Automated Detection and Prediction of Flood Hazards

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Challenge Definition

Floods

According to The European Space Agency and World Health Organization:

- Flooding is the world's most costly and frequent type of natural disaster
- Can cause widespread devastation, resulting in loss of life
- Damages to housing, critical public health infrastructure, agriculture and communications
- Between 1998-2017, floods affected more than 2 billion people worldwide (~26% people)

Body found on Barrington riverbank believed to be elderly woman missing in NSW floods

Empty car belonging to Adele Morrison, 78, was pulled from swollen river in March during torrential rain on mid-north coast

11 Apr 2021

Sydney flood death: another man rescued day before in same place

1:30 AM

Help is on the way: supplies flown into stranded communities as rain eases across NSW

While flood waters will continue to rise in some areas, the worst of the weather is over, the Bureau of Meteorology says

11:47 AM

NSW floods: evacuated Sydney residents told to stay away as water recedes and cleanup begins

Seven townships around Hawkesbury River remain evacuated as SES warns flood water can contain sewage, debris and dead animals

5:06 AM

- Between 80-90% of all documented disasters from natural hazards during the past 10 years have resulted from floods, droughts, tropical cyclones, heat waves and severe storms.
- Climatologists project an increase in extreme weather events including floods due to climate change
- People who live in areas with lack of warning systems and awareness of flooding hazard are among the most vulnerable to floods
- Drowning risks increase with floods particularly in low- and middle-income countries where people live in flood prone areas and the ability to warn, evacuate, or protect communities from floods is weak or only just developing.

⇨ For this reason, we chose the **Automated Detection of Flood Hazards Challenge**

Challenge Definition

Our challenge is to use satellite data to create a **machine learning model** that **detects floods** and build a **web interface** that not only **displays the detected floods**, but also **layers it alongside ancillary data** to help researchers and decision-makers better **understand its impacts and scope.**

What is our Goal?

- Detect floods using weather data and satellite imagery data
- Create a machine learning model that reads in raw measurements and satellite images, analyses them and returns if there are floods detected in certain areas
- Help predict floods soon enough to provide in time rescue missions

Data Machine Learning Model

Three common types of floods

- Flash floods (rapid and excessive rainfall that raises water levels quickly)
- River floods (due to consistent rain of snow melt)
- Coastal floods (caused by storm surges from cyclones and tsunamis)

⇨ Can the causes be predicted?

Ideal Dataset


```
{
  "Location": "Salzburg",
  "Date": "13.05.2021",
  "Amount of Rainfall (mm)": 50,
  "Temperature of Rainfall (°C)": 5,
  "Storm": true,
  "Type of Storm": "Thunder",
  "Duration of Storm (min)": 65,
  "Intensity of Storm": 0.6,
  "Electromagnetic Radiation (kHz)": 10,
  "Soil Texture": "Ts2",
  "Ground Moisture": 0.3,
  "Amount of Vegetation [m²]": 50,
  "Type of Vegetation": "pine",
  "Terrain Steepness": 0.6,
  "Temperature of Ground (°C)": 13,
  "Air Temperature (°C)": 15,
  "Flood": true
}
```

