Multimodal Geo-Information Extraction from Social Media for Supporting Decision-Making in Disaster Management

AGILE Conference 2024

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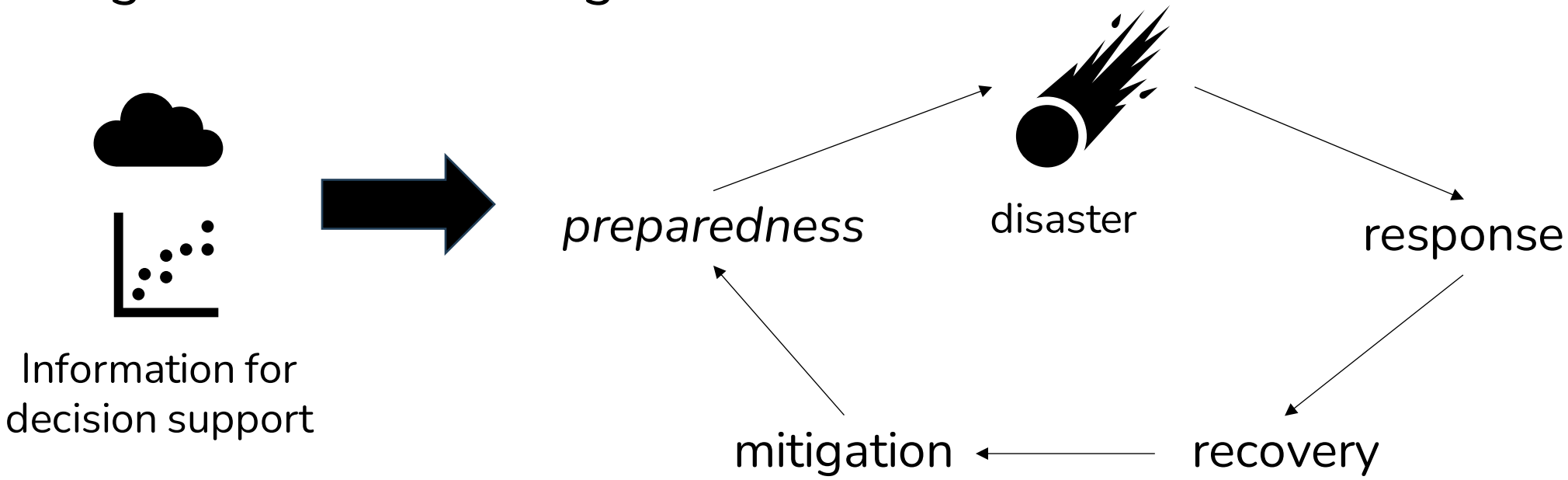
Decision support using social media

Geo-social media as a data source for supporting decision-making in disaster management



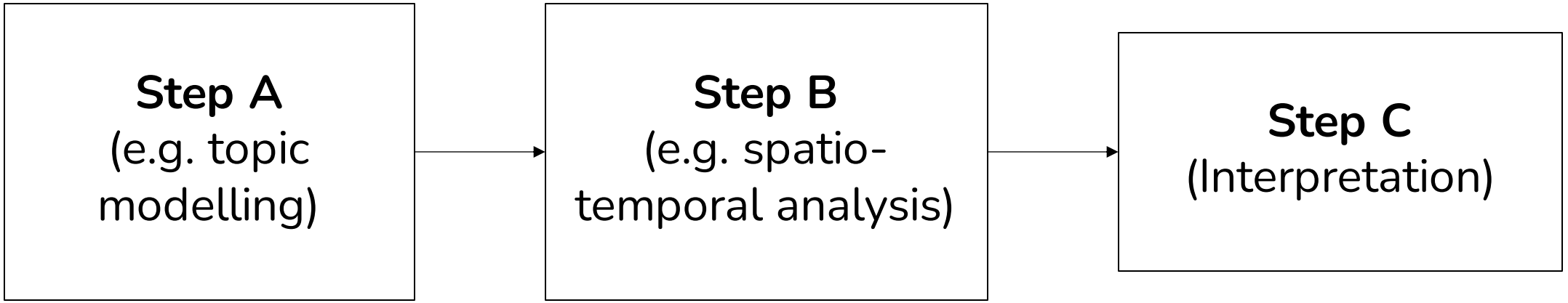
Challenges of multimodality

Multimodal nature of geo-social media posts:

- Space and Time
  - Hotspot analysis, peak detection, “humans as sensors”
- Semantics
  - Topic modelling (LDA, BERTopic), semantic classification
- Sentiment/Emotion
  - Sentiment classification (BERT)

Sequential workflows

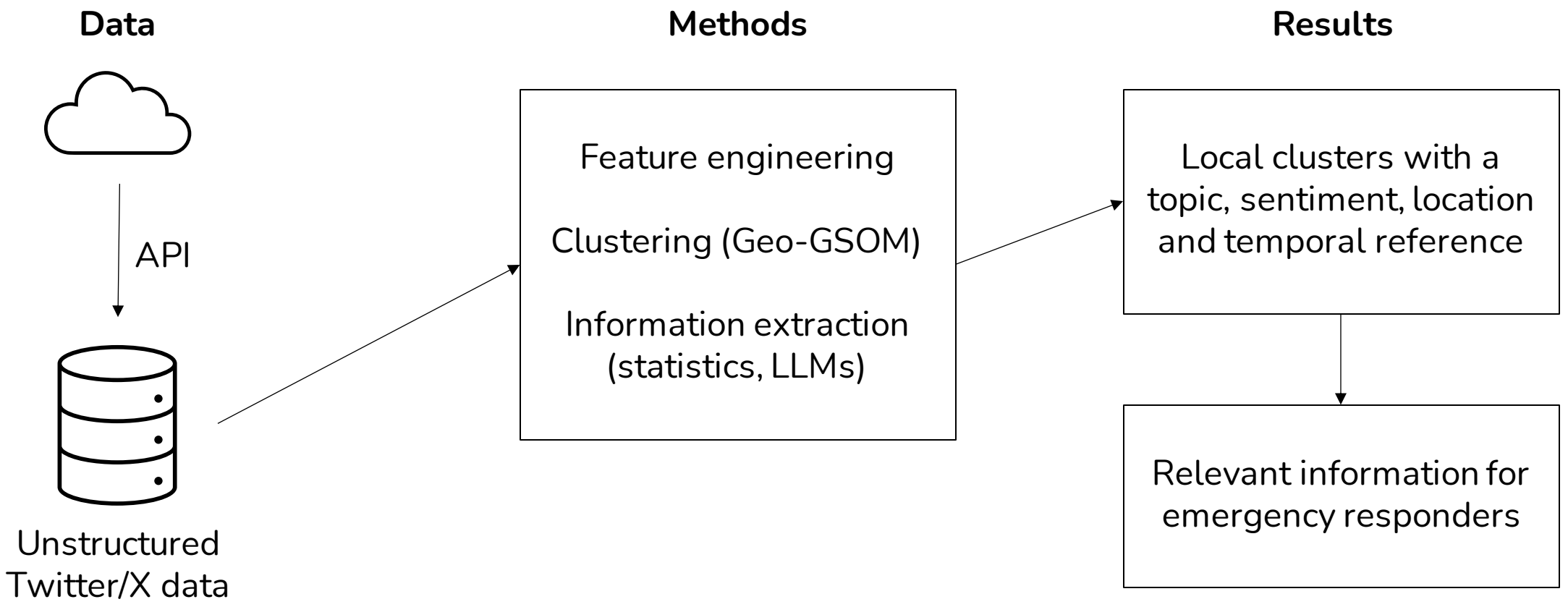
Typical workflow so far:



Beyond sequential workflows

Multimodal geo-social media analysis beyond sequential workflows?

