Databases: Introduction

Imperial College London

Databases are Computer Stores of Data!

Tiny Bank Ltd Customer: McBrien, P.
Strand Branch Current Acc: 10000100
Sortcode: 55-66-67

Trans	Amount	Date
1001	2300.00	5/1/1999
1002	223.45	7/1/1999
1006	10.23	15/1/1999

Tiny Bank Ltd Customer: Poulovassilis, A.
Wimbledon Branch Current Acc: 10000107
Sortcode: 55-66-56

Trans	Amount	Date
1004	-100.00	11/1/1999
1007	345.56	15/1/1999

Tiny Bank Lt Cu 0119
Strand Bra D
Sortcode: 5

Trans	Amount	Date
1001	4000.00	5/1/1999
1008	1230.00	15/1/1999
1009	5600.00	18/1/1999

Tiny Bank Ltd Customer: Boyd, M.
Goodge St Branch Current Acc: 10000103
Sortcode: 55-66-34

Trans	Amount	Date
1005	145.50	12/1/1999

Ti
Wi
So

Trans	Amount	Date
No transactions this month		

Deposit Rates

Account	Rate
101	5.25
119	5.50

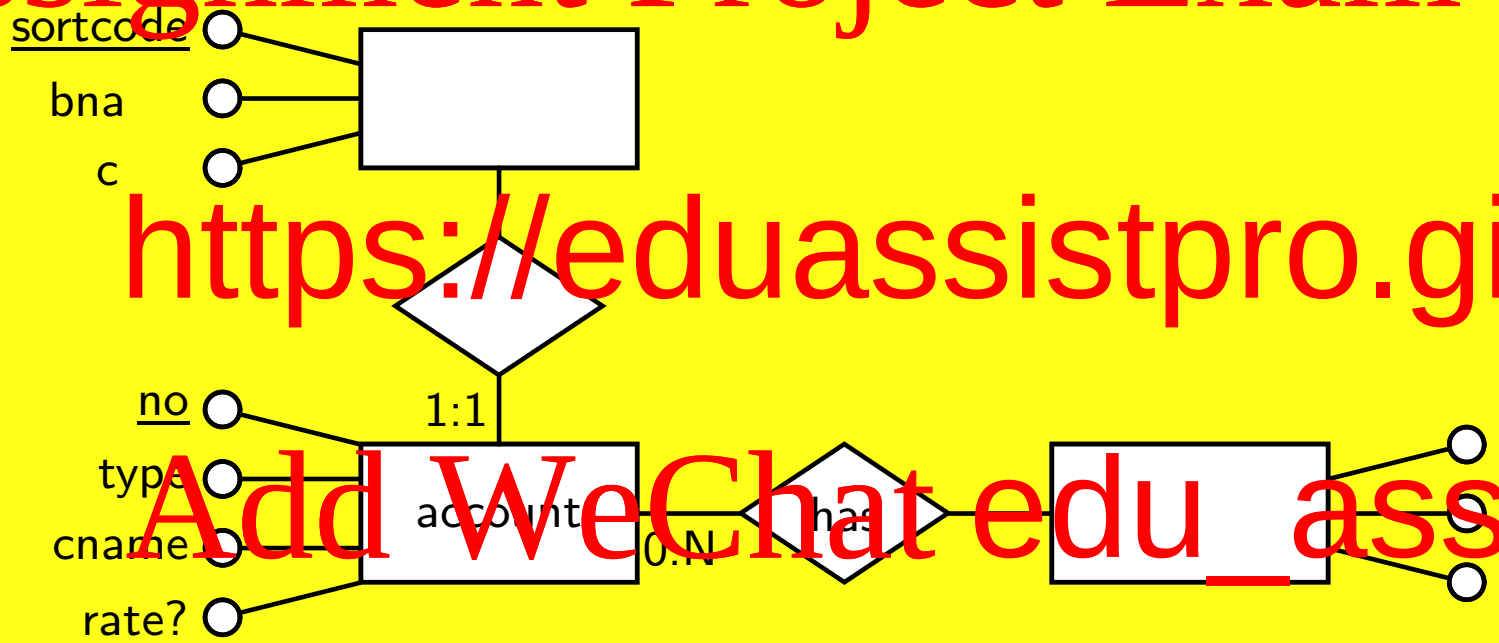
Relational Data Model

Relational Data Model

Roughly: storing data in tables

no	sortc							ount	tdate
100								0.00	1999-01-05
101								00.00	1999-01-05
100		67	Strand	34005.00	current	McBrien, P.		1002 -223.45	1999-01-08
107		56	Wimbledon	84340.45	current	Poulov			1999-01-11
103		34	Goodge St	6900.67	current	Boyd, M			1999-01-12
100		67	Strand	34005.00	current	McBrie			1999-01-15
107		56	Wimbledon	84340.45	current	Poulov			1999-01-15
101		67	Strand	34005.00	deposit	McBrie			1999-01-15
119		56	Wimbledon	84340.45	deposit	Poulovassilis, A.	5.50	1009 5600.00	1999-01-18