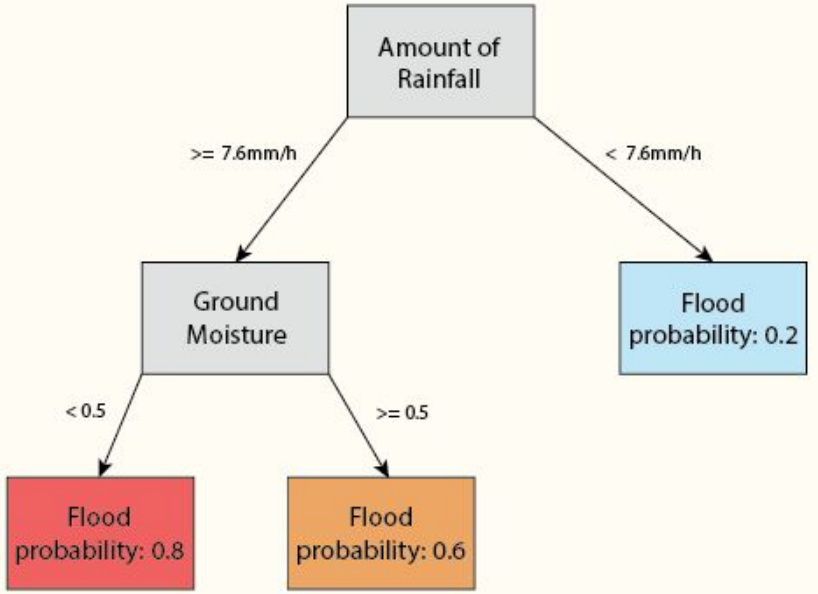

- Common metrics used to detect floods
- Often recorded at weather stations all over the world
- Previously recorded over period of time - long enough to detect repeating patterns
- Other data can also be used

Supervised Machine Learning Model

- Need target variable - either boolean of float to indicate flood or degree of flood respectively
- Depending on the data, also other target variables could be considered
  - number of people or houses affected
  - area affected
  - cost in damage
- Use datasets that have recorded floods in the past to get target variable

Which Machine Learning Algorithm?

- Best to compare different algorithms (compare evaluation metrics such as RMSE, precision, recall)
- Decision tree algorithms



Process

- Pre-process raw data
  - Clean up data
  - Feature selection - remove redundant and irrelevant features (using Random Forest feature importances and correlation)
  - If necessary: Dimensionality reduction (PCA or T-SNE)
- Build XGBoost model on training data
- K-fold cross-validation
- Adjust model to get best RMSE (grid search)
- Feed new data into model to detect/predict floods
- Either general model or model per measurement institute

Clustering

- Unsupervised machine learning
- Group together similar weather patterns
- No target variables needed

Disadvantages

- Only feed in one set of measurements per prediction (not multiple days)
- Use weather data to predict - not far in advance, often inaccurate

  ⇨ Could use multi linear regression model to solve these problems

- Doesn’t provide much information on the current flood situation
- Cannot visualise spread of the flood in real-time
- Only detect/predict floods at measurement institute - doesn’t take into account all parts of river, how river banks are protected against flooding etc.

