A Family of Test Adequacy Criteria for Database-Driven Applications

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Motivation

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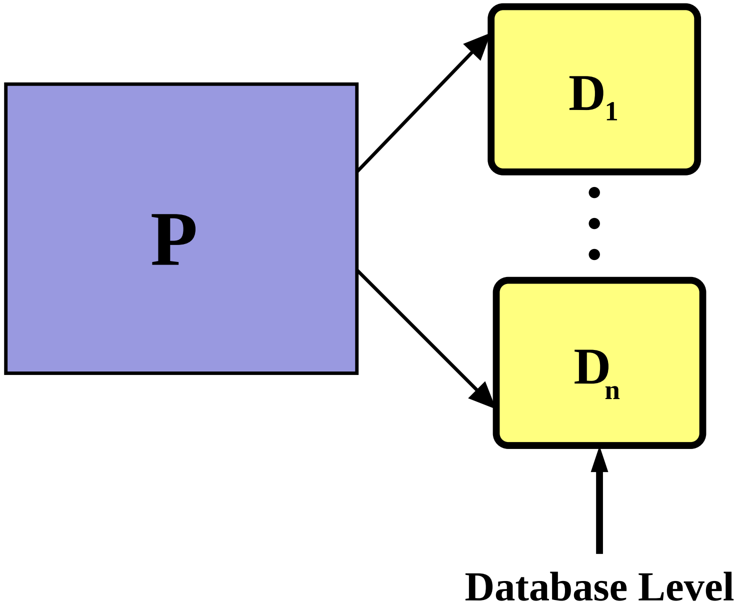
Jeppesen reports airspace boundary problems

About 350 airspace boundaries contained in Jeppesen NavData are incorrect, the FAA has warned. The error occurred at Jeppesen after a software upgrade when information was pulled from a database containing 20,000 airspace boundaries worldwide for the March NavData update, which takes effect March 20.

Testing Challenges

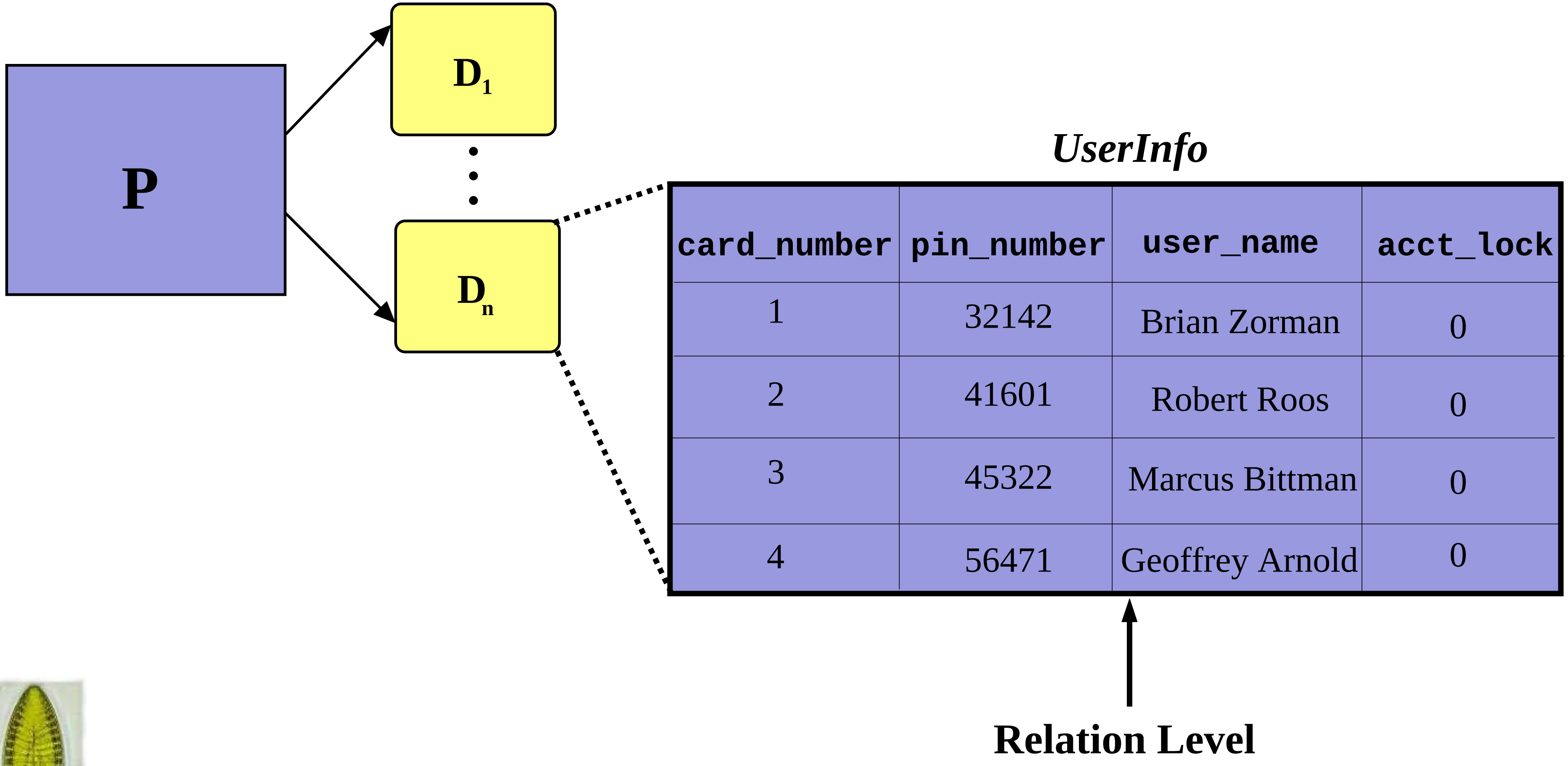
- Should consider the environment in which software applications execute
- Must test a program and its interaction with a database
- Database-driven application’s state space is well-structured, but infinite (Chays et al.)
- Need to show program does not violate database integrity, where *integrity* = *consistency* + *validity* (Motro)
- Must locate program and database coupling points that vary in granularity

