The Need for Hypotheses in Informatics

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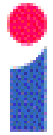
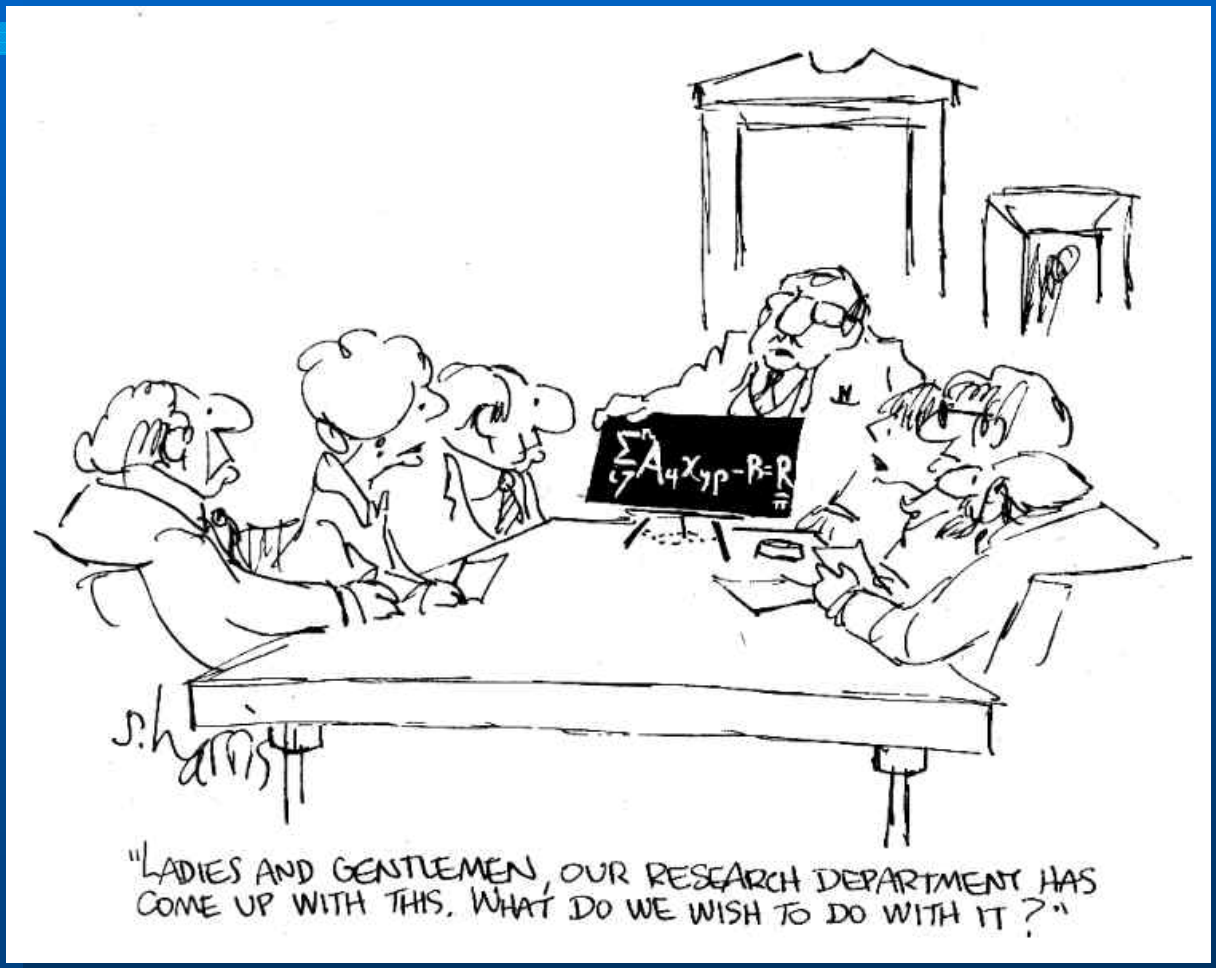