Database Design: ER Modelling



Structured Data: Relational Model

branch

sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	''	

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
			LL	34
			LL	56
			50	56
			LL	56

mid	no		
1000	100		
1001	101	4000.00	5/1/1999
1002	100	-223.45	8/1/1999
1004	107	-100.00	11/1/1999
1005	103	145.50	12/1/1999
1006	100	10.23	15/1/1999
1007	107	345.56	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999

key branch(so
key branch(b
key movemen
key account(n

movement(n $\Rightarrow$

account(sortcode) $\overset{fk}{\Rightarrow}$ branch(sortcode)

Data Model: CSV

branch.csv

```
sortcode,bname,cash
56,"Wimbledon",94340.45
34,
67,
```

movement.csv

```
mid,no,amount,tdate
1000,100,2300.00,5/1/1999
999
999
1999
99
99
1007,107,345.56,15/1/1999
```

```
no,type,c
100,"current","McBrien, P.",,67
101,"deposit","McBrien, P.",5.25,67
103,"current","Boyd, M.",,34
107,"current","Poulovassilis, A.",,56
119,"deposit","Poulovassilis, A.",5.50,56
125,"current","Bailey, J.",,56
```

Semistructured Data: XML


```
⟨bank⟩
  ⟨branch sortcode="67" bname="Strand" cash="34005.00" ⟩
    ⟨account
      ⟨move
      ⟨move
      ⟨move
    ⟨/account
    ⟨account
      ⟨move
      ⟨movement mid="1008" amount="1230.00" tdate="15/1/1999" /⟩
    ⟨/account⟩
  ⟨/branch⟩
⟨/bank⟩
```

SQL DDL: Implementation of the Relational Model

```
CREATE TABLE branch
( sortcode INTEGER NOT NULL,
  bname VARCHAR(20) NOT NULL,
  cash DECIMAL(10,2) NOT NULL,
  CONSTRAINT branch_pk PRIMARY KEY (sortcode)
)

CREATE UNI
  ON branch(b
```

```
CREATE TABLE account
( no INTEGER NOT NULL,
  type CHAR(8) NOT NULL,
  cname VARCHAR(20) NOT NULL,
  rate DECIMAL(4,2) NULL,
  sortcode INTEGER NOT NULL,
  CONSTRAINT account_pk
      PRIMARY KEY (no),
```

```
ENCES branch
N account(type)
```

```
CREA
( mid IN
  no IN
  amo
  tdate DATETIME NOT NULL,
  CONSTRAINT movement_pk
       PRIMARY KEY (mid),
  CONSTRAINT movement_fk
       FOREIGN KEY (no) REFERENCES account
)
```

SQL DML: Implementation of the Relational Algebra

Basic SQL SELECT statements

```
SELECT no,cname,rate
FROM   account
WHERE  type='deposit'
```


SQL Joins

```
SELECT b
FROM   b
WHERE  type='deposit'
```


Same as

```
SELECT bname,no,rate
FROM   account JOIN branch ON branch.so
WHERE  type='deposit'
```


Same as

```
SELECT bname,no,rate
FROM   account,branch
WHERE  branch.sortcode=account.sortcode
AND    type='deposit'
```

RDBMS Products

Product	SQL Language	Company
PostgreSQL	PL/pgSQL	Open Source
MySQL	MySQL	

All partially implement ANSI SQL

Transactions

```
BEGIN TRANSACTION
    UPDATE branch
    SET cash=cash-10000.00
    WHERE sortcode=56

    UP
    SE
    W
COMMIT TRANSACTION
```


The ACID Properties

- **Atomicity** all or nothing
- **Consistency** consistent before $\rightarrow$ consistent after
- **Isolation** independent of any other transaction
- **Durability** completed transaction are durable

Transaction Properties: Atomicity

```
BEGIN TRANSACTION
    UPDATE branch
    SET cash=cash-10000.00
    WHERE sortcode=56
```


Failure to m

Suppose that the system crashes half way through processin d the first part of the transfer has been written to disc

- The database on disc is left in an inconsistent state: the sum d be £137,246.12 but only £127,246.12 recorded
- A DBMS implementing **Atomicity** of transactions would on restart undo the change to branch 56

Transaction Properties: Consistency

```
BEGIN TRANSACTION
    DELETE FROM branch
    WHERE sortcode=56;
    INSERT INTO account
    VALU
END TRAN
```


Failure to m

Suppose that a user deletes branch with sortcode 56, and inse nt number 100 for John Smith at branch sortcode 34

- The database is left in an inconsistent state for two reason
  - it has three accounts recorded for a branch that appears not to exist, and
  - it has two records for account number 100, with different details for the account
- A DBMS implementing **Consistency** of transactions would forbid both of these changes to the database