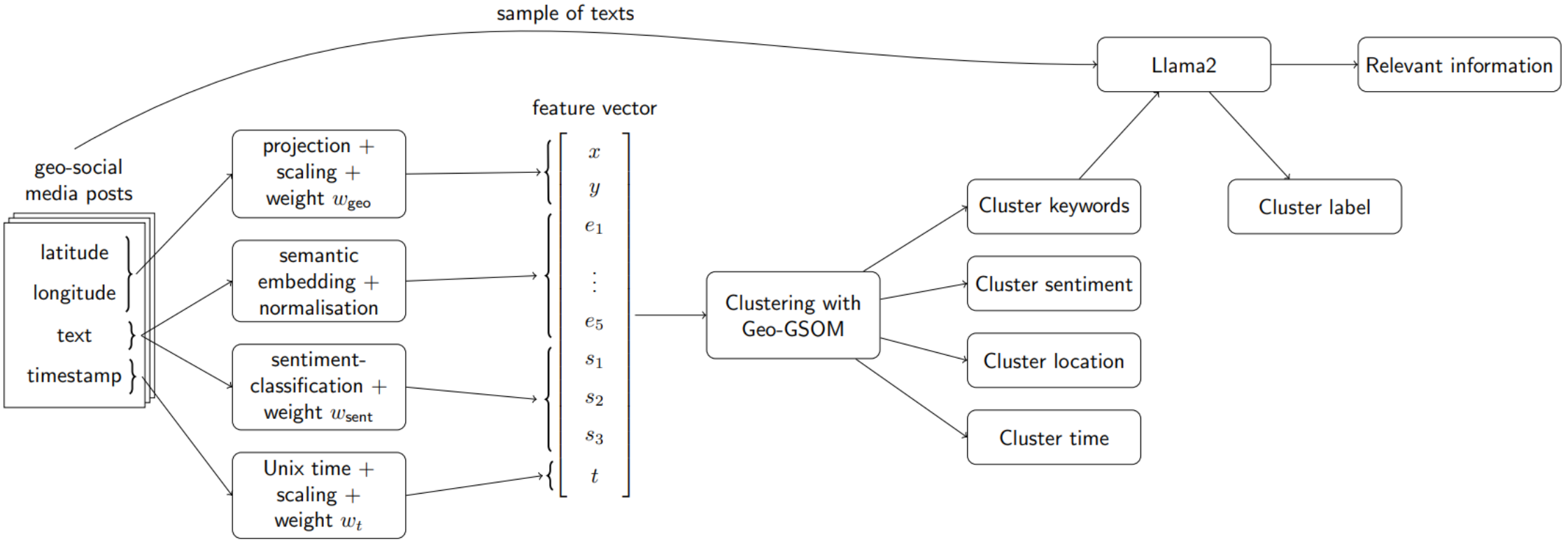
What we propose



Theoretical background

- **Text embeddings**: High-dimensional numeric text embeddings (e.g. Sentence-BERT, USE)
- **Sentiment classification**: Probabilities from logits
- **Self-Organising Maps (SOMs)** and variants
  - Geo-SOM: Geographic SOM
  - GSOM: (Dynamically) Growing SOM

