Next Generation Web Technologies for Hydrological Applications on Client-side Systems

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Abstract

As scientists are confronted with increasingly massive datasets from observations to simulations, one of the biggest challenges is having the right tools to gain scientific insight from the data and communicate the understanding to stakeholders. Recent developments in web technologies make it easy to manage, analyze, visualize, and share large data sets with the public. Web technologies, intelligent systems, artificial intelligence, and virtual and augmented reality techniques provide advanced capabilities for big data analytics, knowledge discovery and smart communication platforms. This talk provides an overview of developments in web systems for hydrological analysis and communication, and presents real-world applications of these techniques in water resources and disaster mitigation.

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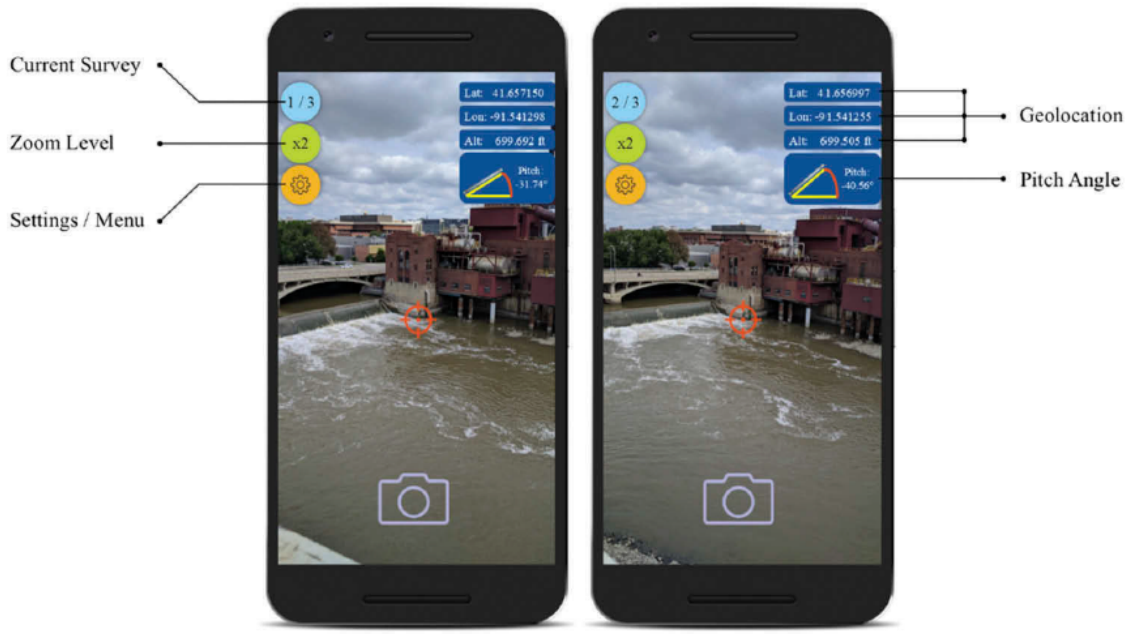
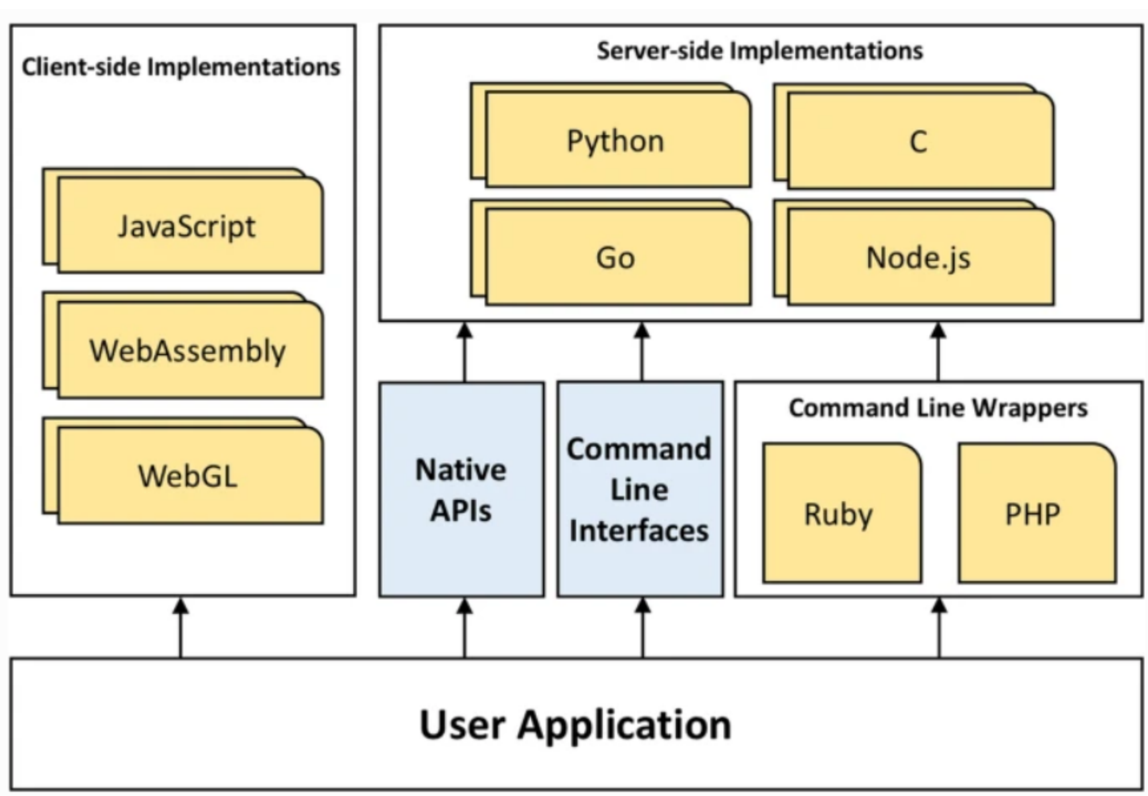
IOT & DATA STANDARDS

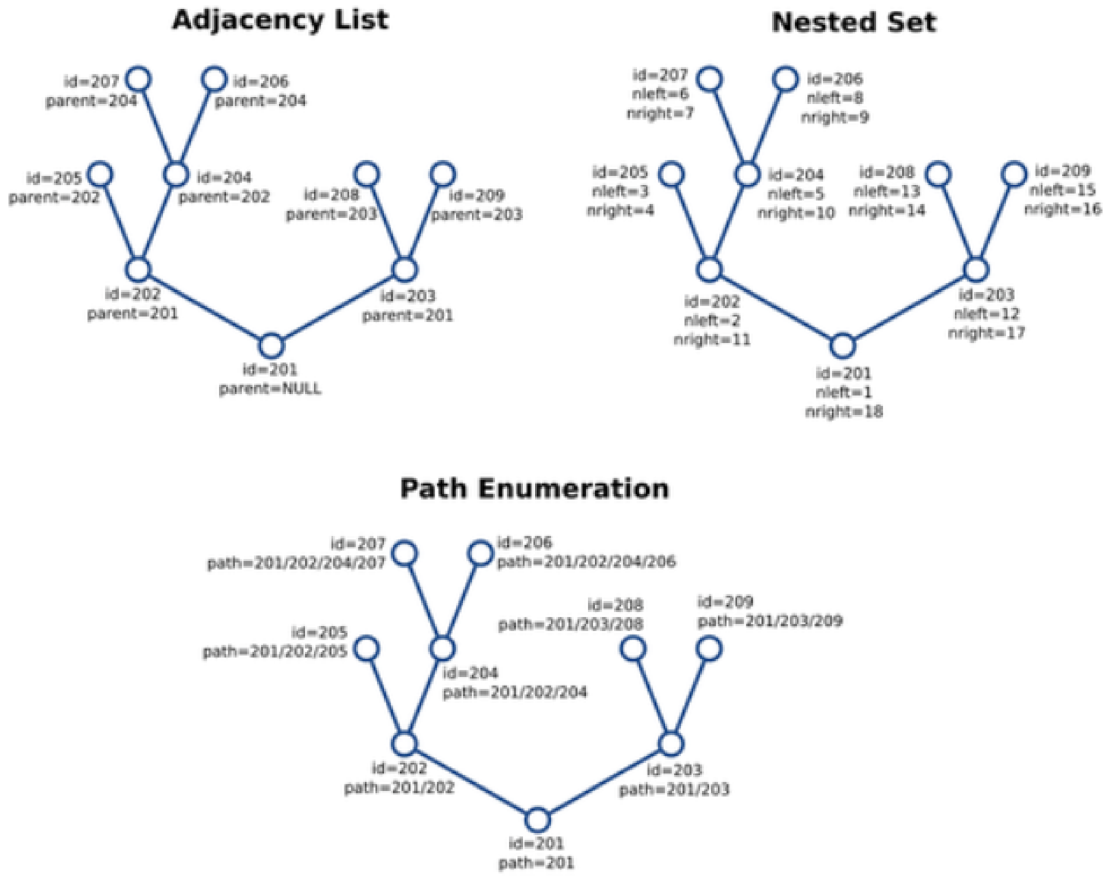
Sample figures from highlighted projects. Please check references for details.



