An AGENDA For Testing Relational Database Applications

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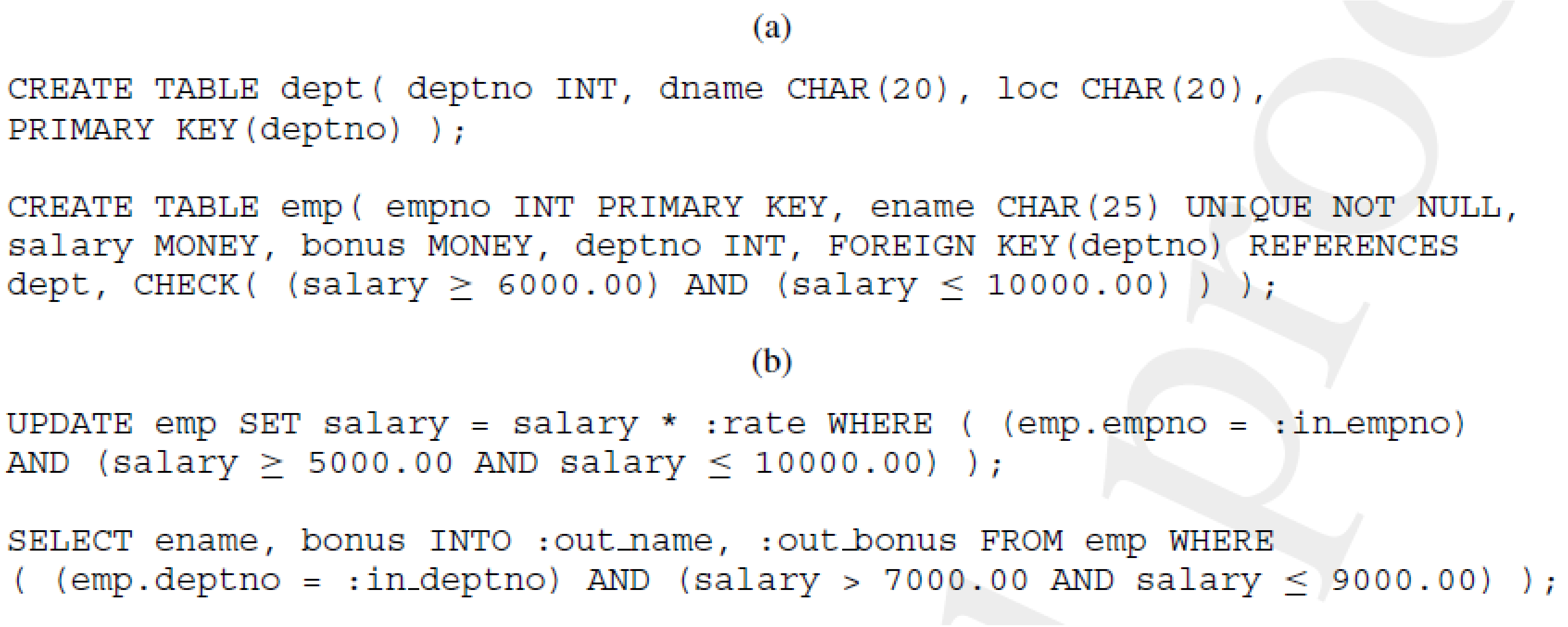
Outline

- Introduction
- System Overview
- AGENDA Parsing Tool
- State Generation Tool
- Input Generation Tool
- State Validation Tool
- Output Validation Tool
- Evaluation
- Conclusion

Introduction

- Issues in testing database applications
  - Role of the database state
  - Controllability
  - Observability
- Populate the database
  - Live data
  - Synthetic data

Introduction



(a)

```
CREATE TABLE dept( deptno INT, dname CHAR(20), loc CHAR(20),
PRIMARY KEY(deptno) );

CREATE TABLE emp( empno INT PRIMARY KEY, ename CHAR(25) UNIQUE NOT NULL,
salary MONEY, bonus MONEY, deptno INT, FOREIGN KEY(deptno) REFERENCES
dept, CHECK( (salary ≥ 6000.00) AND (salary ≤ 10000.00) ) );
```

