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Geospatial Big Data and AI for Smart Humanitarian Mapping

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Abstract:

Human communities worldwide have witnessed a series of catastrophic events, including natural disasters (e.g., hurricanes, floods, wildfires), health crises (e.g., pandemics like COVID-19), and human-induced hazards (e.g., industrial accidents). Despite enormous efforts to predict disasters' occurrences, intensities, and impacts, disaster damages have consistently increased over the past few decades, partially due to the uncertain and complex nature of human-disaster interactions. Building resilient communities that can withstand future disasters has become a global challenge and priority that requires innovative, effective solutions.

A crucial practice in building disaster resilience is humanitarian mapping to identify affected areas, infrastructural and social impacts, and humanitarian needs during disasters. Advances in geospatial big data and artificial intelligence (AI) have opened new frontiers in timely, accurate, and detailed humanitarian mapping. Geospatial big data, derived from sources such as satellite imagery, street-view images, social media, and crowdsourced platforms, offers unprecedented volumes of spatially and temporally rich information. When coupled with AI, these data can be transformed into actionable insights, e.g., power outages, rescue requests, malfunctioned infrastructures, and collapsed buildings. The integration of these technologies into humanitarian mapping facilitates rapid damage assessments, the identification of victims and their needs, and prioritizing resources, paving the way for disaster resilience (Zou et al. 2023).

This research aims to foster Smart Humanitarian Mapping during different disasters using geospatial big data and newly developed AI algorithms. The objectives are three-fold. First, this work establishes a comprehensive framework to employ geospatial big data and AI to enhance humanitarian mapping efforts. Second, we showcase the use of geospatial big data and AI in humanitarian mapping through three case studies, including (1) using social media and large language models (LLM) to map rescue requests, (2) applying nighttime light (NTL) remote sensing and image processing for power outage mapping during winter storms, and (3) leveraging crowdsourcing and natural language processing (NLP) for mutual aid coordination. Finally, this investigation identifies the challenges associated with integrating geospatial big data and AI in humanitarian mapping research and practice and propose possible solutions.

Figure 1 shows the workflow and results of the first study using social media and fine-tuned large language models to map rescue requests during 2017 Hurricane Irma in Florida, U.S. Two novel AI models, VictimFinder (Zhou et al. 2022) and TopoBERT (Zhou et al. 2023), were developed to search and geo-locate victims requesting help on Twitter/X. VictimFinder and TopoBERT achieved state-of-the-art performances with F-1 scores of 0.919 and 0.854.

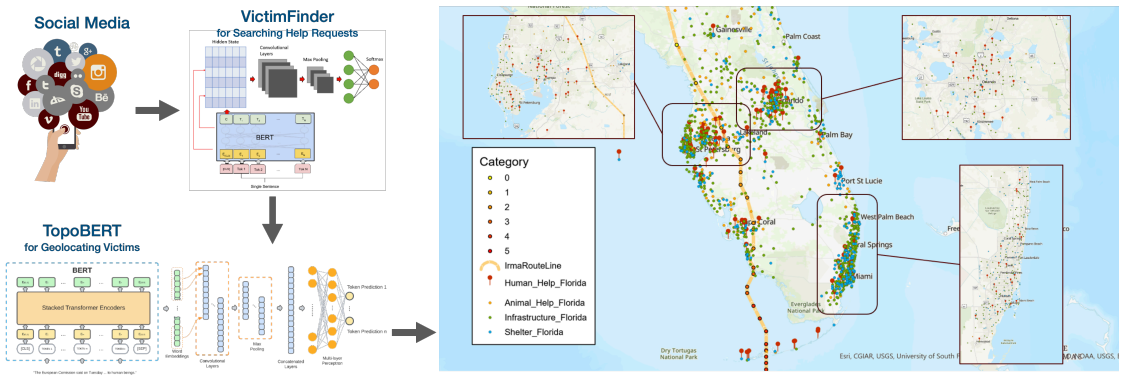


Figure 1. Utilizing social media and large language models to map rescue requests during 2017 Hurricane Irma in Florida, U.S.

Figure 2 displays the workflow and outcomes of the second study using NTL and advanced image processing to map power outages during the 2021 Winter Storm Uri in Texas, U.S. NASA's Black Marble daily NTL images were used. Statistical adjustments were applied to mitigate viewing angle and snow reflection effects. Power outage was detected by comparing storm-time and normal condition NTL images using an empirical adjusted equation.