  ⇨ Solve with satellite imagery

Satellite Imagery Machine Learning Model

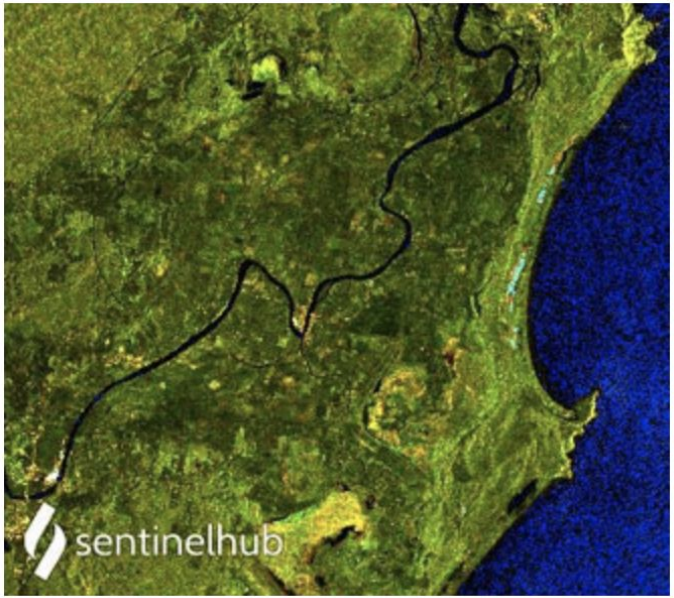
Satellite Imagery Flood Detection

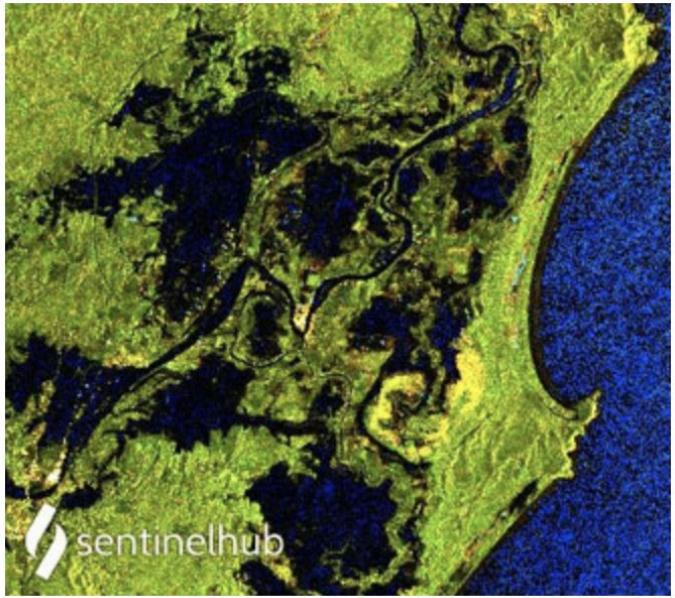
- Satellite imagery is used to detect floods by comparing images of a region over time
- They can be used to monitor an ongoing flood and provide an overview of the situation
- Satellites such as the Copernicus Sentinel-1 are useful, as they use radar data to ‘see’ through clouds, rain and in darkness
- Problem - researchers have to view images manually

Flood Comparison Images Australia April 2017

Flood Relief Australia April 2021

- Inability to deploy aircraft for aerial surveys
- Relied heavily on RADAR systems, including the Copernicus Sentinel-1 SAR to see floods beneath the clouds.





Detection Model

- Use deep learning (convolutional neural networks) to automatically compare images (or image patches) over time and detect indications of floods (e.g. water level rising)
- Compare these indications with weather predictions and other measurements (from decision tree model)
- If probability of flood is over threshold - automatically alert the authorities with ancillary data:
    - Automatically scan number buildings, houses, etc. to determine how many people will be in affected (through annotation services)
    - Compare to past similar floods
    - Where will/could be affected
    - Which areas will be affected next
    - Supply information of that regions flood defence mechanisms
    - Weather forecast for the following days
- Also monitor areas that can lead to floods (e.g. monitor snow melting, upstream)