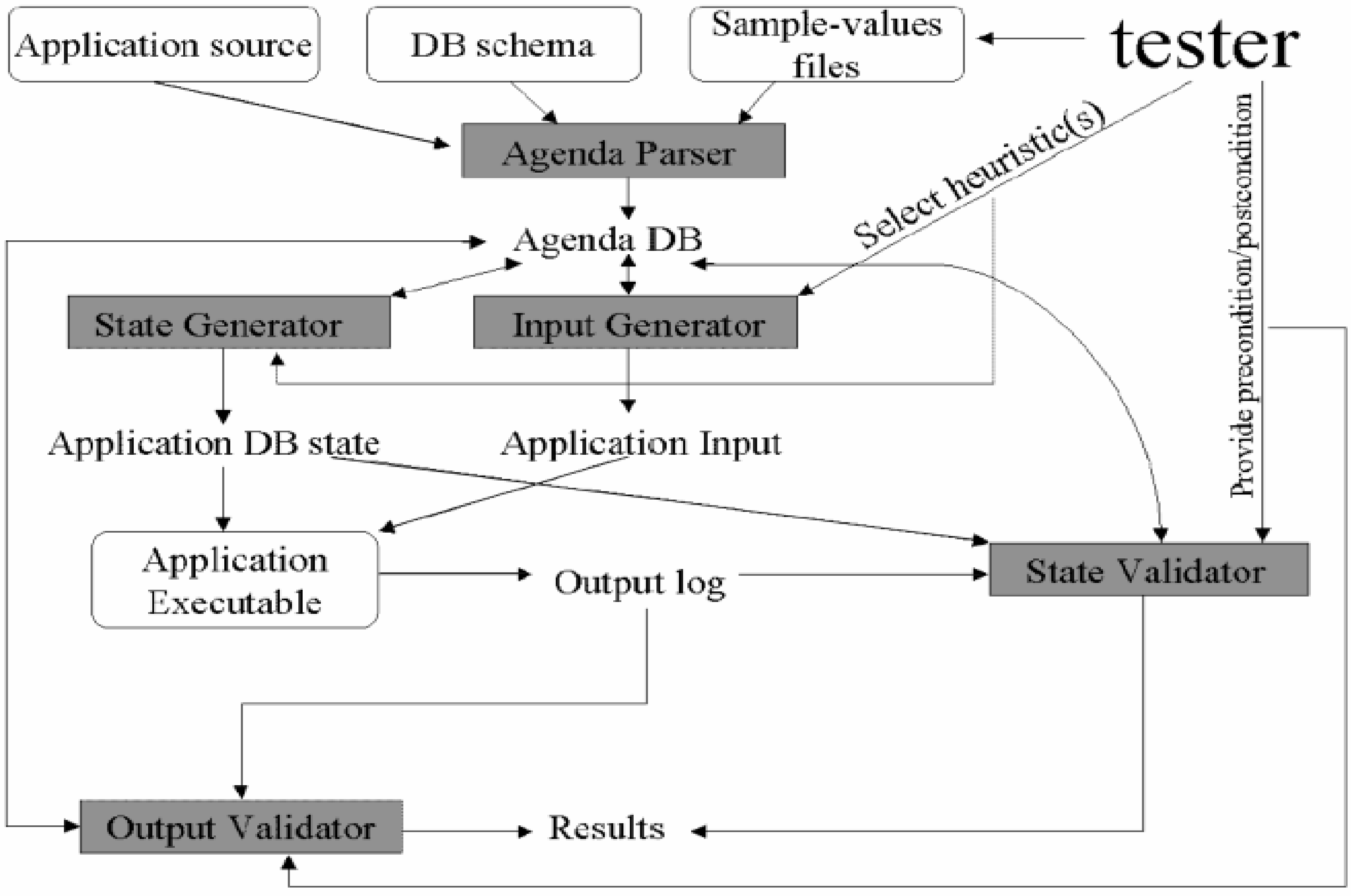
(b)

```
UPDATE emp SET salary = salary * :rate WHERE ( (emp.empno = :in_empno)
AND (salary ≥ 5000.00 AND salary ≤ 10000.00) );

SELECT ename, bonus INTO :out_name, :out_bonus FROM emp WHERE
( (emp.deptno = :in_deptno) AND (salary > 7000.00 AND salary ≤ 9000.00) );
```

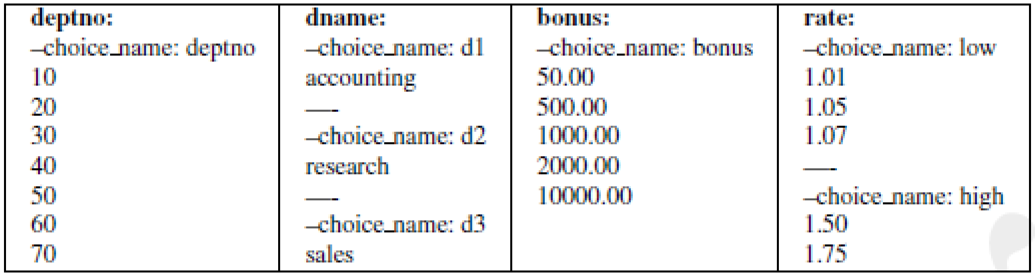
(a) Database Schema Definition in SQL and (b) Queries