Database-Driven Applications



- A program can interact with a database at different levels of granularity

Database-Driven Applications

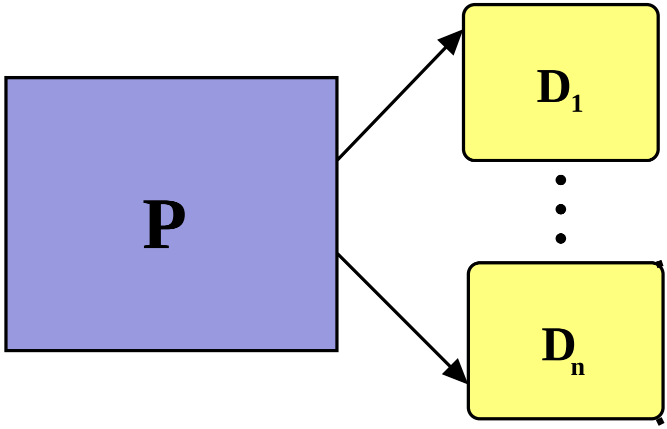


UserInfo

card_number	pin_number	user_name	acct_lock
1	32142	Brian Zorman	0
2	41601	Robert Roos	0
3	45322	Marcus Bittman	0
4	56471	Geoffrey Arnold	0

Relation Level

Database-Driven Applications



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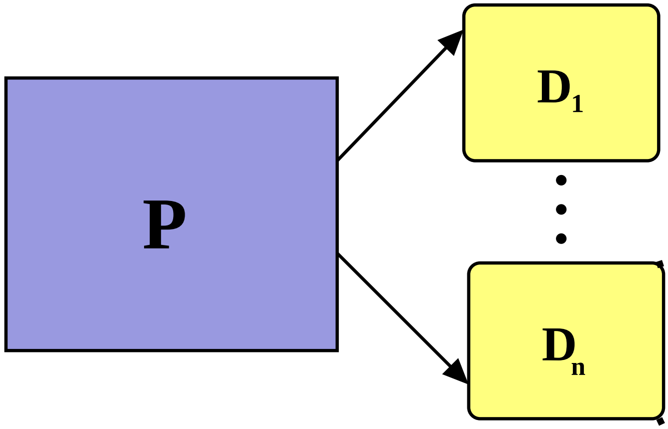
Record Level

Database-Driven Applications



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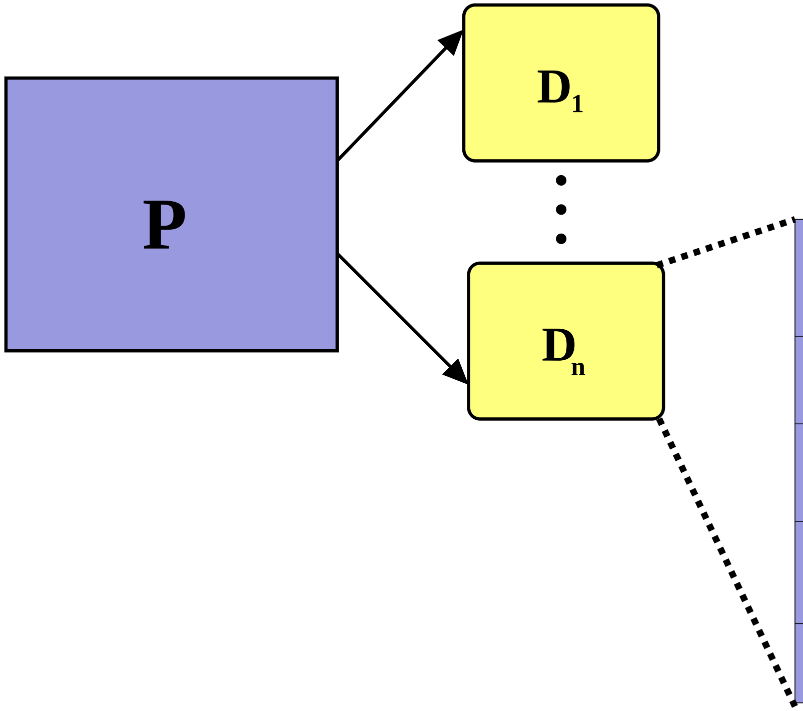
Attribute Level

