Building Damage Classification Post Natural Disasters for Optimized Relief

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Prioritization after post-disaster is key

Essential to determine which areas have suffered the most damage

Most urgent decisions need to be made within 48-72 hours; therefore manual assessment is not practical
MONEY SPENT ON DISASTER RELIEF (US)

United States Billion-Dollar Disaster Events 1980-2022 (CPI-Adjusted)

- Drought Count
- Flooding Count
- Freeze Count
- Severe Storm Count
- Tropical Cyclone Count
- Wildfire Count
- Winter Storm Count

Cost in Billions

Number of Events

Updated: January 10, 2023
Research suggests that climate change will result in more natural disasters over time.

With rising temperatures, we can expect more intense natural disasters, therefore we need better tools to assist in disaster relief.
TARGET USERS

- Crisis Responders
- Governments
- Non-Governmental Organizations
- Multilateral Organizations
TARGET USER QUOTES

“We don’t just care about the buildings. We care about the people in them.”
- World Food Programme Staff

“During prioritization and targeting phases, the algorithm would be really useful alongside population and vulnerability data.”
- World Food Programme Staff
Question 1: Which areas are most severely damaged post-disaster?

Question 2: Based on damage, population, and vulnerability data, which area needs to be prioritized?
This tab shows historical data of hurricane damage, including building polygon layer and optional h3 layers.

This tab is where you can upload a satellite image and building polygons to assess damage.
<table>
<thead>
<tr>
<th>Disaster Type</th>
<th>Building Count</th>
<th>Image Count</th>
<th>Buildings Per Image</th>
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CLASS IMAGE SAMPLES

PRE-Disaster

POST-Disaster

No Damage

Major Damage

Minor Damage
SECONDARY DATA - RASTER DATA FOR VULNERABILITY

RAW POPULATION DATA + RAW GDP & FOOD DATA
(FILTERED FOR HURRICANE AREA)

GDP PER CAPITA + FOOD INSECURITY
H3 is a geospatial analysis tool that provides a hexagonal, hierarchical spatial index to gain insights from large geospatial datasets. The building blocks of H3 are different sized regular hexagonal polygons.
ML PIPELINE

Load & Cleanup
- Acquire XView 2
- Metadata to csv
- Disaster Selection
- Remove noisy images
- Clean up metafiles
- Remove unclassified data

Pre Process
- Create Masks
- Image & Mask Overlay
- Split segmented images per class
- Load as pytorch tensor
- Balance classes

Model Training
- Initialize weights
- Forward Propagation
- Compute Loss
- Backward propagation
- Final weights

Testing & Deployment
- Validation on hold
- Evaluate on test
- Save the best model
- Deploy model on AWS
SEGMENTATION
The process of identifying a region on the image that represents the same target class.

MASKING
The process of separating the segmented region from its background and can be achieved by darkening the background.
PRE PROCESS PIPELINE

Original Image

Masked & Segmented Image

Cropped version - Input to VIT
CNN - RESNET ARCHITECTURE

Stage 1

Input Image (224*224*3)
Vision Transformer (ViT) Architecture

- Patch Embeddings
  - Transformer Block
    - Feed Forward Neural Network
    - Multi-Head Self-Attention
    - Linear Projection + Position Embedding
  - ... (more transformer blocks)

- Classification

Generate Image Patches
UNDER THE HOOD - VISION TRANSFORMERS

Patch Splitting

Linear Projection + Embedding Layer

Transformers - Visual attention

MLP Classification Head

No damage  Minor  Major  Destroyed
**METRICS**

**Precision**

\[
\text{Precision} = \frac{\text{TRUE POSITIVES}}{\text{TRUE POSITIVES} + \text{FALSE POSITIVES}}
\]

**Recall**

\[
\text{Recall} = \frac{\text{TRUE POSITIVES}}{\text{TRUE POSITIVES} + \text{FALSE NEGATIVES}}
\]

**Accuracy**

\[
\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FP} + \text{TN} + \text{FN}}
\]

**F1 Score**

\[
F1 = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}
\]

**Dice Coefficient**

\[
\text{Dice} = \frac{2 \times |X \cap Y|}{|X| + |Y|}
\]
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EVALUATION

CONCLUSIONS

- F1 scores best on “No Damage” class
- Challenges distinguishing between damaged classes
- Both VIT and CNNs perform well on hurricanes — inconclusive which model will perform on all natural disasters
BEST PERFORMING VIT MODEL

AdamW (  
Parameter Group 0  
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  betas: (0.9, 0.999)  
  capturable: False  
  differentiable: False  
  eps: 1e-08  
  foreach: None  
  fused: None  
  lr: 0.00097  
  maximize: False  
  weight_decay: 0.0075 )
BEST PERFORMING VIT EVALUATION RESULTS

**Overall**
- F1-Scores: 54.87%
- Test accuracy: 53.42%
- Precision: 59.29%
- Recall: 53.42%

**Class-Wise Metrics**
- Destroyed: 72%
- Major-Damage: 40%
- Minor-Damage: 56%
- No-Damage: 54%
TECHNICAL CHALLENGES

- Low resolution satellite images
- Segmentation and masking
- Pre-processing data
FUTURE PLANS

- Use staged approach to use both CNNs and VIT
- Process new satellite images without polygons provided—polygonize output for localization models
- Expand model to other natural disasters such as floods, fires, and earthquakes
CONCLUSION

We have used machine learning and satellite imagery to identify areas that have been hardest hit by hurricanes and combined it with demographic data to make clear where vulnerable populations in those areas live.
QUESTIONS?
SECONDARY DATA -
RASTER LEVEL DATA TO MEASURE INVULNERABILITY

Raster Data - a spatial resolution of 30 arc-seconds (~1 km at equator)

- **Population Data** - Population input data are collected from the results of the 2010 round of Population and Housing Censuses. We are using 2020 projected data. To create the raster population data sets, the population estimates were distributed to raster level using an areal-weighting method.

- **GDP Data** - Use LitPop (nighttime light images and the LandScan Global Population database) maps to disaggregate national GDP in 2005 and to downscaled to raster level, and we are using 2020 projected data.

- **Food Insecurity Hotspot Data** - The Famine Early Warning Systems Network (FEWS NET) periodically collaborate with partners on household surveys as well as joint assessments in hotspot areas that have experienced consecutive food insecurity events. The food insecurity level ranging from 1 to 5, with 1: Minimal, 2: Stressed, 3: Crisis, 4: Emergency, and 5: Famine. What we are using are the average of the quarterly reported data over the 10 year period.
• **GSD**: the distance between two consecutive pixel centers measured on the ground. The bigger the value of the image GSD, the lower the spatial resolution of the image and the less visible details.

• **Azimuth and Elevation**: are two angles that describe the position of a point in the sky. **Azimuth** is the measure of direction in the horizontal plane, starting from the north and going clockwise. **Elevation** is the measure of height in the vertical plane, starting from the horizon and going up.
NATURAL DISASTERS

Natural disasters refer to extreme and catastrophic events caused by natural processes or forces, resulting in significant damage, destruction, and loss of life.

These events occur without human intervention and can have severe impacts on the environment, infrastructure, and communities.
WHAT TO DO?

Be prepared for aftershocks and continue to follow the "Drop, Cover, and Hold On" technique.

If you are indoors, stay there. Avoid running outside during the shaking, as falling debris or broken glass may pose a risk.

Stay informed about the latest updates and information from local authorities regarding the earthquake and potential aftershocks.

Keep away from potential hazards, such as tall furniture, bookshelves, or cabinets that could topple over.