Screenshots of the smartphone application for the initial two surveys.

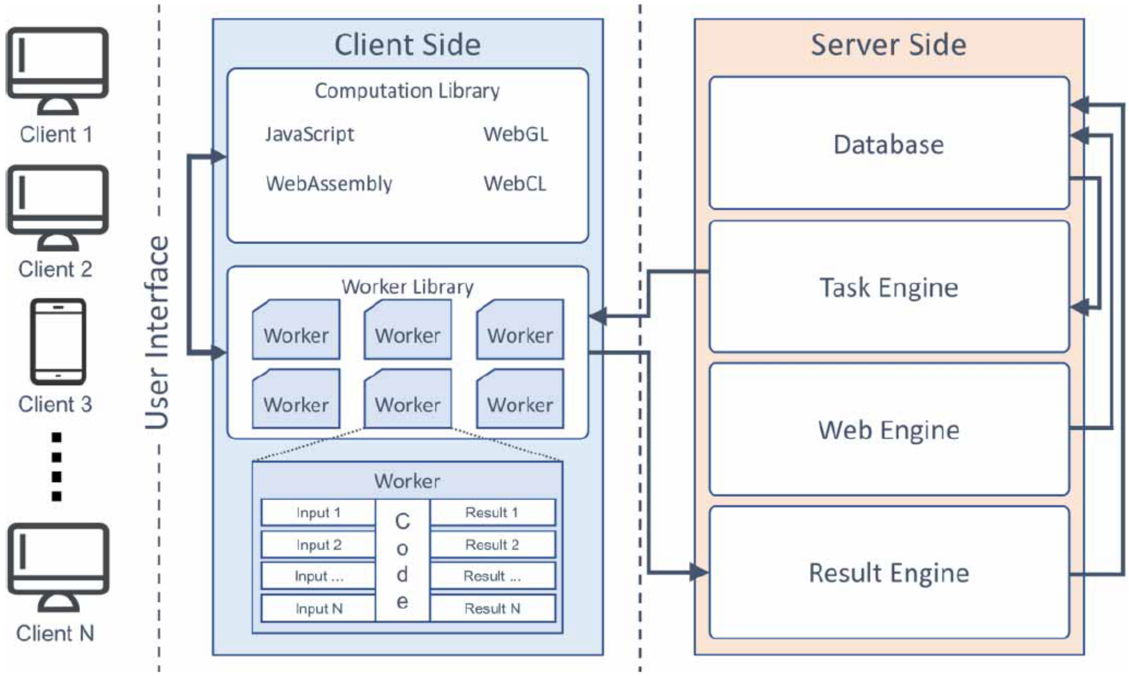


Overview of the watershed delineation implementations

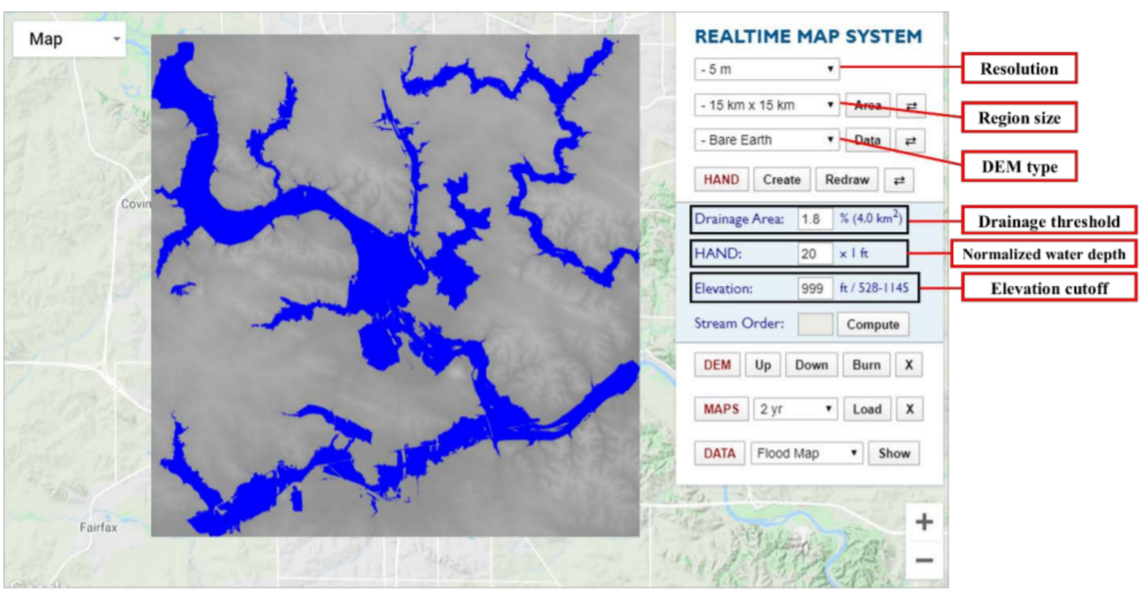


Tree network models—Adjacency List, Nested Set, and Path Enumeration.