Database-Driven Applications



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Attribute Value Level

Test Adequacy Criteria

- P violates a database D_i's validity when it:
  - **(1-v)** inserts entities into D_i that do not reflect real world
- P violates a database D_i's completeness when it:
  - **(1-c)** deletes entities from D_i that still reflect real world
- In order to verify **(1-v)** and **(1-c)**, T must cause P to define and then use entities within $D_1, \ldots, D_n$!

Data Flow Information

- Interaction point: `‘‘UPDATE UserInfo SET acct_lock=1’’ + ‘‘WHERE card_number=’’ + c_n + ‘‘;’’;`
    - Database Level: *define(BankDB)*
    - Attribute Level: *define(acct_lock)* and *use(card_number)*
- Data flow information varies with respect to the granularity of the database interaction

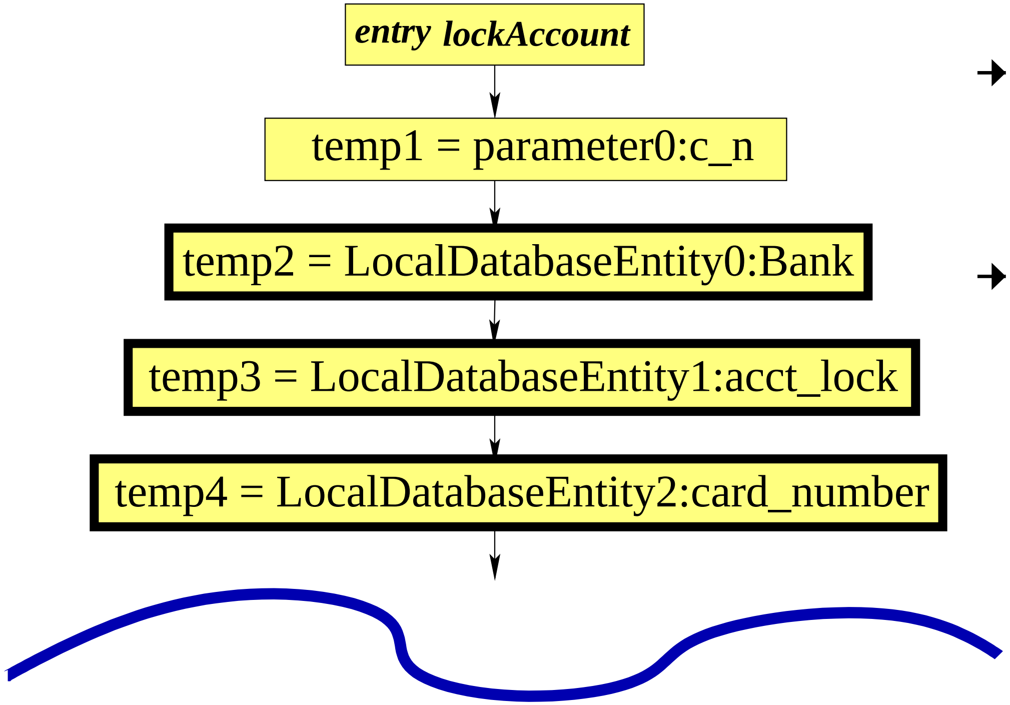
Database Entities

UserInfo

card_number	pin_number	user_name	acct_lock
1	32142	Brian Zorman	0
2	41601	Robert Roos	0
3	45322	Marcus Bittman	0
4	56471	Geoffrey Arnold	0

