



# Toward a Foundation Model for Efficient Damage Assessment Following Natural Disasters

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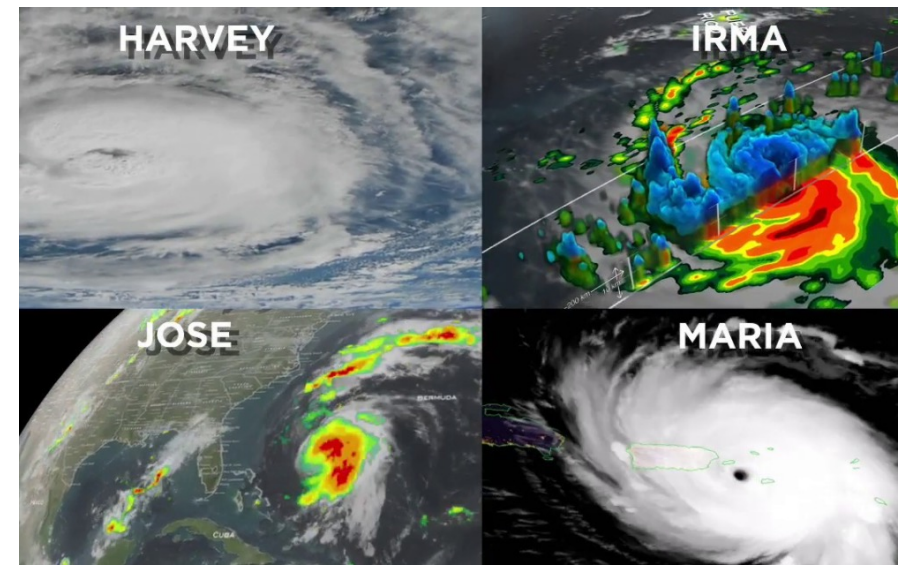


**Catastrophe Modeling Center**



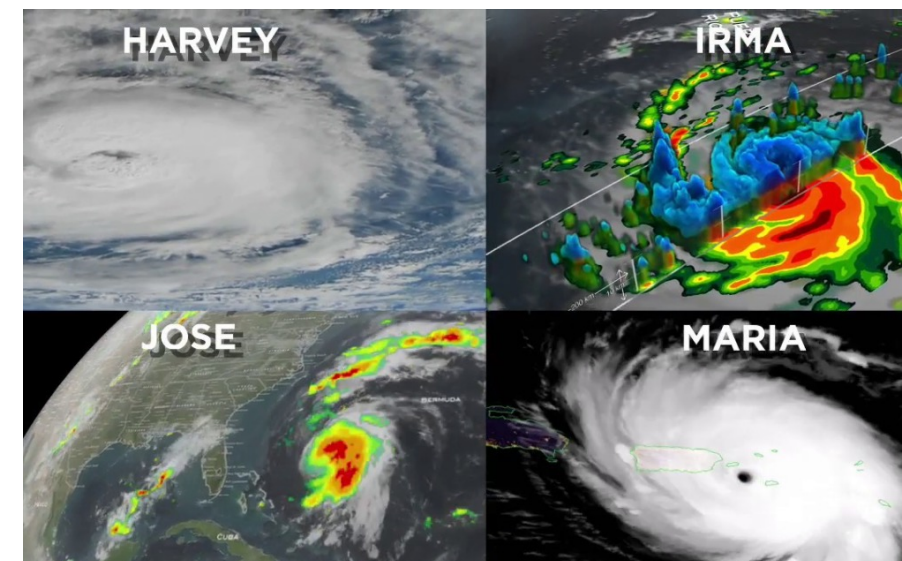
# Introduction

- ❖ Frequent, and increasingly severe natural disasters threaten human health, infrastructure, and natural systems.
- ❖ Only in 2023, the nation faced 28 weather and climate disaster events, each causing losses surpassing 1 billion dollars.
- ❖ The provision of accurate, timely, and understandable information has the potential to revolutionize disaster management.

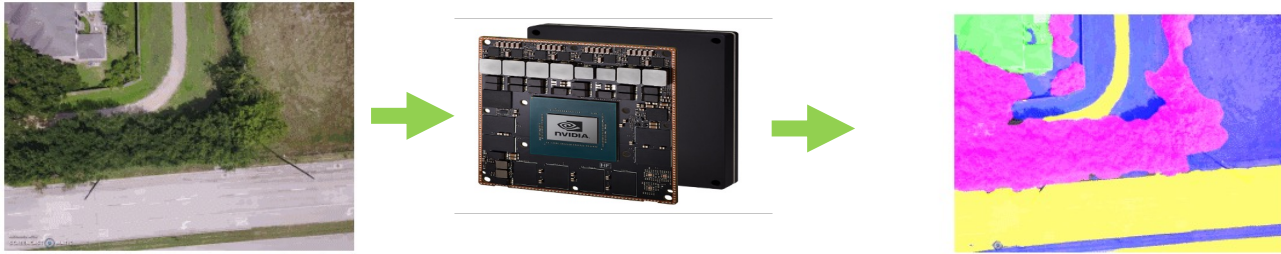


# Introduction

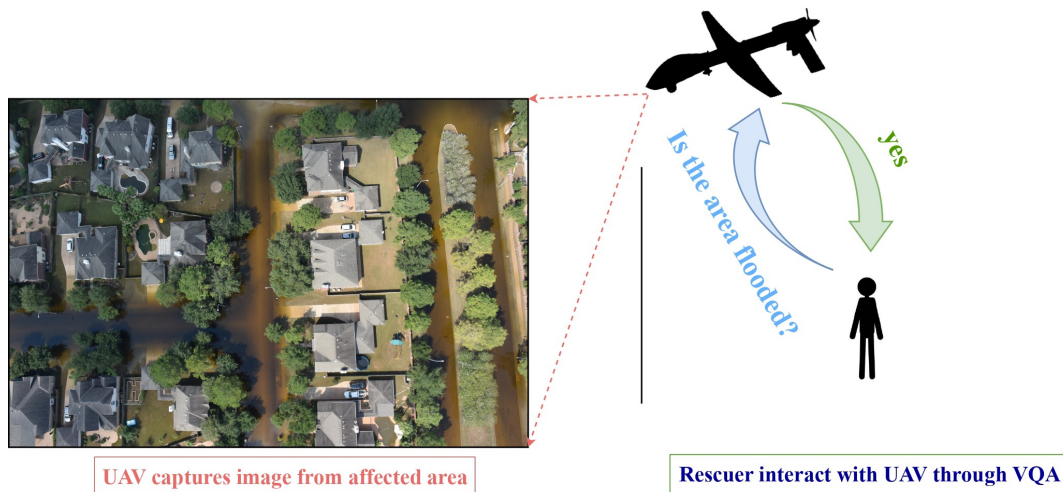
- ❖ For **quick response and recovery** in large scale, access to aerial images are critically important for the response team.
- ❖ The emergence of **small unmanned aerial vehicles (UAV)** along with inexpensive sensors presents the opportunity to collect **thousands of images after each natural disaster** with **high flexibility and easy maneuverability** for rapid response and recovery.
- ❖ While traditional analyses provide some insights into the data, the complexity, scale, and multi-disciplinary nature of the data **necessitate advanced real-time, generative, and interactive** intelligent solutions.