Transaction Properties: Isolation

```
BEGIN TRANSACTION
    UPDATE branch
    SET    cash=cash-10000.00
    WHERE  sortcode=56

    UPDA
    SET
    WHERE sortcode=34
END TRANSACTION
```

```
BEGIN TRANSACTION

SELECT SUM(cash) AS net_cash

END
```


Failure to maintain Isolation

Suppose that the system sums the cash in the bank in one transaction, half way through processing a cash transfer in another transaction

- The result of the summation of cash in the bank erroneously reports £127,246.12, whereas the movement of cash always leaves a total of £137,246.12
- A DBMS implementing **Isolation** of transactions ensures that transactions always report results based on the values of committed transactions

Transaction Properties: Durability

```
BEGIN TRANSACTION
    UPDATE branch
    SET    cash=cash −10000.00
    WHERE  sortcode=56
    UPDATE branch
    SET
    WHE
END TRAN
```

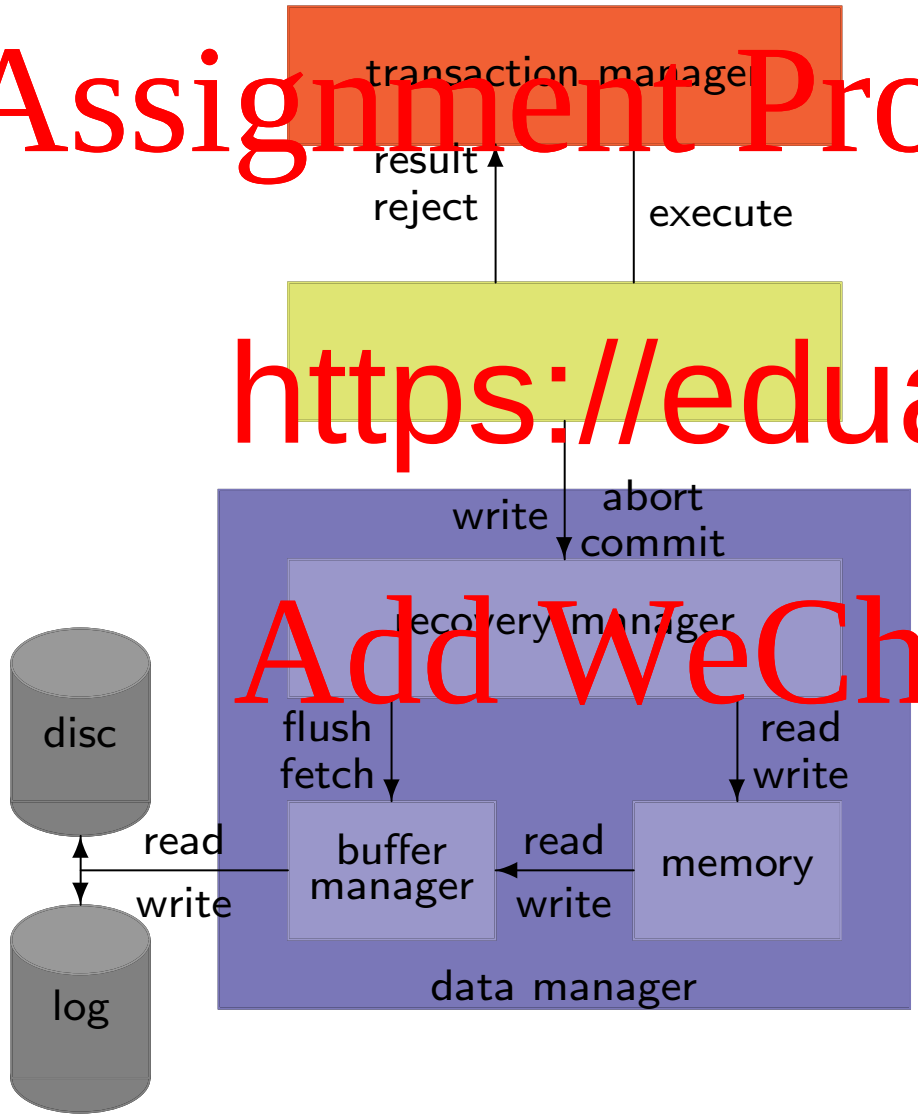
CRASH

Failure to maintain Durability

Suppose that the system crashes after informing the user tha transfer of cash, but has not yet written to disc the update to

- The database on disc is left in an inconsistent state, with £10,000 'missing'
- A DBMS implementing **Durability** of transactions would on restart complete the change to branch 34 (or alternatively never inform a user of commitment with writing the results to disc).

