#### Foundational Issues: Still Meaningful

#### UniLog'2018 Logic for Dynamic Real World Information

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### Nature of This Talk

#### ESSENTIALLY INFORMAL

- Formal issues will be raised, but ignoring lots of detail
- SURVEY
  - Logic and Semantics of Software Systems
  - Design and Implementation Issues
  - Unanticipated "Failures"
  - Examples from Experience

### Software Engineering: Radical View?

- Identify subject system (physical world?)
- Analyze elements: entities, properties, relationships, transformations, and processes
- Select a sufficiently expressive formal (logical, deductive) system
- Choose symbolic vocabulary logical (formal operations) vs. nonlogical (arguments)
- Map elements to symbols
  - transforms and processes  $\rightarrow$  deductions or algorithms using formal operations
  - entities, properties, relationships  $\rightarrow$  nonlogical symbols or data structures

#### **Decision Procedures**

- Program Logic if then else, while, etc.
  - partitions the representational space into disjoint regions
- Querying databases
  - DBMS based on formal deductive system such as relational
- Informational Systems
  - e.g., reporting, analytical, decision support
- Advisory Systems
  - e.g., recommenders, business intelligence systems
- Semi-automated Systems
  - e.g., automobile cruise control and braking
- Fully automated Systems
  - e.g., factory robots, trading systems, autopilots (air and car)

#### **Decision Procedures**

- Intelligent/Adaptive (AI/ML)
  - classifiers, recognizers, planners, etc.
  - dominant methods: neural networks vs. statistical learning
- Semantic Representation Issues Matter
  - feature selection
  - dimensionality
  - convergence
  - number of independent random variables
  - probability distributions (discrete? quantum?)
  - continuity

### **Semantics: Interpretations**

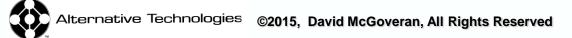
- Subject/Intrinsic Interpretation usually informal
  - finite vs. infinite (round trip floating point rounding errors?)
  - continuous vs. discrete
  - bounded vs. unbounded
- Canonical Interpretation formal/internal
  - The interpretation the logical system is meant to represent
  - An interpretation is "permissible" if consistent with canonical
- Expected Interpretation
  - What the architect/designer/developers expect (usually implicit!)
  - must be permissible
- Realized Interpretation
  - how the system is actually understood and used

### **Semantics:** Representations

- Subject System vs. Formal System
- Mapping Correspondence between symbol (formal system) and meaning (subject system)
  - Extensional set of elements we "point" to
  - Intensional a specification of the above set, applied to a "welldefined" universe
- Deductive System Implementation Logic
  - FOL (untyped vs. typed)
  - Computationally/Turing Complete
- "Simulated" Logic
  - languages: natural, SQL, etc.
  - Propositional, FOL, SOL, Fuzzy, nVL, Modal, Probabilistic, etc.

#### Foundations: How Well Defined? (Relational Data Model Example)

- Finite, Countably Infinite, or Uncountably Infinite [finite]
- Untyped or Typed [typed]
- Truth Values
  - How many and which are designated/anti-designated [bivalent]
- Truth Functional
  - compound wffs evaluated by evaluating components [evaluation is mechanical and based on data in database]
- Theory of Truth
  - e.g., correspondence (meaning assignments) vs. coherence (truth value assignments)[both!]



### Foundations: How Well Defined?

#### Tautologies

- wffs true for all permissible interpretations (e.g., P ∨ ¬P)
  [tautological query returns every accessed proposition]
- Sound
  - every provable (i.e., deducible) wff S is true for all permissible interpretations [every query represents a set of true and only true propositions]
- Negation Consistent
  - for every wff S, either S or else ¬S is a theorem [a syntactically correct query and its negation have disjoint results]
- Expressively Complete
  - can express all of the intended subject [users can query every possible proposition about the subject]

#### Foundations: How Well Defined?

#### Deductively Complete

- every true wff S is provable [every fact represented in the database can be accessed via a query]
- Decidable
  - general algorithm to evaluate truth value of any wff [users never write/verify a database/application specific evaluation algorithm]
  - [Finite FOL and Wittgenstein quantifier reduction FOL deduction, propositional evaluation]
- Familiarity: Principle of Least Surprise
  - **Example**: The Many-valued Logic (nVL) of SQL
    - » Can you say "complexity"?
    - » K3 fragment? (versus extension versus deviant)
    - » Inconsistent semantics: DBMS product dependent!

#### Interpretation by Users

- What meanings will users give symbols?
  - This is the realized interpretation
  - Even mnemonic text on a display does not preclude semantic misalignment
- Are both the expected and realized interpretations permissible?
  - Semantic consistency with the formal logical system
- Are the realized interpretation and the expected interpretation at least compatible?
  - How do we know?

## Interacting Semantic Systems

- Implication: Representation of one = Interpretation of other
  - Requires mutual semantic consistency among all systems
  - Problems similar to human communication problems
  - THE problem of system integration: assumes global control
  - Examples: airline systems, digital cable systems
- Realms of Complex System Behavior
- Stability under some inputs
- Unpredictable/Potentially Chaotic Behavior
  - Increases with diversity & semantically inconsistency of interacting systems
  - Examples: Wall Street 10/19/1987, Drone GPS spoofing 12/4/2011

### **Unexpected Semantic Systems**

- Users as "systems"
  - Users can be understood as "systems" in their own right
  - BUT: They (may) have unstable semantics and system(s) of inference!
- Unintended Operational Environments
  - Input sources matter, especially when sensor-based !
- Unanticipated Combinations
  - **Example**: Consider this complex, interacting combination
  - Self-driving cars from multiple manufacturers
    - » Different policies about reacting to obstacles like people
  - Adaptive traffic management systems in cities
  - Adaptive routing systems (Google maps, Trip, etc.)

### So What Can We Do?

- Identify Logic Systems and Their Characteristics
- Identify Assumptions
  - Semantics
  - Axioms
  - Intended Operational Environment
- Anticipate Failure Modes
- Make these available for users and other decision system designers/developers
- Initiate Research Into Interacting Semantic Systems
- Establish an "Underwriter's Laboratory"
  - Determine how to "label" systems with appropriate characteristics

# **Questions?** Slides by Email Request

