Reaching Out with Eventful Astronomy

Kirk Borne
George Mason University
The LSST will represent a 10K-100K times increase in the VOEvent network traffic. This poses significant real-time classification demands on the event stream: from data to knowledge! from sensors to sense!
The Scientific Data Flood

Drinking from a FIREHOSE

Scientific Data Flood

Large Science Project

Pipeline

Scientist
How will we respond?

We need something better...
We need something better, Jim!
We need computers … but *not* the usual kind!

We need the classical kind (which pre-dates computing devices)
Modes of Computing

• **Numerical Computation** (*in silico*)
  – Fast, efficient
  – Processing power is rapidly increasing
  – Model-dependent, subjective, only as good as your best hypothesis

• **Computational Intelligence**
  – Data-driven, objective (machine learning)
  – Often relies on human-generated training data
  – Often generated by a single investigator
  – Primitive algorithms
  – Not as good as humans on most tasks

• **Human Computation** (*Carbon-based Computing*)
  – Data-driven, objective (human cognition)
  – Creates training sets, Cross-checks machine results
  – Excellent at finding patterns, image classification
  – Capable of classifying anomalies that machines don’t understand
  – Slow at numerical processing, low bandwidth, easily distracted
It takes a human to interpret a complex image
It takes a human to interpret a complex image ... usually ...

"It's black, and it looks like a hole. I'd say it's a black hole."
Citizen Science

• Exploits the cognitive abilities of Human Computation!
• Novel mode of data collection:
  – Citizen Science! = Volunteer Science = Participatory Science
  – e.g., VGI = Volunteer Geographic Information (Goodchild ’07)
  – e.g., Galaxy Zoo @ http://www.galaxyzoo.org/
• Citizen science refers to the involvement of volunteer non-professionals in the research enterprise.
• The Citizen Science experience …
  – must be engaging,
  – must work with real scientific data/information,
  – must not be busy-work (all clicks must count),
  – must address authentic science research questions that are beyond the capacity of science teams and enterprises, and
  – must involve the scientists.
Examples of Volunteer Science

- AAVSO (Amer. Assoc. of Variable Star Observers)
- Audubon Bird Counts
- Project Budburst
- Stardust@Home
- VGI (Volunteer Geographic Information)
- CoCoRaHS (Community Collaborative Rain, Hail and Snow network)
- Galaxy Zoo (~20 refereed pubs so far…)
- Zooniverse (buffet of Zoos)
- U-Science (semantic science 2.0) [ref: Borne 2009]
  - includes Biodas.org, Wikiproteins, HPKB, AstroDAS
  - Ubiquitous, User-oriented, User-led, Universal, Untethered, You-centric Science
Anybody can participate and contribute to the science...
Galaxy Zoo helps scientists by engaging the public (hundreds of thousands of us) to classify millions of galaxies:

- Galaxy Zoo project:
  - ~260,000 participants *(and growing)*
  - ~1 million galaxies have been labeled *(classified)*
  - ~180 million classifications have been collected
Classify Galaxies

Answer the question below using the buttons provided.

Is the galaxy simply smooth and rounded, with no sign of a disk?

- [ ] Smooth
- [ ] Features or disk
- [ ] Star or artifact

Need help?
Classify Galaxies

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Need help?
True color picture of Hanny’s Voorwerp:
Hanny’s Object – the green blob is probably a light echo from an old Quasar that burned out 100,000 years ago
The Zooniverse*: Advancing Science through User-Guided Learning in Massive Data Streams

* NSF CDI funded program @ http://zooniverse.org
The Zooniverse
http://zooniverse.org/

• New funded NSF CDI grant (PI: L.Fortson, Adler Planetarium; co-PI J. Wallin & collaborator K.Borne, GMU; & collaborators at Oxford U)

• Building a framework for new Citizen Science projects, including user-based research tools

• Science domains:
  – Astronomy (Galaxy Merger Zoo)
  – The Moon (Lunar Reconnaissance Orbiter)
  – The Sun (STEREO dual spacecraft)
  – Egyptology (the Papyri Project)
  – and more (… accepting proposals from community)
Egyptology (the Papyri Project)