Social Media and Mobile Notification

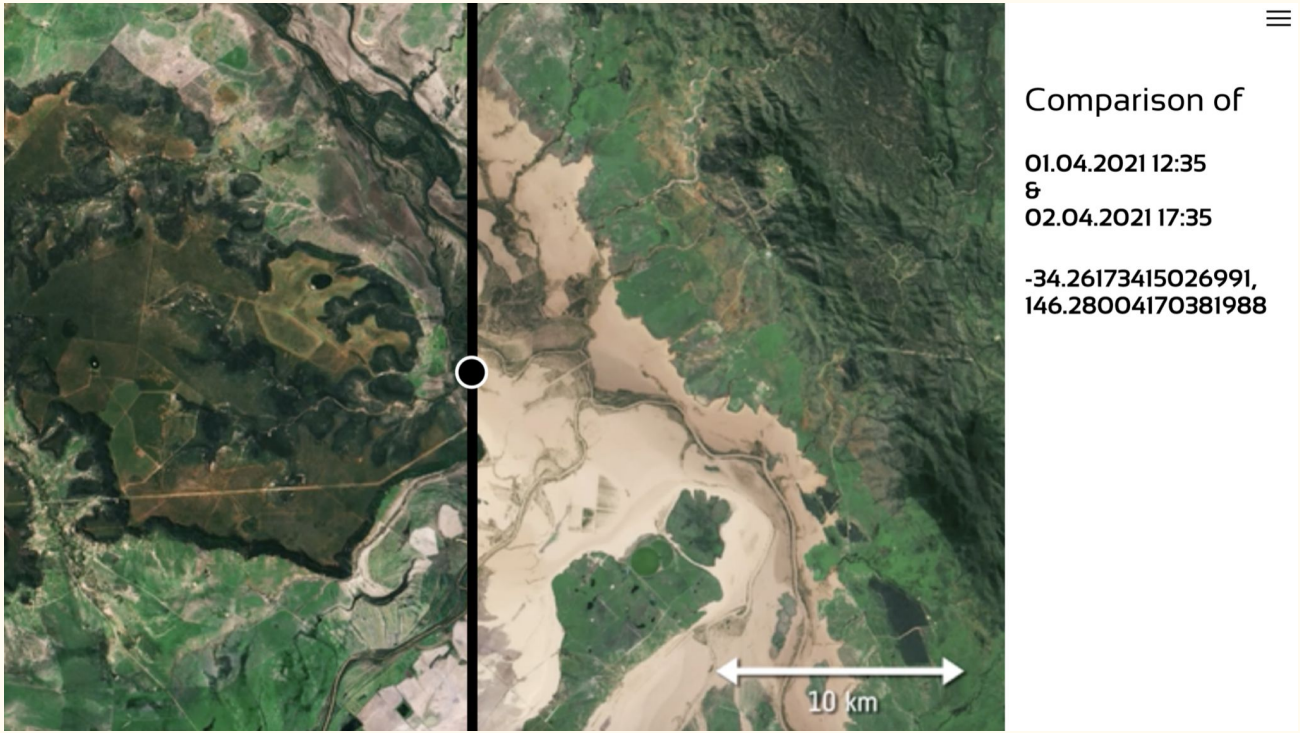
- People share videos, photos, information in real-time
- Monitor social media during hazards to determine which areas need relief, who is in trouble, what the situation on the ground is
- But a lot of unstructured data to filter through
- Create a mobile app for flood relief/notifications - not just for floods
- More organised data, less likely to be fake reports, alert authorities of floods that satellites might not have picked up
- Also use the app to quickly notify people about risk area and provide correct, trustworthy and custom information on how to proceed

Prototypes

Prototypes

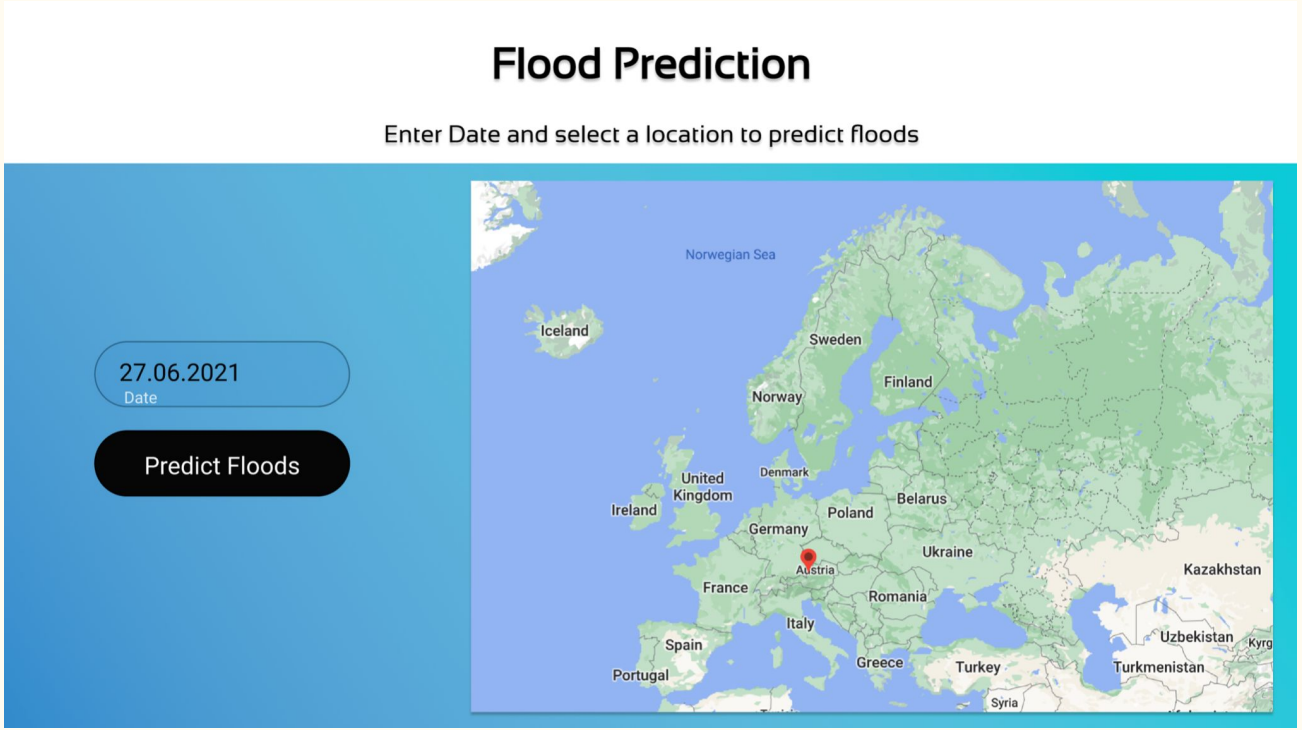
- Combine weather forecast, other measurements and satellite image comparison and information to automatically detect/predict/handle floods
- Manual flood prediction
- Mobile app for flood notifications