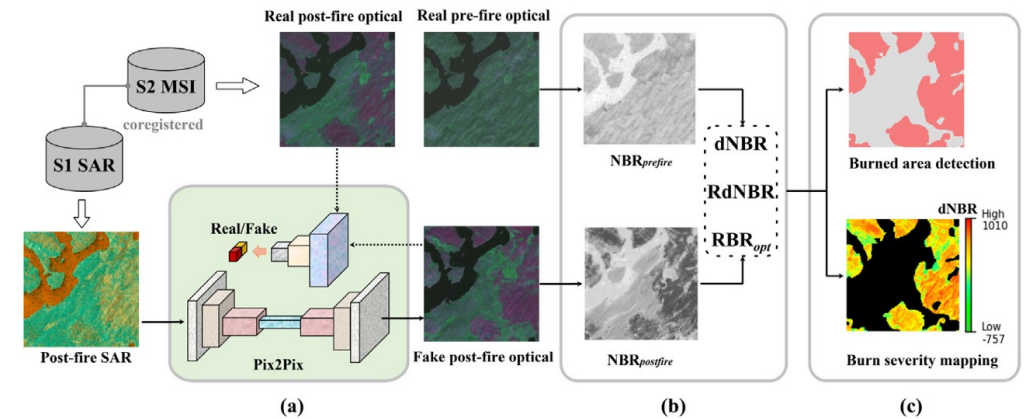
## Real-time scene Understanding



## Interactive, interpretable multi-modal visual-Language Models



## Multi-sensor Generative Models



# FloodNet and RescueNet

- Images were collected by the Center for Robot-Assisted Search and Rescue using sUAV (DJI Mavic- Pro Quadcopter) after several Hurricanes including Harvey and Michael.



# Dataset:FloodNet

Real Image	Ground Truth Segmented Image	QA Pair	Legend
 <p data-bbox="494 554 777 575">Image Class: Non-Flooded</p>		<p data-bbox="1335 265 1717 322">What is the overall condition of the given image? <b>Non-Flooded</b></p> <p data-bbox="1335 344 1753 365">How many buildings are non flooded? <b>6</b></p> <p data-bbox="1335 394 1763 415">How many buildings are in this image? <b>6</b></p> <p data-bbox="1335 444 1651 465">Is the entire road flooded? <b>No</b></p> <p data-bbox="1335 479 1681 536">What is the condition of the road in this image? <b>Non-Flooded</b></p>	
 <p data-bbox="519 876 751 898">Image Class: Flooded</p>		<p data-bbox="1335 619 1773 648">How many buildings are in this image? <b>19</b></p> <p data-bbox="1335 648 1651 669">Is the entire road flooded? <b>No</b></p> <p data-bbox="1335 705 1819 762">What is the condition of the road in this image? <b>Flooded and Non-Flooded</b></p> <p data-bbox="1335 798 1717 819">How many buildings are flooded? <b>19</b></p>	
 <p data-bbox="519 1208 751 1229">Image Class: Flooded</p>		<p data-bbox="1335 943 1671 1001">What is the condition of the road in this image? <b>Flooded</b></p> <p data-bbox="1335 1043 1753 1065">How many buildings are in the image? <b>5</b></p> <p data-bbox="1335 1108 1809 1165">How many non flooded buildings can be seen in this image? <b>3</b></p>	

M. Rahnemoonfar, T. Chowdhury, A. Sarkar, D. Varshney, M. Yari and R. R. Murphy, "FloodNet: A High Resolution Aerial Imagery Dataset for Post Flood Scene Understanding," in *IEEE Access*, vol. 9, pp. 89644-89654, 2021