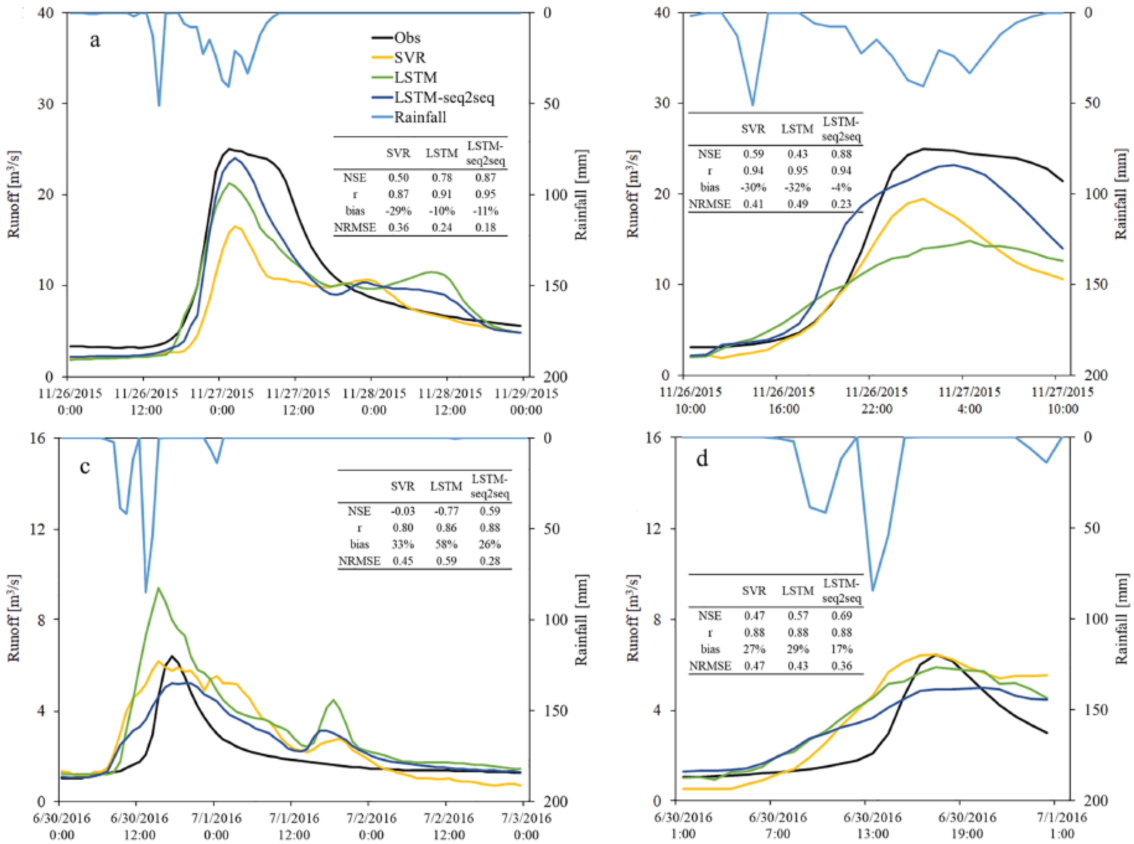
SCIENTIFIC COMPUTING



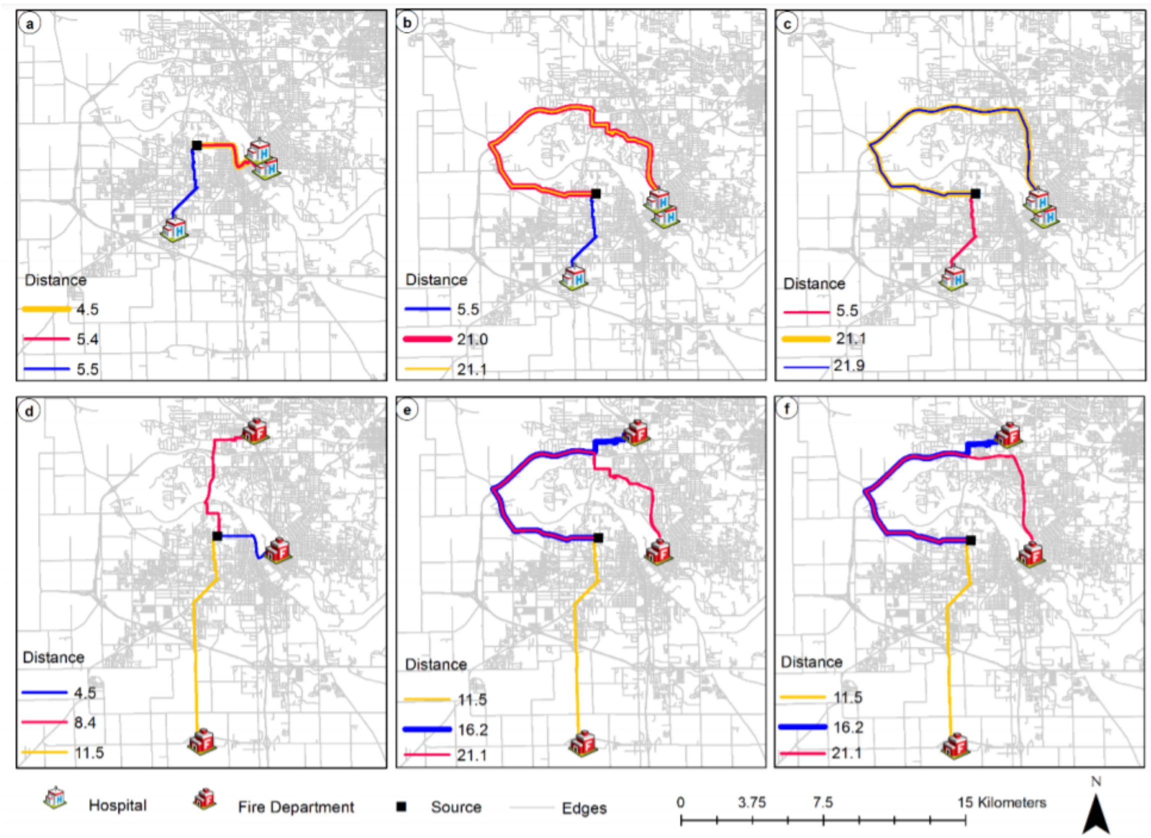
Architecture of the volunteer distributed computing framework.



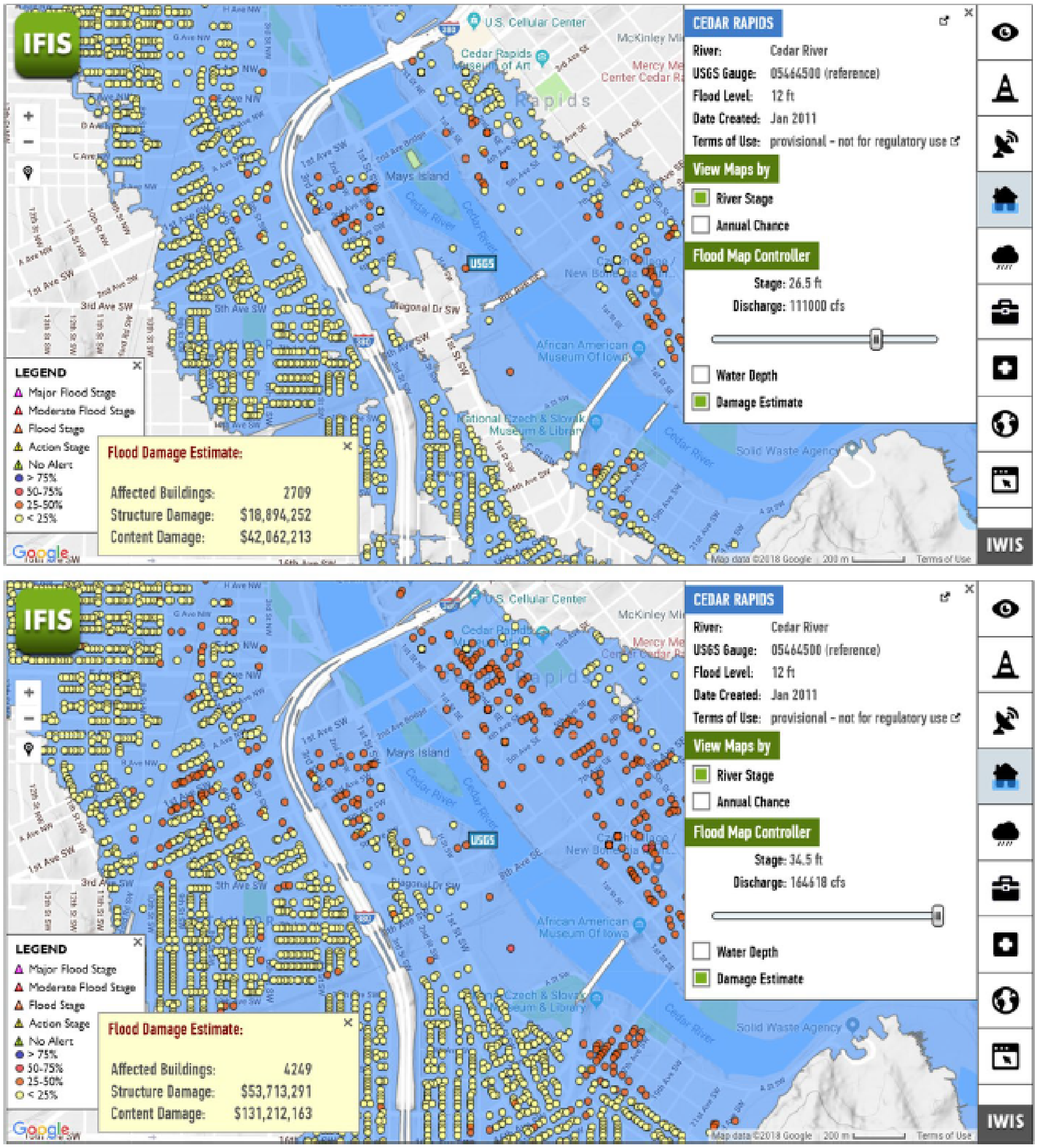
The interface of the real-time map system developed by the UIHILab