The Significance of Research



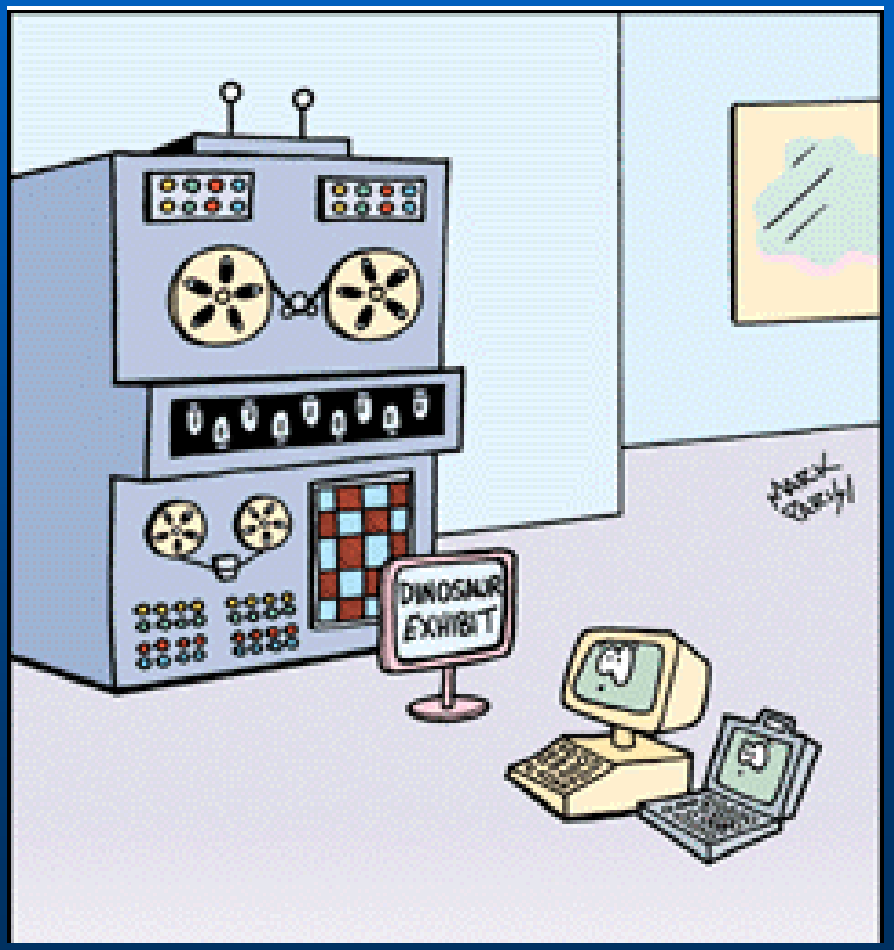
Importance of Hypotheses

- Science and engineering proceed by
  - the formulation of hypotheses
  - and the provision of supporting (or refuting) evidence for them.
- Informatics should be no exception.
- But the provision of explicit hypotheses in Informatics is rare.
- This causes lots of problems.
- My mission – to persuade you to rectify this situation.

Problems of Omitting Hypotheses

- Usually many possible hypotheses.
- Ambiguity is major cause of referee/reader misunderstanding.
- Vagueness is major cause of poor methodology:
  - Inconclusive evidence;
  - Unfocussed research direction.

Advancing the State of the Art



Exploration of Technique Space

- **Informatics as the space of computational techniques.**
- **Job of Informatics to explore this space.**
  - **Which techniques are good for which tasks?**
  - **What are properties of these techniques?**
  - **What are relationships between these techniques?**

What are Informatics Techniques?