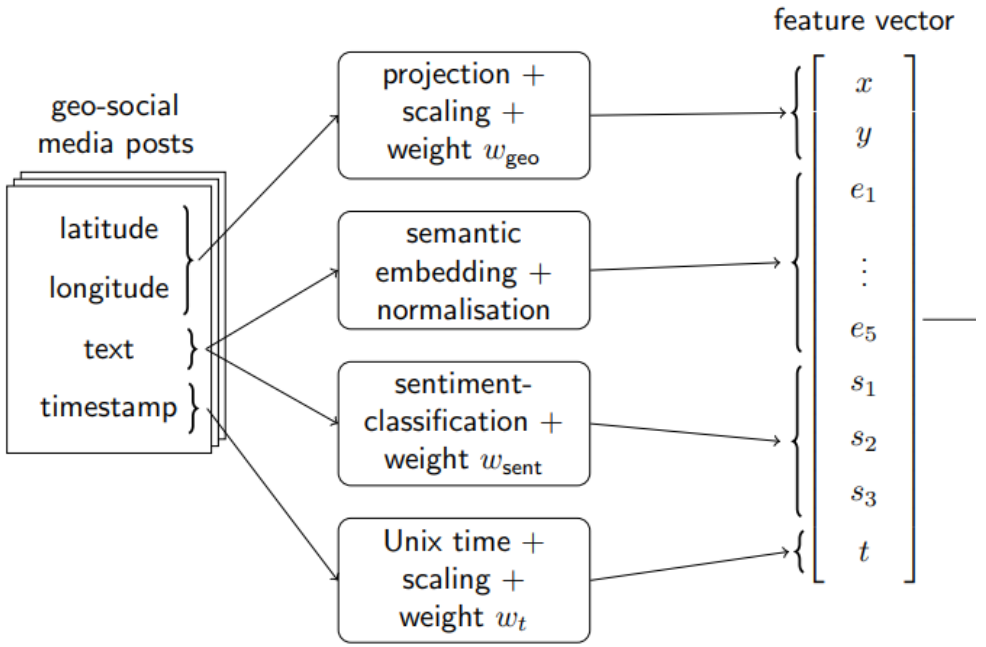
Methodology in detail



Step (1): Feature engineering

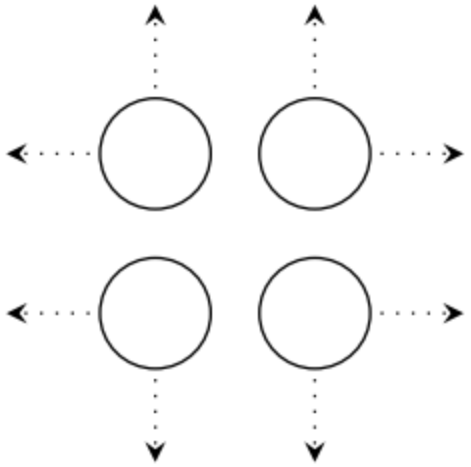
Joint feature vector for each post:

- 5 dimensions for semantics (SBERT + UMAP)
- 3 dimension for sentiment distribution (RoBERTa)
- 2 dimensions for location (projected & normalised coordinates)
- 1 dimension for time (normalised)