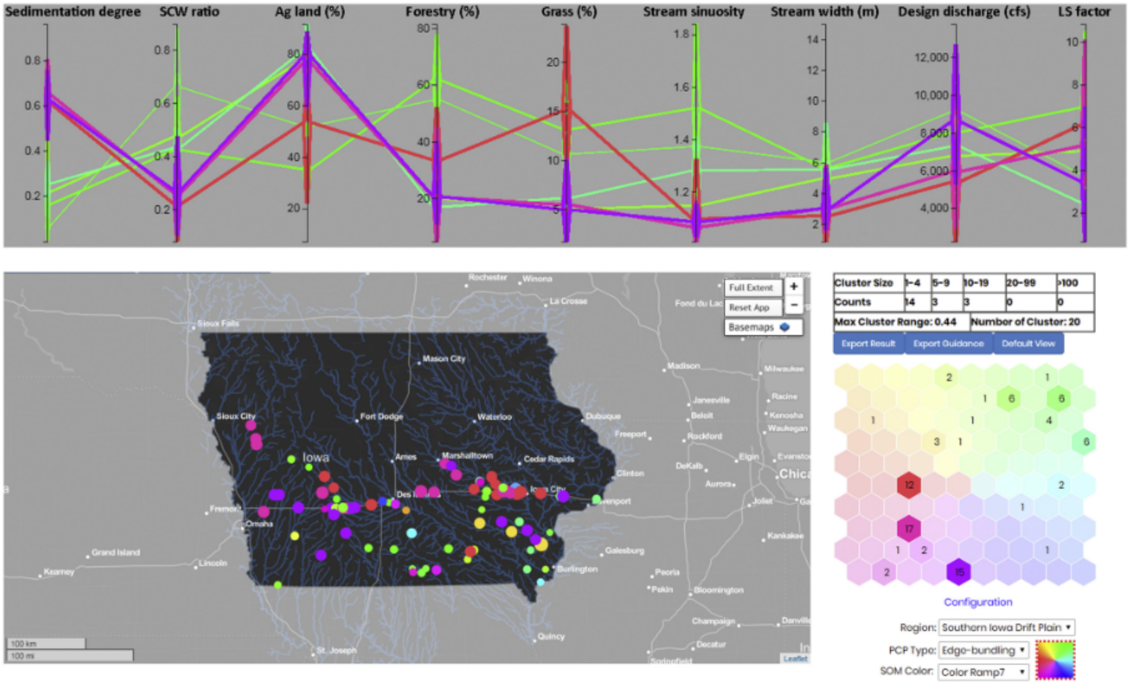
Observations and model predictions of two rainfall events in WY2016. (a, c) The 24-hour-ahead predictions for two events in a 3-day window. (b, d) A single prediction for the next 24 hr on November 26, 2015, 10 a.m., and June 30, 2016, 1 a.m.



Distance (km) to reach the closest hospital under no flood (a) 100-year flood extent (b) and 500-year flood extent (c) and the closet fire department under no flood (d), 100-year flood extent (e), and 500-year flood extent (f).

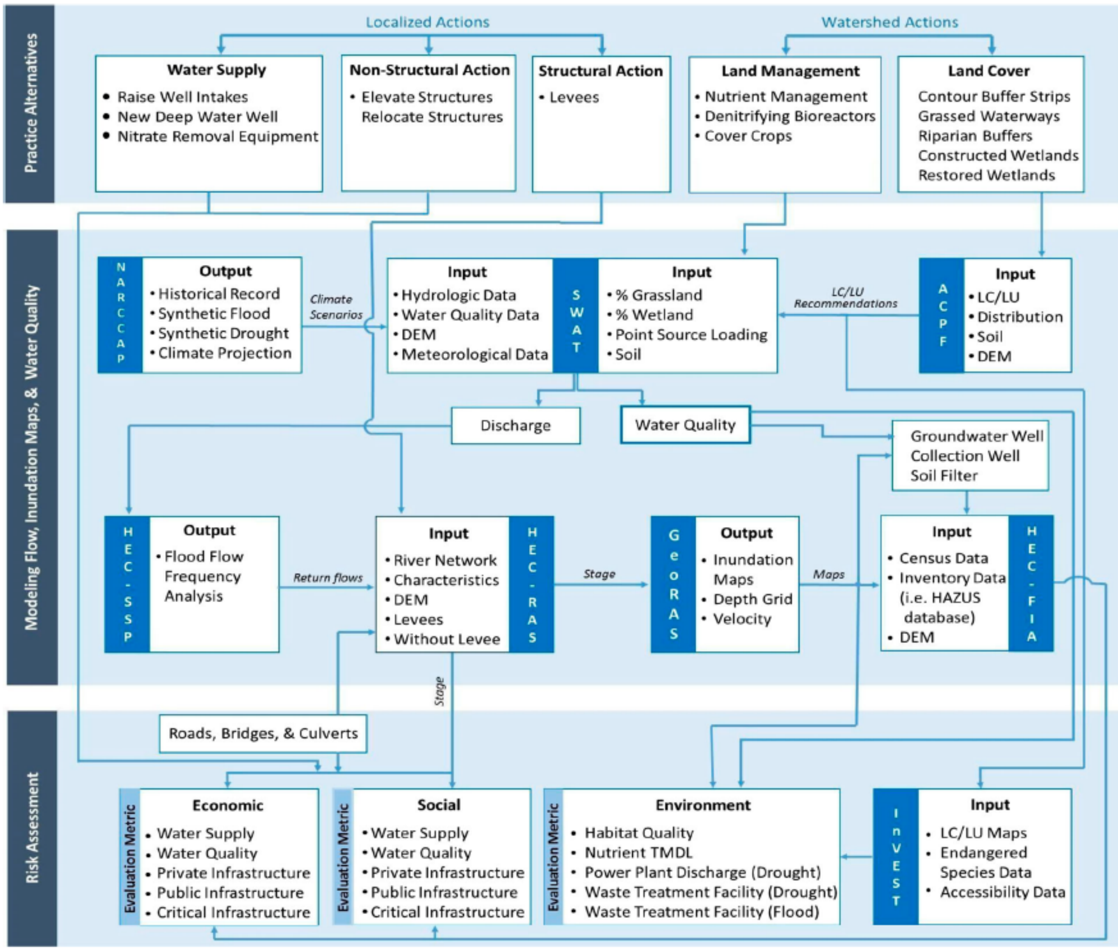


Flooded buildings in 26.5-foot (~200-year, top) and 34.5-foot (~500-year, bottom) stage height floods in Cedar Rapids

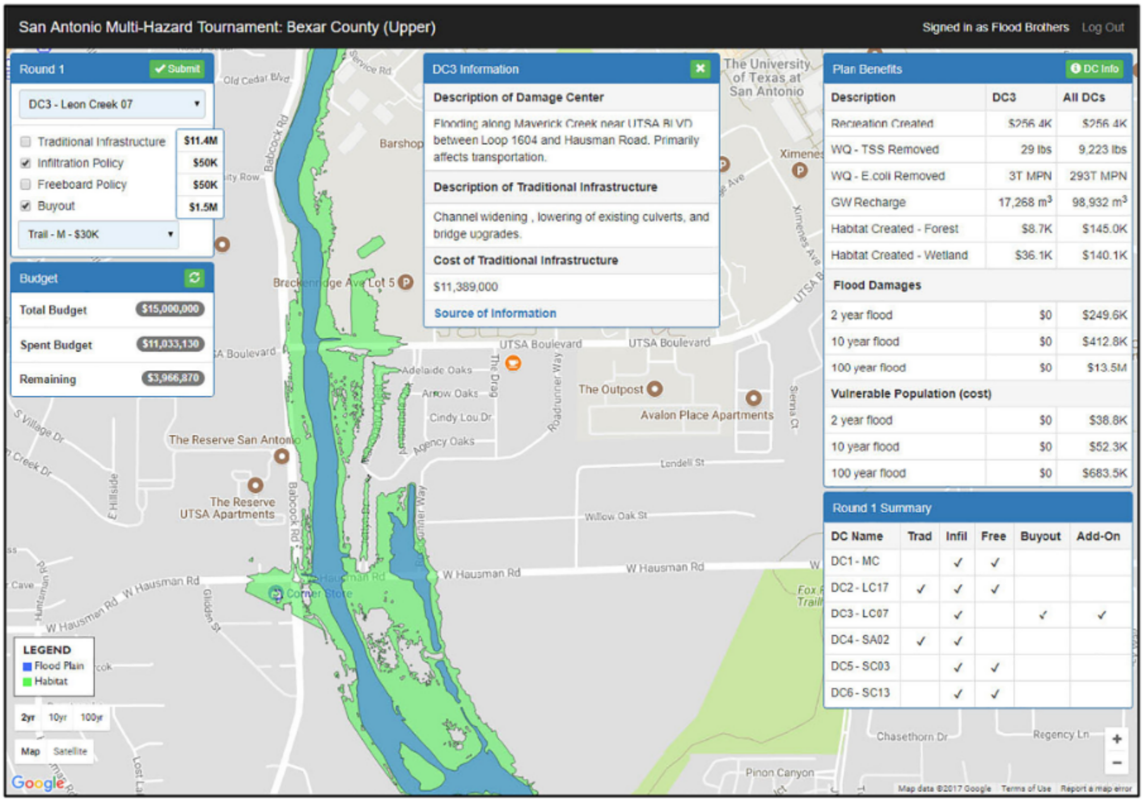


Empirical relationships between drivers and the culvert sedimentation degrees in the Southern Iowa Drift Plain regions.