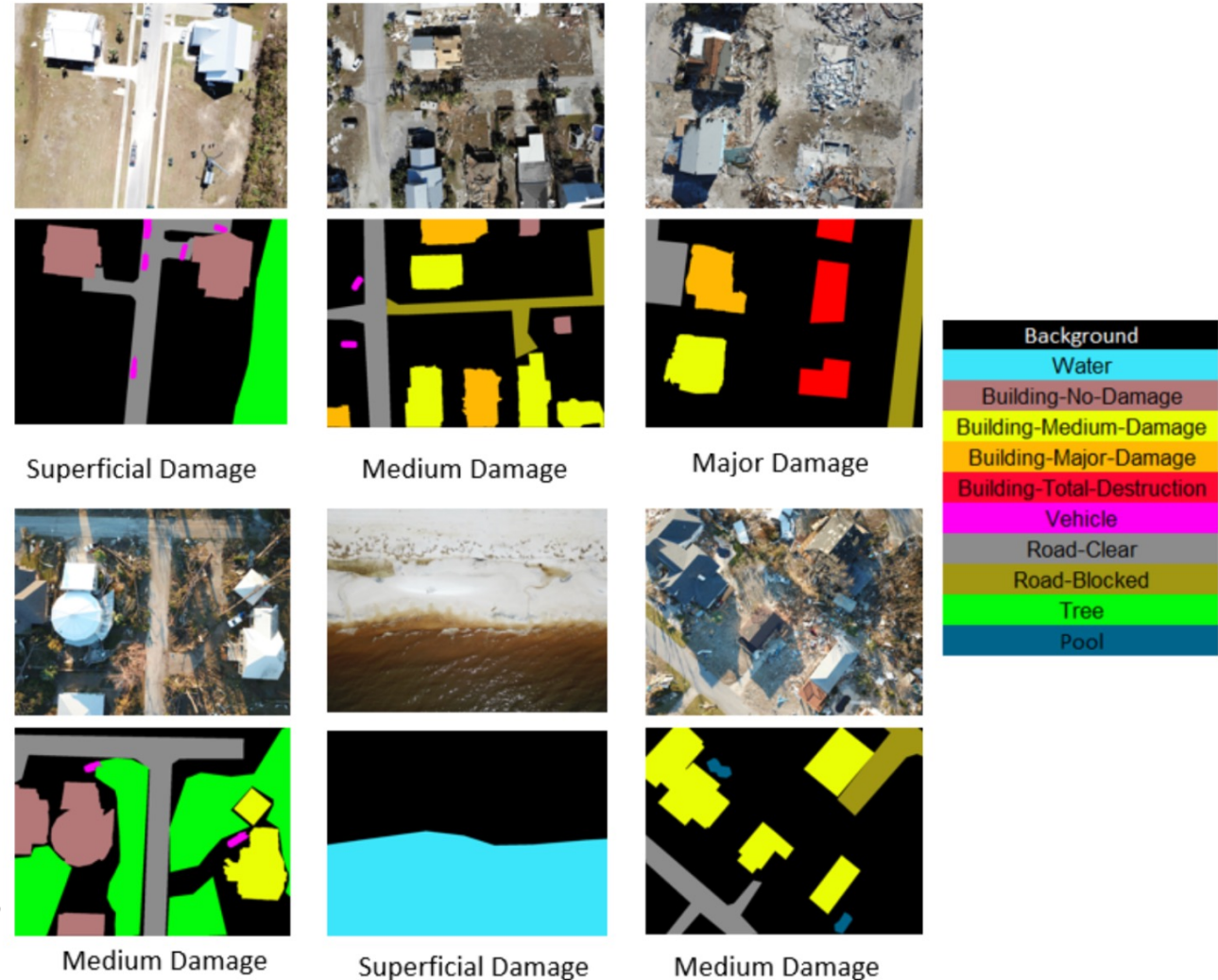
# FloodNet



# Dataset: RescueNet

Number of polygons of different buildings based on their damage levels.

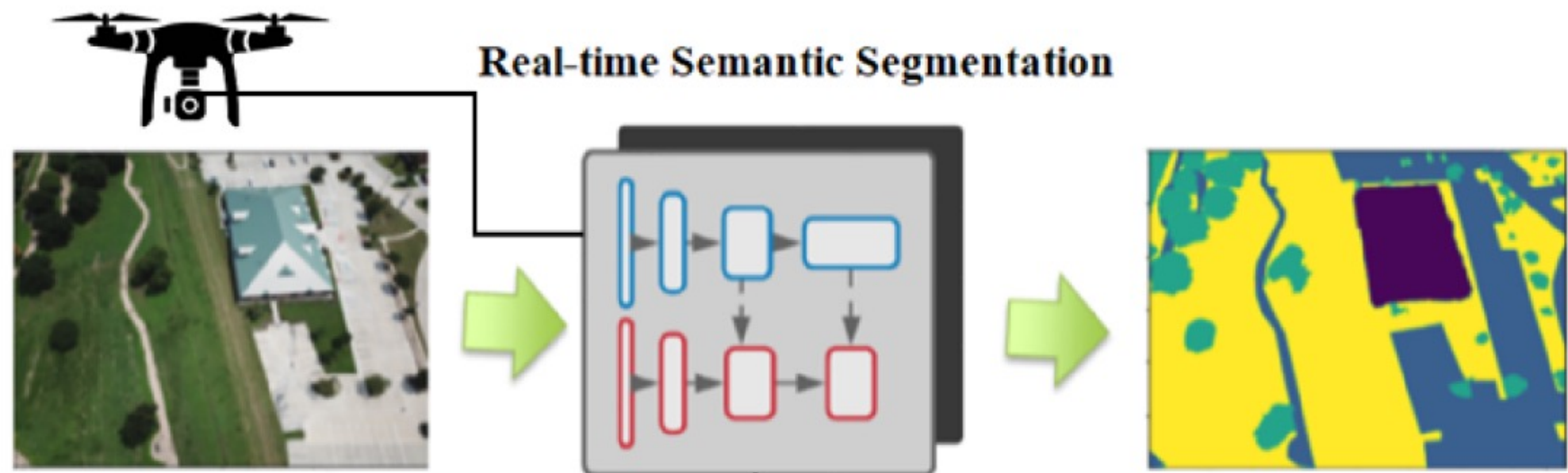
Damage Level	Number of Polygons
No Damage	4011
Medium Damage	3119
Major Damage	1693
Total Destruction	2080



Rahnemoonfar, M., Chowdhury, T. & Murphy, R. RescueNet: A High - Resolution UAV Semantic Segmentation Dataset for Natural Disaster Damage Assessment. *Nature, Sci Data* 10, 913 (2023)





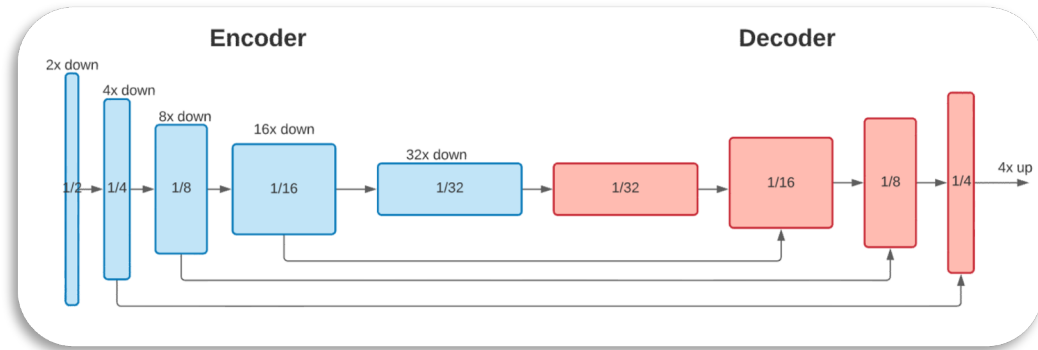


<b>Encoder-Decoder Architecture</b>	
UNet-based Architectures	UNetFormer
HarDNet	SegFormer