Oxyrhynchus Papyri Project @ http://www.papyrology.ox.ac.uk/
The Zooniverse: a Buffet of Zoos
http://zooniverse.org/

• Galaxy Zoo project (released July 2007):
  – http://www.galaxyzoo.org/
  – Classify galaxies (Spiral, Elliptical, Merger, or image artifact)

• Galaxy Merger Zoo (release November 2009)
  – http://mergers.galaxyzoo.org/
  – Run N-body simulations to find best model to match a real merger
  – One new merger every day

• The Hunt for Supernovae (released December 2009)
  – http://supernova.galaxyzoo.org/
  – Real-time event detection and classification

• Solar Storm Watch (released March 2010)
  – http://solarstormwatch.com/
  – Spot solar storms (CMEs) in near real-time
Merging/Colliding Galaxies are the building blocks of the Universe: \[1 + 1 = 1\]
Galaxy Mergers Zoo Gallery

SDSS 587726033843585146

GALAXY ZOO
UNDERSTANDING COSMIC MERGERS
Galaxy Mergers Zoo Gallery

Sloan image

SDSS 587739646743412797
Galaxy Mergers Zoo Gallery

SDSS 587739721900163101

GALAXY ZOO
UNDERSTANDING COSMIC MERGERS
Galaxy Mergers Zoo Gallery

SDSS 588011124116422756
Key Feature of Zooniverse:
Data mining from the volunteer-contributed labels

- Train the automated pipeline classifiers with:
  - Improved classification algorithms
  - Better identification of anomalies
  - Fewer classification errors
- Millions of training examples
- Hundreds of millions of class labels
- Statistics deluxe! …
  - Users (see paper: http://arxiv.org/abs/0909.2925 )
  - Uncertainty quantification
  - Classification certainty vs. Classification dispersion

Zooniverse
Real Science Online
First Case Study: test SDSS science catalog attributes to find which attributes correlate most strongly with user-classified mergers.
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Galaxies Gone Wild!
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Correlation Zoo!

Combinatorial Explosion!!
Challenge Problems

- Zooniverse Data Mining (Machine Learning) Challenge Problems (2011-2013)

Other similar examples:
- KDD cups
- Netflix Prize (#1 and #2)
- GREAT08 Challenge
- Digging into Data Challenge 2009 (diggingintodata.org)
- Transportation challenge problems
- KD2u.org – knowledge discovery from challenge data sets
- Photometric redshift (photo-z) challenge
- Supernova Classification Challenge (ends May 1, 2010)
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Next in the queue: Light Curve Zoo (LCZ)

- **LCZ**
  - development test project (2010-2012) for LSST
- **What?**
  - Explore the effectiveness of Citizen Scientists to characterize light curves (photometric time series)
- **Eventual application**: LSST light curves
- **Initial implementation**: MACHO light curves
- **When?**
  - Design and implementation – next 6-12 months
  - Deployment – 2011
Light Curve Zoo (LCZ)

- **User experience:**
  - Similar to Galaxy Zoo 2: user-directed decision tree
  - **Periodic** or **non-periodic**?

- **Periodic:**
  - Select trial periods, amplitudes, phasing zero-points
  - Find best-fit light curve:
    » Compare with sample variability classes, and/or
    » Using visual inspection, and/or
    » Plots of residuals

- **Non-periodic:**
  - Select **characterizations** that describe the light curve:
    » amplitude, shape, color, rise time, decay time, duty cycle
    » These will be fed to scientists and to classifiers for classification.
Sample training set of light curves for Categorization of Time Series Behavior

- Periodic -- sinusoidal:
  ![Sinusoidal wave](image1)

- Periodic -- smooth non-sine:
  ![Smooth non-sine wave](image2)

- Periodic -- spiked events:
  ![Spiked events](image3) (Chirp)

- Aperiodic events (noise?):
  ![Aperiodic events](image4)

- Single spiked events:
  ![Single spiked event](image5)

- Single long-duration event:
  ![Long-duration event](image6)
Challenge Areas and The Future Man-Machine Partnership

- Data volumes
- Scalability
- Real-time analytics
- One-pass data stream
- Trust
Related References