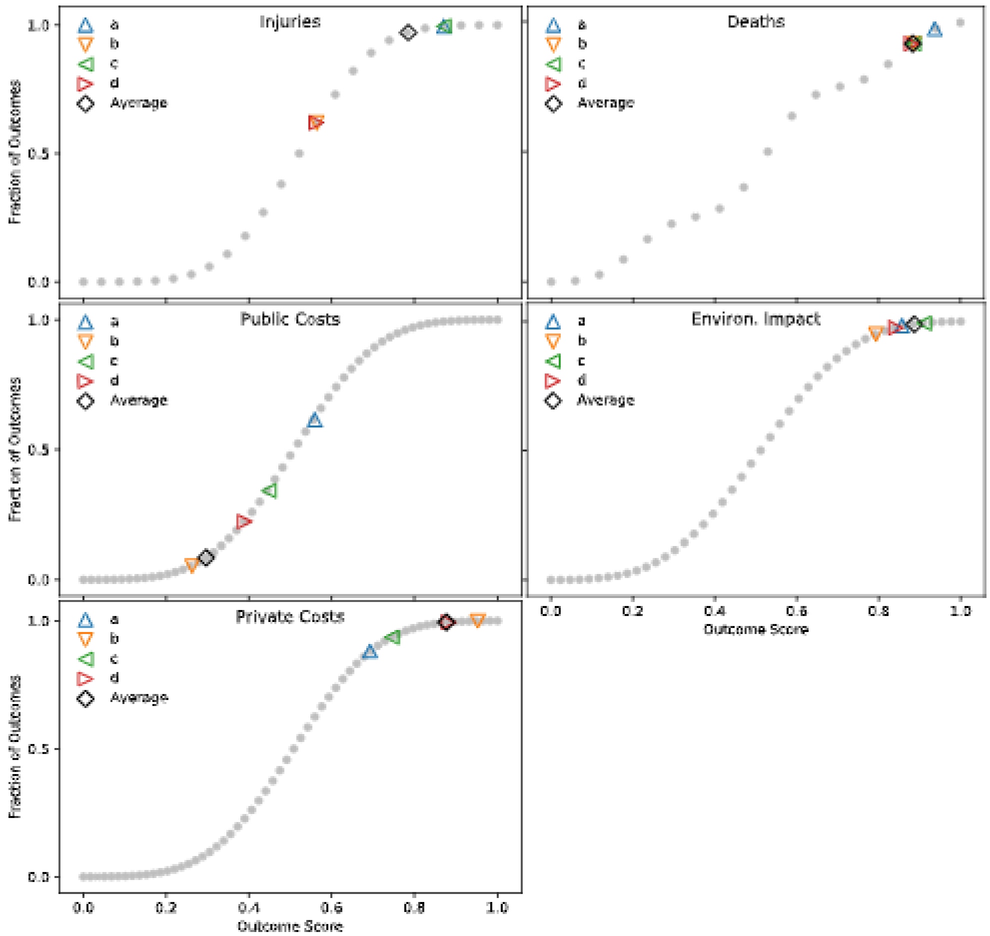
DECISION SUPPORT



The modelling components that drive the IoWaDSS scoring output with examples of model inputs and outputs.



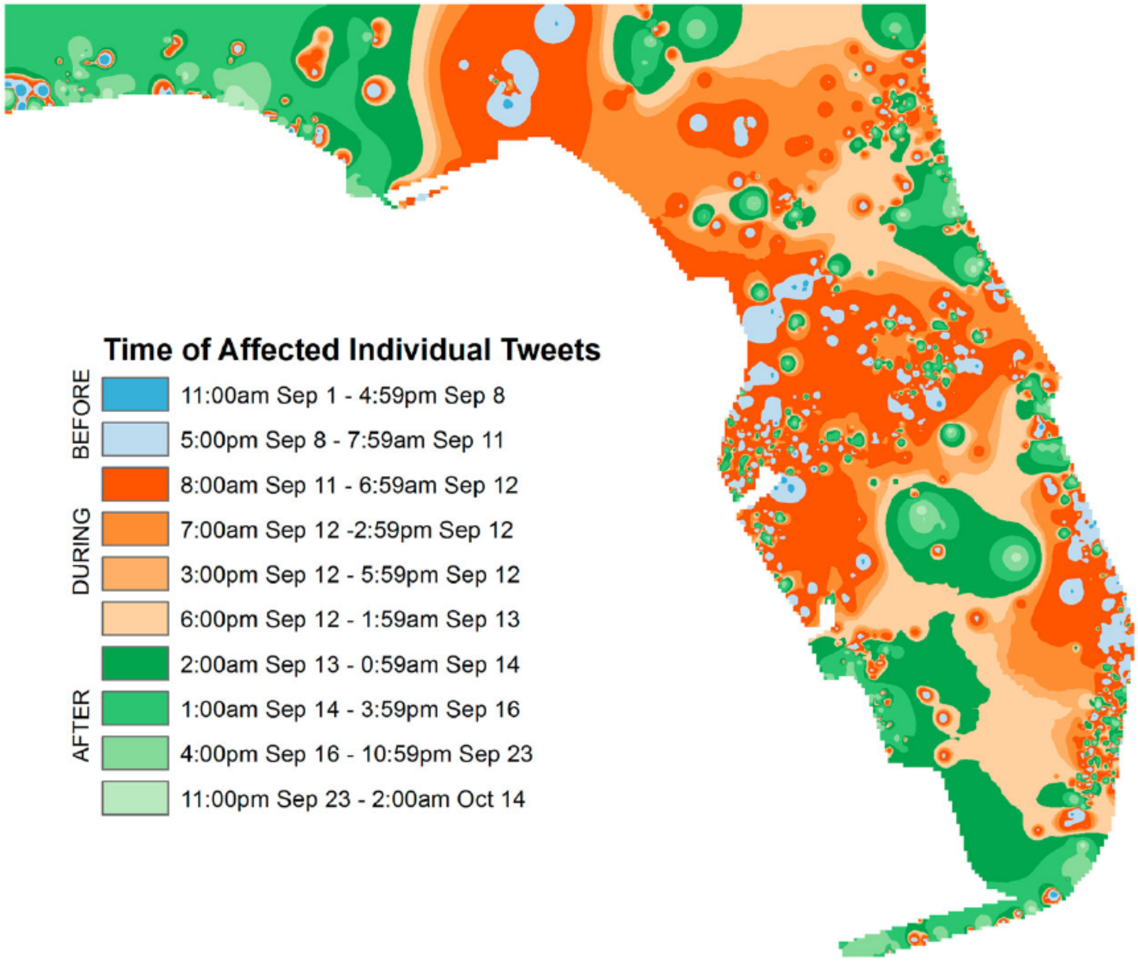
Gameplay - multi-hazard tournament main application page.