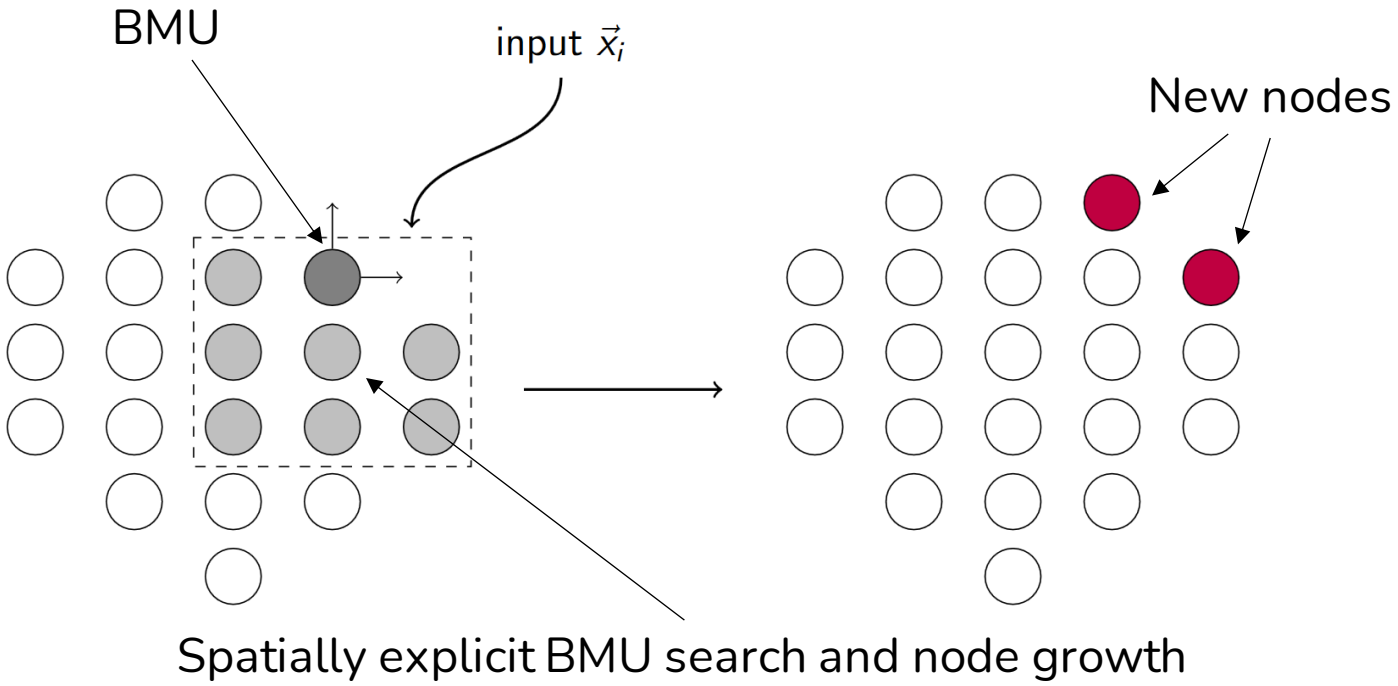


Step (2): Clustering

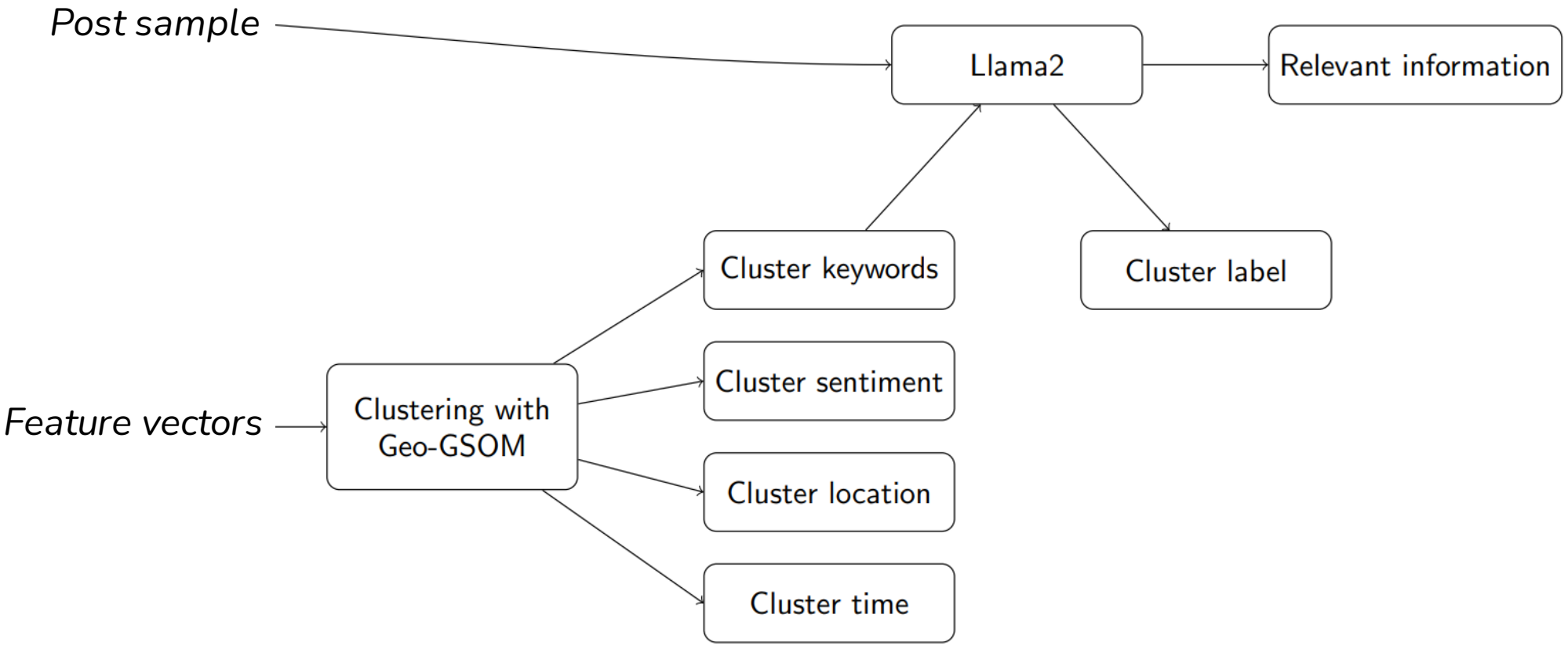
Geo-GSOM: Geographic Growing Self-Organising Map