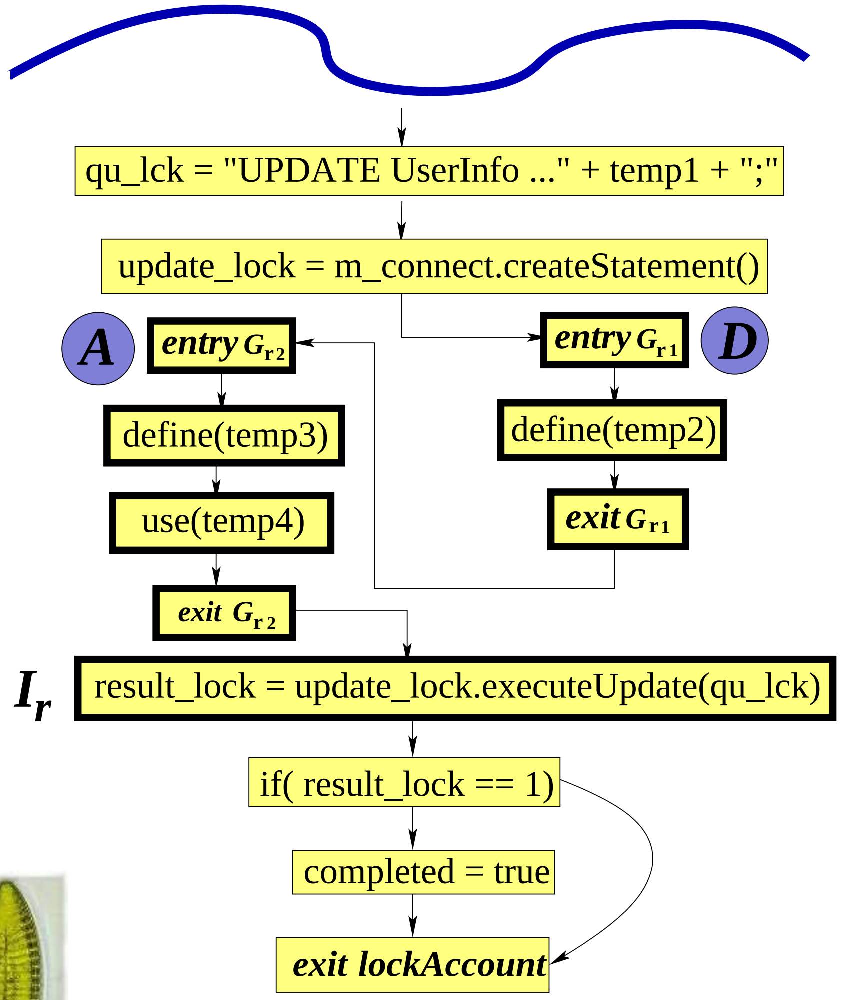
$$A_v(I_r) = \{ \boxed{1} , \boxed{32142} , \ldots , \boxed{\text{Geoffrey Arnold}} , \boxed{0} \}$$

The DICFG: A Unified Representation


entry lockAccount
temp1 = parameter0:c_n
temp2 = LocalDatabaseEntity0:Bank
temp3 = LocalDatabaseEntity1:acct_lock
temp4 = LocalDatabaseEntity2:card_number

- “Database-enhanced” CFG for `lockAccount`
- Define temporaries to represent the program’s interaction at the levels of database and attribute

The DICFG: A Unified Representation



qu_lck = "UPDATE UserInfo ..." + temp1 + ";"

update_lock = m_connect.createStatement()

A

entry G_{r2}

define(temp3)

use(temp4)

exit G_{r2}

entry G_{r1}

D

define(temp2)

exit G_{r1}

I_r

result_lock = update_lock.executeUpdate(qu_lck)

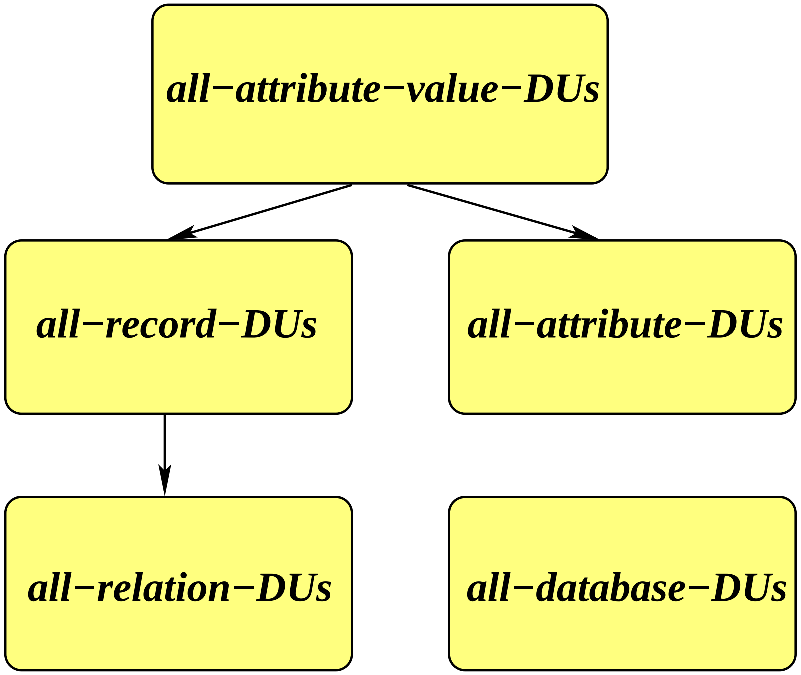
if(result_lock == 1)

completed = true

exit lockAccount

- Database interaction graphs (DIGs) are placed before the database interaction point I_r
- Multiple DIGs can be integrated into a single CFG