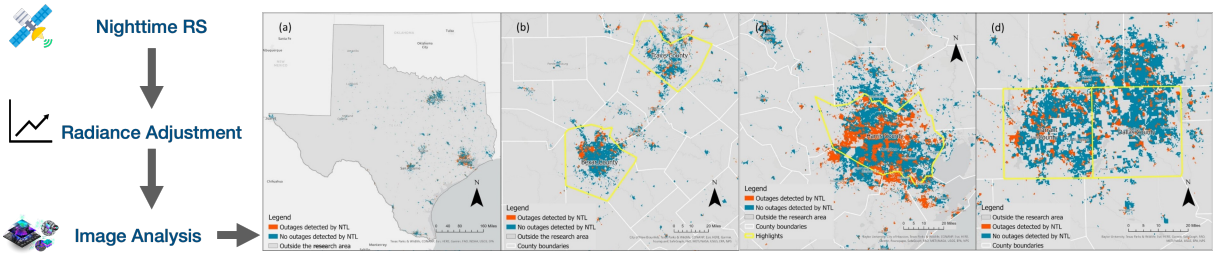
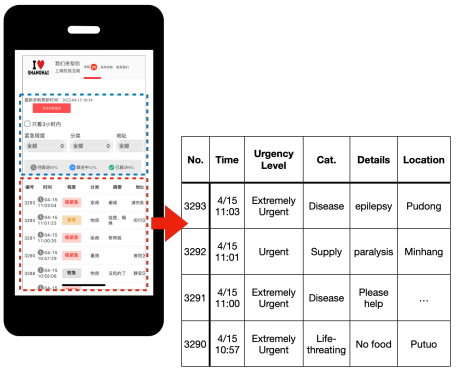


Figure 2. Applying nighttime remote sensing and image analysis to map power outages in 2021 Winter Storm Uri in Texas, U.S.

Figure 3 illustrates the third study using a mutual help app and NLP to map humanitarian needs during the 2022 COVID-19 outbreak in Shanghai, China. A total of 4396 help requests were obtained and analyzed. The results indicate that the help requests were clustered in downtown Shanghai. The help requests' content unveils a need for medication and groceries under lockdown. It also underscores that the elderly population was affected most by the lockdown.



No.	Time	Urgency Level	Cat.	Details	Location
3293	4/15 11:03	Extremely Urgent	Disease	epilepsy	Pudong
3292	4/15 11:01	Urgent	Supply	paralysis	Minhang
3291	4/15 11:00	Extremely Urgent	Disease	Please help	...
3290	4/15 10:57	Extremely Urgent	Life-threating	No food	Putuo

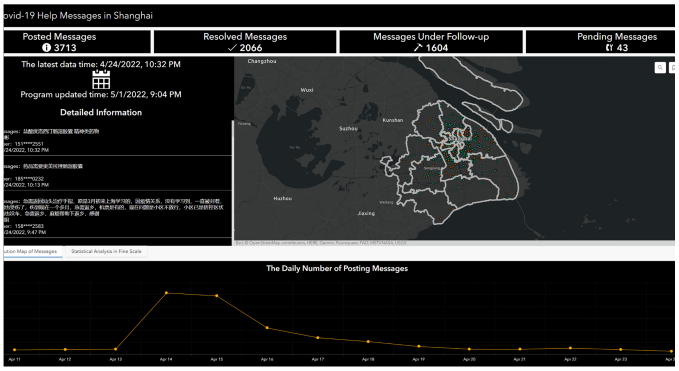


Figure 3. Using a mutual help app and NLP to map humanitarian needs during 2022 COVID-19 Outbreak in Shanghai, China

This research highlights the transformative potential of geospatial big data and AI in advancing smart humanitarian mapping across diverse disaster scenarios. By integrating social media data, nighttime remote sensing, and crowdsourced platforms with cutting-edge AI models, the work enhanced our capabilities in mapping rescue requests, power outages, and humanitarian needs during disasters. These efforts not only provide actionable insights for disaster response but also address challenges in implementing these technologies, contributing to the development of more resilient and equitable communities worldwide.

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References

Zou, L., Mostafavi, A., Zhou, B., Lin, B., Mandal, D., Yang, M., Abedin, J. and Cai, H., 2023. GeoAI for Disaster Response. In *Handbook of Geospatial Artificial Intelligence* (pp. 287-304). CRC Press.

Zhou, B., Zou, L., Mostafavi, A., Lin, B., Yang, M., Gharaibeh, N., Cai, H., Abedin, J. and Mandal, D., 2022. VictimFinder: Harvesting rescue requests in disaster response from social media with BERT. *Computers, Environment and Urban Systems*, *95*, p.101824.

Zhou, B., Zou, L., Hu, Y., Qiang, Y. and Goldberg, D., 2023. TopoBERT: a plug and play toponym recognition module harnessing fine-tuned BERT. *International Journal of Digital Earth*, *16*(1), pp.3045-3064.

Xu, J., Qiang, Y., Cai, H. and Zou, L., 2023. Power outage and environmental justice in Winter Storm Uri: an analytical workflow based on nighttime light remote sensing. *International Journal of Digital Earth, 16*(1), pp.2259-2278.