- **Information Representation:**
  - **e.g. databases, hash tables, production rules, neural nets.**
- **Algorithms:**
  - **e.g. quick sort, depth-first search, parser.**
- **Architectures:**
  - **e.g. von Neumann, parallel, agents.**
- **Software Engineering Processes:**
  - **e.g. extreme programming, knowledge acquisition/requirements capture.**
- **Theories:**
  - **e.g. denotational semantics, process algebras, computational logics, hidden Markov models.**

The Space of Informatics Techniques

- **Multi-dimensional space of techniques,**
  - **linked by relationships.**
- **Rival techniques for same task,**
  - **with tradeoffs of properties.**
- **Complementary techniques which interact.**
- **Build systems from/with collections of techniques.**

Exploration of Techniques Space

- Invention of new technique,
- Investigation of technique,
  - e.g. discovery of properties of, or relationships between, techniques.
- Extension or improvement of old technique,
- New application of a technique,
  - to artificial or natural systems.
- Combine several techniques into a system.

Hypotheses in Informatics

- **Claim about task, system, technique or parameter, e.g.:**
  - **All techniques to solve task X will have property Y.**
  - **System X is superior to system Y on dimension Z.**
  - **Technique X has property Y.**
  - **X is the optimal setting of parameter Y.**
- **Properties and relations along scientific, engineering or cognitive science dimensions.**

Rarely explicitly stated

Different Dimensions

Scientific Dimensions 1

- **Behaviour**: ***the effect or result of the technique,***
  - **correctness *vs* quality,**
  - **need external 'gold standard';**
- **Coverage**: ***the range of application of the technique,***
  - **complete *vs* partial;**
- **Efficiency**: ***the resources consumed by the technique,***
  - **e.g. time or space used,**
  - **usually as approx. function, e.g. linear, quadratic, exponential, terminating.**

Scientific Dimensions 2

- **Sometimes mixture of dimensions.**
- **Property *vs* comparative relation.**
- **Task *vs* systems *vs* techniques *vs* parameters.**

Engineering Dimensions

- **Fitness**: ***how well it meets user requirements.***
- **Usability**: ***how easy to use?***
- **Dependability**: ***how reliable, secure, safe?***
- **Maintainability**: ***how evolvable to meet changes in user requirements?***
- **Scalability**: ***whether it still works on complex examples?***

Cognitive Science Dimensions

- **External**: ***match to external behaviours,***
  - **both correct and erroneous.**
- **Internal**: ***match to internal processing,***
  - **clues from e.g. protocol analysis.**
- **Adaptability**: ***range of occurring behaviours modelled***
  - ***... and non-occurring behaviours not modelled.***
- **Evolvability**: ***ability to model process of development.***

All this to some level of abstraction.

Kinds of Research

- **Different levels:**
  - **task, system, technique, parameter.**
- **Theory *vs* experiment,**
  - **exploratory *vs* hypothesis testing.**
- **Properties *vs* relations,**
  - **which dimension?**

Deepening Understanding of Techniques 1

- **Formal proof of hypothesis,**
  - **e.g. correctness, completeness, termination, complexity.**
- **Experimental exploration and hypothesis testing.**
  - **e.g. complexity, success rate, coverage,**
  - **both absolute and relative to others,**
  - **comparison may be with animal/human.**