Test Adequacy Criteria



all−attribute−value−DUs

all−record−DUs

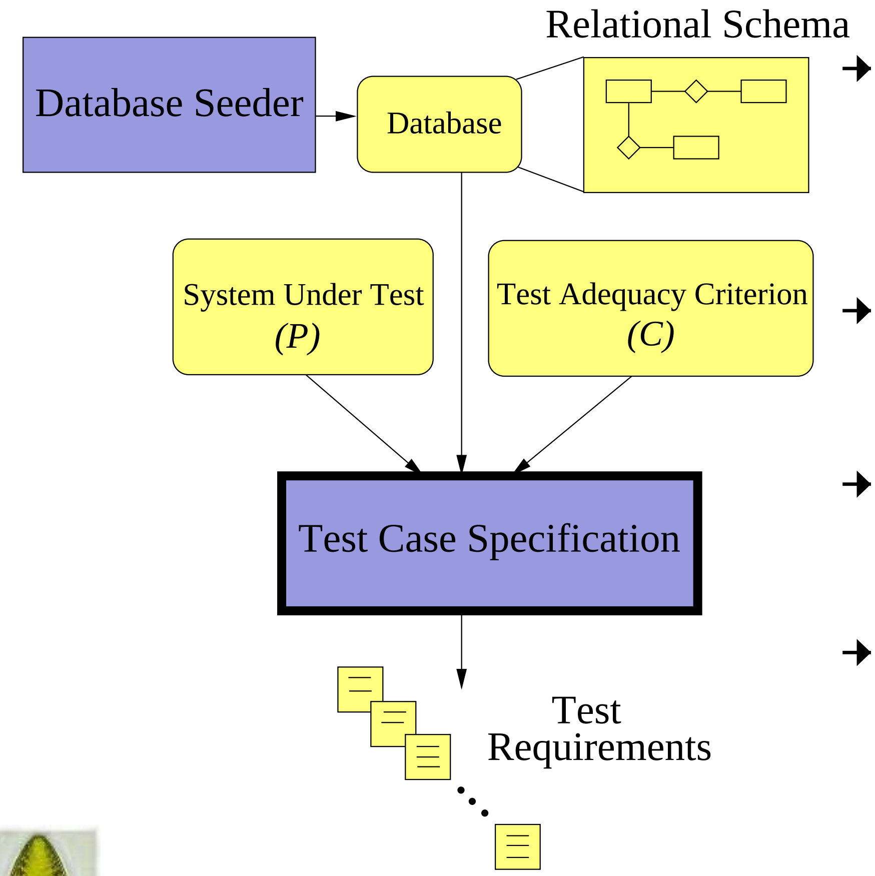
all−attribute−DUs

all−relation−DUs

all−database−DUs

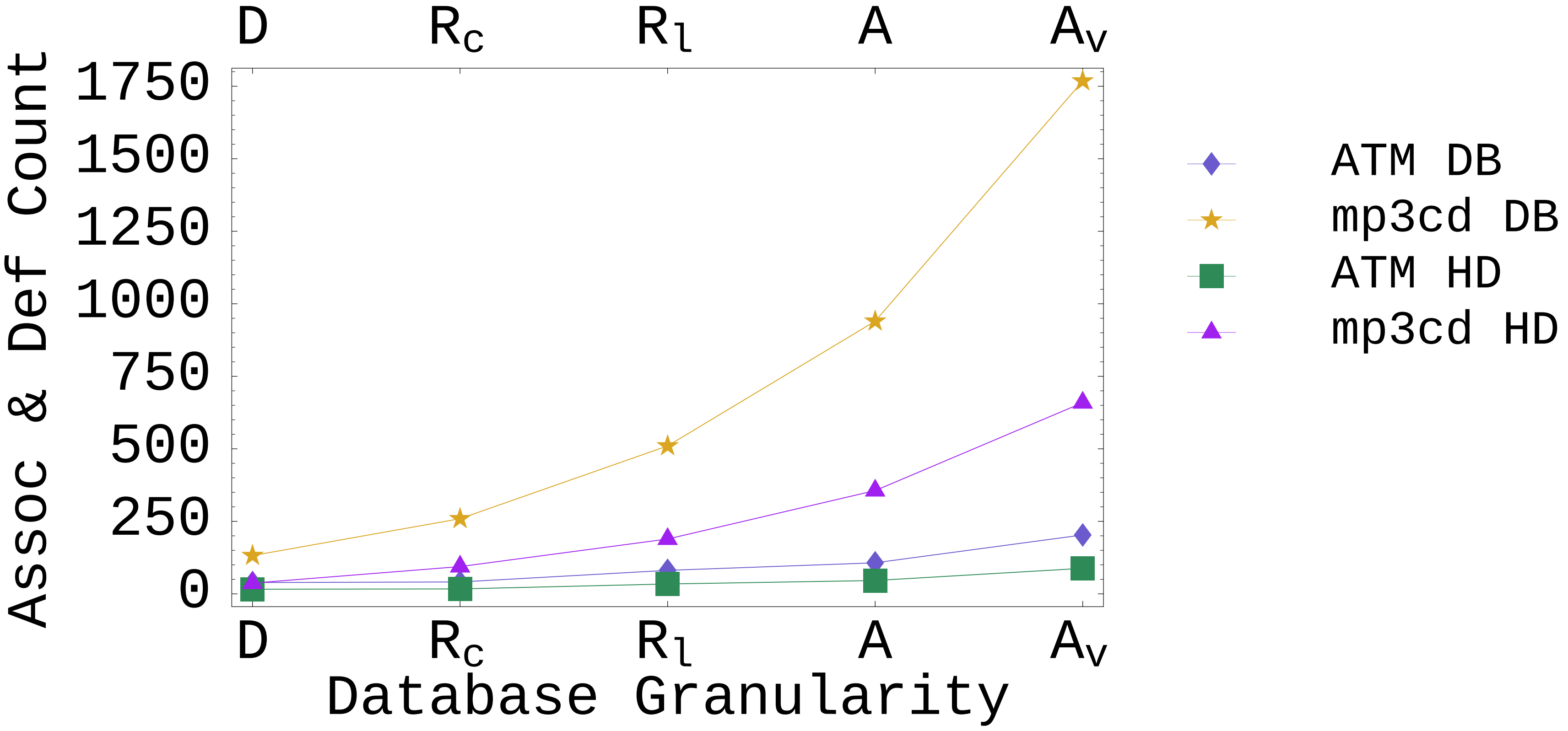
- Database interaction association (DIA) involves the *def* and *use* of a database entity
- DIAs can be located in the DICFG with data flow analysis
- *all-database-DUs* requires tests to exercise all DIAs for all of the accessed databases