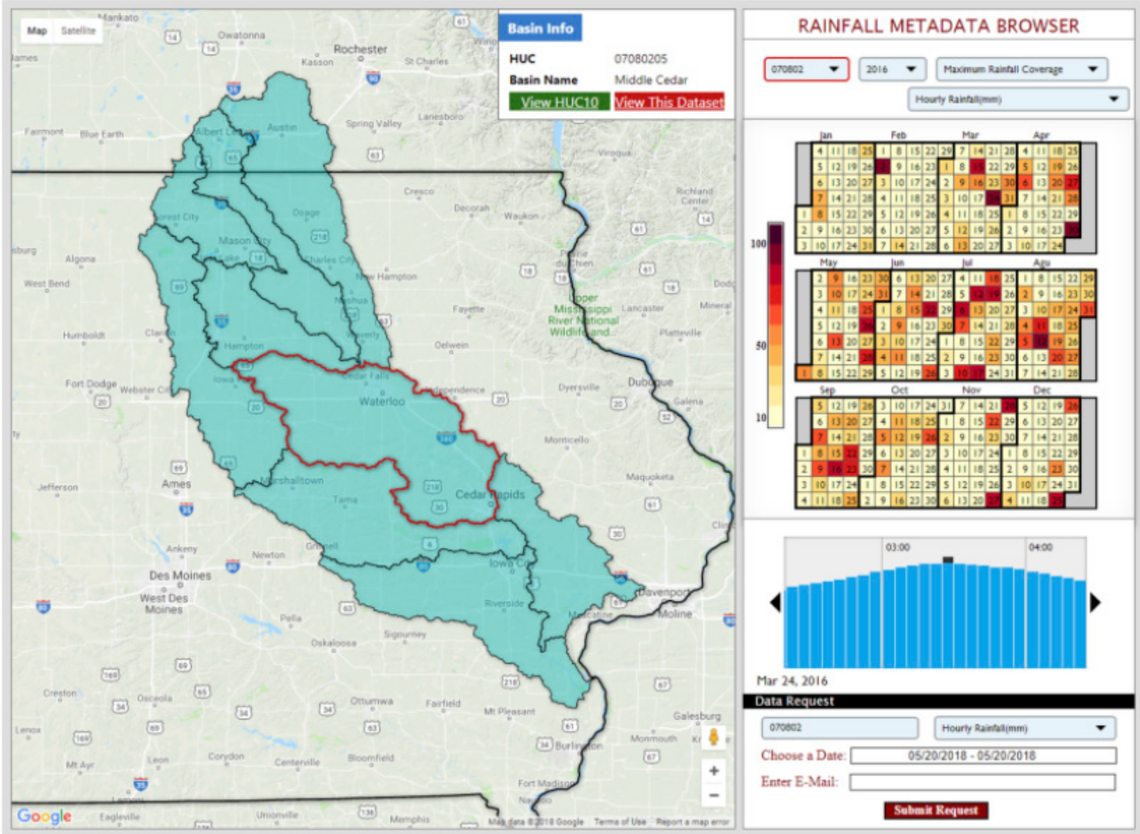
Ranking curves for each of the five learned models along each of the five relevant belief features. Overall, the learned models performed well. Model a, which had the highest cumulative score when considering minimization of damages, scored highest among the models in three categories: deaths, injuries, public costs. Yet, it also performed the worst in minimizing private costs and was third in environmental impact minimization.

DATA PROCESSING

Set of 256x256 GAN-Generated Satellite River Imagery. Across these 64 images, the final results show highly realistic river satellite imagery with little to no flaws in image quality. Specifically, this set of images was generated by the last checkpoint (iteration #96,000 for the 256x256 generation block of the PGGAN).

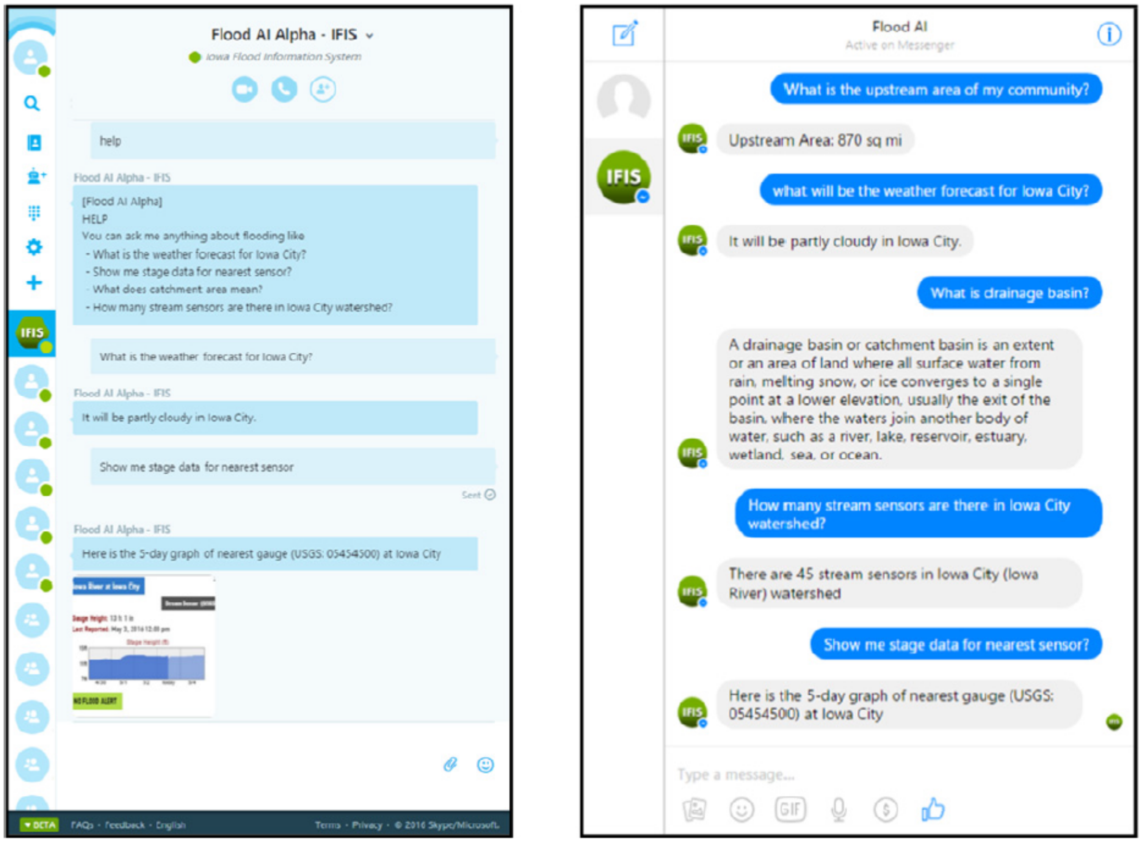


Temporal progression of affected individuals and infrastructure tweets by area. On average, Blue areas tweeted before, orange areas tweeted during, and green areas tweeted after Hurricane Irma.

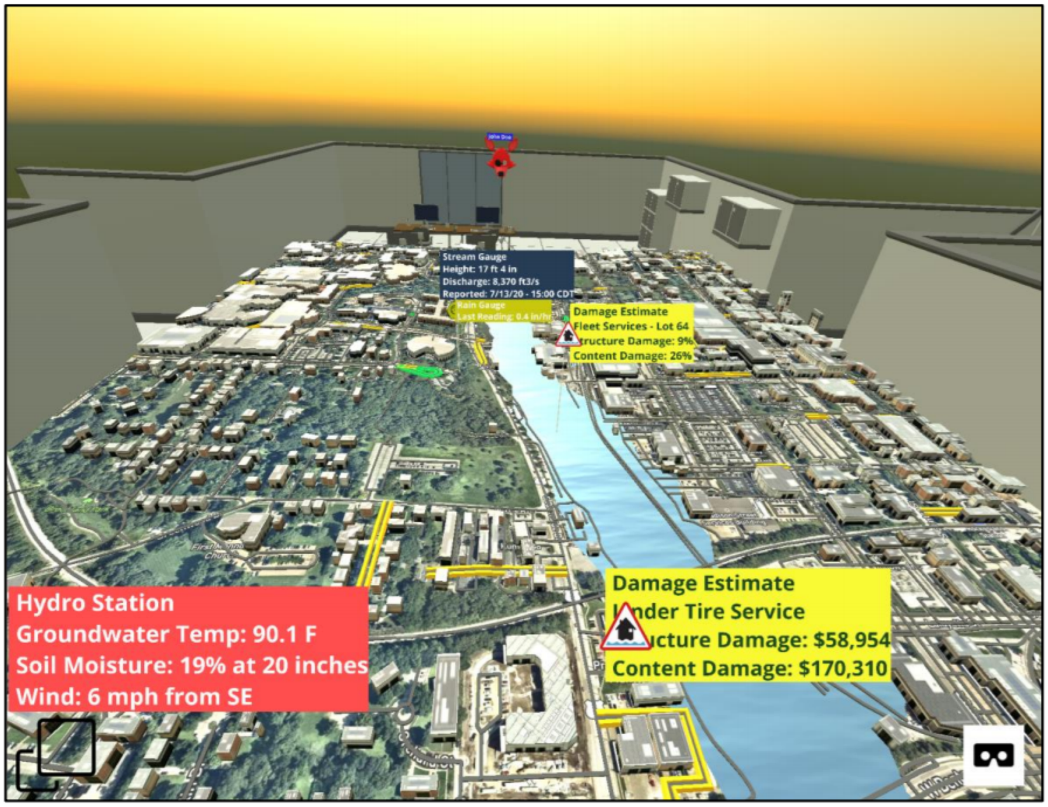


A screenshot of the IFC-Cloud-NEXRAD Graphical User Interface.