System Overview

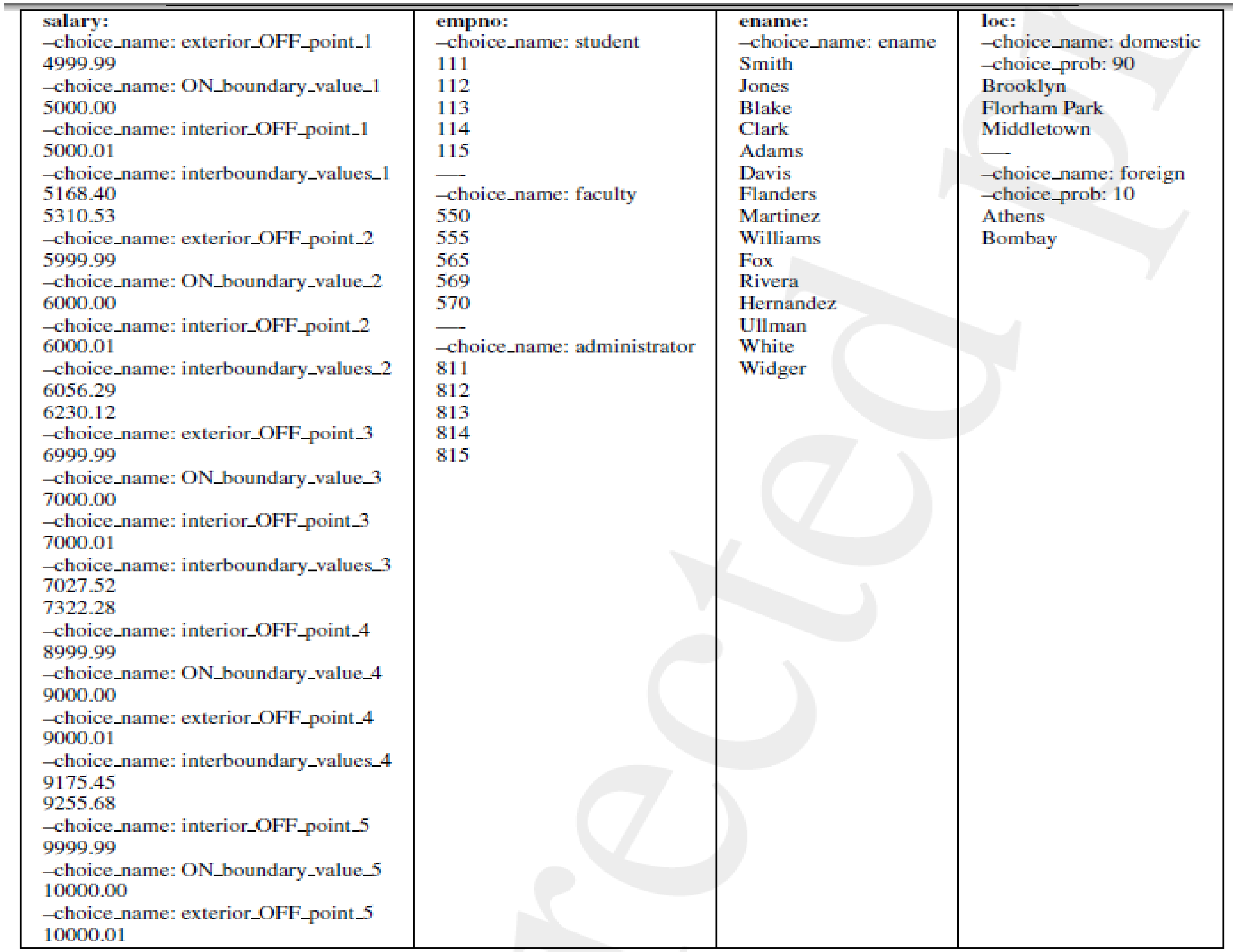


AGENDA Parsing Tool

- PostgreSQL parser forms the core
  - Abstract Syntax Tree
  - Extracts information about tables, attributes and constraints
  - Input/output host variables and associations



deptno:	dname:	bonus:	rate:
–choice_name: deptno 10 20 30 40 50 60 70	–choice_name: d1 accounting —– –choice_name: d2 research —– –choice_name: d3 sales	–choice_name: bonus 50.00 500.00 1000.00 2000.00 10000.00	–choice_name: low 1.01 1.05 1.07 —– –choice_name: high 1.50 1.75



salary:	empno:	ename:	loc:
–choice_name: exterior_OFF_point_1 4999.99 –choice_name: ON_boundary_value_1 5000.00 –choice_name: interior_OFF_point_1 5000.01 –choice_name: interboundary_values_1 5168.40 5310.53 –choice_name: exterior_OFF_point_2 5999.99 –choice_name: ON_boundary_value_2 6000.00 –choice_name: interior_OFF_point_2 6000.01 –choice_name: interboundary_values_2 6056.29 6230.12 –choice_name: exterior_OFF_point_3 6999.99 –choice_name: ON_boundary_value_3 7000.00 –choice_name: interior_OFF_point_3 7000.01 –choice_name: interboundary_values_3 7027.52 7322.28 –choice_name: interior_OFF_point_4 8999.99 –choice_name: ON_boundary_value_4 9000.00 –choice_name: exterior_OFF_point_4 9000.01 –choice_name: interboundary_values_4 9175.45 9255.68 –choice_name: interior_OFF_point_5 9999.99 –choice_name: ON_boundary_value_5 10000.00 –choice_name: exterior_OFF_point_5 10000.01	–choice_name: student 111 112 113 114 115 —– –choice_name: faculty 550 555 565 569 570 —– –choice_name: administrator 811 812 813 814 815	–choice_name: ename Smith Jones Blake Clark Adams Davis Flanders Martinez Williams Fox Rivera Hernandez Ullman White Widger	–choice_name: domestic –choice_prob: 90 Brooklyn Florham Park Middletown —– –choice_name: foreign –choice_prob: 10 Athens Bombay