<b>Two-Pathway Architecture</b>	
BiseNetV1	DDRNet
BiseNetV2	PIDNet

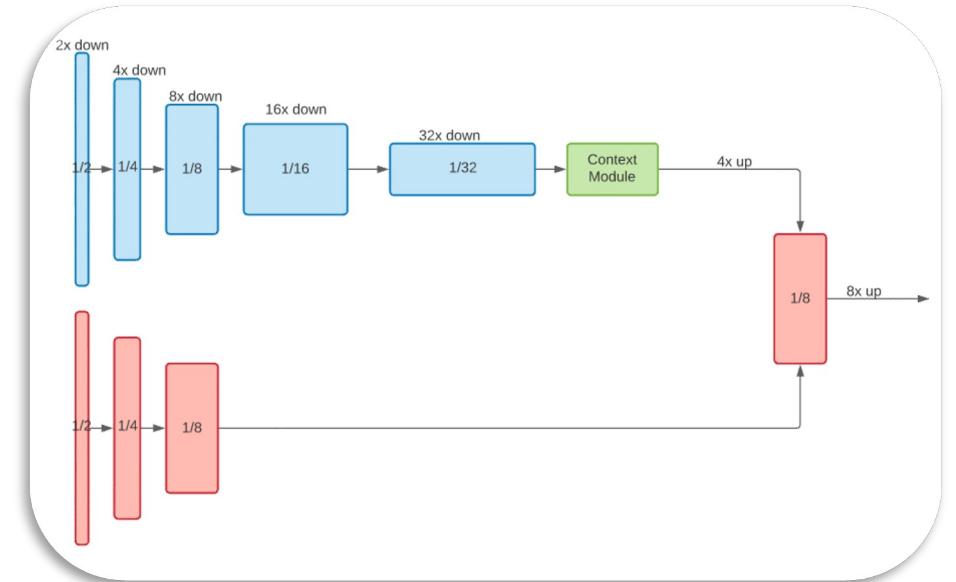
# Real-Time Semantic Segmentations

Encoder-Decoder Structure



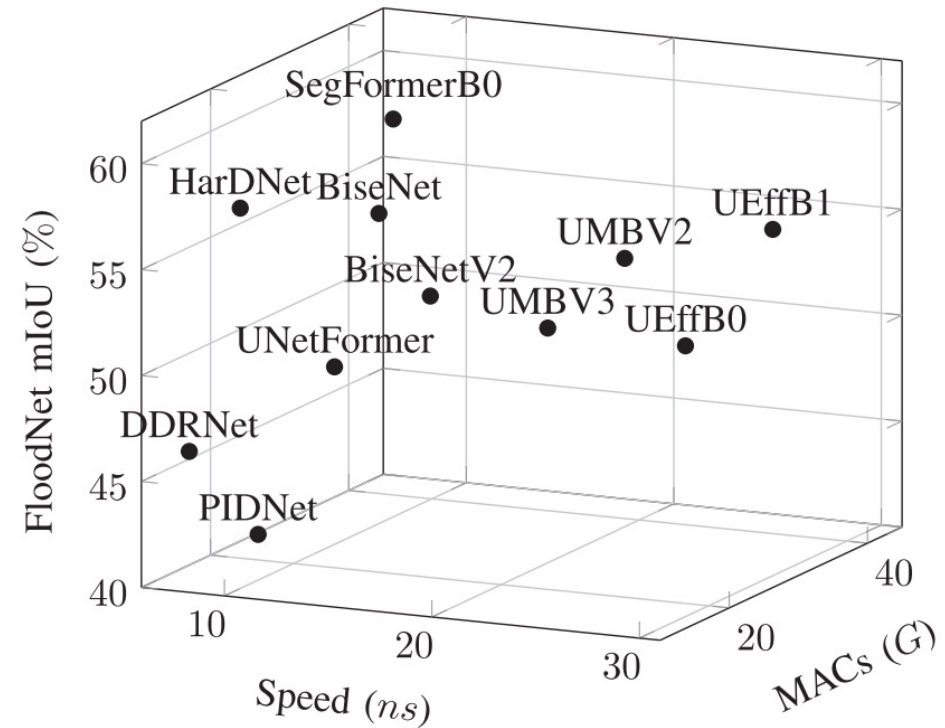
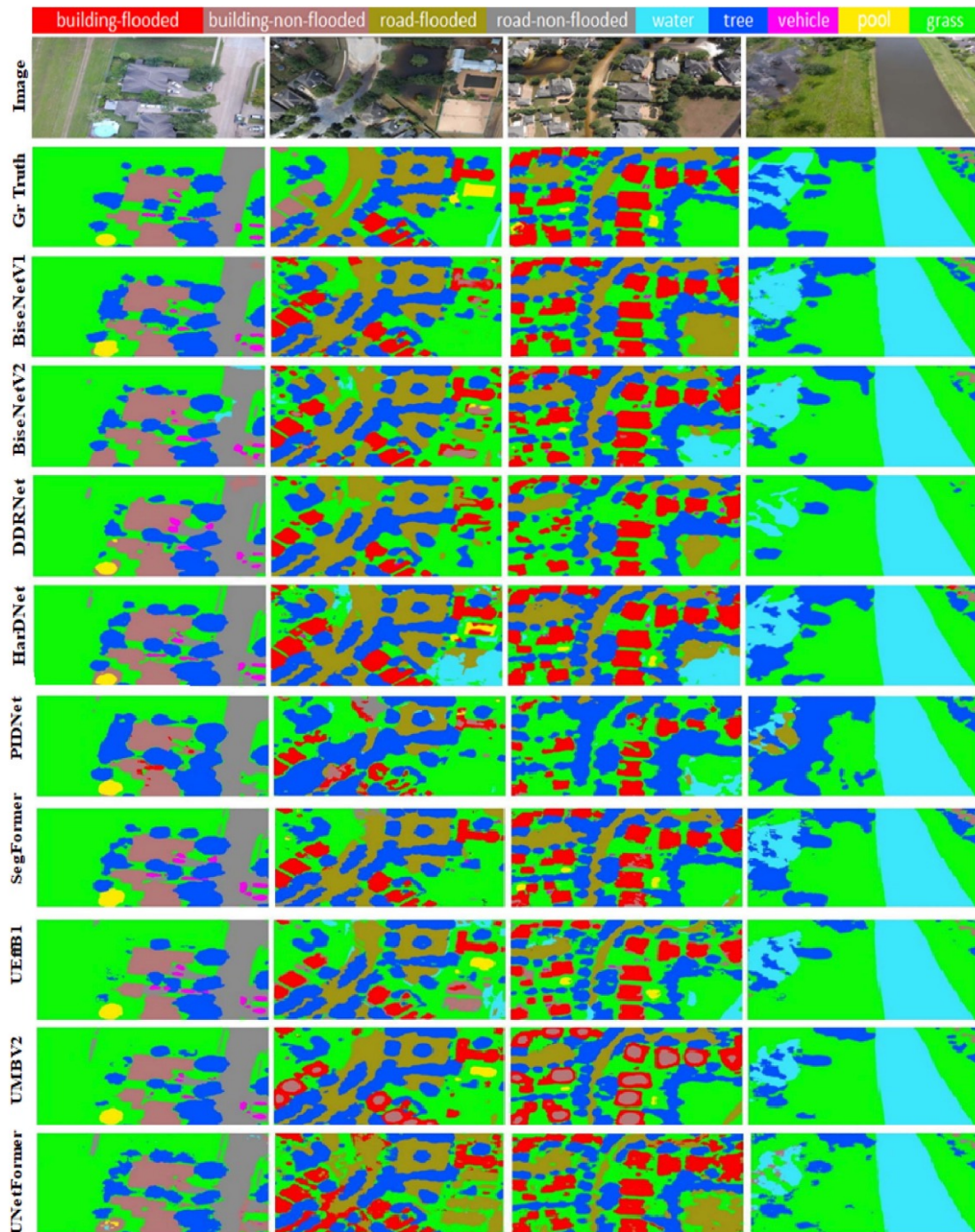
1. UNet-MobileNet-V2 (UMBV2)
2. UNet-MobileNet-V3 (UMBV3)
3. Unet- EfficientNet-b0 to b6 (Eff-Unet)
4. SegFormer
5. HarDNet