VISUALIZATION



Instant messaging interfaces integrated to Flood AI chatbots.



A case study for flood management use case for Iowa City, IA, showing a flood animation and relevant data layers (i.e. stream gauges, rain gauges, hydro stations for groundwater and soil moisture data, estimated flood damages for current or forecasted flood scenarios, and traffic congestion).

AUTHOR INFORMATION

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Dr. Demir received his PhD in Environmental Informatics from University of Georgia. He is an Assistant Professor at the Civil and Environmental Engineering, and Electrical and Computer Engineering departments at the University of Iowa. Dr. Demir's research focuses on hydroinformatics, environmental information systems, scientific visualization, big data analytics, intelligent systems, and information communication. His research projects include intelligent systems, smart assistants and chatbots for flooding, crowdsourced augmented reality applications for environmental monitoring, virtual reality and cyber learning systems for hydrological simulations, and holographic applications for emergency management. Dr. Demir currently serves as Editor for Journal of Hydroinformatics (IWA), Environmental Modeling and Software (Elsevier) and Smart Water (Spring) and various national and international informatics and cyberinfrastructure leadership committees including the CUAHSI Informatics Committee, NSF EarthCube Technology and Architecture Committee and International Joint Committee on Hydroinformatics (IWA/IAHR/IAHS).

ABSTRACT

As scientists are confronted with increasingly massive datasets from observations to simulations, one of the biggest challenges is having the right tools to gain scientific insight from the data and communicate the understanding to stakeholders. Recent developments in web technologies make it easy to manage, analyze, visualize, and share large data sets with the public. Web technologies, intelligent systems, artificial intelligence, and virtual and augmented reality techniques provide advanced capabilities for big data analytics, knowledge discovery and smart communication platforms. This talk provides an overview of developments in web systems for hydrological analysis and communication, and presents real-world applications of these techniques in water resources and disaster mitigation.

(https://agu.confex.com/data/abstract/agu/fm20/6/2/Paper_730326_abstract_695551_0.png)

REFERENCES

References

Check our website for project details and full list of references.

https://hydroinformatics.uiowa.edu/publications.php (https://hydroinformatics.uiowa.edu/publications.php)

1. Sermet, Y. and Demir, I., 2020. A Semantic Web Framework for Automated Smart Assistants: COVID-19 Case Study. IEEE Transactions on Big Data, AI for COVID-19 Special Issue. arXiv:2007.00747.
Link: https://arxiv.org/abs/2007.00747 (in review)

2. Ewing, G., & Demir, I. 2020. An Ethical Decision-Making Framework with Serious Gaming: Smart Water Case Study on Flooding. Journal of Hydroinformatics. EarthArXiv. June 23.
DOI: https://doi.org/10.31223/osf.io/y873g (in review)

3. Li, Z., Mount, J. and Demir, I., 2020. Evaluation of Model Parameters of HAND Model for Real-Time Flood Inundation Mapping: Iowa Case Study. Hydrological Science Journal. EarthArXiv. July 1.
DOI: https://doi.org/10.31223/osf.io/hqpzg (in review)

4. Demiray, B.Z., Sit, M. and Demir, I., 2020. D-SRGAN: DEM Super-Resolution with Generative Adversarial Network. SN Computer Science. arXiv:2004.04788 [cs.CV]
Link: https://arxiv.org/abs/2004.04788 (in review)

5. Yildirim, E., Demir, I., 2020. An Integrated Flood Risk Assessment and Mitigation Framework: Middle Cedar River Basin Case Study, International Journal of Disaster Risk Reduction. EarthArXiv. August 20.
DOI: https://doi.org/10.31223/osf.io/68zc4 (in review)

6. Sit, M.A., Langel, R.J., Thompson, D., Cwiertny, D.M., Demir, I., 2020. Web-based Data Analytics Framework for Well Forecasting and Groundwater Quality. Science of the Total Environment, 2020. EarthArXiv. August 16.
DOI: https://doi.org/10.31223/osf.io/e5avq (in review)

7. Haltas, I., Yildirim, E., Oztas, F., Demir, I., 2020. A Comprehensive Flood Event Specification and Inventory: 1930-2020 Turkey Case Study, International Journal of Disaster Risk Reduction, 2020. EarthArXiv. August 16.
DOI: https://doi.org/10.31223/osf.io/yc49t (in review)

8. Sermet, Y., Demir, I., 2020. GeospatialVR: A Web-based Virtual Reality Framework for Collaborative Environmental Simulations. Environmental Modeling and Software, 2020. EarthArXiv. August 8.
DOI: https://doi.org/10.31223/osf.io/ks2yz (in review)

9. Alabbad, Y., Mount, J, Campbell, A. M., Demir, I., 2020. Wayfinding and Accessibility Analysis for Critical Amenities in Iowa During Flood Events, International Journal of Disaster Risk Reduction. 2020. EarthArXiv. August 16.
DOI: https://doi.org/10.31223/osf.io/2yha5 (in review)

10. Teague, A., Sermet, Y., Demir, I., Muste, M., 2020. Serious Gaming for Water Resources Planning and Hazard Mitigation. Water Resources Research, 2020. EarthArXiv. August 3.
DOI: https://doi.org/10.31223/osf.io/vcy5e (in review)

11. Sit, M.A., Demiray, B.Z., Xiang, Z., Ewing, G., Sermet, Y. and Demir, I., 2020. A Comprehensive Review of Deep Learning Applications in Hydrology and Water Resources. Water Science & Technology. EarthArXiv. June, 19.
DOI: https://doi.org/10.31223/osf.io/xs36g (in press)

12. Xiang, Z. and Demir, I., 2020. Distributed long-term hourly streamflow predictions using deep learning–A case study for State of Iowa. Environmental Modelling & Software, p.104761.
DOI: https://doi.org/10.1016/j.envsoft.2020.104761

13. Sermet, Y., Demir, I. and Muste, M., 2020. A serious gaming framework for decision support on hydrological hazards. Science of The Total Environment, p.138895.
DOI: https://doi.org/10.1016/j.scitotenv.2020.138895

14. Agliamzanov, R., Sit, M. and Demir, I., 2020. Hydrology@ Home: a distributed volunteer computing framework for hydrological research and applications. Journal of Hydroinformatics, 22(2), pp.235-248.
DOI: https://doi.org/10.2166/hydro.2019.170

15. Xiang, Z., Yan, J. and Demir, I., 2020. A Rainfall-Runoff Model With LSTM-Based Sequence-to-Sequence Learning. Water resources research, 56(1).
DOI: https://doi.org/10.1029/2019WR025326

16. Sermet, Y., Villanueva, P., Sit, M.A. and Demir, I., 2020. Crowdsourced approaches for stage measurements at ungauged locations using smartphones. Hydrological Sciences Journal, 65(5), pp.813-822.
DOI: https://doi.org/10.1080/02626667.2019.1659508

17. Xu, H., Windsor, M., Muste, M. and Demir, I., 2020. A web-based decision support system for collaborative mitigation of multiple water-related hazards using serious gaming. Journal of Environmental Management, 255, p.109887.
DOI: https://doi.org/10.1016/j.jenvman.2019.109887