Input files for department-employee database

AGENDA Parsing Tool

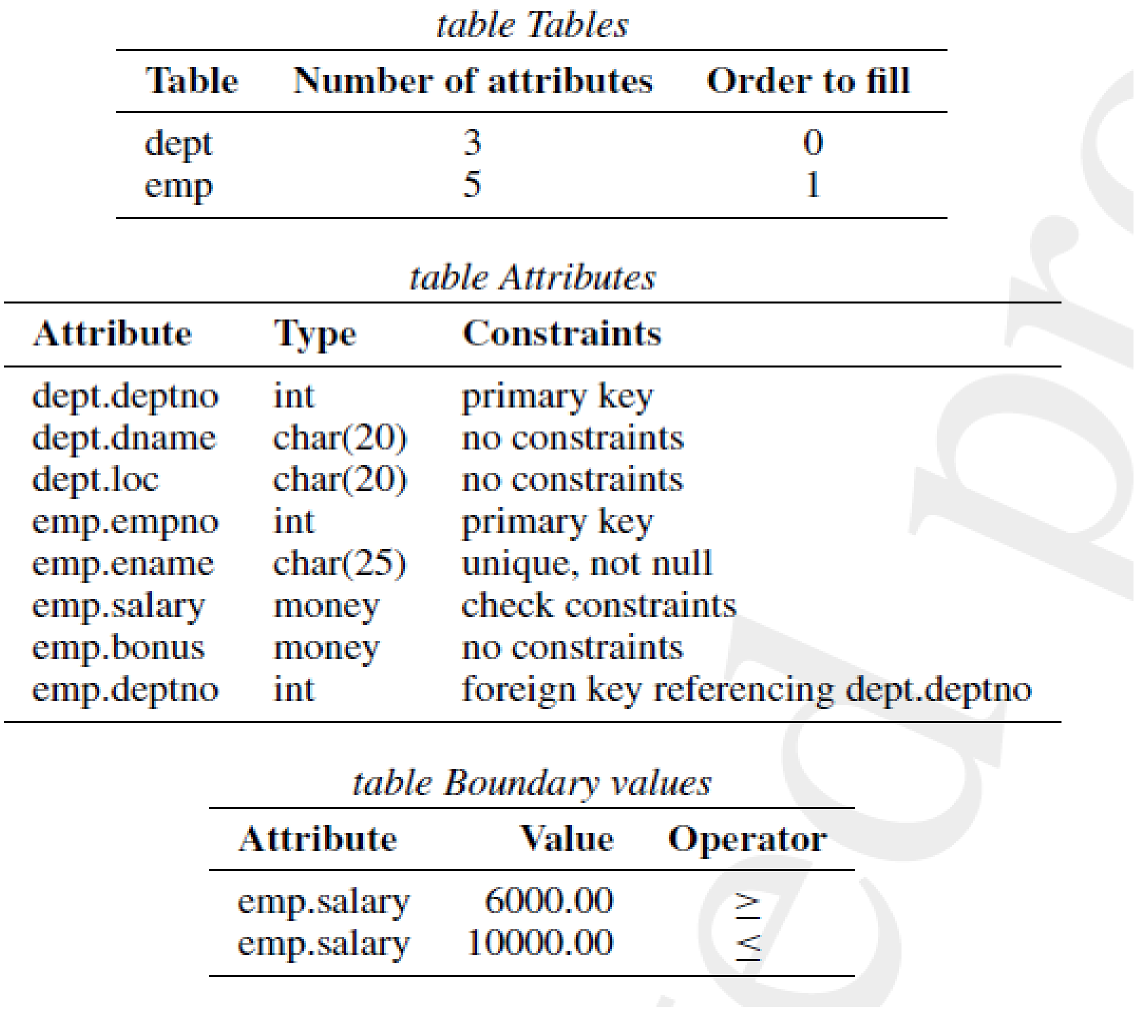


table Tables

Table	Number of attributes	Order to fill
dept	3	0
emp	5	1

table Attributes

Attribute	Type	Constraints
dept.deptno	int	primary key
dept.dname	char(20)	no constraints
dept.loc	char(20)	no constraints
emp.empno	int	primary key
emp.ename	char(25)	unique, not null
emp.salary	money	check constraints
emp.bonus	money	no constraints
emp.deptno	int	foreign key referencing dept.deptno

table Boundary values

Attribute	Value	Operator
emp.salary	6000.00	≥
emp.salary	10000.00	≤

Information in the AGENDA DB after parsing the schema

State Generation Tool

- Populates the database
- ON and OFF boundary values
- Referential integrity constraints
- Heuristics for state generation
  - Boundary values
  - Duplicates
  - Nulls
  - All groups

