Dependable System Evaluation/Validation: What Lies Ahead During the Next 25 Years?

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Caveats

- With regard to most any aspect of the theory, design, implementation, evaluation, validation, and application of computer and communication systems, it’s absurd to accurately predict progress over the next 25 years.
- The famous (and recently deceased) economist John Kenneth Galbraith once remarked that

  “The only function of economic forecasting is to make astrology look respectable.”

- The same might be said for technology forecasting.

Nevertheless, We Do It

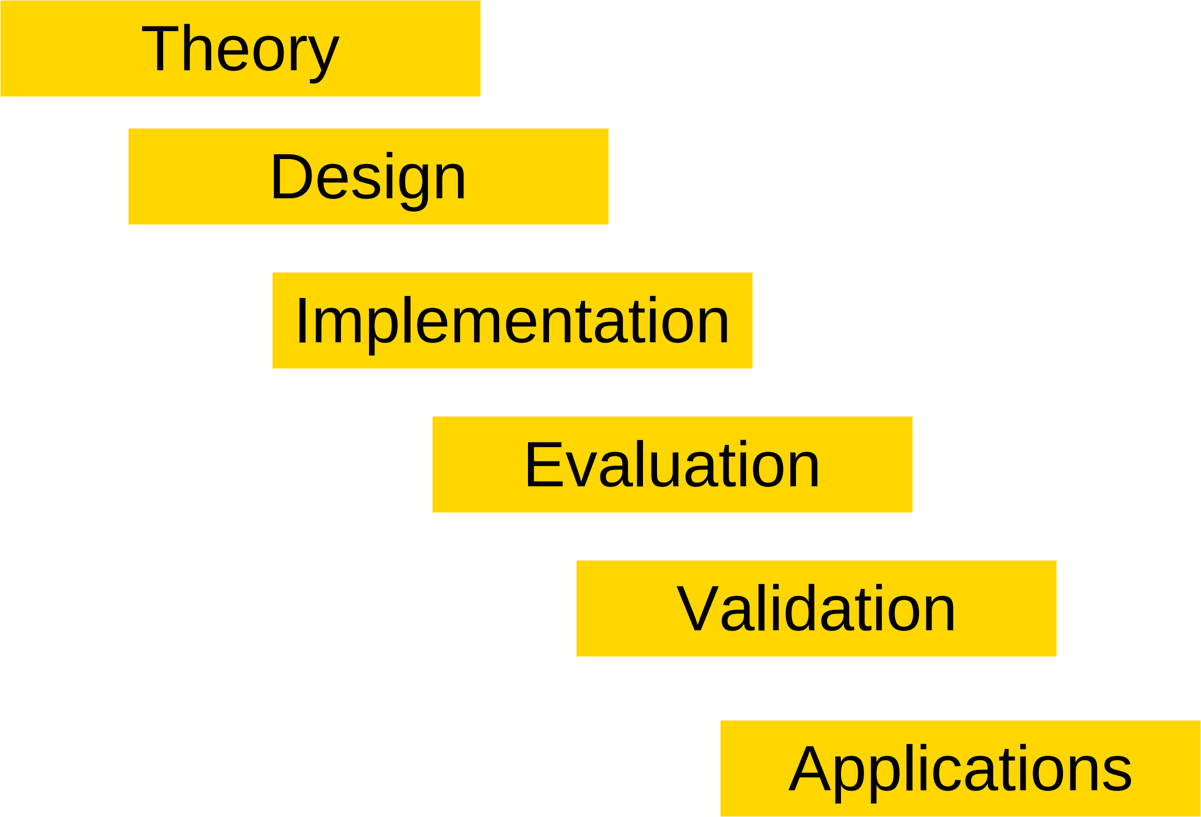
- Envisioning future needs and how to fulfill them is what fuels progress in all aspects of information technology (IT).

- In particular, when introducing new courses and research directions at a university, we are in effect predicting what will benefit our students in the workplace over the next couple of decades.

Assumptions

- Rapid growth in IT utilization and economic globalization (“earth flattening”) will continue during the next 25 years.
- In particular, the following will not occur:
  - A cataclysmic disaster, either natural or man-made, that dramatically alters life as we know it.
  - Unwise tampering with roles played by academia, industry, government, and professional societies that seriously impedes the pace of IT development.

