LOOKING UNDER THE STREET LAMP

Physics Lessons from Computer Science

Physics Off the Beaten Path

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PHYSICS IS COMPUTER SCIENCE!

- **LARGE HADRON COLLIDER, CERN**
  - ATLAS EXPERIMENTS
  - MASSIVE DATA COLLECTION
    - » 320 MB/SEC ELECTRICAL SIGNAL OUTPUT
    - » EVENT SUMMARY DATA IN AN OBJECT ORIENTED MODEL
    - » 1 GB/SEC ANALYSIS OBJECT DATA
    - » 3.156×10^{17} BYTES/YEAR IF RUN CONTINUOUSLY

- **DATABASES, DATA MINING, AND ANALYSIS**
  - EXAMPLE ANALYSIS OF VERY LARGE DATABASES

- **INFORMAL CONCEPTUAL TALK**
  - FOCUS ON COMPUTER TRANSACTIONS

TRANSACTION BASICS

- ## DATABASES
  - ORGANIZED COLLECTION OF DATA
  - DATABASE MANAGEMENT SOFTWARE
  - READ AND WRITE CAPABILITIES
  - DATABASE STATES

- ## TRANSACTIONS
  - A USER INTERATION WITH THE DATABASE
  - GROUPINGS OF OPERATIONS
  - EQUIVALENT TO A DATA TRANSFORMATION
  - BANKING EXAMPLES: DEPOSITS, WITHDRAWALS, TRANSFERS
  - TRANSITION DATABASE BETWEEN TWO STATES THAT SATISFY CONSTRAINTS

TRANSACTION BASICS

- ## CONCURRENT TRANSACTIONS
  - MULTIPLE SIMULTANEOUS TRANSACTIONS
  - POSSIBILITY OF INTERFERENCE
    - » OVERWRITE EACH OTHERS CHANGES
    - » CHANGE RELIED UPON DATA

- ## THE FORMAL FIX: ACID PROPERTIES
  - ATOMICITY
  - CONSISTENCY
  - ISOLATION
  - DURABILITY

TRANSACTION BASICS

- ## ATOMICITY

  Either all the operations in the group execute successfully or none do. Thus, they operate as if they were a single transformation.

- ## CONSISTENCY

  The states of the database immediately before and immediately after the transaction executes are consistent with respect to all constraints on the database.

TRANSACTION BASICS

- ## ISOLATION

  The action of the transaction on the database is as if the transaction had run in isolation from all other transactions (interpreted as permitting no interaction between concurrent transactions).

- ## DURABILITY

  The database state resulting from transaction execution persists in non-volatile storage until altered by another transaction, so that each observed database state and the observed history of database states may be relied upon.

TRANSACTION BASICS

- ## SERIALIZABILITY FOR ISOLATION
  - RESULT OF CONCURRENT EXECUTION IS IDENTICAL TO <u>SOME</u> SEQUENTIAL EXECUTION
  - TRANSACTION A STARTED BEFORE TRANSACTION B
  - OPERATIONS OF A AND B ARE INTERLEAVED
  - COMPLETED (CALLED "COMMIT")
  - EFFECT IS AS IF TRANSACTION B RUN, THEN TRANSACTION A

TRANSACTION BASICS

- **CORRECTNESS OF UPDATING AND QUERYING**
- **CRITICAL FOR SHARED DATABASES**
- **DISTRIBUTED TRANSACTIONS**
  - ATOMIC BEHAVIOR AND CONSISTENCY
  - MULTIPLE DATABASES BEHAVE SIMILAR TO A SINGLE DATABASE
- **SUBTLE THEORETICAL ASSUMPTIONS**
  - WELL DEFINED GROUP IN ADVANCE OF EXECUTION
  - CONSTRAINTS FIXED OVER TIME
  - FIXED SEMANTICS
  - ISOLATION OVER TEMPORAL ORDER
  - UNIQUE, RECOVERABLE HISTORY

TRANSACTION BASICS

- **PERFORMANCE IMPACT OF ACID PROPERTIES**
  - PRACTITIONERS FAIL TO ENFORCE ATOMICITY OF DISTRIBUTED TRANSACTIONS
  - OFTEN REMOVE OR FAIL TO DEFINE CONSTRAINTS
  - PERMIT BREAKING OF ISOLATION
    - » PERMITS CLASSES OF ERRORS
  - RISK LOSS OF DURABILTY
    - » GROUP CHANGES OF MULTIPLE TRANSACTIONS
    - » WRITE ALL <u>AFTER</u> COMMIT
- **NUMERIOUS ATTEMPTS TO FIX**

