Pitt-Google
Cloud-Based Broker

Michael Wood-Vasey (Pitt)
on behalf of
Christine Mazzola, Daniel Perrefort, Troy Raen (Pitt)
Ross Thomson (Google)

https://github.com/mwvgroup/Pitt-Google-Broker
We Will Provide

- The public alert data to **everyone**
- **Scalable replication** to N brokers
- **Semantically compressed streams** to 1,000 consumers
- Public analog of PPDB: “**AlertDB**”
- **Cross-matching** across surveys and wavelength
- **Re-playable classifications** based on publicly-available classifiers and a Bayesian belief network meta-classifier.

https://github.com/mwvgroup/Pitt-Google-Broker
Conceptual Design

Google Cloud Platform (GCP)
Motivating Use Cases

• To provide specific use cases, we currently plan to develop our broker around three example questions:

  • Supernova Cosmology
  
  • Cataclysmic Variables

  • Transient and variable populations through large-scale classification

• We welcome additional collaborators with motivating use cases to improve the reach and suitability of the broker and interface.
Semantically Compressed Alert Stream

• A concise version of the stream a factor of 100 times smaller can be more easily (and cheaply) distributed to a large community of up to 10,000 users.

• In a Cloud computing model, charging is often dominated by ingress/egress from data centers, regions, or processing steps.

• What are the 10(?) numbers that best summarize an event for filtering? The LSST Project DIAObject design includes space 52 (32 periodic, 20 non-periodic) numbers whose definition is TBD. What should those be?
Cloud Pub/Sub

- Publishers and Subscribers organized around Topics.
- Topics can be flexibly defined. All SNela at z>0.2 Transients in LMC Microlensing toward Galactic bulge, ...
- Infrastructure supported under GCP and AWS.

https://cloud.google.com/pubsub/docs/overview
https://aws.amazon.com/pub-sub-messaging/
AlertDB for the World

• An approximate analog to the LSST Prompt Processing Products Database (PPDB) that provides database functionality to the key elements of the LSST alert stream.

• Allow people with time interests on the scale of hours to have access to the information on the alert stream without having to wait for the 24-hour update of the planned Prompt Processing Products Database.

• Provide PPDB-like access to anyone in the world.

• Maintain information sufficient reproduce state at any given date to re-play classifications for filtering and simulations.
Providing both Streams and AlertDB through Google

- The alert stream will be ingested into a BigQuery database, which will be on the scale of billions of entries.

- BigQuery supports streaming ingest and large numbers of simultaneous users.

- Streams supported over either Kafka or Pub/Sub.

  - If you want the full stream, Kafka is fine

  - Pub/Sub can do the full stream, and is likely particularly better suited to Topic for subsets.
Planned APIs

- Direct connections to the Kafka stream or Pub/Sub from within Google Cloud or the outside world ($$$).

- SQL access to the accumulated AlertDB through BigQuery.

- A higher-level Python API to support more abstract operations

- A higher-level Python API to support integration with additional external databases and resources

- A service to which Target and Observations Monitor (TOM) system can connect.
Classification and Cross-Matching

- Will load publicly-available datasets (Gaia, SDSS, Pan-STARRS, …) into Google Cloud to facilitate cross-matching.

- Will implement multiple publicly-available classifiers representing a range of objects (e.g., SuperNNova (Möller+19), UPSILoN (Kim+16), …).

- Broker meta-classifier will be structured as a Bayesian belief network (see next slides).

- Classifications and cross-matching will be re-playable.

- Codes are being included in a modular way to allow individuals to move their analyses between the 60-second, 24-hour, and yearly data with connections to LSST Science Platform for those with LSST Data Rights.

- API hooks will provide access to any stage of the pipeline (e.g., run your own classifier).
Bayesian Belief Network

Statistical model of causal relationships between:

A. Alert data
B. Class
C. Redshift
D. Contextual info from cross-matching
E. Results from multiple, publicly-available ("targeted") classifiers, (i.e., SNe classifier, variable stars classifier, ...).

- conditional independencies simplify the full joint probability to

\[ P(A,B,C,D,E) = \prod_{\text{nodes}} P(\text{node} \mid \text{parents}) \]
Bayesian Belief Network

Training and Prediction

1. Model each $P(\text{node} | \text{parents})$, leaving parameters free
2. Constrain parameters with priors
3. Learn parameters by maximizing $P(\text{data} | \text{params}) \times P(\text{params})$ (unsupervised learning)
4. Use inference to make class (and redshift) determination
Bayesian Belief Network

Redshift separation allows for missing, multiple, uncertain, and/or unassociated cross matches.

Can we achieve accurate results using a significantly reduced representation of the lightcurve?

Learns probability distributions of results from each targeted classifier on the full range of lightcurves expected in LSST.
Costing Model

• Combining technical expertise with negotiation to make the most efficient use of the cost model for Cloud services.

• We will prioritize

  • Providing condensed, but information-rich streams to everyone

  • Setting up clear code instructions for how someone can run their own server

  • Consider joint funding models if additional external users would rather just pay money to contribute to a single main service.

• Apply for external public and private funding to support fuller public access.

