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Synthetic Sensors in a Digital Mine

Exploring the “what if?” in geology through a RESTful open-source framework for cloud-based simulation and analysis

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Testing new methods in mineral exploration can be prohibitively expensive. The simulation of sensor platforms and corresponding incoming data streams is a way in which we can test hypotheses about new instruments and methods.

Motivation

The spatial and temporal extent of geological phenomena makes experiments in geology difficult to conduct, if not entirely impossible and collection of data is laborious and expensive – so expensive that most of the time we cannot test a hypothesis. The aim, in many cases, is to gather enough data to build a predictive geological model.

Even in a mine, where data are abundant, a model remains incomplete because the information at the level of a blasting block is two orders of magnitude larger than the sample from a drill core, and we have to take measurement errors into account. So, what confidence can we have in a model based on sparse data, uncertainties and measurement error?

To allow hypothesis testing we built an environment to interrogate a model geology with simulations of sensors. The modular architecture allow us to upscale the system and deploy it in a cloud environment.

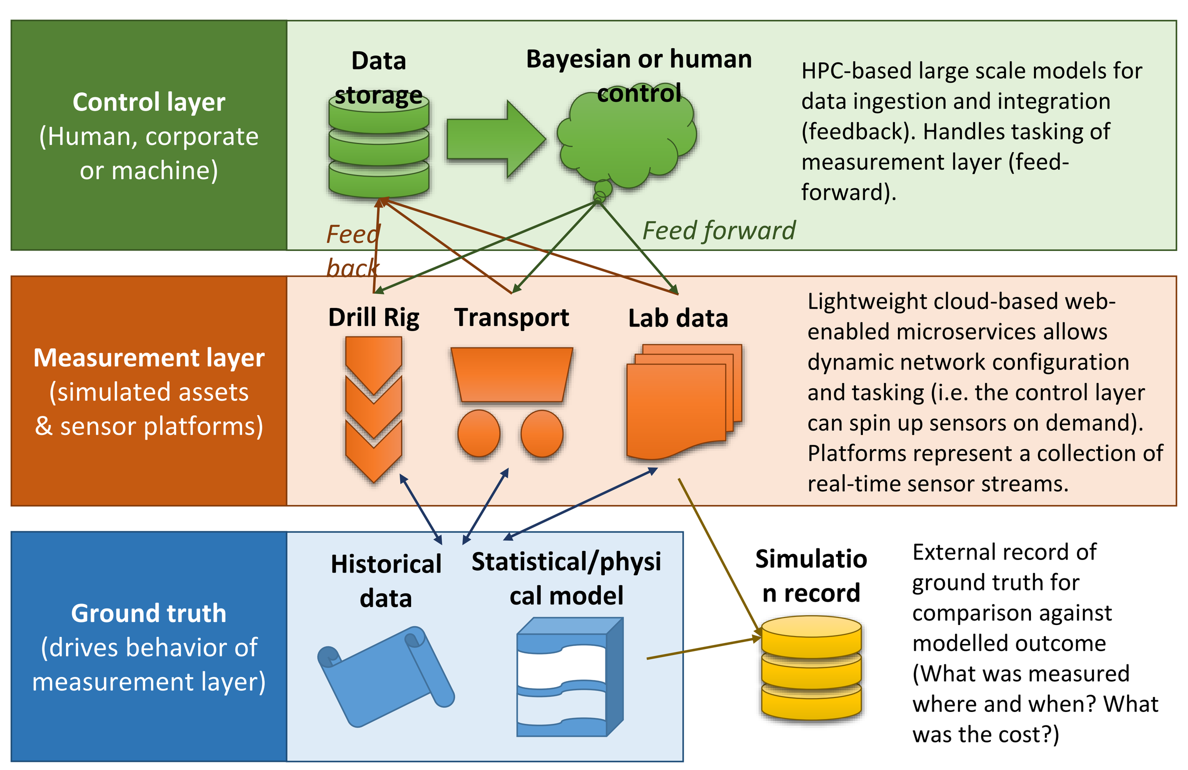

Figure 1: Architecture sketch of the data and simulation environment. Our sandbox consists of three layers: (a) a ground-truth layer that contains geological models, which can be statistically based on historical operations data, (b) a measurement layer - a network of RESTful synthetic sensor microservices which can simulate measurements of ground-truth properties, and (c) a control layer, which integrates the sensor streams and drives the measurement and optimisation strategies. The control layer could be a new machine learner, or simply a company’s existing data infrastructure.

