Groundwater Monitoring Using Handpump Data in Rural Africa

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Overview

- Monitor groundwater depth using handpump vibration data.
- Builds on [1, 2, 3, 4] to track handpump usage and facilitate handpump maintenance systems in rural Kenya.
- Cost-effective and scalable infrastructure where traditional technology/data may be limited or non-existent.
- Intended to complement existing hydrogeological modelling.

Method

- Combines novelty detection with regression approach (LSTM).
- Designed alongside a handpump maintenance infrastructure.
- Can also incorporate hydroclimatic and hydrogeological data.

Results

- The novelty scores of training (blue dots) and test (red dots) examples are represented by the log-likelihood of examples given the normal model.
- Usually the novelty scores appear to be higher (i.e. the log-likelihood values are lower) immediately following a repair (dashed black lines).
- The post-repair vibration data are calibrated to match the pre-repair data.
- The estimates for training, validation, and test sets are shown in blue, orange, and red respectively.
- A summary of results (estimation errors in metres) for all handpumps for both MLP and LSTM techniques are provided in the Table.
- The fractional change in water columns at the boreholes at two locations are shown with respect to a common reference date.

	SP1	SP2	MP1	MP2	MP3	DP1	DP2
MLP	0.14	0.26	0.31	0.29	0.18	0.60	0.85
	0.12	0.19	0.15	0.11	0.10	0.34	0.71
LSTM	0.09	0.12	0.23	0.14	0.15	0.43	1.07
	0.04	0.06	0.17	0.11	0.12	0.47	0.41

Discussion

- Frequent handpump breakdown and subsequent repair complicates learning a consistent model.
- Current solution uses novelty scores and vibration data calibration.
- In future, explore more principled methods, e.g. transfer learning.
- Designed to be implemented at scale using a network of pumps.
- In future, explore multi-task LSTM to model multiple handpumps simultaneously and fuse hydro-climatic and hydrogeological data.

Ethical Considerations

- Although intended to enable sustainable groundwater management among competing users (e.g. community vs. industry), incompetent management poses risks to vulnerable population.
- The data may also unintentionally induce forced migration of households out of areas abundant in groundwater resource.
- A successful implementation relies on both adequately training local experts as well as ensuring sound groundwater governance.

References

[1] Patrick Thomson, Rob Hope, and Tim Foster. GSM-enabled remote monitoring of rural handpumps: a proof-of-concept study. *Journal of Hydroinformatics*, 14(4):829–839, 05 2012.

[2] Farah E Colchester, Heloise G Marais, Patrick Thomson, Robert Hope, and David A Clifton. Smart handpumps: a preliminary data analysis. *IET Conference Proceedings*, pages 7–7(1), 2014.

[3] Farah E Colchester, Heloise G Marais, Patrick Thomson, Robert Hope, and David A Clifton. Accidental infrastructure for groundwater monitoring in africa. *Environmental Modelling Software*, 91:241 – 250, 2017.

[4] H. Greeff, A. Manandhar, P. Thomson, R. Hope, and D. A. Clifton. Distributed inference condition monitoring system for rural infrastructure in the developing world. *IEEE Sensors Journal*, 19(5):1820–1828, March 2019.