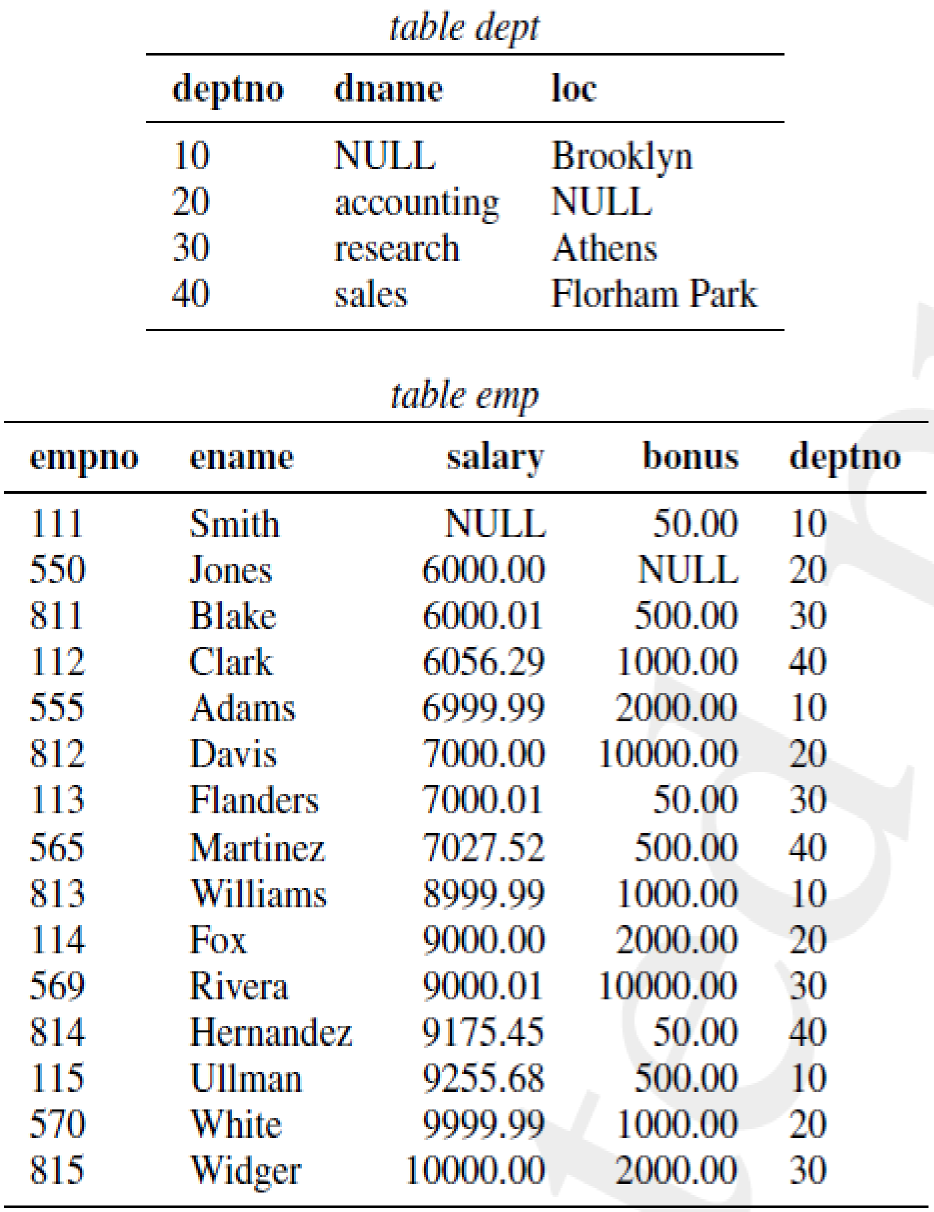


table dept

deptno	dname	loc
10	NULL	Brooklyn
20	accounting	NULL
30	research	Athens
40	sales	Florham Park

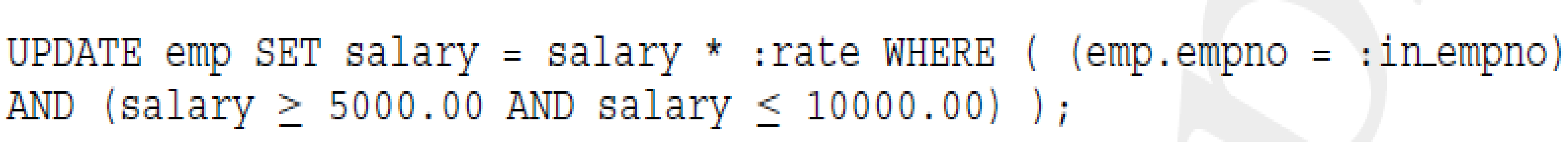
table emp

empno	ename	salary	bonus	deptno
111	Smith	NULL	50.00	10
550	Jones	6000.00	NULL	20
811	Blake	6000.01	500.00	30
112	Clark	6056.29	1000.00	40
555	Adams	6999.99	2000.00	10
812	Davis	7000.00	10000.00	20
113	Flanders	7000.01	50.00	30
565	Martinez	7027.52	500.00	40
813	Williams	8999.99	1000.00	10
114	Fox	9000.00	2000.00	20
569	Rivera	9000.01	10000.00	30
814	Hernandez	9175.45	50.00	40
115	Ullman	9255.68	500.00	10
570	White	9999.99	1000.00	20
815	Widger	10000.00	2000.00	30