EMERGENT TRANSACTIONS

- **OVER A DECADE OF RESEARCH**
- **TWO PATENTS**
  - FOR EXAMPLE: U.. Patent 7,103,597
- **INVERTS TRANSACTION DEFINITION**
  - EXAMINE STATES AFTER CHANGE
  - IF CONSISTENT WITH CONSTRAINTS, THEN POTENTIAL TRANSACTION BOUNDARY CALLED A "CONSISTENCY POINT"
- **FLEXIBILITY**
  - CONSTRAINTS CAN CHANGE
  - GROUP OF OPERATIONS DYNAMIC
  - TRANSACTIONS CAN SHARE STATE AT CONSISTENCY POINTS
  - AUTOMATED ERROR CORRECTION
  - REDUCES PERFORMANCE COST

EMERGENT TRANSACTIONS

- ## INTERPRETING DATABASE HISTORIES
  - RECORD OF OPERATIONS AND STATES
- ## TEMPORALITY
  - DATA ELEMENT LOCAL TIME: INCREMENT WHENEVER TOUCHED
  - TRANSACTION ORDER CAN CHANGE
  - CHANGES EFFECTIVE TEMPORAL ORDER
  - GLOBAL TIME DEPENDS ON CONSTRAINTS
- ## OBJECTS
  - TRANSACTIONS DEFINE OBJECTS
  - <u>BUT</u> CONSTRAINTS DETERMINE TRANSACTIONS

EMERGENT TRANSACTIONS

- ## USING THE THEORY: EXAMPLE
  - DATABASE FORENSICS
    - » MISSING TRANSACTION HISTORY
    - » MUST DETERMINE CONSTRAINTS

- ## OBSERVATIONS
  - FOR TRANSACTIONS WITH INVERSE, TEMPORAL HISTORY IS SYMMETRIC ABOUT TRANSACTION
  - FOR COMMUTATIVE TRANSACTIONS, TEMPORAL HISTORY IS SYMMETRIC ACROSS TRANSACTIONS
  - ADDING CONSTRAINTS CAN MAKE A TRANSACTION INVERTIBLE
    - » EXAMPLE: AVERAGE VELOCITY AND DISTRIBUTION

EMERGENT TRANSACTIONS

- ## OBSERVATIONS
  - ROLLBACK AND RECOVERY ALTERNATIVES CAN
    - » MAKE AN INTERVENING TRANSACTION DISAPPEAR
    - » MAKE A POTENTIAL TRANSACTION CAUSAL
    - » ALTER THE EXECUTION ORDER OF TWO OR MORE TRANSACTIONS
  - CHANGING CONSTRAINTS CAN CHANGE OUR UNDERSTANDING OF WHAT OBJECTS ARE REPRESENTED BY THE DATA
    - » CHANGES CONSISTENCY POINTS
    - » ALTERS DATA ELEMENTS WITHIN TRANSACTION BOUNDARIES

AND THAT'S PHYSICS

- **INTERACTION EVENTS ARE TRANSACTIONS**
  - EVENTS SATISFY A SET OF CONSTRAINTS
    - » CONSERVATION LAWS
    - » MOMENTUM

- **PARTICLES BETWEEN EVENTS ARE OBJECTS**
  - CONCEPTUAL AT BEST
  - CONNECTION BETWEEN EVENTS IS A CONSTRAINT ISSUE

- **MACROSCOPIC TIME**
  - IS INTERPRETATION
  - WE IMPOSE FROM A "CLASSICAL FRAME"
  - CANNOT JUSTIFY IDENTIFYING WITH MICROSCOPIC TIME
    - » INTERNAL TO EVENT

AND THAT'S PHYSICS

- ## DISCRETE ATTRIBUTE DISTANCES
  - FOUNDATIONS OF DISCRETE PHYSICS
  - ANALOGOUS TO DIGITAL EVENT SIGNATURE
  - NO A PRIORI PRECEDENCE
  - NO JUSTIFICATION FOR ANALYTICITY OR EVEN A MONOTONIC CORRELATION

- ## ELECTROMAGNETIC ATTRIBUTE DISTANCE
  - MACROSCOPIC FRAME
  - INVALID WITHIN EVENTS UNLESS EVENT IS COMPOUND
    - » SIMILAR TO HAVING INTERNAL CONSISTENCY POINTS
    - » MEANS NOT COHERENT, COUPLED TO OTHER EVENTS

- ## MULTIPLY CONNECTED SPACE
  - ACTION AT A DISTANCE

AND THAT'S PHYSICS

- **SUMMARY**
  - **SO WHERE DOES THE "ELECTROMAGNETIC" STREETLAMP SHINE?**
  - **IT DEPENDS ON THE CONSTRAINTS WE IMPOSE (OR EXPECT)**

"The Old One is discrete but ornery: He presents us with more combinations than he permits us to count. Hence we see 'randomness' or 'miracles' and are humbled." – McGoveran, 2009

REFERENCES

- **TBD**

Questions?