Pan-STARRS
Introduction to the
Published Science
Products Subsystem (PSPS)
The Role of PSPS Within Pan-STARRS

Legend

- PS: subsystem
- External System
- Preferred SkyClient
- "pixel data" arrow
- "meta & object data" arrow
- "commands" arrow
Space... is big. Really big. You just won't believe how vastly hugely mindbogglingly big it is...

Douglas Adams
The Hitchhiker's Guide to the Galaxy
**PSPS Table Data Example**

<table>
<thead>
<tr>
<th>ObjID</th>
<th>detectID</th>
<th>filterType</th>
<th>ra</th>
<th>dec</th>
<th>calMag</th>
</tr>
</thead>
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<td>19.2003059387207</td>
</tr>
</tbody>
</table>

First 10 rows of 100,000,000,000 give or take.
Image Processing Pipeline Challenge

- The Camera is capable of delivering ~2 exposures per minute in a night of observations.
- Each image is 3.2 Gigabytes in size.
- Averaging 400 exposures in a night.
- 1-2 Terabytes stored for one night of observation.
- A exposure can have 50,000 to 3,000,000 detections of celestial objects.
- Several gigabytes of catalog data a night.
Published Science Products
Subsystem Software Components

- **Object Data Manger (ODM)** - The ODM is a collection of systems that are responsible for loading data measured by the IPP or other Pan-STARRS Science Servers and publish them to the user.

- **The Databases** - In the PSPS PS1 design; two main databases are the ODM and the Solar System Data Manager (SSDM) are being implemented by the Project team.

- **Data Retrieval Layer (DRL)** - This acts as a security measure that monitors data access. Users desiring data must request it through the DRL through a standard application programming interface (API). All PSPS client interfaces must go through the DRL.

- **Pan-STARRS Science Interface (PSI)** – This is a web interface that accesses the DRL to allow users an application to access data. Users can do a variety of functions such as execute queries against data products, monitor progress of queries, and obtain query results with a personal database called MyDB.

- **Other client software** – There are also other client side software to access PSPS including stand alone command line programs and Pan-STARRS Virtual Observatory PSVO.
PSPS
Object Data Manager (ODM)

- This is the software that does all the loading of data from the IPP into PSPS.
- Contains its own database called the Workflow Manager Database (WMD) that stores all details about everything that has been loaded into PSPS.
- A PSPS publication of science data grows through several stages called workflows being loading, merging, copying, and finally publication.
- Loads published data from IPP via a datastore server in the forms of batches.
PSPS ODM Data Flow
What is a data batch?

- Essentially a batch is some IPP data published into a compressed file for loading into PSPS.

- Batches have several types: Initialization, Detection, Stack Detection, and Object.

- The vast majority of batches consists of all the science information that IPP has processes about a single image or a stack.

- Batches are loaded sequentially as they are published on a data store server. However any kind of defined order in terms of coordinates, date the image was taken, etc is not relevant.

- Once a batch is within the ODM; each workflow goes through rigorous validation processes which if any fail will not publish anything within that batch.
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Batch Example

Detection Batch consists of the following tables and rows:

- 1 entry into FrameMeta. This contains specific information about the entire image.
- 60 ImageMeta entries. Specific about each OTA or chip within the image.
- Up to 3 million Detection entries.
- Potentially the same number of entries in the Object table.
Frame Name

o5722g0351o

- o - means the frame was commanded by OTIS, Observatory, Telescope Instrument Software, not the camera engineering interface for example.

- 5722 is the last four digits of the Mean Julian Day.

- g means this is an exposure from GPC1. So for example an image from the ISP has an i here. When we have GPC2 we will another letter for that, maybe h.

- 0351 means this is the 0351 the image of the night (as given by the MJD).

- The trailing o means this is an object exposure, as opposed to a dark or flat or bias.
A Batch Size Example

**One frame named:** o5722g0351o **raBore:** 265.110456 **decBore:** -22.755691

<table>
<thead>
<tr>
<th>Table</th>
<th>Total CSV Files</th>
<th>Row Size (Bytes)</th>
<th>Total Rows</th>
<th>Total Space (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FrameMeta</td>
<td>1</td>
<td>254</td>
<td>1</td>
<td>254</td>
</tr>
<tr>
<td>ImageMeta</td>
<td>60</td>
<td>319</td>
<td>60</td>
<td>19,140</td>
</tr>
<tr>
<td>Detection</td>
<td>60</td>
<td>245</td>
<td>778,323</td>
<td>190,689,135</td>
</tr>
<tr>
<td>DetectionCalib</td>
<td>60</td>
<td>104</td>
<td>778,323</td>
<td>80,945,592</td>
</tr>
<tr>
<td>Object</td>
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<td>535</td>
<td>778,323</td>
<td>416,402,805</td>
</tr>
<tr>
<td>ObjectCalColor</td>
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<td>50</td>
<td>778,323</td>
<td>38,916,150</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>726973076 or 0.677 Gigabytes</strong></td>
</tr>
</tbody>
</table>
PS1 3PI Coverage
# PS1 Three Year Science Data Size

<table>
<thead>
<tr>
<th>Table</th>
<th>Estimated number of Rows</th>
<th>Size per row (Bytes)</th>
<th>Size of entire Table (GB)</th>
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</thead>
<tbody>
<tr>
<td>Static Tables (i.e., Filters, Flags, Surveys)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>FrameMeta</td>
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<td>ImageMeta</td>
<td>27,000,000</td>
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<tr>
<td>StackMeta</td>
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<tr>
<td>StackApFlux</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>38,475.30</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Defining the PSPS Distributed Database

General specifics:

- The database is stored over a cluster of computers within a private network.