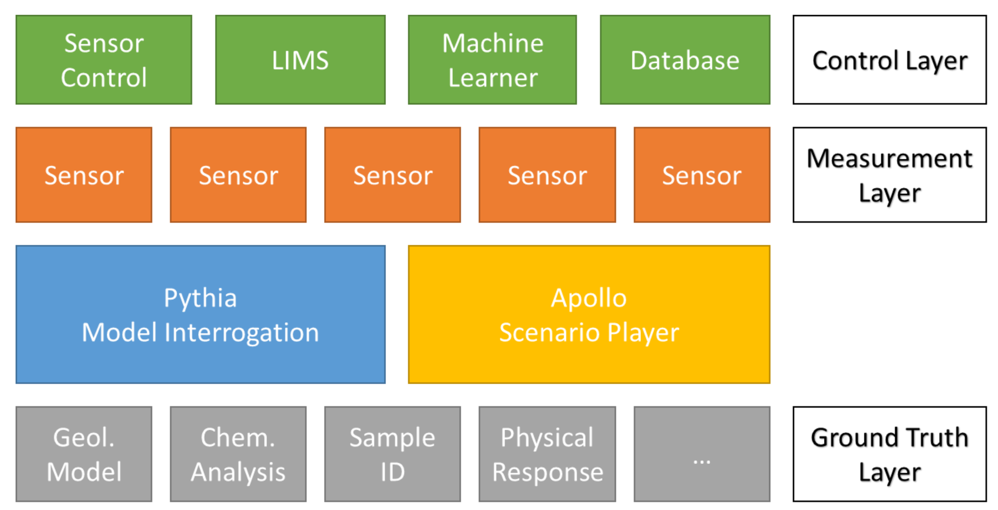

Figure 2: Block diagram of the architecture elements for sensor simulation. Main components are Pythia to accept sensor sampling requests to interrogate the Ground Truth Layer, and Apollo as scenario player of a simulation.

Architecture

Our simulation and data processing layers are implemented using Flask and Gunicorn, which are open source Python web application framework and server, the PyData stack (numpy, scipy etc) and Rabbit MQ (an open-source queuing library). Sensor data is encoded using a JSON-LD version of the SensorML and Observations and Measurements standards. Containerisation of the synthetic sensors using Docker and CoreOS allows rapid and scalable deployment of large numbers of sensors, as well as sensor discovery to form a self-organized dynamic network of sensors.