DBMS Architecture



Transaction Manager

BEGIN TRANSACTION

10000.00

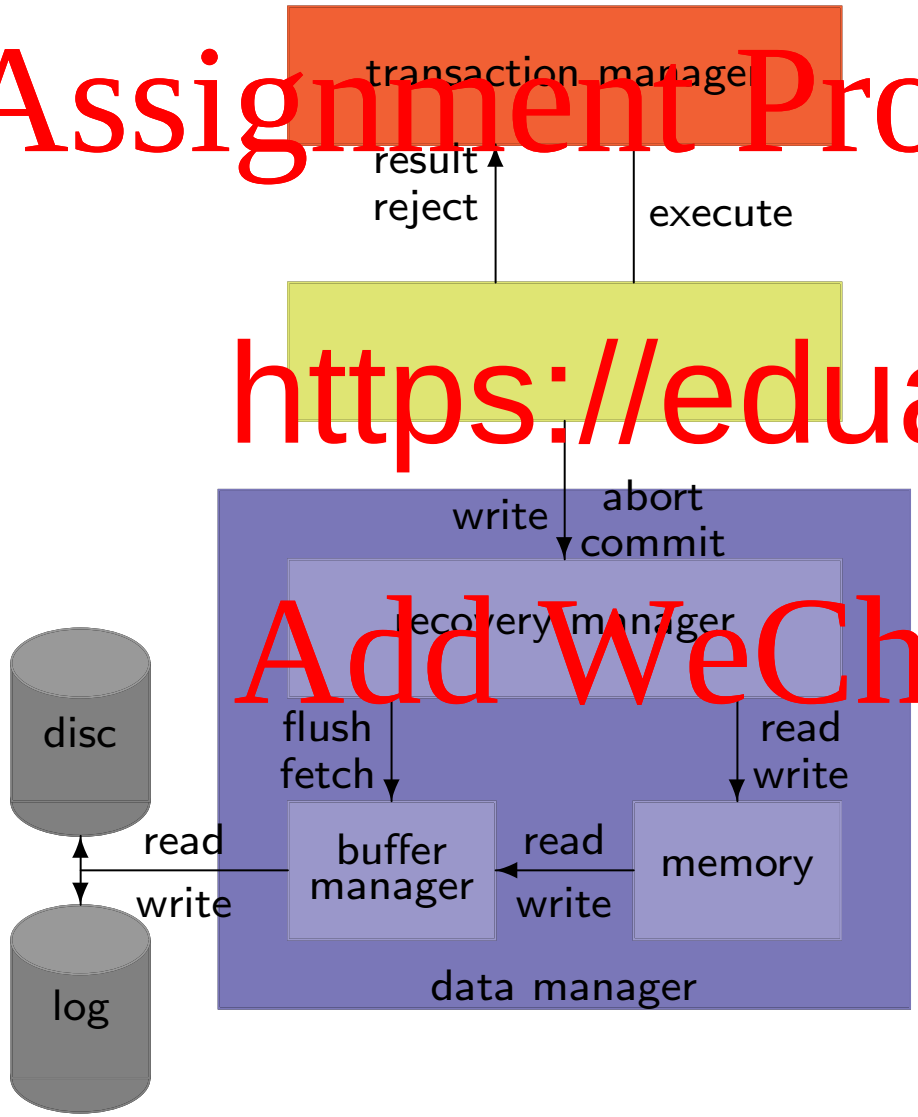
6

UPDATE branch

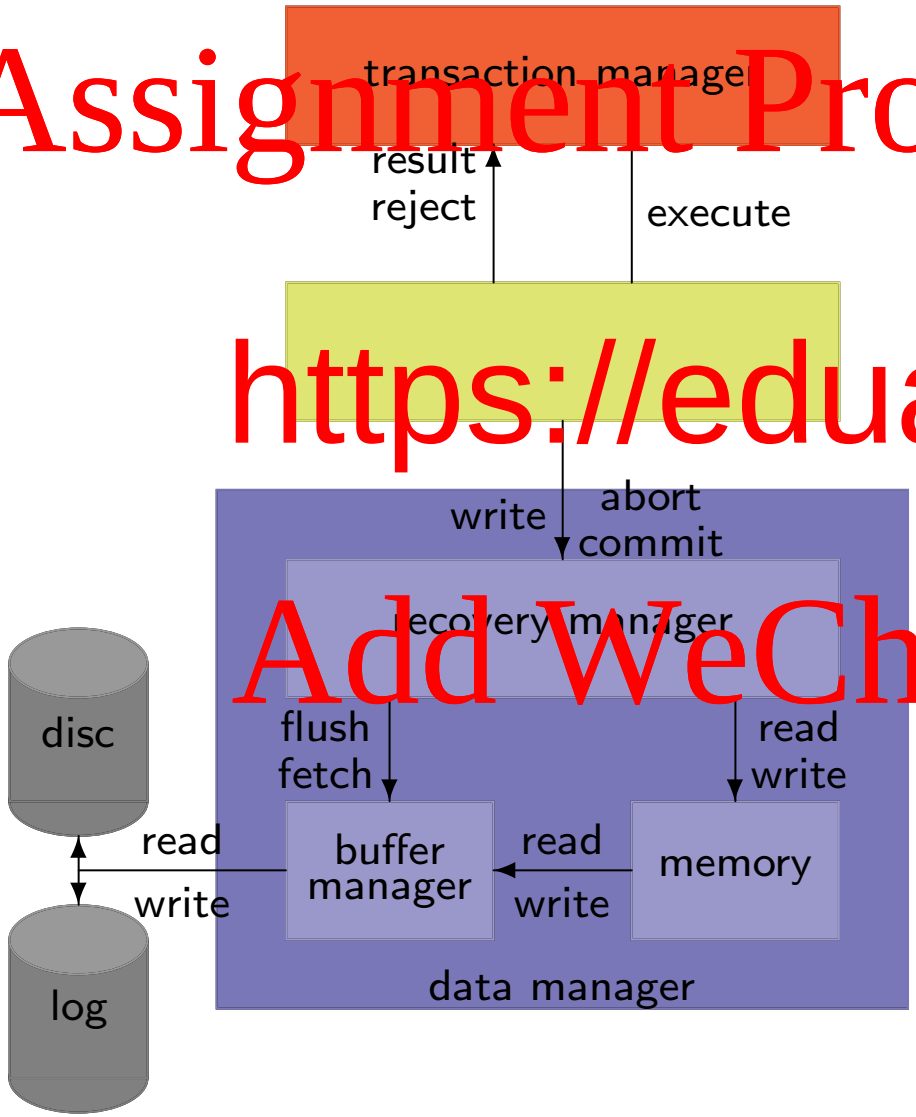
END T

$$r_1[b_{56}], w_1[b_{56}], r_1[b_{34}], w_1[b_{34}]$$