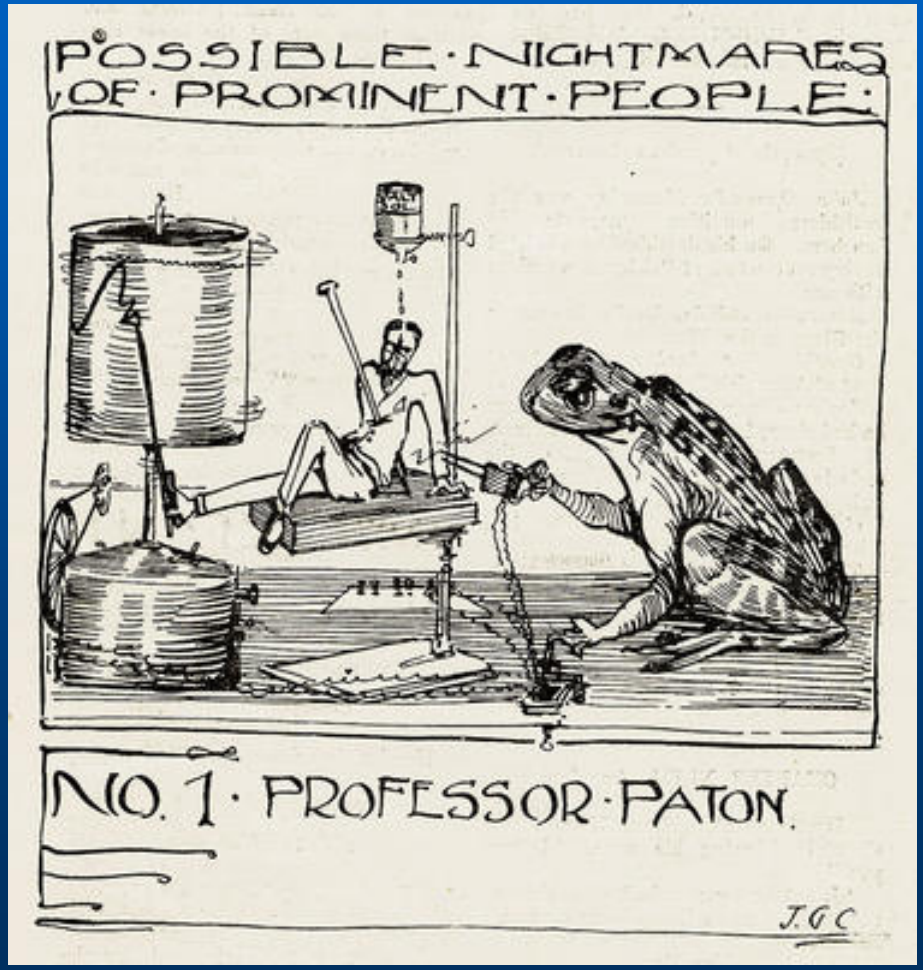
Deepening Understanding of Techniques 2

- **Tradeoffs between properties/relations,**
  - **e.g. time/space vs problem type/size, phase boundaries.**
- **Discover two apparently different techniques are the same,**
  - **or that one is a special case of the other,**
  - **or that different techniques have the same name.**

Theoretical Research

- Apply to task or technique.
- Use of mathematics for definition and proof.
- Theorem as hypothesis; proof as evidence.
- Advantages:
  - Abstract analysis of task;
  - Suggest new techniques, e.g. generate and test;
  - Enables proof of general properties/relationships,
    - cover potential infinity of examples;
    - Suggest extensions and generalisations;
- Disadvantage:
  - Sometimes difficult to reflect realities of task.

Experimentation



Experimental Research

- **Kinds:**
  - **exploratory vs hypothesis testing.**
- **Generality of Testing:**
  - **test examples are representative.**
- **Results Support Hypothesis:**
  - **and not due to another cause.**

How to Show Examples Representative

- Distinguish development from test examples.
- Use lots of dissimilar examples.
- Collect examples from an independent source.
- Use the shared examples of the field.
- Use challenging examples.
- Use acute examples

How to Show that Results Support Hypothesis

- **Vary one thing at a time,**
  - **then only one cause possible.**
  - **Unfortunately, not always feasible.**
- **Analyse/compare program trace(s),**
  - **to reveal cause of results.**
- **Use program analysis tools,**
  - **e.g. to identify cause/effect correspondences**

Summary

- Informatics advances via formulation of hypotheses,
  - and providing supporting (or refuting) evidence for them.
- Hypothesis typically establish or compare properties along some dimension.
- Property dimensions include:
  - Scientific: behaviour, coverage, efficiency.
  - Engineering: fitness, usability, dependability, maintainability, scalability.
  - Cognitive Science: external, internal, adaptability, evolvability.
- Both theory and experiment can provide evidence.