Two-Pathway Structure



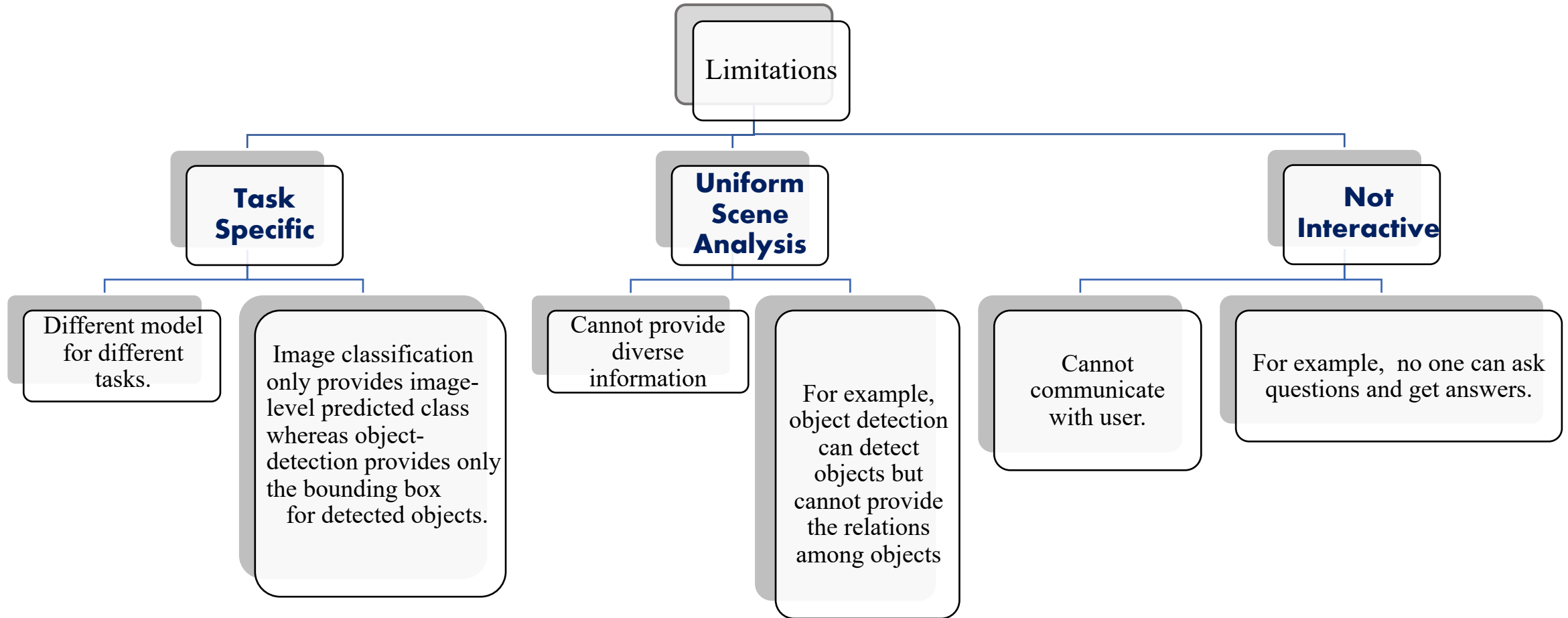
1. BiSeNetV1
2. BiSeNetV2
3. DDRNet

**These architectures are efficient and reduce computation and energy costs**



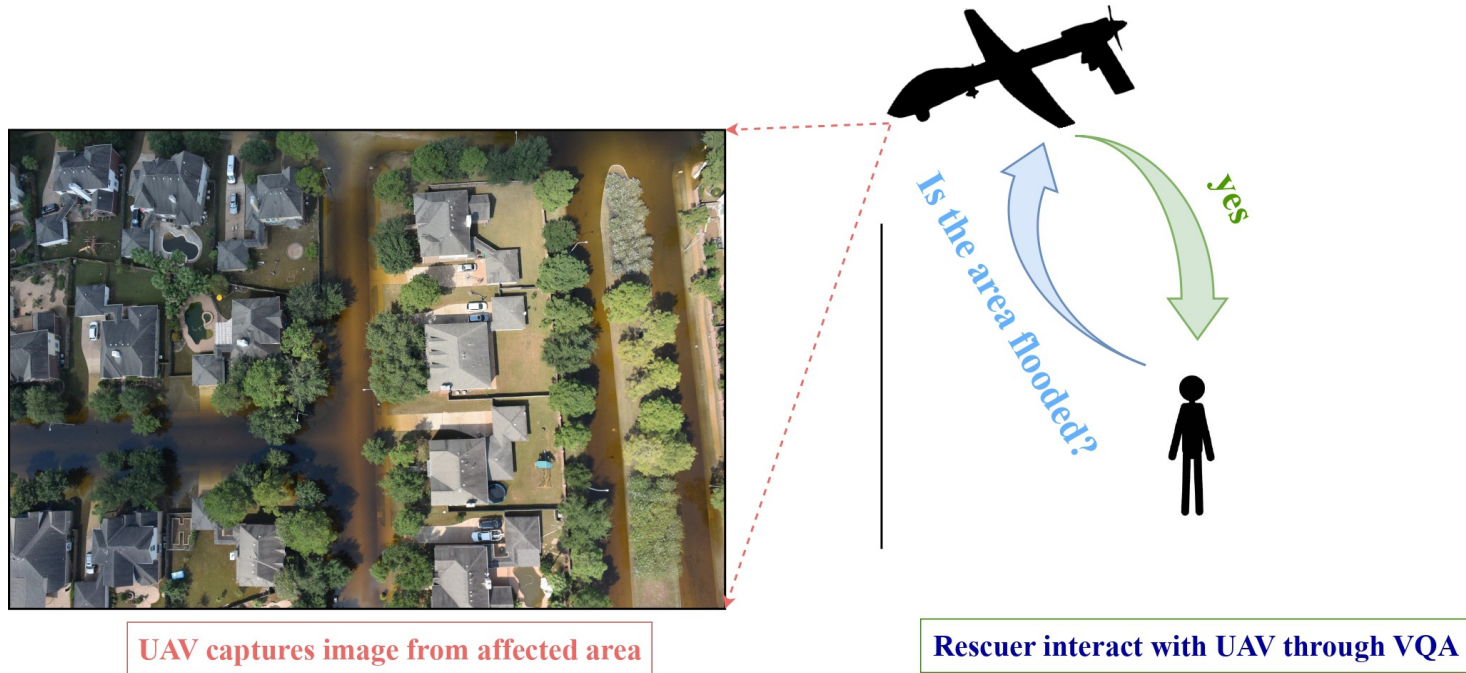
F. Safavi and M. Rahnemoonfar, "Comparative Study of Real-Time Semantic Segmentation Networks in Aerial Images During Flooding Events," in *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 16, pp. 15-31, 2023