Generating Test Requirements



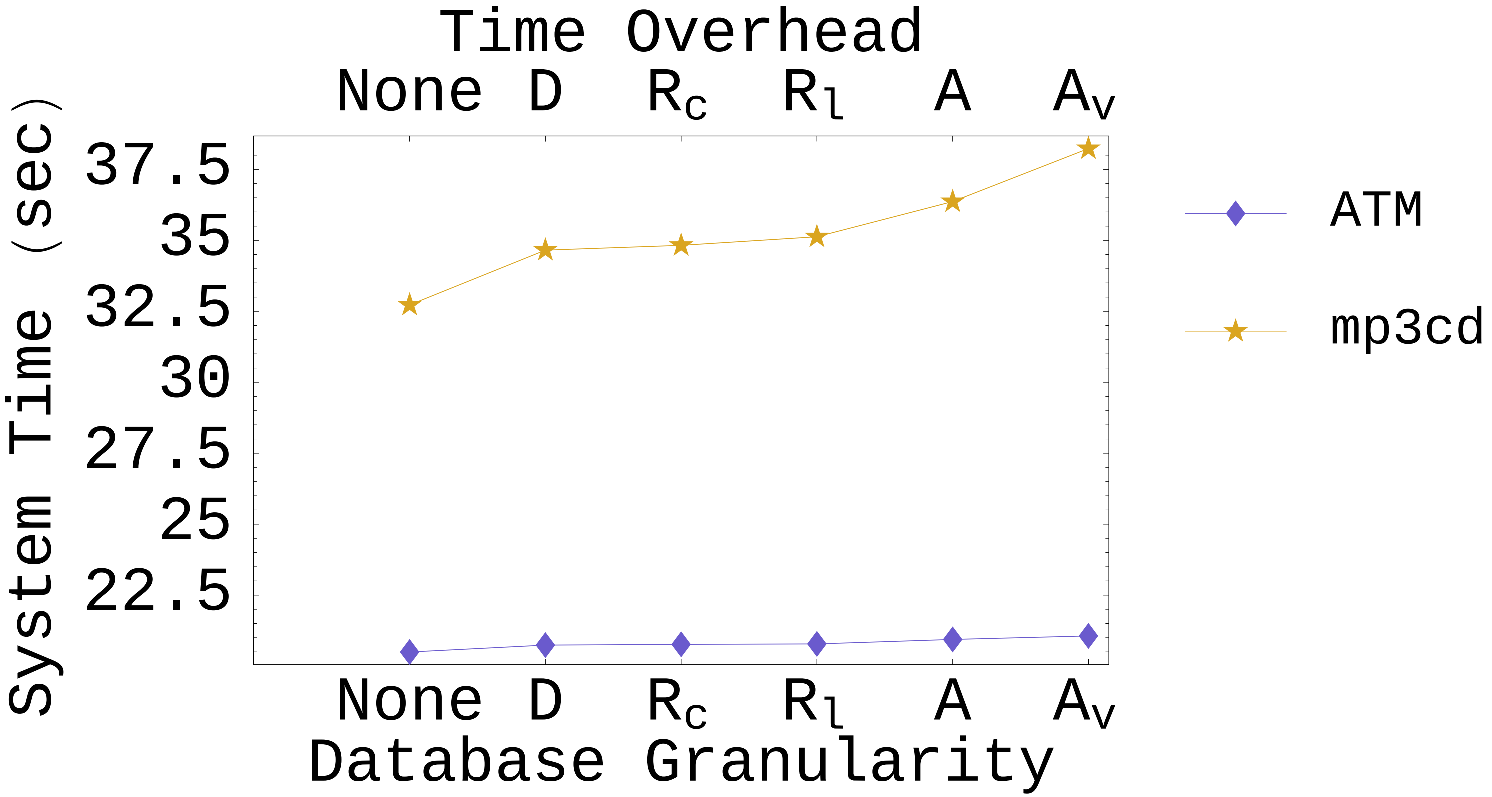
- Measured time and space overhead when computing family of test adequacy criteria
- Modified `ATM` and `mp3cd` to contain appropriate database interaction points
- Soot 1.2.5 to calculate intraprocedural associations
- GNU/Linux workstation with kernel 2.4.18-smp and dual 1 GHz Pentium III Xeon processors