- There is a central node within the system where actual database connections are made. To a user, it gives the perception that PSPS is just one very big database.

- Partitioned Tables - The tables within PSPS that are particularly large (Detections and Stack Detections) are partitioned across the linked servers (aka slices).

- Each slice is created by dividing up areas of the sky. They are basically ranges of Object Identification numbers.

- There are also views participating in the Distributed Partitioned View (DVP) which reside in different databases among the linked servers.

- A published table is actually written to disk in a sequential order based on the Object ID.
ObjectID Clusters Data Spatially

\[
\begin{align*}
\text{Dec} &= -16.71611583^\circ \\
\text{ZH} &= 0.008333^\circ
\end{align*}
\]

\[
\text{ZID} = \frac{(\text{Dec}+90)}{\text{ZH}} = 08794.0661
\]

ObjectID = 087941012871550661

\[
\text{RA} = 101.287155^\circ
\]

ObjectID is unique when objects are separated by >0.0043 arcsec
Database Types

Detection Batch consists of the following tables and rows:

- **WMD** – Workflow Management Database. This is the database the ODM uses to keep information on all its science databases.

- **Load Databases** – These contain the initial loaded batches. Each batch is loaded as its own separate table on a designated node.

- **Cold Databases** – These databases are where the merging takes place. It starts initially as a copy of all the PSPS Databases. Later the load databases are written into the Cold databases and merged in sequential order. Note that the Cold database is not accessible to users but can be used as a recovery mechanism.

- **Warm and Hot Databases** – These databases are published from the latest merged Cold database. There are copies of each other but with the slight difference of how they are queried. Users query the Warms for longer queries in a queue where the results go in a personal database called MyDB. The Hot database is for faster queries that results the results directly via http web service. See Data Retrieval Layer section for details.
Machine Roles

The PSPS ODM consists of the following machines:

- Load Merge Machines – These are the machines that do the loading into the load databases and merge these into the cold.

- Slice – These machines contain the Hot and Warm versions of the distributed databases. The larger tables (i.e., detections, stack detections) are stored across these servers.

- Head – The central database of the warm and hot databases. Direct queries connections are made to these machine. The distributed views from here span the slices.

- Administration – The machine contains the WMD and runs the merge workflow.

Note: In principle your query should run independent of the architecture. In practice two different formulations of the same query could have drastically different performance because of this architecture (i.e., size of a cone search).
Loading Workflow

Diagram showing the workflow steps involving IPP DataStore, DXLayer, Batch Files, Register Load Request, and WMD, along with Load Details and Load Request/Response.
The Merge workflow writes the data in sequentially on the physical disk ordered by ObjID. This is a technique called a \textit{clustered index} and make queries run fast.
Merge Workflow
Copy/Flip Workflow

The purpose of this copy is to make the new data available to the user without them having to be aware of it. The query today might not have the same results tomorrow because of these constant updates.
The Data Retrieval Layer

The Data Retrieval Layer software component acts as an Application Program Interface (API) for accessing PSPS data.

Some useful background information about the DRL:

- The DRL acts as a security and monitor middleware for all user based queries.
- Some of the code uses CasJobs which was used by Sloan.
- Controls security by giving authorized users session tokens that expire if not used.
- Gives the ability for users to send queries to either a short queue which results the results directly or a long queue that inserts results into a personal database.
- Keeps tracks and all user queries and can provide progress.
- Can access both MS-SQL Server and MySQL (for SSDM) databases. This is the point of contact for future DB expansion.
- All commands to the DRL are via Simple Object Access Protocol (SOAP).
Four-Tier Architecture
DRL Usage Example - A PSPS Slow Query
PSPS Client Side Software

PSPS has several client applications for accessing Science Data:

- Pan-STARRS Science Interface (PSI) – A web interface that allows users to execute, monitor, and manage their queries. Extra functionality includes graphing, MyDB management, and the ability to change your profile (i.e., email, password, etc).

- Pan-STARRS Virtual Observatory (PSVO) – A java based client side program allowing access to PSPS data that works with many common tools such as VOPlot.

- Examples of stand alone programs that run in Java, Python, and Perl. The clients usually only need the ability to run the code and some common SOAP libraries.
Demo
Find the Bugs!
References and Credits

- **PSPS Help** - http://psps.ifa.hawaii.edu/psps-trac
- **PSI** – http://psps.ifa.hawaii.edu
- **PSPS Team Members** – Ken Chambers, Conrad Holmberg, Thomas (Xin) Chen, Heather Flewelling, and Sue Werner.
- IPP Team Members - Eugene Magnier, Bill Sweeney, Chris Waters, Serge Chastel, Mark Huber.
- **Systems Administration**: Rita Mattson, Haydn Huntley, Gavin Sao
- **Credit(s)** – Dr. Jim Heasley, Maria Antonia Nieto-Santisteban, and Richard Wilton.