An Agent for Supervising Real Observations in a Virtual Astronomical World

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Topics

① Notes about this project

② Notes about optimal DN encoding for CCDs

① Observing 'modes'

Classical observing

+ Remote operations

+ Queue scheduling

+ Robotic telescopes

+ HTN technologies

+ VOEvent messaging

= A fully autonomous observing paradigm

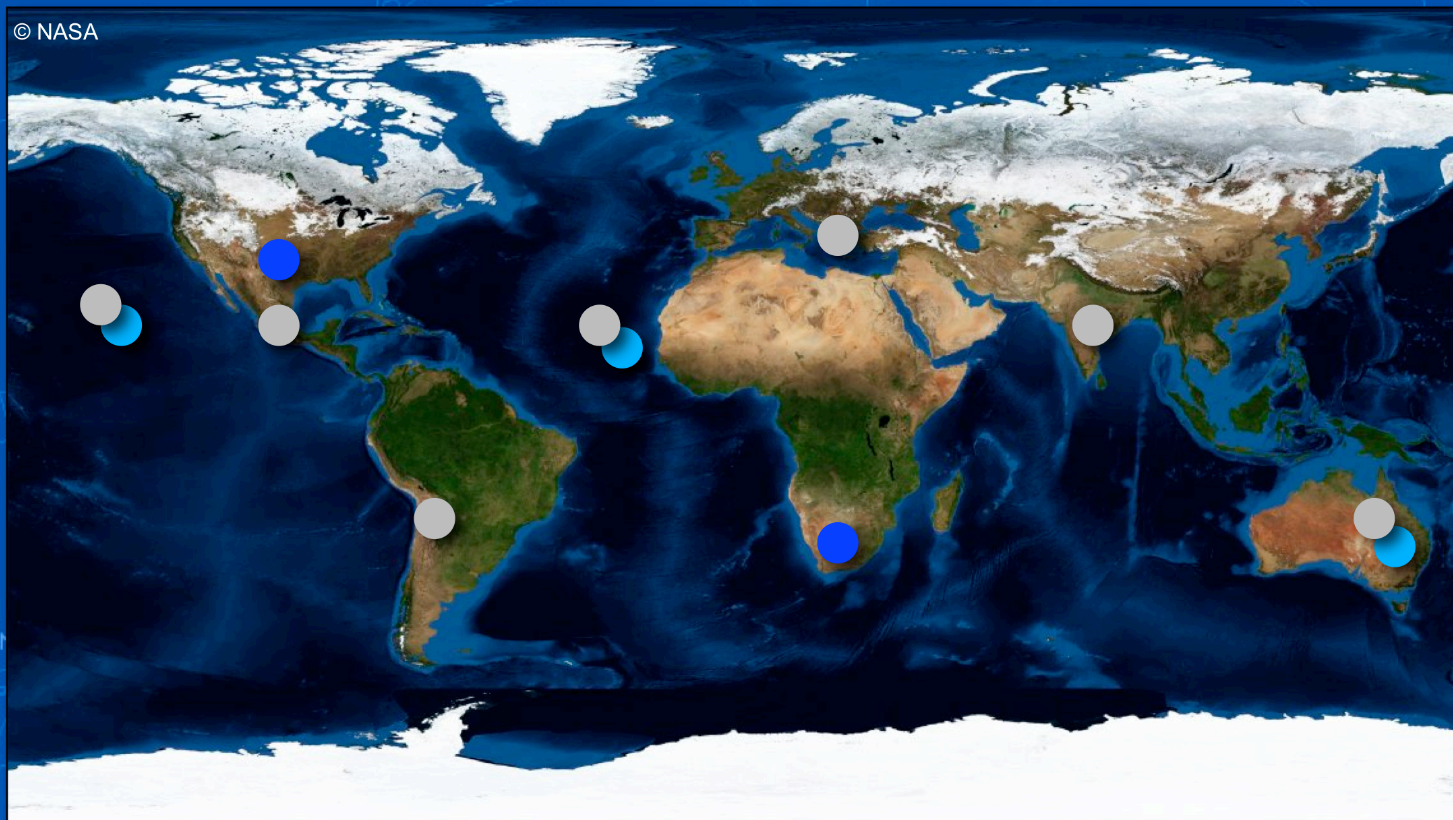
Not just for Time domain

Classical observing

- Want to preserve the flavor of classical observing as we build new power tools
- Even William Herschel had an autonomous agent – his sister, Caroline:

VOEvent

- IVOA standard (XML)
- Describe transient celestial events
  - Who, What, WhenWhere, How, Why
  - Publish/Subscribe architecture
  - Registry, query, transport, authentication, …
  - Time series, orbital elem., schemata, references, …
- Construct workflows ("citations")
- To create (follow) empirical threads



Robonet-2.0 + MONET
+ others from 2009

UNIVERSITY OF EXETER

CFP for 2008/09

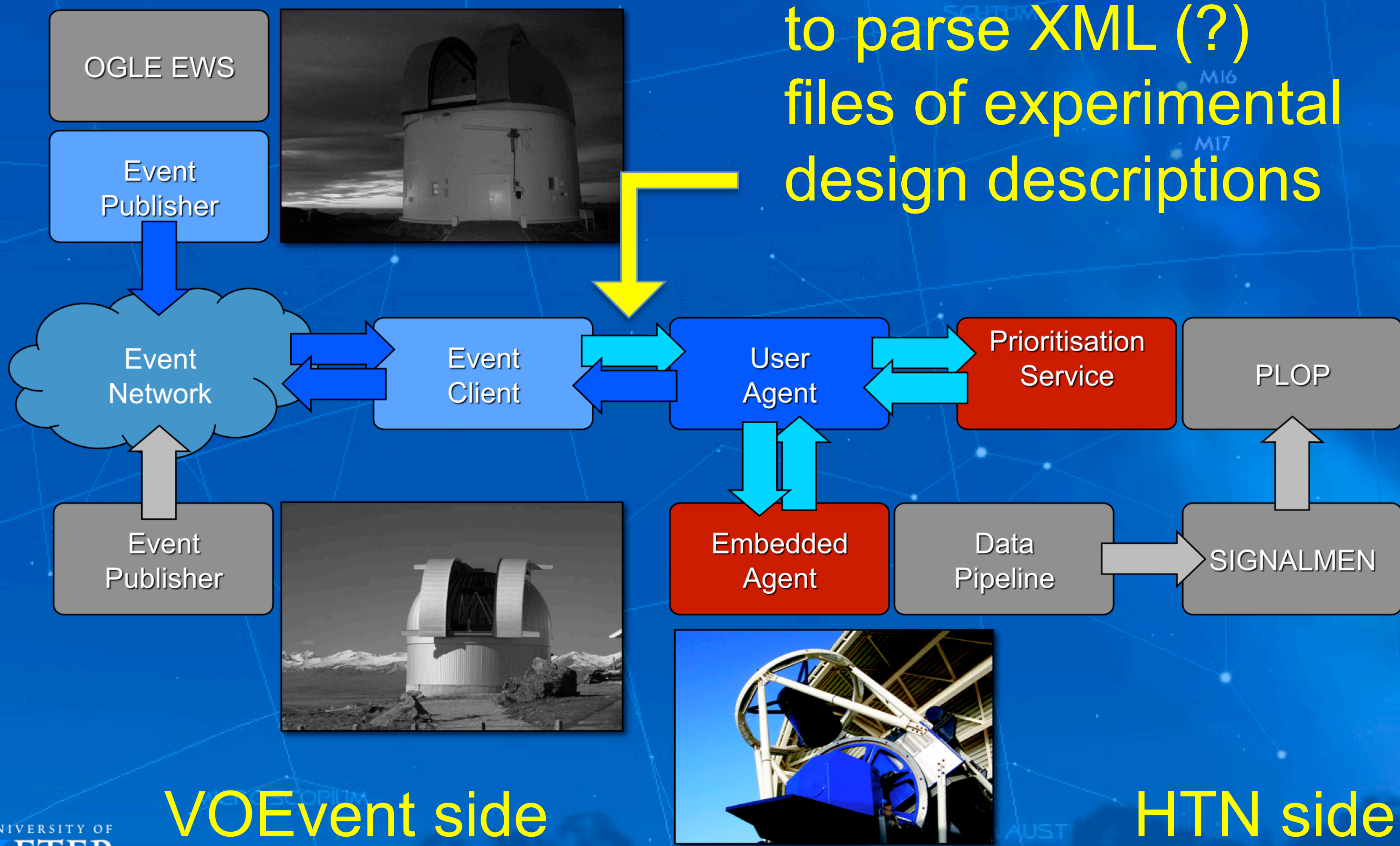
Faulkes North
Faulkes South
Liverpool Telescope
MONET/North