DBMS Architecture



DBMS Architecture



Scheduler

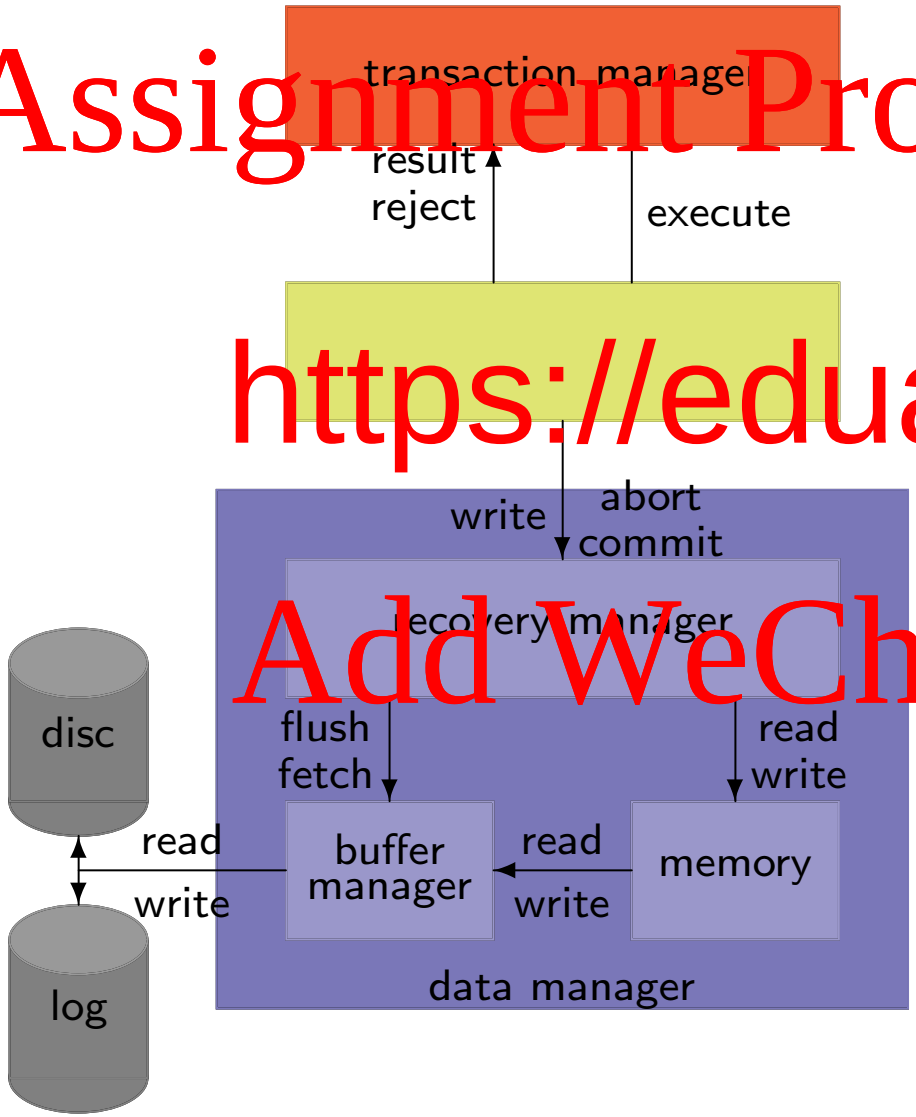
execute($r_1[b_{56}], w_1[b_{56}], r_1[b_{34}], w_1[b_{34}]$)

execute($r_2[b_{56}], r_2[b_{34}], r_2[b_{67}]$)

