication Technologies and Development, Bangalore, India, 2007, pp. 1-10, doi: 10.1109/ICTD.2007.4937387.

[6] E. A. Basha, S. Ravela, and D. Rus, "Model-based monitoring for early warning flood detection," Proceedings of the 6th ACM conference on Embedded network sensor systems, Nov. 2008, doi: https://doi.org/10.1145/1460412.1460442.

[7] Zanaga, D., Van De Kerchove, R., Daems, D., De Keersmaecker, W., Brockmann, C., Kirches, G., Wevers, J., Cartus, O., Santoro, M., Fritz, S., Lesiv, M., Herold, M., Tsendbazar, N.E., Xu, P., Ramoino, F., Arino, O., 2022. ESA WorldCover 10 m 2021 v200. (doi:10.5281/zenodo.7254221)

[8] K. Okamoto, T. Iguchi, N. Takahashi, K. Iwanami and T. Ushio, 2005: The global satellite mapping of precipitation (GSMaP) project, 25th IGARSS Proceedings, pp. 3414-3416.

[9] Lin, Yun, Bhardwaj, and Hill, "Urban Flood Detection with Sentinel-1 Multi-Temporal Synthetic Aperture Radar (SAR) Observations in a Bayesian Framework: A Case Study for Hurricane Matthew," Remote Sensing, vol. 11, no. 15, p. 1778, Jul. 2019, doi: https://doi.org/10.3390/rs11151778.

[10] X. Wu et al., "A Near-Real-Time Flood Detection Method Based on Deep Learning and SAR Images," Remote Sensing, vol. 15, no. 8, p. 2046, Jan. 2023, doi: https://doi.org/10.3390/rs15082046.

[11] "Flood hazard map of Bangladesh. — download scientific diagram." [Online]. Available: https://www.researchgate.net/figure/Flood-hazard-map-of-Bangladesh_fig7_352515872. [Accessed: 13-Mar-2023].

[12] "After floods in Bangladesh," Caritas, Sep. 16, 2017. https://www.caritas.org/2017/09/after-floods-in-bangladesh/ (accessed Mar. 13, 2023).

[13] S. Sengupta and J. A. Manik, "A Quarter of Bangladesh Is Flooded. Millions Have Lost Everything.," The New York Times, Jul. 30, 2020. Available: https://www.nytimes.com/2020/07/30/climate/bangladesh-floods.html

[14] Bangladesh: A Country Underwater, a Culture on the Move, "Bangladesh: A Country Underwater, a Culture on the Move," NRDC, May 09, 2019. https://www.nrdc.org/onearth/bangladesh-country-underwater-culture-move

[15] "Flood Barrier Neo-Barrier Composite systems, smart modular protectionNeo Composite," neocomposite. https://www.neocomposite.com/flooding-barriers