A database state produced by the tool

Input Generation Tool

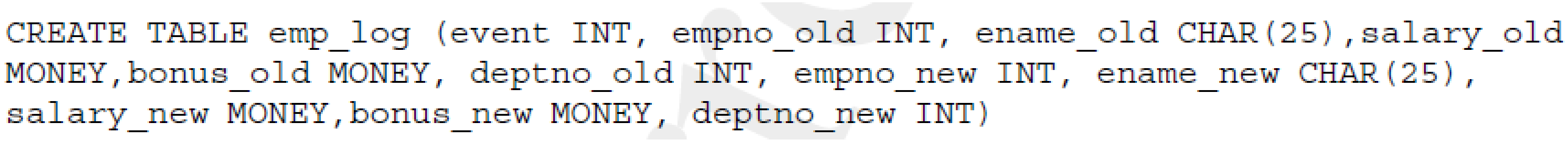
- Generates test cases by instantiating application’s inputs with actual values
- Test heuristics include:
  - Boundary values
  - Duplicates from the Application DB state
  - Nulls
  - All groups
  - All templates



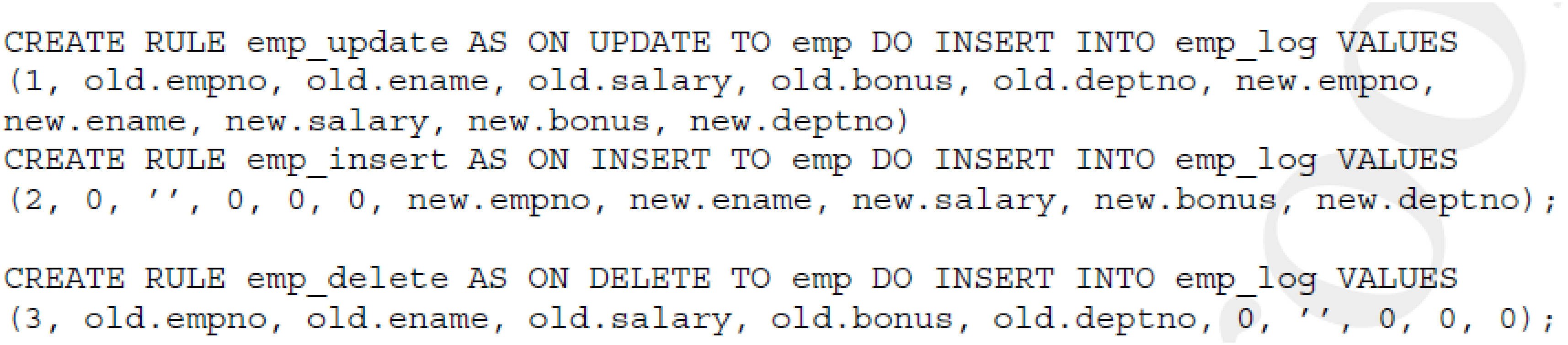
```
UPDATE emp SET salary = salary * :rate WHERE ( (emp.empno = :in_empno)
AND (salary ≥ 5000.00 AND salary ≤ 10000.00) );
```

State Validation Tool

- Automatic logging of changes in the application tables
  - Triggers
  - Active Rules



```
CREATE TABLE emp_log (event INT, empno_old INT, ename_old CHAR(25),salary_old
MONEY,bonus_old MONEY, deptno_old INT, empno_new INT, ename_new CHAR(25),
salary_new MONEY,bonus_new MONEY, deptno_new INT)
```



```
CREATE RULE emp_update AS ON UPDATE TO emp DO INSERT INTO emp_log VALUES
(1, old.empno, old.ename, old.salary, old.bonus, old.deptno, new.empno,
new.ename, new.salary, new.bonus, new.deptno)
CREATE RULE emp_insert AS ON INSERT TO emp DO INSERT INTO emp_log VALUES
(2, 0, ’’, 0, 0, 0, new.empno, new.ename, new.salary, new.bonus, new.deptno);

CREATE RULE emp_delete AS ON DELETE TO emp DO INSERT INTO emp_log VALUES
(3, old.empno, old.ename, old.salary, old.bonus, old.deptno, 0, ’’, 0, 0, 0);
```