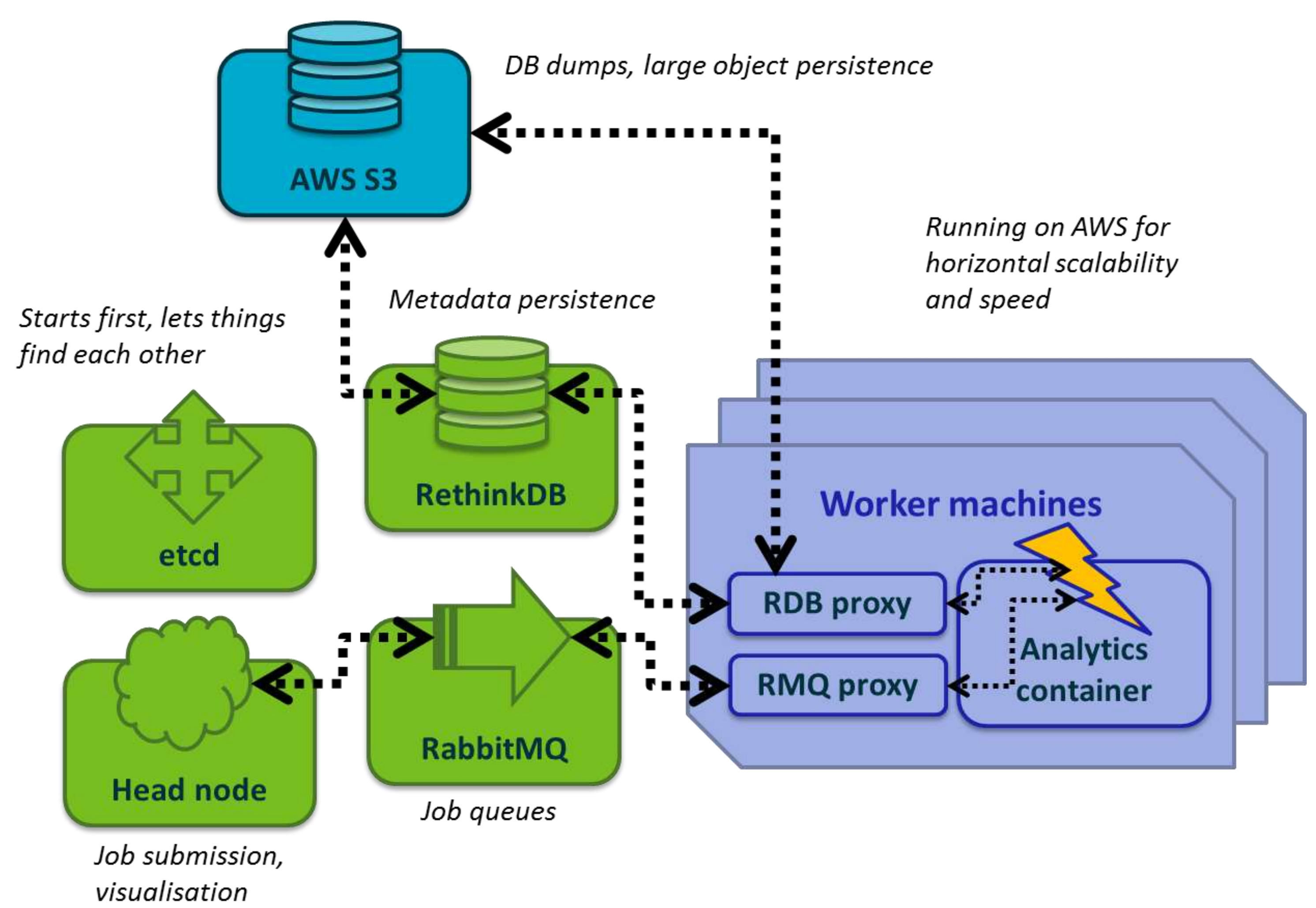

Figure 3: Software components of Pythia/Apollo. Scalability of the system is achieved by modularisation of the measurement layer into micro services. Sensor sampling requests are sent to a job queue and farmed out to workers. The simulation of a sensor is encapsulated in a Docker Container to allow rapid and parallel deployment of sensor simulations in a cloud environment. The sensor responses and associated metadata are fed into a metadata and data persistence layer. Repeated queries to the same sensor for the same time and place can be fetched from the persistence layer.

Simulating Geology

Data are generated from synthetic geological models. The worker machines simulate the sensor responses for a given geological material and sensing technology (e.g. XRF, XRD, gravity, magnetics).