Dependable Systems and Networks: Avenues for Progress



Theory

Design

Implementation

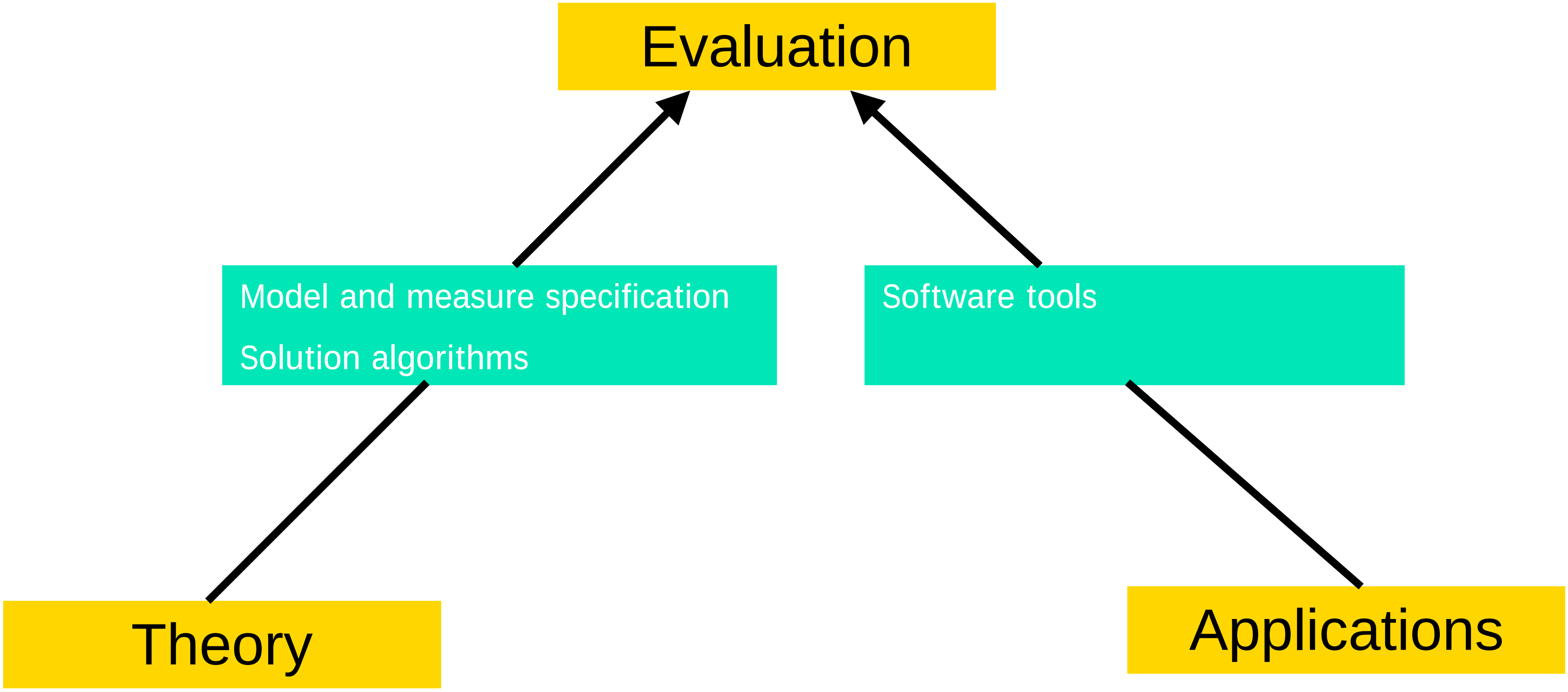
Evaluation

Validation

Applications

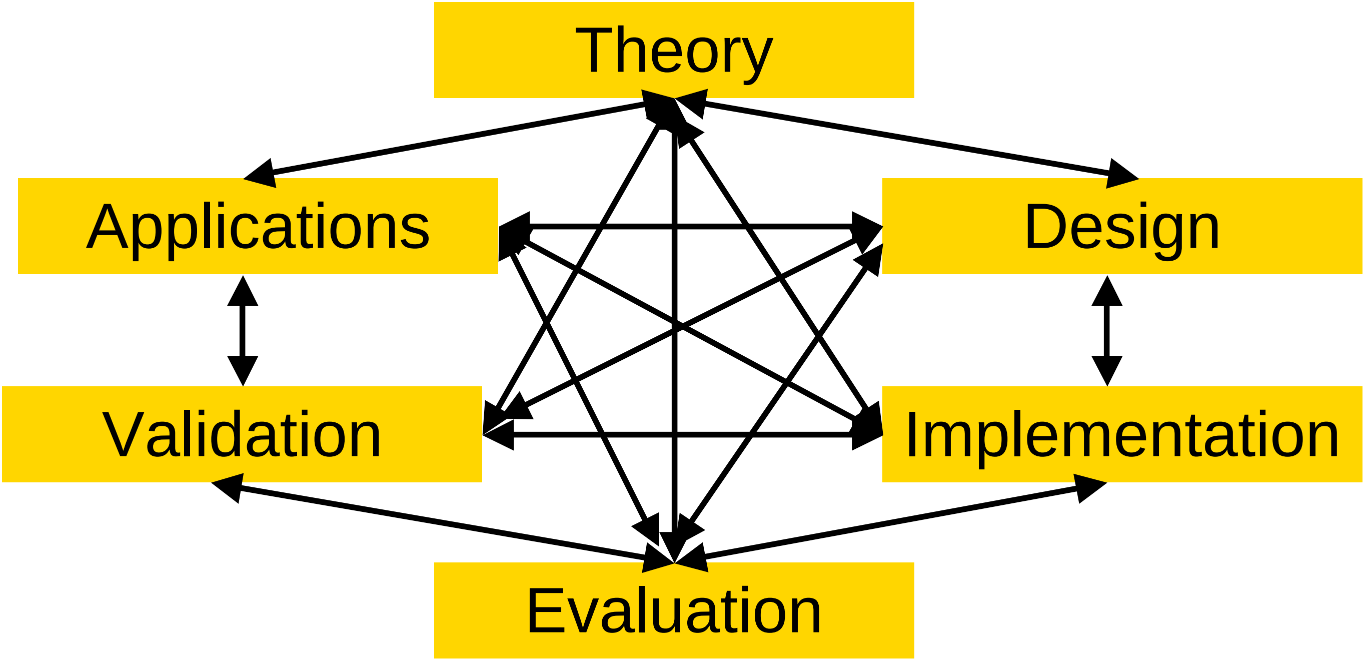
Avenues Are Interdependent: Forecasting Must Consider Dependencies

