Foundational Issues: Still Meaningful

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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 → deductions or algorithms using formal operations
  - entities, properties, relationships → 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 "well-defined" 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