# Limitation of Existing Approaches

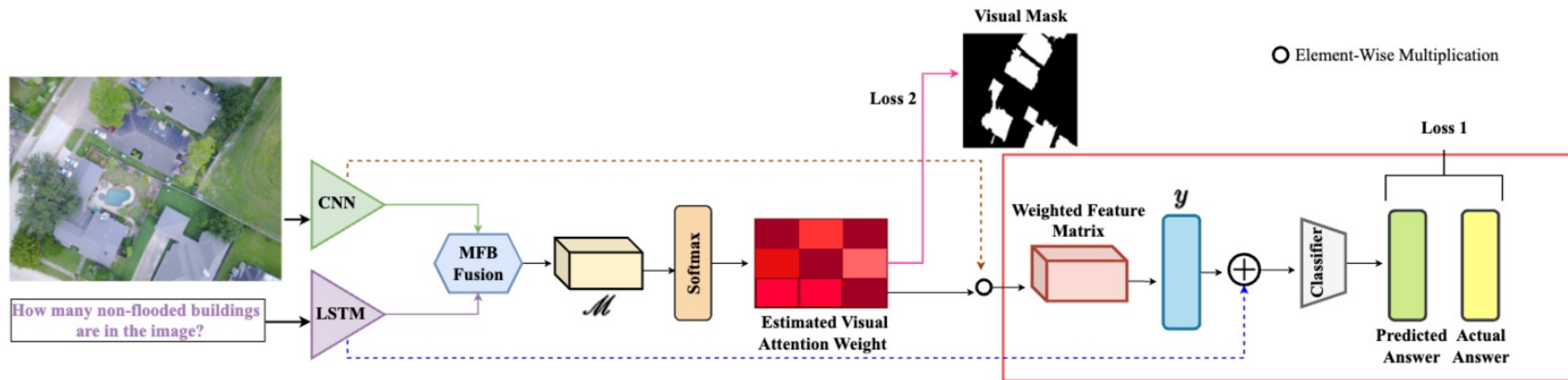


# Visual Question Answering

- **Multi-modal AI task.**
- **Provide diverse information from images depending on questions.**
- **Rapid response and recovery**
- **High-level scene information.**
- **Direct interaction with first responders and users.**



# SAM-VQA: Supervised Attention-Based Visual Question Answering Model for Post-Disaster Damage Assessment on Remote Sensing Imagery

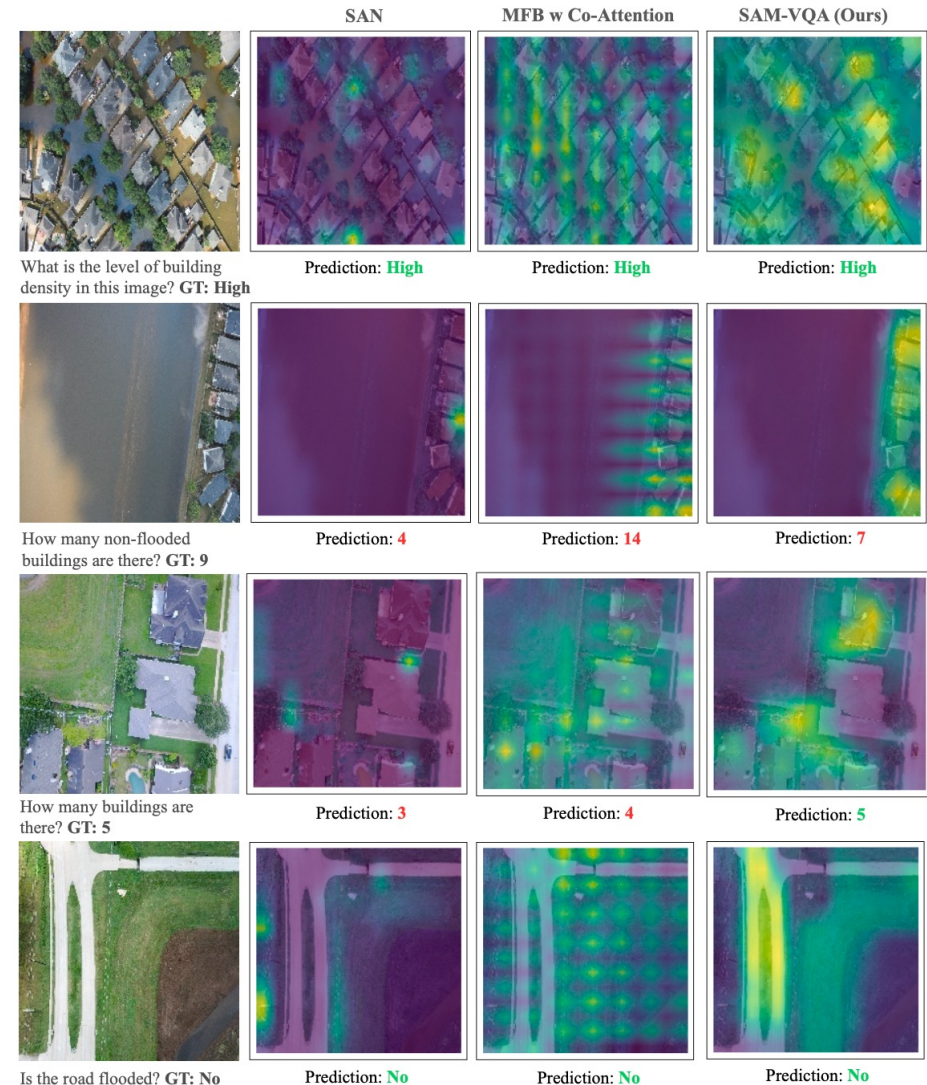
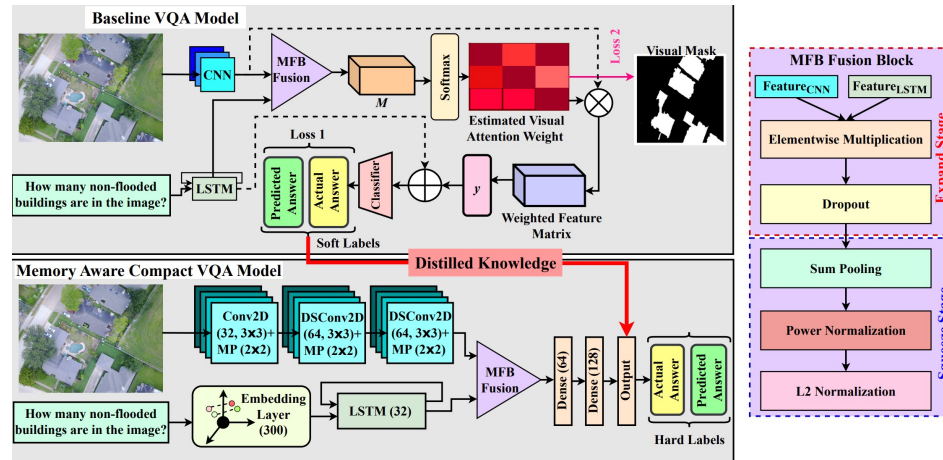