$[b_{56}$

$1 \quad 34 \quad 1 \quad 34 \quad 1 \quad 2 \quad 34], r_2[b_{67}], c_2$

DBMS Architecture

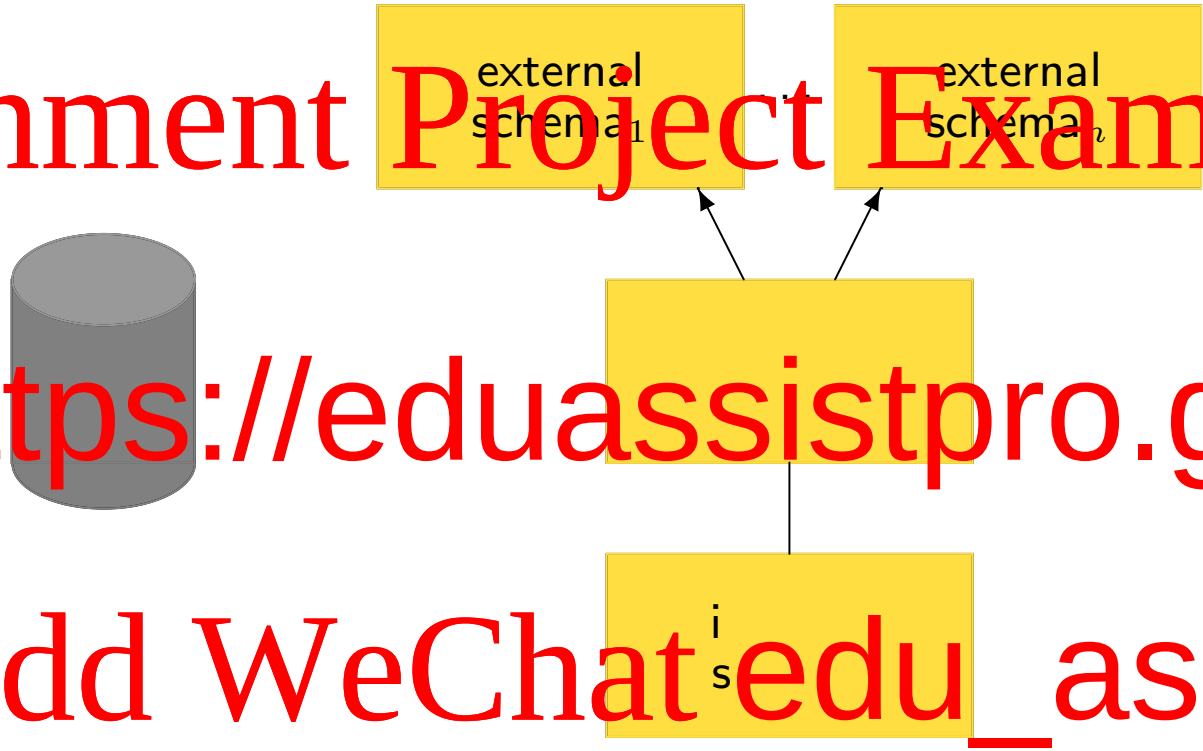


Data Manager

$b_1, r_1[b_{56}], w_1[b_{56}], b_2,$
$r_2[b_{56}]$

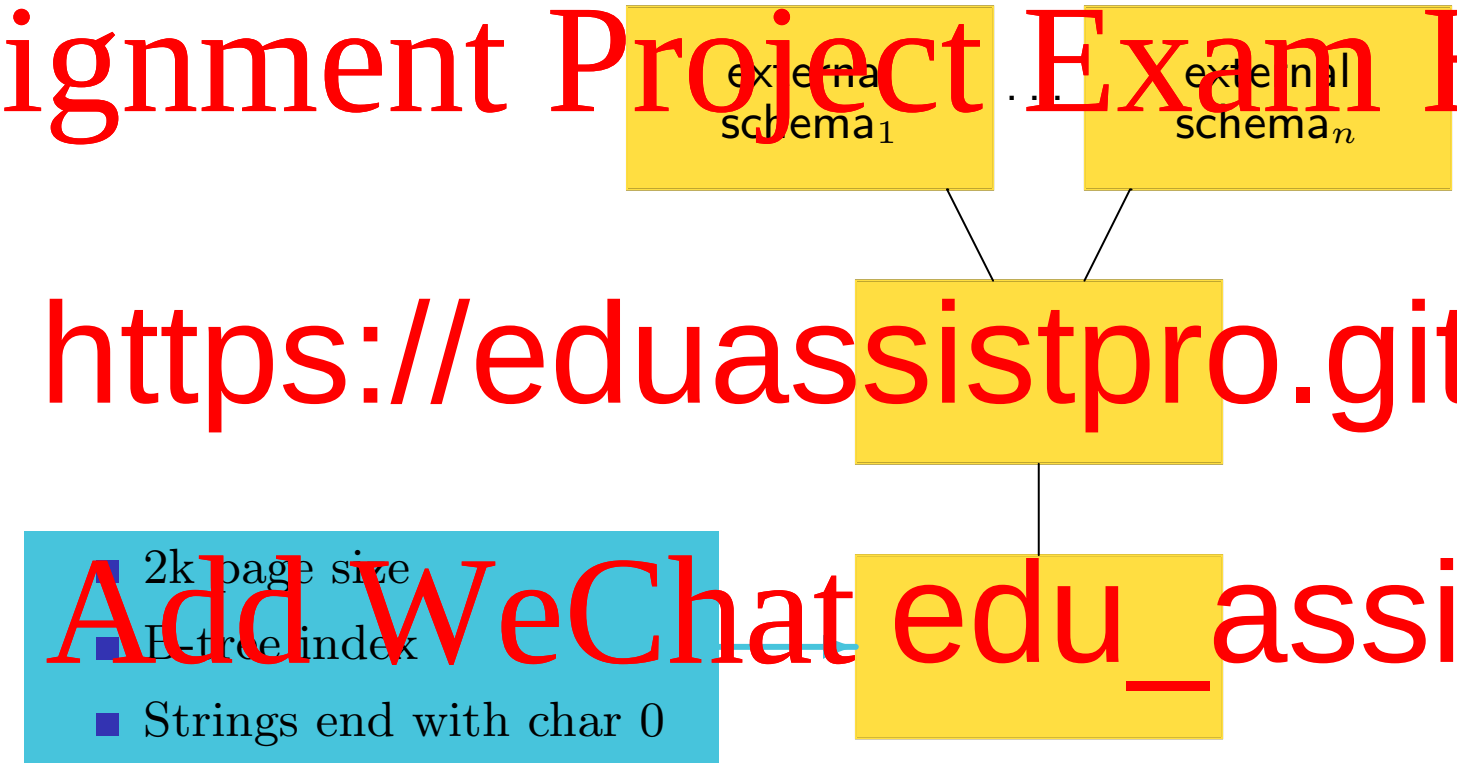
M_r M_r
$M_r(P_1), B_r(P_1), D_r(P_1), M_w(P_1), L_w(P_1),$