Counting Associations and Definitions



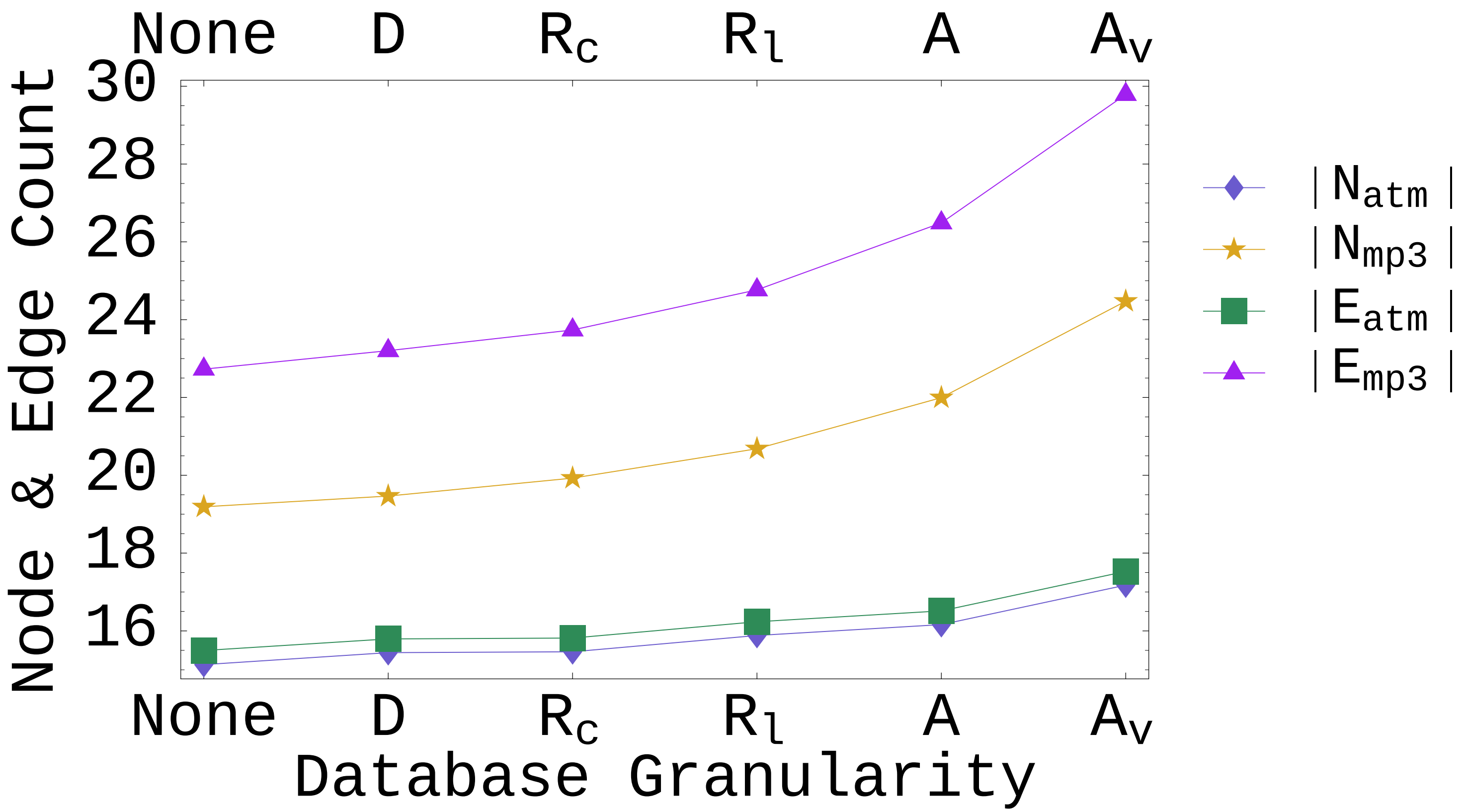
- DIAs at attribute value level represent 16.8% of `mp3cd`'s and 9.6% of ATM's total number of intraprocedural associations