- For example, evaluation depends highly on both theory and applications.



Dependencies

- Indeed, progress in each depends to a lesser or greater extent on progress in each of the others.



Which Avenue Will Dominate?

- In other words, which will be the most influential in shaping dependable computing progress over the next 25 years?
- This is a difficult question, tantamount to the age-old question concerning whether the chicken or the egg occurred first.
- However, based on the history of computing, it is likely that applications will be the principal driver.
- Early examples:
  - Polynomial calculations → Babbage's analytical engine
  - Artillery trajectory calculations → ENIAC
  - Computer sharing via communication links → ARPANET

Application Examples

- Personal computing
  - PCs, hand-helds, wrist-tops, …
- Management and control
  - Embedded computers in home appliances, entertainment systems, cars, trains, aircraft, …
  - Home networks, manufacturing LANs, enterprise networks, ATC systems, military C2 systems, …
- Science and engineering applications
  - Supercomputer clusters , engineering tools (design, evaluation, validation), …
- World-wide communication and information sharing
  - Telecom nets, Internet(s), …

Evaluation/Validation of Dependable Systems

- What systems pose the most difficult evaluation and validation challenges during the next 25 years?

Networked systems shared by a large number of users

- Why?
  - As compared with most other computer-based systems, there are typically additional difficulties due to
    - a wide variety of supported services
    - complicated service specifications
    - geographically distributed implementations involving diverse hardware and software components
    - extreme penalties (large losses of money, perhaps lives) in the case of severe failures due to either accidental faults or security breaches.

Measures

- Of principal importance in system evaluation are the measures used to quantify what a system
  - is, e.g., the integrity of its resources, and
  - does, e.g., how well it serves its users
- Generally, what a system does can be represented by
  - random variables
    - system-oriented (e.g., resource utilization, fault-recovery time)
    - user-oriented (e.g., throughput, end-to-end delay)
- A probabilistic measure of an RV provides its quantification
  - mean, higher order moments, PDF
- Note: Although this jargon appears to be model-oriented, it applies as well to direct measurements of an actual system.

Measure Types

- Measure Types
  - Reliability
  - Availability
  - Safety
  - Security
  - Performability, QoS
  - Not yet considered
- A trend that will likely continue the next 25 years
  - Escalation of measure concerns to higher levels of service
    - Video professor phenomenon
      - Original products – how to use Windows, Excel, etc.
      - Most recent CD – how to buy and sell on e-bay

Measure Specification/Formulation

- Specification
  - Natural language
  - Formal (logical, analytical)
  - Not too difficult
- Formulation
  - Model-based evaluation - HARD
  - Based on actual system – EASIER
    - Sometimes obtained directly
    - In the case of more complex performability and QoS measures, formulation is a function of lower-level RVs that can be monitored directly

Model-Based Evaluation

- Measures need to be formulated in terms of model behavior
- Current practice
  - 🗀✆ Based on the measure’s specification, construct a high-level model of the system that appears to support its evaluation
  - 🗎✆ Elaborate model accordingly
  - 🗏✆ Iterate
    - Attempt to formulate measure
    - Revise model

    until formulation appears to be correct
  - 🗐✆ Verify formulation
- Steps 3) and 4) are currently (human) labor intensive, requiring a great deal of knowledge regarding the system and expertise regarding use of the modeling tool (not practical to do this without a tool).

How This Will Be Done 25 Years From Now (Hopefully)

- 2031 practice
  - Construct a detailed model of the system (possible even in the case of a large multi-user computer network).
  - Given a specified measure, its formulation and verification are fully automated via tools that require minimum human interaction.
- What will this permit?
  - Widespread application of model-based evaluation, and in turn, model-based validation wrt quantitative requirements.
    - Rapid prototyping
    - Models in the loop of autonomic systems
    - Service qualities guaranteed
    - And on and on

Some WG Members Circa 2031 (Hopefully)