Author(s): August E. Evrard, PhD. 2010

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Cyberscience: Computational Science and the Rise of the Fourth Paradigm

Honors 352, Class #0.1

August E. (Gus) Evrard, PhD

Fall 2010
The **IDEA Institute** offers many different ways for you to explore science and math teaching! We have two different opportunities available this semester for dedicated science and math undergraduate students to collaborate with high school and middle school teachers.

If you enjoy learning science and mathematics and would love to share your knowledge with others, get involved in **FUTURE or Science Saturdays**.

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**Attend an IDEA Institute informational meeting!**

**Monday, September 13, 4:00 - 5:30 p.m.**

**Tuesday, September 14, 4:00 - 5:30 p.m.**

In the IDEA Institute:

3236 Undergraduate Science Building

Snacks provided
In today’s news...

Today

• reading quiz

• short lecture (Prof. Gus) - Jim Gray’s fourth paradigm = IBM’s smarter planet?

• discussion: the participants and processes of scientific research

• blog / google site access
Thomas Samuel Kuhn (1922-1996) became one of the most influential philosophers of science of the twentieth century, perhaps the most influential—his The Structure of Scientific Revolutions is one of the most cited academic books of all time. His contribution to the philosophy science marked not only a break with several key positivist doctrines but also inaugurated a new style of philosophy of science that brought it much closer to the history of science. His account of the development of science held that science enjoys periods of stable growth punctuated by revisionary revolutions, to which he added the controversial ‘incommensurability thesis’, that theories from differing periods suffer from certain deep kinds of failure of comparability.
Nth paradigm?

The historian of science Thomas Kuhn gave paradigm its contemporary meaning when he adopted the word to refer to the **set of practices that define a scientific discipline at any particular period of time**. Kuhn himself came to prefer the terms *exemplar* and *normal science*, which have more precise philosophical meanings. However in his book *The Structure of Scientific Revolutions* Kuhn defines a **scientific paradigm** as:

- what is to be observed and scrutinized
- the kind of questions that are supposed to be asked and probed for answers in relation to this subject
- how these questions are to be structured
- how the results of scientific investigations should be interpreted

Alternatively, the Oxford English Dictionary defines paradigm as "a pattern or model, an exemplar." Thus an additional component of Kuhn's definition of paradigm is:

- how is an experiment to be conducted, and what equipment is available to conduct the experiment.

Jim Gray’s four scientific paradigms / branches

1. **empiricism**
   observe phenomenon and attempt to classify
   Ptolemy’s universe of concentric spheres

2. **theory**
   describe above classifications with mathematical models
   Newtonian/Einsteinian gravity

3. **computation**
   build ‘virtual’ physical systems via solution of math models
   Cosmic structure formation

4. **data-driven synthesis (?)**
   unite empirical, theoretical and computational branches with data
   (X-info and Comp-X)
   Matter/energy content of the universe
cosmic web of large-scale dark matter
image ~10 billion light-years wide derived from billion-particle N-body simulation
data-rich research permeates all domains (X)

X-Info

- The evolution of X-Info and Comp-X for each discipline X
- How to codify and represent our knowledge

The Generic Problems

- Data ingest
- Managing a petabyte
- Common schema
- How to organize it
- How to reorganize it
- How to share it with others

- Query and Vis tools
- Building and executing models
- Integrating data and literature
- Documenting experiments
- Curation and long-term preservation

© FAIR USE Jim Gray’s The Fourth Paradigm: Data-Intensive Scientific Discovery.
challenges

1. unifying the tiers
   – data collections across the scales, from small labs to international consortia
   – published literature with underlying data (raw, derived) and data processing algorithms/codes
   – ironing the seams across disciplines
     
     Disciplinary scientists and organizations (e.g., National Academy of Science, National Science Foundation)

2. semantics
   – describing objects, attributes, methods in a robust, scaleable manner
   – curating and archiving collections
     
     Disciplinary scientists, Librarians!

3. funding
   – recognize value of data-driven synthesis (DDS) infrastructure
   – maintain `single investigator’ support while growing new capabilities
     
     Federal and state government agencies, scientific industry partners, universities!
Building a smarter planet, for business (and science?)

Welcome to a smarter planet

This week’s feature

Do you understand how to build a smarter planet?

These experts do, and they offer insights into security, traceability and other elements of smart

Meet them now

Smarter healthcare

On the mend

Electronic medical records, mobile computing devices and health support networks could give the system a smarter prognosis

Learn more

What is a smarter planet?

3 big ideas to build one smarter planet

1. Instrument the world’s systems
2. Interconnect them
3. Make them intelligent

Here's how we make it work

Discuss: Nature of Scientific Research

• who participates?

• what are the processes involved? (end-to-end view)

• how are the participants rewarded?
Lab next Tuesday

• three groups: PC / Mac / Linux

• bring cameras
Slide 3: Giuseppe Bertini (1825–1898), "Galileo Galilei showing the Doge of Venice how to use the telescope"

Slide 4: Image of a flyer regarding an event that has already taken place. For more information, please go to www.ideainstitute.umich.edu.


Slide 7, Image 1 (left): Please see original biographical information of Thomas Samuel Kuhn at http://plato.stanford.edu/entries/thomas-kuhn/.

Slide 9: Jim Gray’s The Fourth Paradigm: Data-Intensive Scientific Discovery.


Slide 11: Jim Gray’s The Fourth Paradigm: Data-Intensive Scientific Discovery.