A. Sarkar, T. Chowdhury, R. R. Murphy, A. Gangopadhyay and M. Rahnemoonfar, "SAM-VQA: Supervised Attention-Based Visual Question Answering Model for Post-Disaster Damage Assessment on Remote Sensing Imagery," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 61, pp. 1-16, 2023, Art no. 4702716, doi: 10.1109/TGRS.2023.3276293.

# Interpretable and Memory-Aware VQA

ACCURACY COMPARISON BETWEEN SAM-VQA AND OTHER BASELINE MODELS ON THE TEST DATASET FOR DIFFERENT QUESTION CATEGORIES

VQA-Model	Simple Counting	Complex Counting	Road Condition	Building Condition	Density Estimation	Risk Assessment	Entire Image	Overall
Question-only	0.14	0.14	0.82	0.81	0.25	0.79	0.88	0.63
VIS + LSTM [44]	0.16	0.14	0.97	0.92	0.55	0.94	0.97	0.75
CNN + LSTM [43]	0.22	0.22	0.97	0.93	0.63	0.94	0.97	0.77
MFB+CoAtt [2]	0.27	0.27	0.98	0.91	0.68	0.97	0.98	0.79
SAN [1]	0.30	0.28	0.98	0.93	0.68	0.97	0.98	0.80
<b>SAM-VQA (ours)</b>	<b>0.35</b>	<b>0.32</b>	<b>0.98</b>	<b>0.94</b>	<b>0.74</b>	<b>0.97</b>	<b>0.98</b>	<b>0.81</b>



A. Sarkar, T. Chowdhury, R. R. Murphy, A. Gangopadhyay and M. Rahneemoonfar, "SAM-VQA: Supervised Attention-Based Visual Question Answering Model for Post-Disaster Damage Assessment on Remote Sensing Imagery," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 61, pp. 1-16, 2023, Art no. 4702716, doi: 10.1109/TGRS.2023.3276293.

Rashid et.al, "TinyVQA: Compact multimodal deep neural network for visual question answering on resource-constrained hardware," in TinyML research symposium, 2024



# Flood Simulation: Integrating UAS Imagery and AI-Generated Data with Diffusion Model



This image shows an aerial view of a residential area experiencing severe flooding. The water has inundated the streets and has encroached upon the houses, covering lawns and driveways. The roofs of homes are visible, but the lower areas of the properties are submerged in water, indicating the depth of the flood. Trees are partially submerged, and the overall scene indicates a significant natural disaster, possibly caused by extreme weather events such as heavy rainfall, a hurricane, or a river overflowing its banks. It is likely that such a flood would lead to evacuations and require emergency response efforts.