Measuring Time Overhead



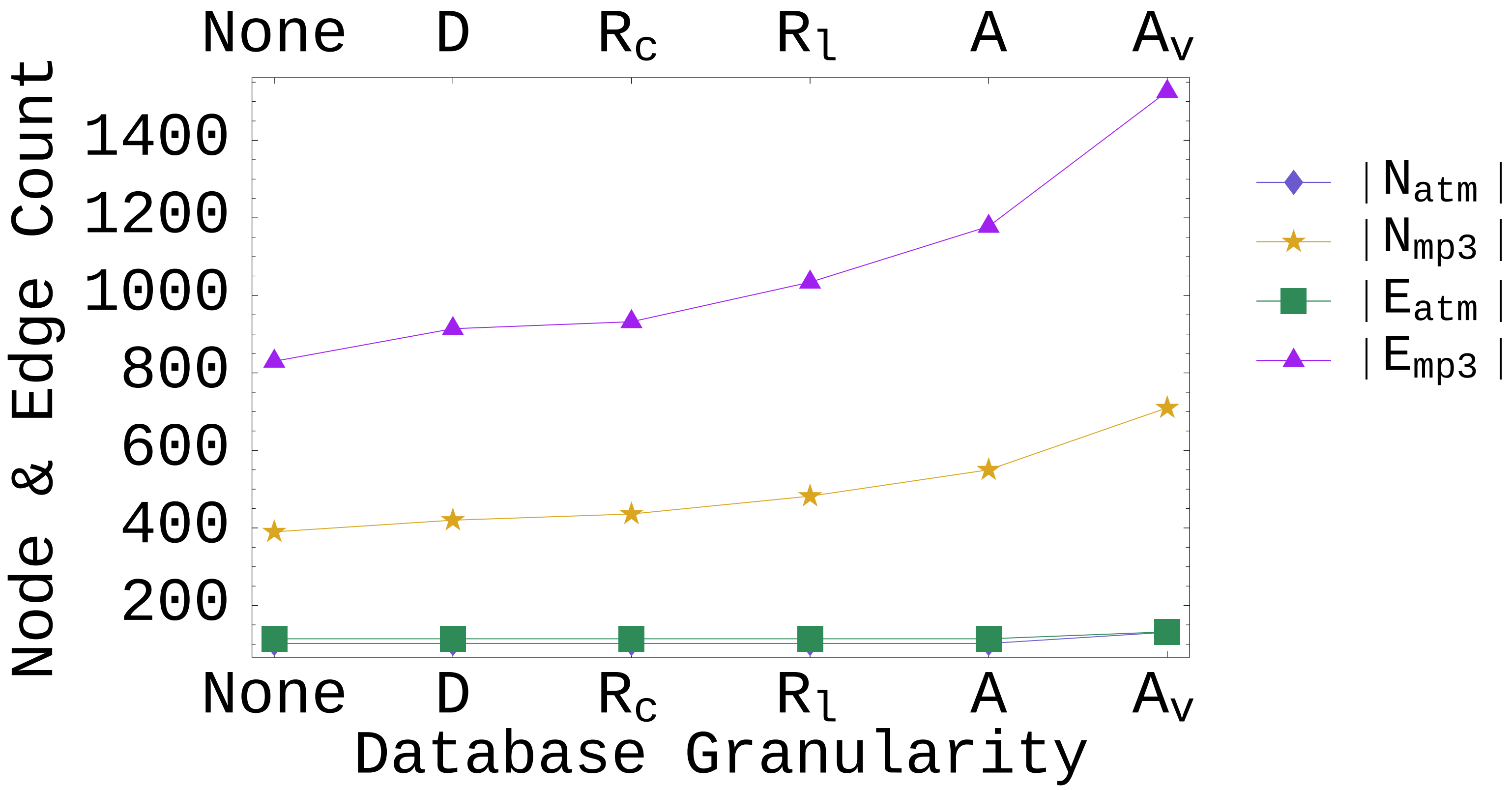
- Computing DIAs at the attribute value level incurs no more than a 5 second time overhead

Measuring Average Space Overhead



- mp3cd shows a more marked increase in the average number of nodes and edges than ATM

Measuring Maximum Space Overhead



- mp3cd shows a significantly greater maximum space overhead than ATM

Conclusions

- Must test the program's interaction with the database
- Unique family of test adequacy criteria to detect type (1) violations of database validity and completeness
- Intraprocedural database interactions can be computed from a DICFG with minimal time and space overhead
- High number of hanging definitions indicates that the scope of data flow analysis could be broadened
- This data flow-based test adequacy criteria can serve as the foundation for algorithms that measure test suite quality, automatically generate test cases, and support regression testing

`http://cs.allegheny.edu/~gkapfham/research/diatoms/`