HTN III meeting at LCOGT

University of Exeter

Closed loop

New component to parse XML (?) files of experimental design descriptions



② DN encoding

Continuation of FITS tile compression collaboration with Bill Pence & Rick White

…however, any half-baked ideas are mine alone

CCDs are linear

1) What does this mean?

2) It <u>does not</u> mean that DNs must be represented on a linear scale

Heteroskedasticity

- A vector of random variables (= image) is *heteroscedastic* if different variances
- CCD and CMOS are photon counting devices
  – thus shot noise
  – so these are poisson processes, not gaussian
  – with: noise ~ sqrt (signal)
- Many statistical techniques assume homoscedasticity, eg., least squares fitting
- Penalty may be negligible –> significant

Variance stabilization

- Techniques exist to "stabilize" variance
- Anscombe transform

  (he described Johnson's result extended from Bartlett)

  Convert poisson to (near) gaussian with unit variance:

  $$I'(x,y) = 2 * \mathrm{sqrt}(I(x,y) + 3/8)$$

  (for $I >\sim 30$)

- also Box-Cox, many references

Generalized Anscombe Transform

- Real CCDs are Gaussian + Poisson
- Bijaoui with Starck & Murtagh:

$$I'(x,y) = (2/g) * \mathrm{sqrt}\left(g*I(x,y) + g^2*(3/8) + s^2 - g*\mathrm{bias}\right)$$

$g = gain,\ s = sigma$

Rearranged:

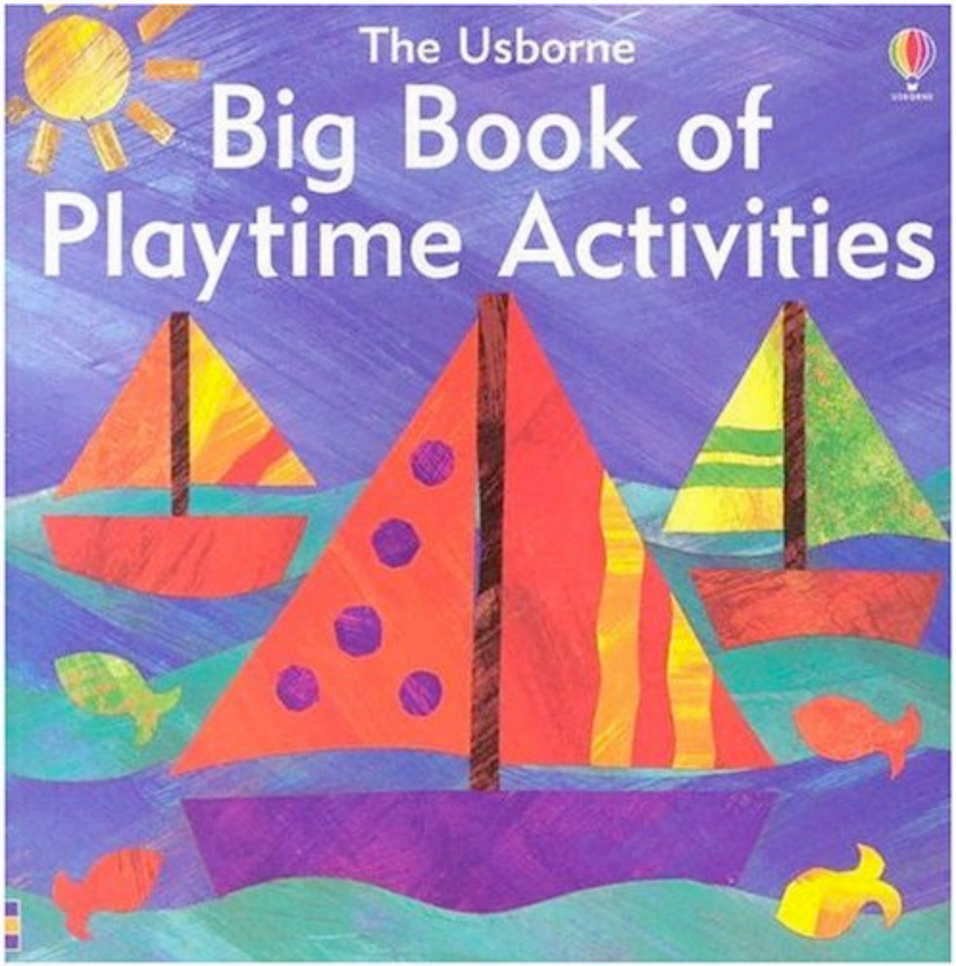
$$I'(x,y) = 2 * \text{sqrt}\left((I(x,y) - \text{bias}) / g + \text{read}^2 + g^2 * (3/8)\right)$$