$L_w(c_1), M_r(P_1),$
$M_r(P_2), L_w(c_2), D_w(P_1), D_w(P_2)$

ANSI/SPARC Model



- ANSI/SPARC model views three levels of abstractions
- **schema** means *structure of the database*

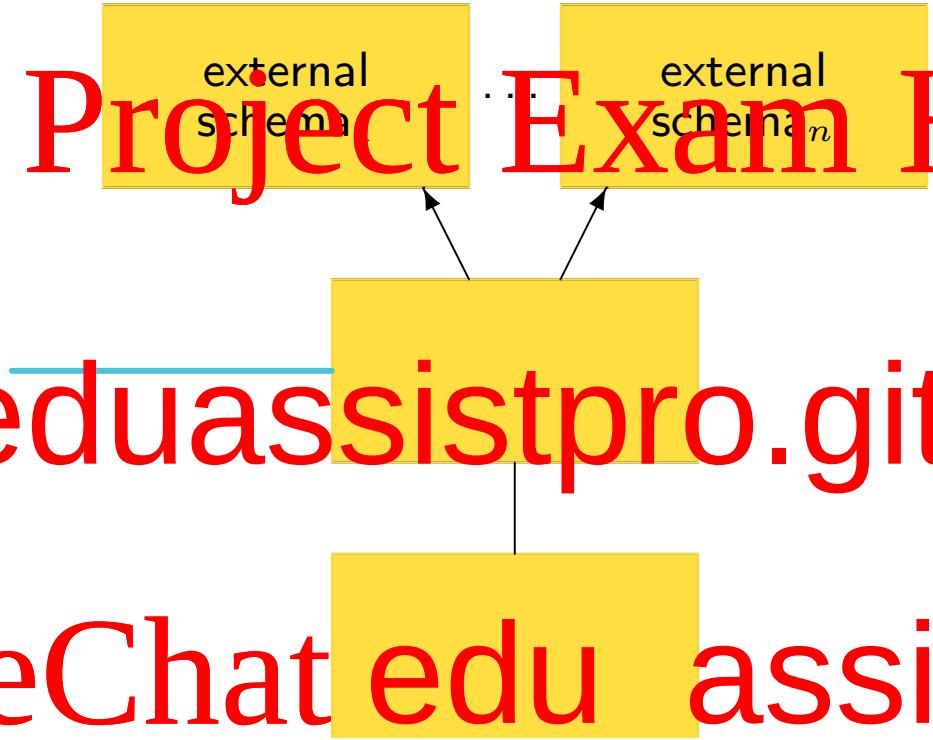
ANSI/SPARC Model (Internal Schema)