Real-time satellite images for automatic flood detection & overview



https://www.figma.com/proto/xXCMzRhXGFf88YZJJ7CD5K/Satellite-Images?node-id=1%3A108&scaling=contain&page-id=0%3A1

Flood information and prediction



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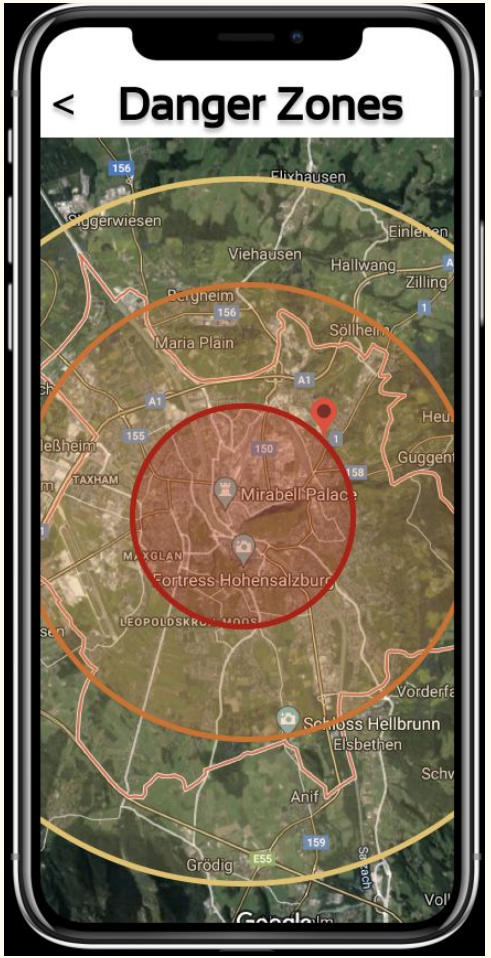
Mobile app for flood notifications



https://www.figma.com/proto/E8h2KzmAtvqXElwrLbhv0t/Notification-app?scaling=scale-down&page-id=0%3A1&node-id=1%3A3

Summary

- Not new - addition to research already done
- Flood detection is already happening
- Prediction could possibly save more lives, act faster, more time to evacuate
- Also in poorer regions
- Link to our final project paper

Sources

- https://www.esa.int/Applications/Observing_the_Earth/Securing_Our_Environment/Flood_monitoring
- https://www.who.int/health-topics/floods#tab=tab_1
- https://www.who.int/news-room/fact-sheets/detail/drowning
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- https://www.esa.int/ESA_Multimedia/Videos/2017/04/2017_Queensland_floods