read = some term in the read noise

Was reminded of…

- The CCD photon transfer technique
- For example, IRAF task, *findgain*, to measure the gain of a CCD from flatfield and bias exposures
- Gain is the slope of the mean-variance relation
- So went looking for…

Janesick's Big Book



Ur References:

- *Scientific Charge Coupled Devices*, Janesick, SPIE Press, 2001
- *Photon Transfer, DN -> lambda*, Janesick, SPIE Press, 2007

Noise sampling

Brighter pixels oversample the noise:

- ADC quantizing noise = sqrt (1 / 12)
- To avoid aliasing, keep gain < readnoise
- So readnoise ~ 1 DN rms (1 bit)

High end governed by shot noise *(& full well)*

- Noise @ DN = 64K (16 bits) is 256 (8 bits)

Compact encoding

- Fully 7 bits of the brightest pixels represent uselessly oversampled noise
- Low end is properly (?) sampled
- Intermediate pixels ~ square root
- Thus can encode CCD / CMOS images into far fewer DNs

"Square rooter"

Hardware or software:

$$DN_{out} = \text{sqrt}\,(DN_{in}) * 2^{(N_{out} - \text{bitpix}/2)}$$

same as Anscombe if $N_{out} = 1 + \text{bitpix}/2$

ie., $N_{out} = 9$ for bitpix = 16

Implementation

Something like:

- Map input to output DNs via Look Up Table
- Modify FITS (or perhaps tile compression convention) to convey and apply LUTs
- For some purposes, use raw square root values:
  - Display
  - Multiresolution/wavelets

Optimal encoding

- Only *technically* lossy

- Ideally would apply this before the ADC
- After ADC, penalty is a modest sqrt(1/12)

Compression

- Advantage is not as dramatic in bits
- Reducing 64K range (16 bits) to 0.5K range (9 bits) is R = 1.78

Compression, cont.

- Combine with Rice:

  Data Compression for NGST

  – Nieto-Santisteban, *et al.*, ADASS VIII, 1999

Various other references, eg.:

Poisson Recoding of Solar Images for Enhanced Compression

– Nicula, *et al.*, Solar Phys. 228, 2005

Issue #1

- As Bill's talk showed, only the background noise matters in typical astronomical cases
- Need to handle low end properly
- Transition to linear?

  (also to keep radicand positive)
- But that squanders advantage where needed
- Must go (actually) lossy?

Issue #2

- CCDs (+ CMOS) are Gaussian + Poisson
- Raw detectors also have fixed pattern noise:

$$\text{Sensitivity} = \text{sqrt}\,(\text{read}^2 + \eta * S + (P_N * S)^2)$$

$\eta = e^- / \gamma$ (= 1 for CCDs)

P_N (~ 1 %)

- FPN dominates bright pixels!

Issue #3

- Bringing generalized Anscombe and "generalized Janesick" into alignment
  - Easy to get lost in DNs versus electrons
  - What Janesick calls sensitivity, most call gain