(a) Only vegetation

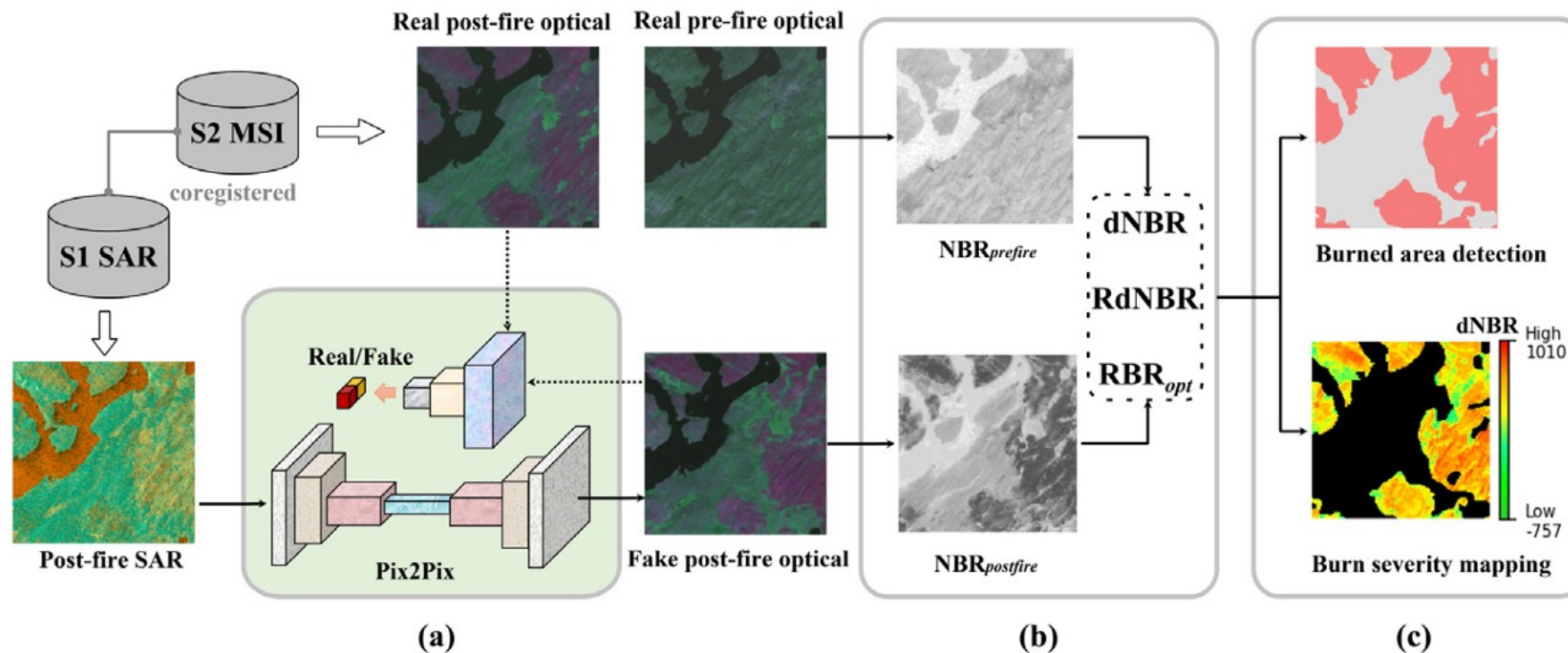


(b) Vegetation and a few buildings



(c) Residential areas with many buildings

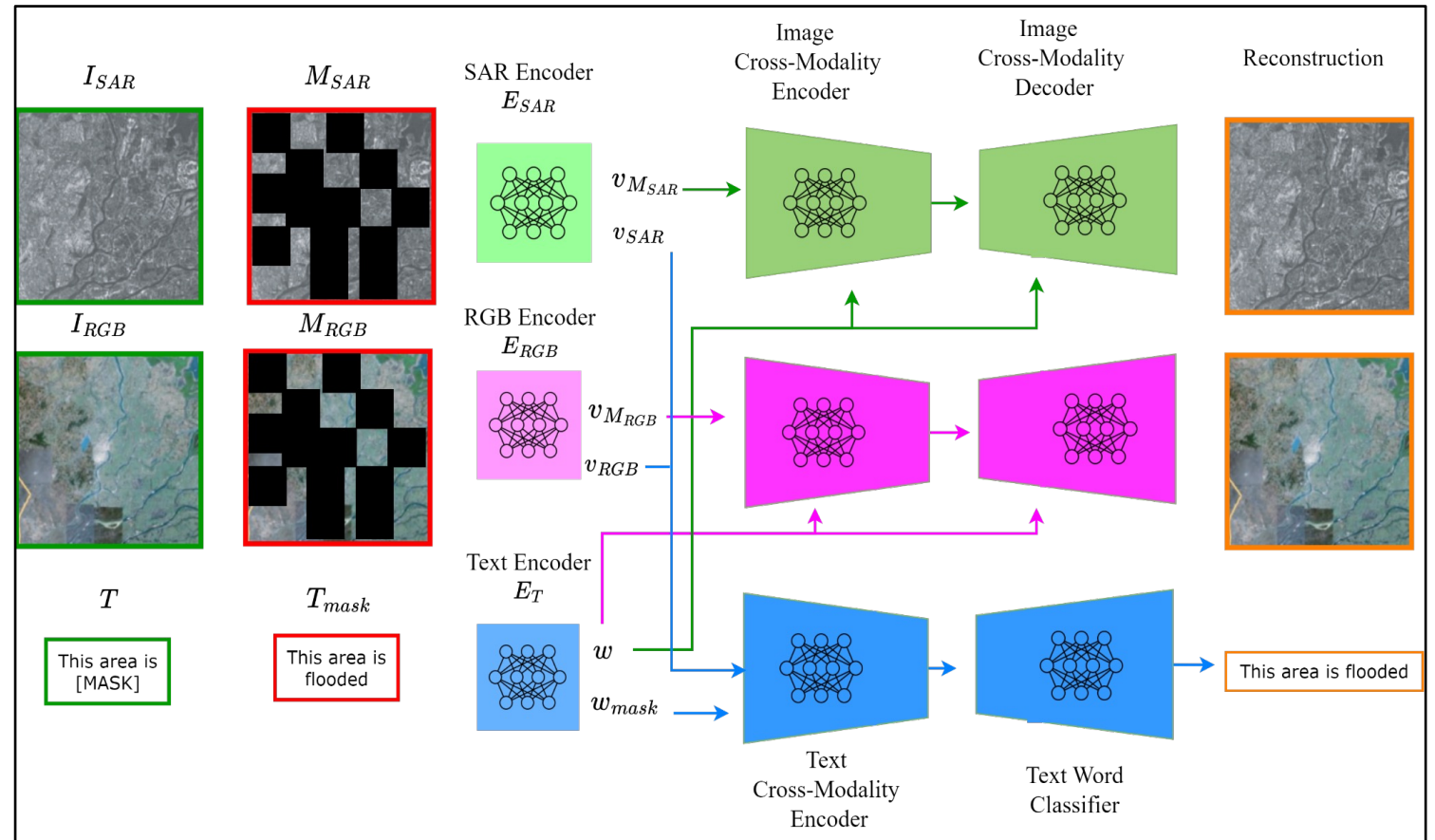
# GAN-based SAR and optical image translation for wildfire impact assessment using multi-source remote sensing data



Xikun Hu, Puzhao Zhang, Yifang Ban, Maryam Rahnemoonfar, GAN-based SAR and optical image translation for wildfire impact assessment using multi-source remote sensing data, Remote Sensing of Environment, Volume 289, 2023

# A Foundation Model for Efficient Damage Assessment

- Multiple disasters
- Multi-modal ( Vision, Language,...)
- Heterogeneous sensors
- Unlabeled data
- Efficient and Real-time



# Acknowledgments



amazon research awards

A photograph of a building with a window and a tree branch overhanging a body of water. The text "Thank you!" is overlaid on the image.

Thank you!

For questions, collaboration,  
partnership, or opportunities  
contact me

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