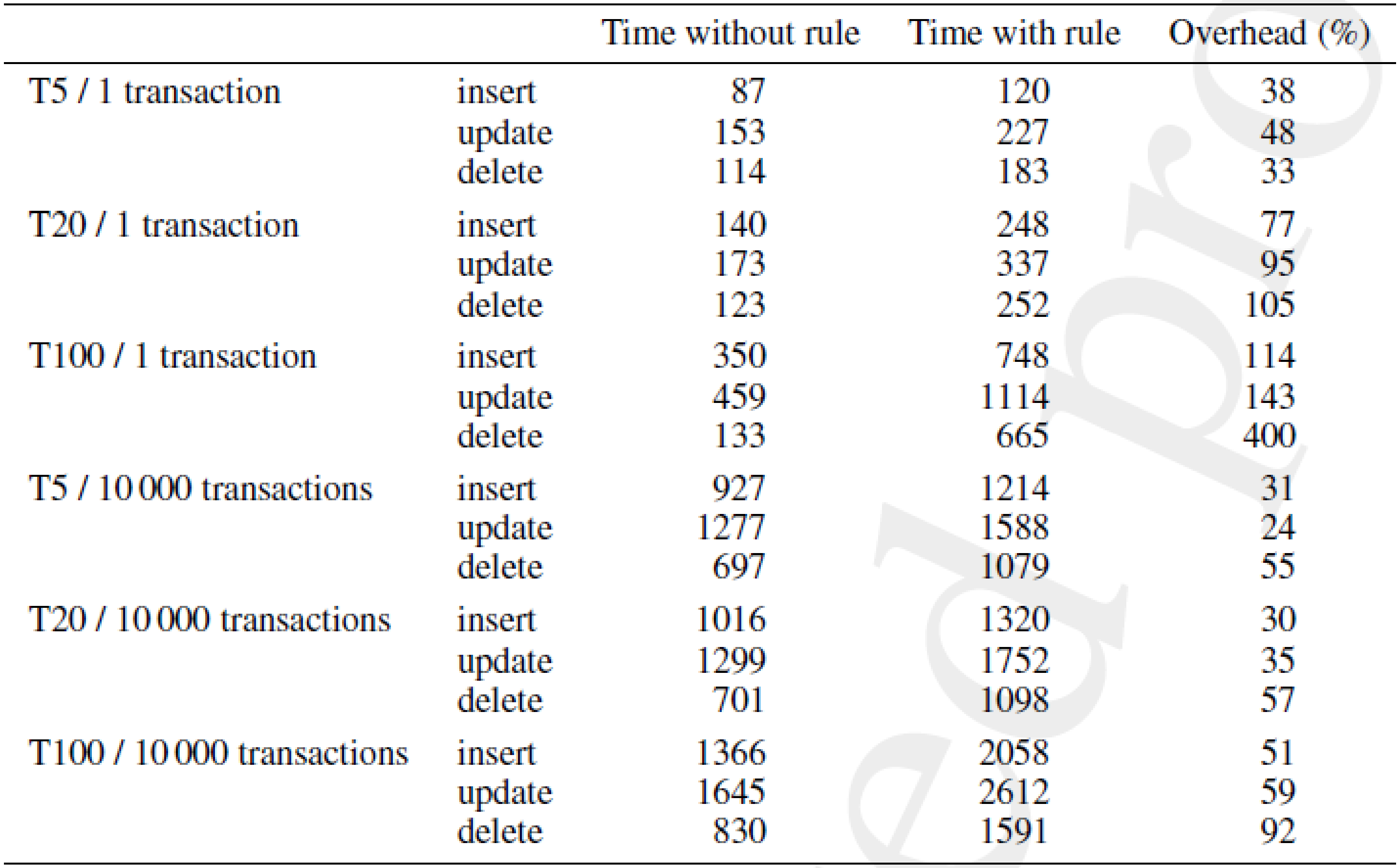
State Validation Tool

- Checking the state change by means of database constraints
  - Issues when checking database state
  - General procedure of State Validator
    - Generate log tables
    - Providing precondition/postcondition for test templates
    - Formation of integrity constraints
    - Application of constraints and cross verification
    - Drop integrity constraints and clear log tables

Output Validation Tool

- Similar to State Validation Tool
  - When application query is a SELECT statement, it is handled by Output Validator
  - Cannot use triggers/rules
- General procedure of the Output Validator
  - Store results of SELECT query in log tables
  - Formation of integrity constraints
  - Application of constraints and cross verification
  - Drop integrity constraints and clear log tables