- Describes the physical layout of data

ANSI/SPARC Model (Conceptual Schema)

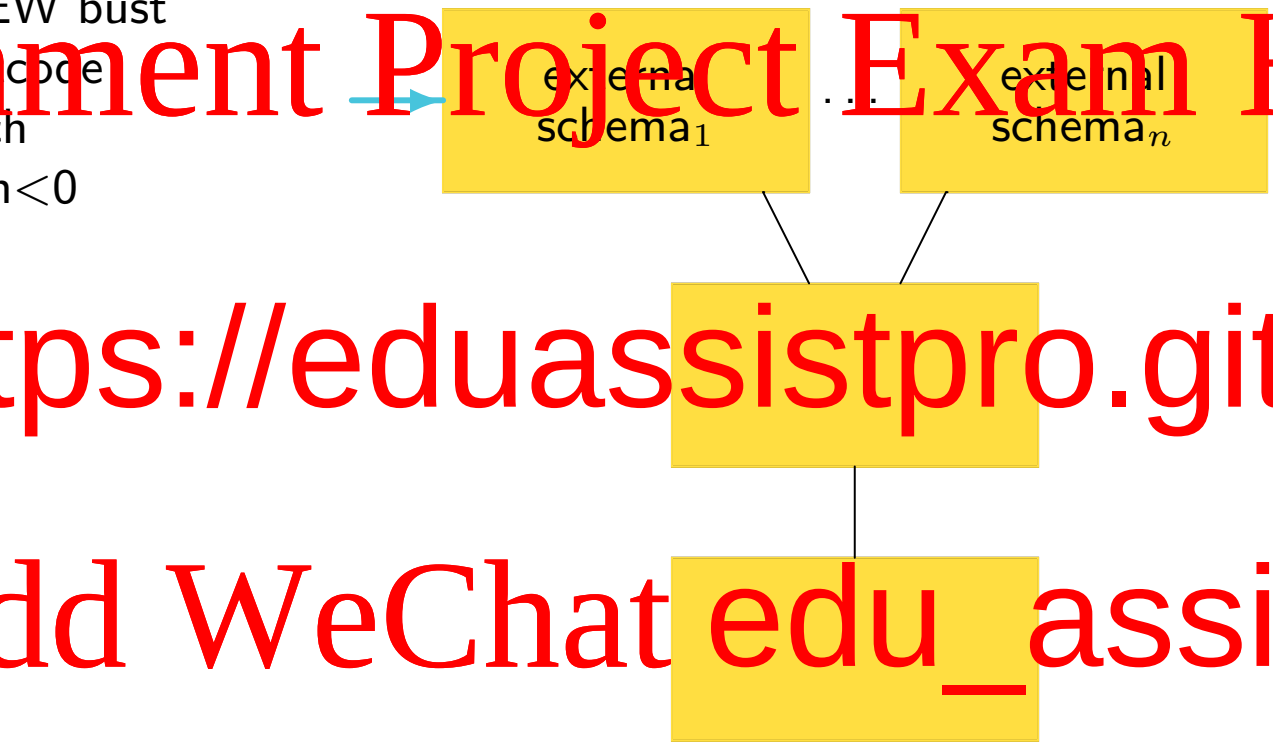

```
CREATE TABLE branch
(    sortcode INTEGER,
     bname VARCHAR(20),
     ca
)

SELE
FROM branch
WHERE cash<0
```



- defined in **data definition language** (**DDL**)
- queried using **data manipulation language** (**DML**)
- controlled by **database administrator** (**DBA**)

ANSI/SPARC Model (External Schema)


```
CREATE VIEW bust
SELECT sor_code
FROM branch
WHERE cash<0
```



- Define a schema for a particular user/application

Course Format

Schedule

- Three hours combined lectures/tutorials per week, running into week 10
- Coursework that helps you prepare for the exam
- May Exam

Books

Several good ial in more advanced courses are:

- *Fundamentals of Database Systems*, 6th Ed, Elmasri and Navathe, Addison Wesley
- *Database Systems: The Complete Book*, 2nd Ed, Garcia-Molina, Ullman and Widom, Pearson
- *Database Systems*, 5th Ed, Connolly and Begg, Addison Wesley

Course Resources

Course Web Site

http://www.doc.ic.ac.uk/~pjm/db/

- Lecture slides
- Exam
  - s

Resources

- **CATe** course work handout and submission
- **Piazza** discussion forum
- **email** course email list

If you are not on Level 2 on CATe, nothing works!

Course Content

Conceptual Layer: Relational Algebra

- SQL
- Datalog

Conceptu

- Prope
- Database design using ER models

Physical Layer: Transaction Processing

- Serialisability
- Recovery and Checkpointing