Computational challenges of the AARTFAAC all-sky monitor

Folkert Huizinga
University of Amsterdam
AARTFAAC

Field of view: 120 degrees
RMS: 1 Jy (1s)
Resolution: 40 arcmin
Range: 30-80 MHz
Bandwidth: 13.8 MHz
We Start Here
Data Flow Overview
Correlator

Circular Buffer

Antennas

GPU

PPF Bank → Bandpass Correction → Correlate Integrate

Best Effort Queue

Imaging

J. Romein
## Imaging Computational Challenges

<table>
<thead>
<tr>
<th></th>
<th>Version 1</th>
<th>Version 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visibilities</strong></td>
<td>41616</td>
<td>166464</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>4 MHz</td>
<td>13.8 MHz</td>
</tr>
<tr>
<td><strong>Data rate</strong></td>
<td>0.89 Gb/s</td>
<td>12.25 Gb/s</td>
</tr>
</tbody>
</table>

Latency $\leq$ 1s using 1s integration time
Imaging Pipeline Candidates

**Storm**
- + Twitter
- + Define your own topology easily
- - Meta data overhead

**Pelican**
- + Designed for streaming data
- + Astronomy examples/projects
- + *Modular*
- - Small userbase

**ØMQ**
- - Low level
- + Large userbase, docs
Pelican Framework

- **Emulator**
  - Read from disk
- **Server**
  - Creates chunks
  - Sends tcp packets
  - First come first served
- **Pipeline**
  - Reconstructs data from chunks
  - Process data with modules
  - Send/Store elsewhere
Imaging Pipeline Design

- Pipeline 1
  - Calibrator
  - Flagger
  - Imager
- Pipeline 2
  - Calibrator
  - Flagger
  - Imager
- Pipeline n
  - Calibrator
  - Flagger
  - Imager
- Correlator
- Emulator
- Server
- Split on band
- Image cube
- Transients Pipeline

Monitoring and Control
Imaging Calibration

Init cal based on catalogue derived model

Initialization

Yes

Convergence?

System noise estimation

No

Catalog model source positions

Direction Independent Gain Estimation

Models source flux estimation

Wijnholds & van der Veen 2009
Imaging Calibration

Model positions update

Initialization

Catalog model source positions

Convergence?

Direction Independent Gain Estimation

System noise estimation

Modelsource flux estimation

Yes

No

Init cal based on catalogue derived model

Viberg et al. 1997
Imaging Calibration

- Init cal based on catalogue derived model
- Model positions update
- Refined final cal using new positions
- Convergence?
  - Yes: System noise estimation
  - No: Direction Independent Gain Estimation
- Models source flux estimation

WSF corrected source positions

Initialization

Wijnholds & van der Veen 2009
Imaging Calibration

- Init cal based on catalogue derived model
- Model positions update
- Refined final cal using new positions
- Subtract bright sources

Initialization
- WSF corrected source positions
- Direction Independent Gain Estimation
- Modelsoure flux estimation

Convergence?
- Yes
- No

System noise estimation
## Performance Results

<table>
<thead>
<tr>
<th>Calibration</th>
<th>CPU Usage</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial calibration</td>
<td>4%</td>
<td>0.03s</td>
</tr>
<tr>
<td>Model positions update</td>
<td>90%</td>
<td>0.63s</td>
</tr>
<tr>
<td>Final calibration</td>
<td>4%</td>
<td>0.03s</td>
</tr>
<tr>
<td>Imaging</td>
<td>2%</td>
<td>0.02s</td>
</tr>
</tbody>
</table>

Intel(R) Core(TM) i7-2600 CPU @ 3.40GHz
Averaged over night- and day-time data
Promotion Video
Imaging Results Uncalibrated

Rec: 3, Time:4848774152.52, Freq:54873657.226562
Imaging Results Calibrated

Rec.3, Time:4848774153.52, Freq:54873657.226562
Imaging Results Subtraction

Rec: 3, Time: 4848774153.52, Freq: 54873657.226562
Transients Pipeline and Storage

Image Cube → Quality Control → Source Finding → Lightcurve Storage → Classification & Analysis → Response Scheduling

Source Association → Transient & Variability Analysis

Real-time Database

Real-time Processing

Off-line & External Systems

Archive Database → Other Facilities
Conclusions

● Single channel single core ≤ 1 second
● Easily scalable as such
● Pelican is a modular and fast solution for streaming data
● Further optimizations on calibration in version 2
Questions

Aartfaac  http://www.aartfaac.org
Pelican   https://github.com/pelican/pelican
Eigen3    http://eigen.tuxfamily.org
Docker    http://www.docker.com