• Dominant cost under is storage and Pub/Sub subscriptions. Could request discount in exchange for the data being publicly available. Because making it public is, in fact, the point, we are optimistic.
GCP Pricing: Conservative

- Without negotiated discounts, a conservative pricing is with 1,000 simultaneous users

<table>
<thead>
<tr>
<th>BigQuery</th>
<th>Value</th>
<th>Unit</th>
<th>Price [USD]</th>
<th>Unit</th>
<th>Price/max year [USD]</th>
<th>Price/10 years** [USD]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full AlertDB Storage</td>
<td>400 TB</td>
<td>0.02 /GB/month</td>
<td>98,304</td>
<td></td>
<td></td>
<td>491,520</td>
</tr>
<tr>
<td>Summary AlertDB Storage</td>
<td>4 TB</td>
<td>0.02 /GB/month</td>
<td>983</td>
<td></td>
<td></td>
<td>4,915</td>
</tr>
<tr>
<td>Full+Summary Query Access</td>
<td>1,000 slots</td>
<td>8,500 /500 slots/month</td>
<td>204,000</td>
<td></td>
<td></td>
<td>2,040,000</td>
</tr>
<tr>
<td>Pub/Sub*</td>
<td>1 TB</td>
<td>40 /TB</td>
<td>14,400</td>
<td></td>
<td></td>
<td>144,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>303,287</td>
<td></td>
<td></td>
<td><strong>2,680,435</strong></td>
</tr>
</tbody>
</table>

[*] Assume distribution of 100x compress stream to 1024 users
[**] For Storage: Price/10 years is 1/2 * (10 max years)
GCP Pricing: Optimistic

- Take storage at non-recent rate (> 90 days)
  400 TB/month of queries simultaneous users

<table>
<thead>
<tr>
<th>BigQuery</th>
<th>Value</th>
<th>Unit</th>
<th>Price [USD]</th>
<th>Unit</th>
<th>Price/max year [USD]</th>
<th>Price/10 years** [USD]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full AlertDB Storage</td>
<td>400 TB</td>
<td>0.01 /GB/month</td>
<td>49,152</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summary AlertDB Storage</td>
<td>4 TB</td>
<td>0.01 /GB/month</td>
<td>492</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full+Summary Query Access</td>
<td>400 TB</td>
<td>5 /TB</td>
<td>24,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pub/Sub*</td>
<td>1 TB</td>
<td>40 /TB / day</td>
<td>14,400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td>73,644</td>
<td></td>
<td>632,218</td>
<td></td>
</tr>
</tbody>
</table>

[*] Assume distribution of 100x compress stream to 1024 users
[**] For Storage: Price/10 years is 1/2 * (10 max years)
# GCP Pricing: Public Data Set

- Convince Google to host AlertDB as Public Data Set. Pay for Large Access for 500 simultaneous users.

<table>
<thead>
<tr>
<th>BigQuery</th>
<th>Value</th>
<th>Unit</th>
<th>Price [USD]</th>
<th>Unit</th>
<th>Price/max year [USD]</th>
<th>Price/10 years** [USD]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full AlertDB Storage</td>
<td>400 TB</td>
<td>/GB/month</td>
<td>0</td>
<td>/GB/month</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Summary AlertDB Storage</td>
<td>4 TB</td>
<td>/GB/month</td>
<td>0</td>
<td>/GB/month</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Full+Summary Query Access</td>
<td>400 TB</td>
<td>/TB</td>
<td>5</td>
<td>/TB</td>
<td>24,000</td>
<td>240,000</td>
</tr>
<tr>
<td>Pub/Sub*</td>
<td>1 TB</td>
<td>/day</td>
<td>10</td>
<td>/TB</td>
<td>3,600</td>
<td>36,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24,000</td>
<td>276,000</td>
</tr>
</tbody>
</table>

[*] Assume distribution of 100x compress stream to 1024 users
[**] For Storage: Price/10 years is 1/2 * (10 max years)
Current Status

• Prototype backend:
  • Ingest Kafka stream from ZTF Archived into BigQuery
  • Pub/Sub module to publish and subscribe

• Prototype webpage interface:
  • Test Sandbox: https://ardent-cycling-243415.appspot.com/

• Interest from and Engagement with Google
• GCP grant of $5,000 GCP credits for 2020
• Google Software Architect design consulting in 2020

https://github.com/mwvgroup/Pitt-Google-Broker
Example Landing Page

**Filters**

- **All Objects**
  - ObjectID

- **Classification**
  - Type
  - Confidence
    - >

- **Position**
  - ra
    - BETWEEN
  - dec
    - BETWEEN

**Alerts**

<table>
<thead>
<tr>
<th>ObjectID</th>
<th>visitID</th>
<th>visitDate</th>
<th>ra</th>
<th>dec</th>
<th>flux</th>
<th>fluxBand</th>
<th>pm</th>
<th>parallax</th>
</tr>
</thead>
<tbody>
<tr>
<td>8617405</td>
<td>48250083</td>
<td>Jul 17, 2019</td>
<td>95.2187355</td>
<td>7.2155175</td>
<td>0.199</td>
<td>6500</td>
<td>283</td>
<td>0.025</td>
</tr>
<tr>
<td>15465124</td>
<td>83966235</td>
<td>Jul 17, 2019</td>
<td>150.2495306</td>
<td>79.5114188</td>
<td>0.821</td>
<td>8000</td>
<td>409</td>
<td>0.036</td>
</tr>
</tbody>
</table>

**Upcoming Visits**

- scheduled visit: Jul 10, 2019
  - ra: 150.25
  - dec: 79.51
  - ObjectID: 15,465,124
Discussion Questions

• Our raison d’être is essentially to collaborate and make this whole process easier for both consumers and developers.

• We aim to provide a cloud-based solution and framework

• We aim to provide streams to the world: raw, annotated, filtered

• We will have all of the postage stamps available. We haven’t thought about how to support processing of these images within GCP.