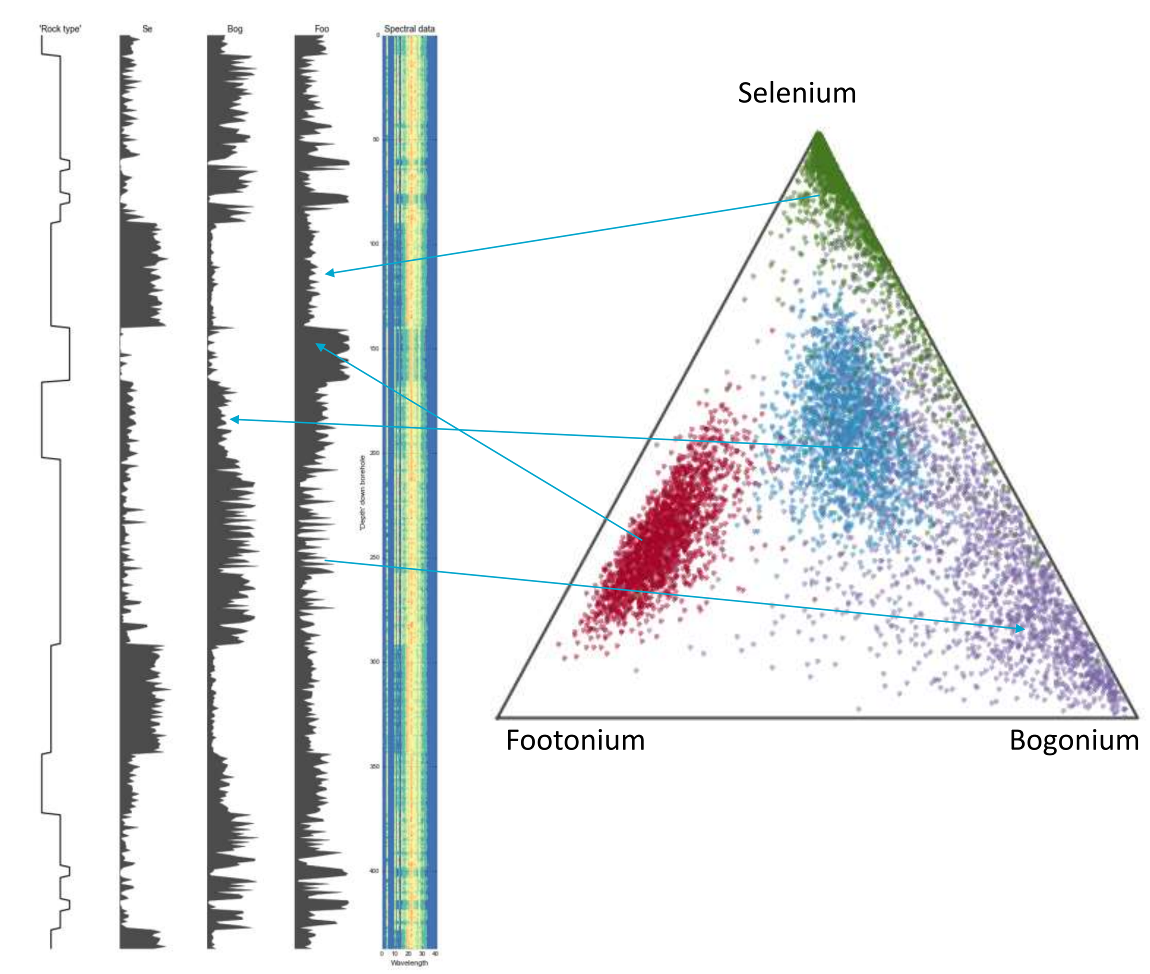

Figure 4: Simulation of the XRF spectra generated from a synthetic drill core. The core consists of three minerals in varying abundance, charaterised by three hypothetical elements.

Outlook

Faults happen in real world networks. Future work will investigate the effect of failure on dynamic sensor networks and the impact on the predictive capability of machine learning algorithms.

Future work will also investigate mobile sensor platforms in exploration and in mine production. More generally, this framework for sensor simulation can be used to test hypotheses about sensor deployment and processing in the Internet of Things (IoT).

FOR FURTHER INFORMATION
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