Initial state



Step (3): Information extraction



Case Study: Ahr Valley Flood

11,177 geo-referenced tweets posted in the Ahr Valley region in July 2021

Germany floods: 155 still missing as hopes of further rescues fade

Guardian, 2021

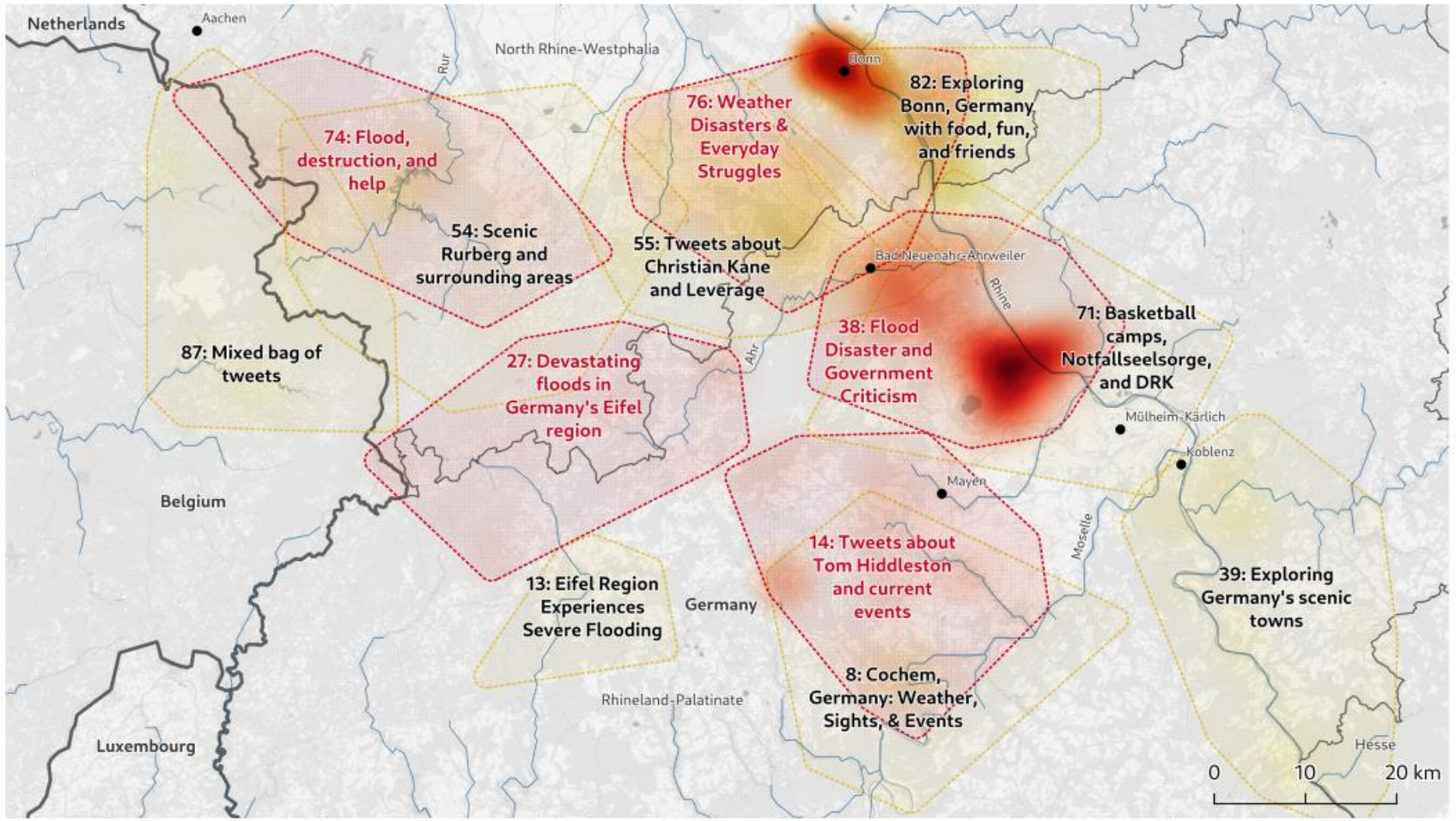
Photo: Sascha Steinbach/EPA

Model setup for multilingual data

- Semantic embedding using multilingual SBERT
- Sentiment classification using Twitter-XLM-RoBERTa
- CRS: ESRI:102031
- Parameterisation with high emphasis on location and semantics

