Graph-based river network analysis for rapid discovery and analysis of linked hydrological data

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Integration of data across the hydroscape

Humans and machines need to understand the context to derive genuine understanding from data.

Environment Agency has data from river samples across >20k sites:
> 12M measurements of nitrogen
> 2.6M measurements of phosphate
> 2.5M measurements of BOD

Can a machine understand this data without information on:

But how do we incorporate this information?
To find and use data related to rivers, the connectivity of sites to rivers is essential information:

- Find monitoring data upstream of a location
- Find nearest flow site for a water quality site
- Which of these sites has a lake upstream?
- How far is the nearest upstream sewage effluent discharge?

Data discovery may need to undertake these queries in real-time.

Machine-driven analyses may need to perform these queries across many sites.
Integration of data across the hydrocape

Building a digital representation of the freshwater environment

Using digital rivers to link:

- Monitoring sites and sensors
- Man made drivers of water quality:
  - Sewage treatment works
  - Crop maps
- Natural influences:
  - Soils
  - Lakes
  - Riparian tree cover

Could extend to include roads, livestock, abstractions, hedges……
**Integration of data across the hydroscape**

- Digital rivers with rapidly accessible connectivity information
- Rivers attributed with key geo-spatial information
- Monitoring sites linked to digital rivers
- Usable summary information to identify sites of interest
- Connectivity data could be pre-processed, but for how many combinations of sites / features?
- GIS networking tools can provide this functionality but there may be limitations in speed and integrating in analytical code-bases
- networkX is a python package for analysis of network datasets
networkX

- undirected graph
- directed graph
- multi-graph
  (can include multiple edges between the same node to describe bifurcations)
Representing a river network as a graph

- edges are river stretches
- nodes are points at intersections or other points of change along a stretch

attributes:
- length
- name
- % length through woodland, urban area, clay soil, etc.
UK river network:

- from 1:50k maps
- 433k nodes, 436k edges,
- total length: 290k km
- networked
- attributed with river name and hydrometric area
Searching river network

- Identify all up/downstream stretches from a point
- Calculate total length of stretches
- <20ms for 98/94% of down/upstream searches

Speeds viable to support real-time discovery / analysis tools
Linking sites and rivers

Water quality data for England

- ~18k water quality sample sites
- Spatial locations not precise wrt rivers
- Matching based on distance
- Many errors, with distance providing uncertainty
- Similarity between river name and site name also provides uncertainty information

Image courtesy Pixabay
Data discovery

Use case: Query site on river stretch, identify all upstream water quality monitoring sites that have more than 5 years data on both phosphorous and nitrate concentrations.

Data discovery for scientific analysis of monitoring data benefits from summary information on availability of data:

- Determinands measured at the site
- Data available for these determinands
- Frequency of measurements
- Measurement procedure / processing (e.g. sampled with lab analyses vs in situ sonde)

Potentially, Data by date (e.g. year), Completeness, Summary statistics?
Data discovery: Working towards expressing monitoring time series data using common standards

- JSON-LD format based on concepts drawn from SSN/SOSA and INSPIRE EMF.
- Enables exposure and linking of vocabulary terms for observed properties, sensors, etc.

Describing:
- Monitoring networks
- Feature of interest / Ultimate feature of interest (e.g. location on river / the river itself)
- Statistical measure
- Sensor and procedure
- Complex model of properties (e.g. phosphorous, dissolved, concentration)

Review of sensor metadata standards: http://nora.nerc.ac.uk/id/eprint/526628/
Integration of data across the hydroscape

Example of analysis:

Automating the analysis of the impact of lakes on nitrogen and phosphorous

Identify all monitoring sites up and downstream of >1000 lakes in UK Lakes Database

The integration of key national scale datasets makes research (human and machine driven) and the development of evidence simpler and more effective
Thanks

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