18. Xu, H., Muste, M. and Demir, I., 2019. Web-based geospatial platform for the analysis and forecasting of sedimentation at culverts. Journal of Hydroinformatics, 21(6), pp.1064-1081.
DOI: http://doi.org/10.2166/hydro.2019.068

19. Sit, M., Sermet, Y. and Demir, I., 2019. Optimized watershed delineation library for server-side and client-side web applications. Open Geospatial Data, Software and Standards, 4(1), p.8.
DOI: https://doi.org/10.1186/s40965-019-0068-9

20. Sermet, Y. and Demir, I., 2019. Towards an information centric flood ontology for information management and communication. Earth Science Informatics, 12(4), pp.541-551.
DOI: https://doi.org/10.1007/s12145-019-00398-9

21. Yildirim, E. & Demir, I., 2019. An integrated web framework for HAZUS-MH flood loss estimation analysis. Natural Hazards, 99(1), pp.275–286.
DOI: https://doi.org/10.1007/s11069-019-03738-6

22. Xu, H., Demir, I., Koylu, C. and Muste, M., 2019. A web-based geovisual analytics platform for identifying potential contributors to culvert sedimentation. Science of The Total Environment, 692, pp.806-817.
DOI: https://doi.org/10.1016/j.scitotenv.2019.07.157

23. Sit, M.A., Koylu, C. & Demir, I., 2019. Identifying disaster-related tweets and their semantic, spatial and temporal context using deep learning, natural language processing and spatial analysis: a case study of Hurricane Irma. International Journal of Digital Earth, 12(11), pp.1205–1229.
DOI: https://doi.org/10.1080/17538947.2018.1563219

24. Seo, B.C., Keem, M., Hammond, R., Demir, I. and Krajewski, W.F., 2019. A pilot infrastructure for searching rainfall metadata and generating rainfall product using the big data of NEXRAD. Environmental Modelling & Software, 117, pp.69-75.
DOI: https://doi.org/10.1016/j.envsoft.2019.03.008

25. Sermet, Y. and Demir, I., 2018. An intelligent system on knowledge generation and communication about flooding. Environmental modelling & software, 108, pp.51-60.
DOI: https://doi.org/10.1016/j.envsoft.2018.06.003

26. Demir, I., Yildirim, E., Sermet, Y. and Sit, M.A., 2018. FLOODSS: Iowa flood information system as a generalized flood cyberinfrastructure. International journal of river basin management, 16(3), pp.393-400.
DOI: https://doi.org/10.1080/15715124.2017.1411927

27. Jones, C.S., Davis, C.A., Drake, C.W., Schilling, K.E., Debionne, S.H., Gilles, D.W., Demir, I. and Weber, L.J., 2018. Iowa statewide stream nitrate load calculated using in situ sensor network. JAWRA Journal of the American Water Resources Association, 54(2), pp.471-486.
DOI: https://doi.org/10.1111/1752-1688.12618

28. Carson, A., Windsor, M., Hill, H., Haigh, T., Wall, N., Smith, J., Olsen, R., Bathke, D., Demir, I. and Muste, M., 2018. Serious gaming for participatory planning of multi-hazard mitigation. International journal of river basin management, 16(3), pp.379-391.
DOI: https://doi.org/10.1080/15715124.2018.1481079

29. Weber, L.J., Muste, M., Bradley, A.A., Amado, A.A., Demir, I., Drake, C.W., Krajewski, W.F., Loeser, T.J., Politano, M.S., Shea, B.R. and Thomas, N.W., 2018. The Iowa Watersheds Project: Iowa's prototype for engaging communities and professionals in watershed hazard mitigation. International journal of river basin management, 16(3), pp.315-328.
DOI: https://doi.org/10.1080/15715124.2017.1387127

30. Demir, I. and Szczepanek, R., 2017. Optimization of river network representation data models for web-based systems. Earth and Space Science, 4(6), pp.336-347.
DOI: https://doi.org/10.1002/2016ea000224

31. Krajewski, W.F., Ceynar, D., Demir, I., Goska, R., Kruger, A., Langel, C., Mantilla, R., Niemeier, F., Quintero, F., Seo, B.C., Small, S., Weber, L., Young, N., 2017. Real-time flood forecasting and information system for the state of Iowa. Bulletin of the American Meteorological Society, 98(3), pp.539-554.
DOI: https://doi.org/10.1175/bams-d-15-00243.1 [article chosen as journal cover image]

32. Gil, Y., David, C., Demir, I., Essawy, B., Fulweiler, R., Goodall, J., Karlstrom, L., Lee. H., Mills, H., Oh, J., Pierce, S., Pope, A., Tzeng, M., Villamizar, S., Yu, X., 2016. Toward the Geoscience Paper of the Future: Best practices for documenting and sharing research from data to software to provenance. Earth and Space Science, 3(10), pp.388-415.
DOI: https://doi.org/10.1002/2015ea000136

33. Demir, I., Conover, H., Krajewski, W.F., Seo, B.C., Goska, R., He, Y., McEniry, M.F., Graves, S.J. and Petersen, W., 2015. Data-enabled field experiment planning, management, and research using cyberinfrastructure. Journal of Hydrometeorology, 16(3), pp.1155-1170.
DOI: https://doi.org/10.1175/jhm-d-14-0163.1

34. Demir, I. and Krajewski, W.F., 2013. Towards an integrated flood information system: centralized data access, analysis, and visualization. Environmental Modelling & Software, 50, pp.77-84.
DOI: https://doi.org/10.1016/j.envsoft.2013.08.009

35. Duffy, C., Gil, Y., Deelman, E., Marru, S., Pierce, M., Demir, I. and Wiener, G., 2012. Designing a road map for geoscience workflows. Eos, Transactions American Geophysical Union, 93(24), pp.225-226.
DOI: https://doi.org/10.1029/2012eo240002

51. Gautam, A., Sit, M.A. and Demir, I., 2020. Realistic River Image Synthesis using Deep Generative Adversarial Networks. arXiv:2003.00826 [cs.CV]
DOI: https://doi.org/10.31223/osf.io/n5b7h

52. Sermet, Y. and Demir, I., 2019. A Generalized Web Component for Domain-Independent Smart Assistants. arXiv preprint arXiv:1909.02507 [cs.HC]
Arxiv: https://arxiv.org/abs/1909.02507

53. Sit, M.A. and Demir, I., 2019. Decentralized Flood Forecasting Using Deep Neural Networks. EarthArXiv - arXiv:1902.02308 [cs.LG]
DOI: https://doi.org/10.31223/osf.io/e9xqr

61. Mount, J., Alabbad, Y., Demir, I., ‘Towards an Integrated and Realtime Wayfinding Framework for Flood Events’, ARIC'19: Proceedings of the 2nd ACM SIGSPATIAL International Workshop on Advances on Resilient and Intelligent Cities, p33-36, November 5, 2019, Chicago, Illinois, USA.
DOI: https://doi.org/10.1145/3356395.3365543

62. Sermet, Y., Demir, I., Kucuksari, S., ‘Overhead Power Line Sag Monitoring through Augmented Reality’, IEEE 2018 North American Power Symposium, September 9-11, 2018, Fargo, ND.
DOI: https://doi.org/10.1109/naps.2018.8600565

63. Sermet, Y., Demir, I., ‘Flood Action VR: A Virtual Reality Framework for Disaster Awareness and Emergency Response Training’, 15th International Conference on Modeling, Simulation and Visualization Methods (MSV'18), July 30-August 2, 2018, Las Vegas, NV.
DOI: https://doi.org/10.1145/3306214.3338550

64. Ebert-Uphoff, I., Thompson, D.R., Demir, I., Gel, Y.R., Hill, M., Karpatne, A., Guereque, M., Kumar, V., Cabral-Cano, E., Smyth., P., ‘A Vision for the Development of Benchmarks to Bridge Geoscience and Data Science’, 7th International Workshop on Climate Informatics, September 20-22, 2017, Boulder, CO.
DOI: http://doi.org/10.5065/D6222SH7

65. Xu, H. Hameed, H., Windsor, M., Muste, M., Demir, I., Smith, J., Hunemuller, T., Stevenson, M. B., 'Decision-Support System for Collaborative Planning on Multi-Hazard Mitigation', 37th IAHR World Congress, August 13-18, 2017, Kuala Lumpur, Malaysia.