Model output: 92 clusters, 13 potentially disaster-related

Multimodal topic map



Mapped clusters with convex hulls

Keywords, tweets and labels

ID	top 15 keywords	exemplary tweets	cluster label
38	ahrweiler, menschen, regierung, nena, erkrankung, hochwasser, ahrtal, jahren, personen, home, sinzig, macht, people, schützen, impfung	"Earlier German chancellor promised these victims would not be forgotten. One question we keep hearing from people here, when will official aid arrive?", "Es gibt z.B. Hochwasserwarnstufen 1-4 aber wenn die zuständigen öffentlichen Stellen nichts tun (schlafen, versagen) wie immer bei solchen Katastrophen ist man hilflos.", "Es ist wirklich schrecklich was das Hochwasser hinterlassen hat. Eine reine Katastrophe. Wir sind sprachlos von der riesigen Spendenaktion und der großen Hilfsbereitschaft. Vielen Dank an Alle. Folgt uns gerne mal auf Twitter."	Flood Disaster and Government Criticism
76	unwetter, halt, laschet, grade, hochwasser, hunger, since, bonn, möchte, wetter, stadt, wasser, richtig, leider, tierheim	"Got called at 3 am in the morning. Luckily the water is getting pumped out by firefighters! Unfortunately, the whole street was flooded - which is why they had to work at night too. A visiting old lady also lost her car in the underground garage. The flood came way too quick.", "Dass die Nachrichten nach dem #Unwetter immer noch schlimmer werden, hätte ich nicht gedacht... Soviele Tote und Zerstörung ....", "RIP washing machines. One car was trapped inside the underground garage when it started flooding....I couldn't find my gummi boots and it was very dark in the basement. It was a great mistake..."	Weather Disasters & Everyday Struggles

Exemplary label mappings computed by Llama2-70B by cluster ID

Emergency-relevant information

ID	sentiment	size	relevant information	temporal mean
8	neutral	37	Flood warning in Germany, especially in the Eifel region. Rescue services are on high alert.	2021-07-15 20:50
13	neutral	17	Updates on current flood situation in Eifel region, Germany.	2021-07-19 06:04
14	negative	74	Severe weather warning in Germany, with heavy rain and thunderstorms expected.	2021-07-16 14:42
27	negative	27	Damage and displacement caused by floods in Schuld and Bad Münstereifel, Germany.	2021-07-17 02:56
38	negative	287	Request for help from people affected by floods in Germany.	2021-07-20 10:22
39	neutral	118	Reports of flooding, landslides, and road closures in Germany.	2021-07-13 22:57
54	neutral	78	Updates on rescue operations and aid distribution in flooded regions of Germany.	2021-07-15 15:43
55	neutral	254	Flood warning and evacuation alert in the Voreifel region due to heavy rainfall and rising river levels.	2021-07-15 16:06
71	neutral	31	Deployments by volunteer fire department and rescue service in Mayen-Koblenz area, Germany.	2021-07-21 20:35
74	negative	34	Impact of floods on people's lives in Germany.	2021-07-20 11:01
76	negative	152	Power outages and evacuation requests due to severe weather in Rhine Valley, Germany.	2021-07-15 10:59
82	neutral	397	Evacuation alerts due to overfilled dams in Wuppertal, Rheinbach, and Radevormwald, Germany.	2021-07-15 20:20
87	neutral	86	Updates on flood situation in Belgium and Netherlands, including rising water levels and evacuations.	2021-07-15 11:42

Emergency-relevant information extracted by Llama2-70B by cluster ID

Summary

Three-step workflow:

1. (Multimodal) feature engineering
2. Clustering
3. Information extraction

Vast reduction of information complexity!

Future work and limitations

- Follow-up study regarding the generalisability of the presented method and the SOM variant
- Additional study examining the clustering approach for pure topic-sentiment modelling[1]
- Further evaluation with disaster managers
- Data availability, LLM bias

[1]Hanny, D., & Resch, B. (2024). Clustering-Based Joint Topic-Sentiment Modeling of Social Media Data: A Neural Networks Approach. Information, 15(4), Article 4.

Acknowledgements

European Commission - European Union under HORIZON EUROPE (HORIZON Research and Innovation Actions), project TEMA

Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK), project GeoSHARING

Further information

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