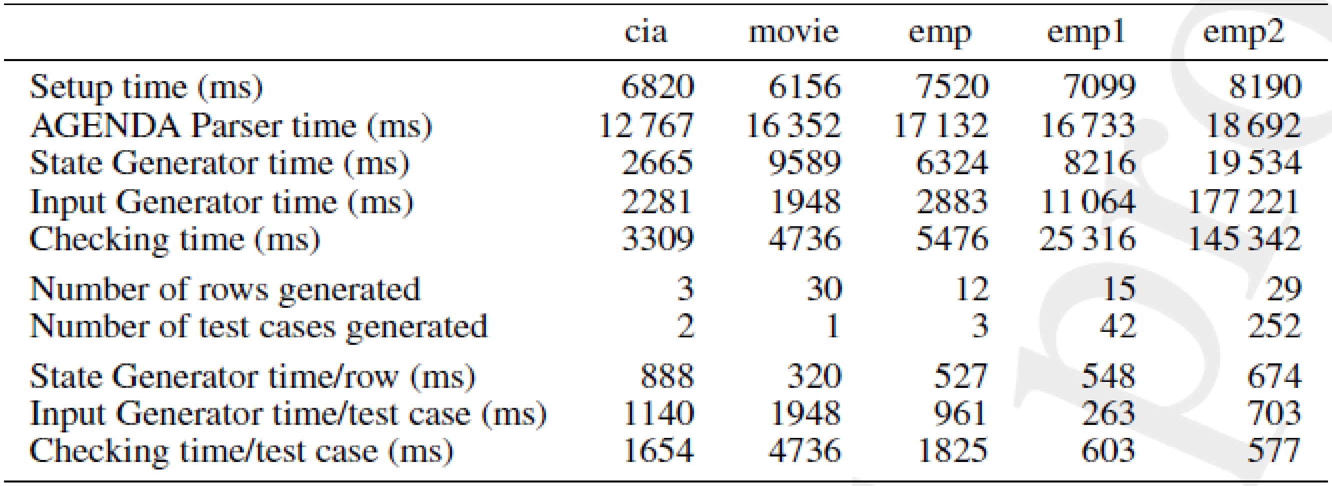
Evaluation



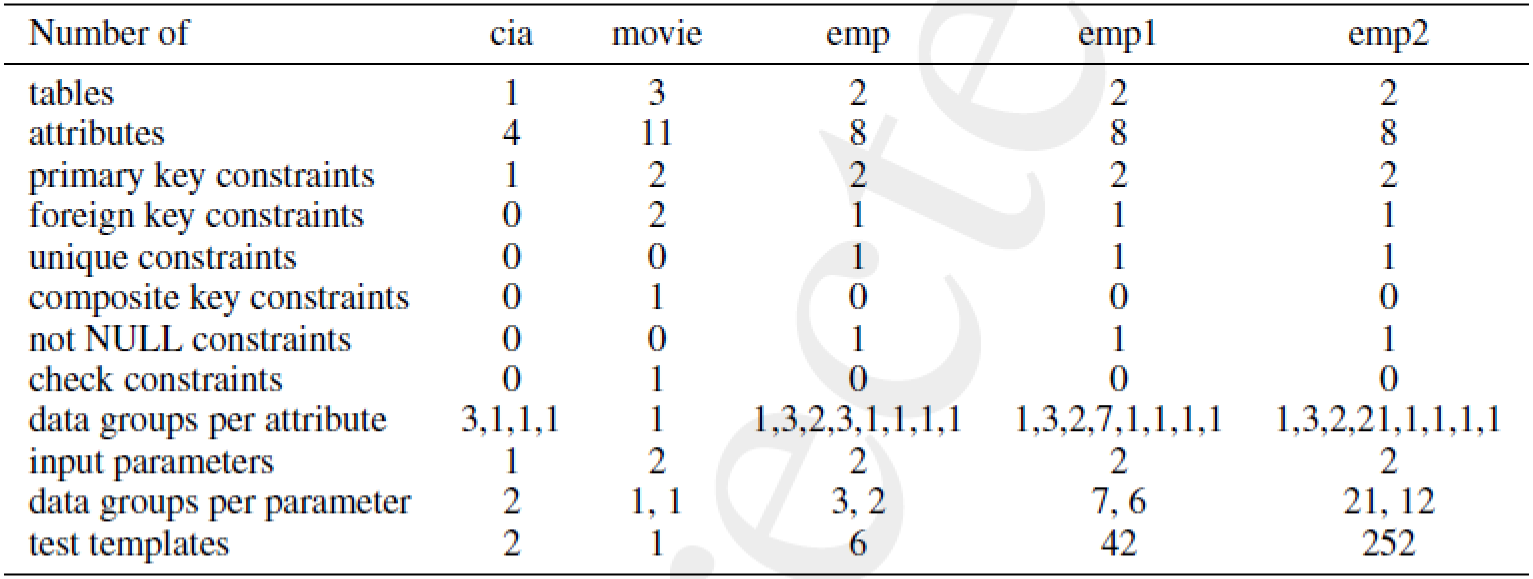
		Time without rule	Time with rule	Overhead (%)
T5 / 1 transaction	insert	87	120	38
	update	153	227	48
	delete	114	183	33
T20 / 1 transaction	insert	140	248	77
	update	173	337	95
	delete	123	252	105
T100 / 1 transaction	insert	350	748	114
	update	459	1114	143
	delete	133	665	400
T5 / 10 000 transactions	insert	927	1214	31
	update	1277	1588	24
	delete	697	1079	55
T20 / 10 000 transactions	insert	1016	1320	30
	update	1299	1752	35
	delete	701	1098	57
T100 / 10 000 transactions	insert	1366	2058	51
	update	1645	2612	59
	delete	830	1591	92

Times for executing transactions with and without rules

Evaluation



	cia	movie	emp	emp1	emp2
Setup time (ms)	6820	6156	7520	7099	8190
AGENDA Parser time (ms)	12 767	16 352	17 132	16 733	18 692
State Generator time (ms)	2665	9589	6324	8216	19 534
Input Generator time (ms)	2281	1948	2883	11 064	177 221
Checking time (ms)	3309	4736	5476	25 316	145 342
Number of rows generated	3	30	12	15	29
Number of test cases generated	2	1	3	42	252
State Generator time/row (ms)	888	320	527	548	674
Input Generator time/test case (ms)	1140	1948	961	263	703
Checking time/test case (ms)	1654	4736	1825	603	577



Number of	cia	movie	emp	emp1	emp2
tables	1	3	2	2	2
attributes	4	11	8	8	8
primary key constraints	1	2	2	2	2
foreign key constraints	0	2	1	1	1
unique constraints	0	0	1	1	1
composite key constraints	0	1	0	0	0
not NULL constraints	0	0	1	1	1
check constraints	0	1	0	0	0
data groups per attribute	3,1,1,1	1	1,3,2,3,1,1,1,1	1,3,2,7,1,1,1,1	1,3,2,21,1,1,1,1
input parameters	1	2	2	2	2
data groups per parameter	2	1, 1	3, 2	7, 6	21, 12
test templates	2	1	6	42	252

Time (ms) for running AGENDA's tools

Conclusion

- New framework proposed in response to the lack of existing approaches for testing database applications
- Tools use active database techniques to capture changes in the database
- Current version is targeted toward simple applications consisting of single queries