These slides are for use with

Database Systems

Concepts, Languages and Architectures

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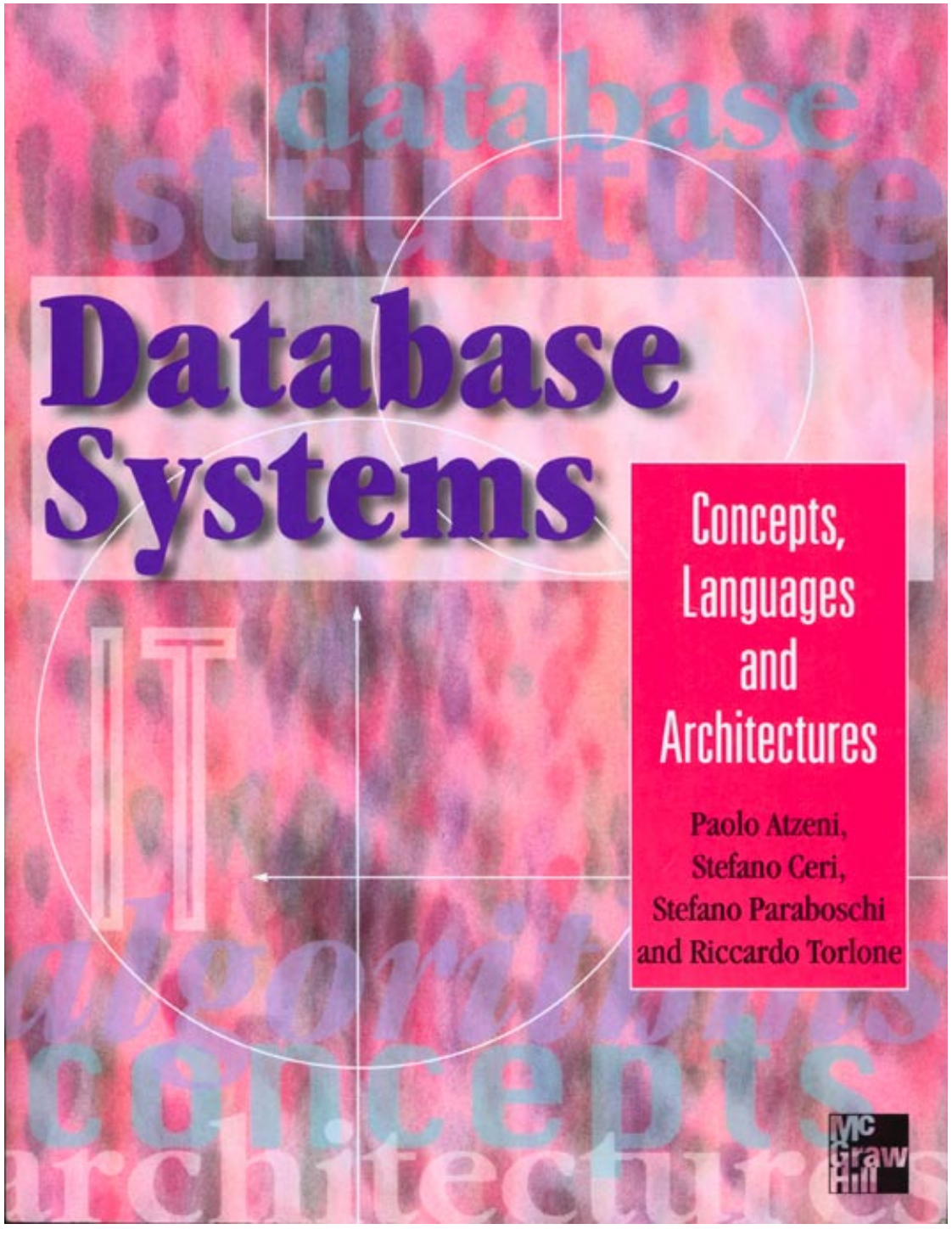

Chapter 12

Active databases

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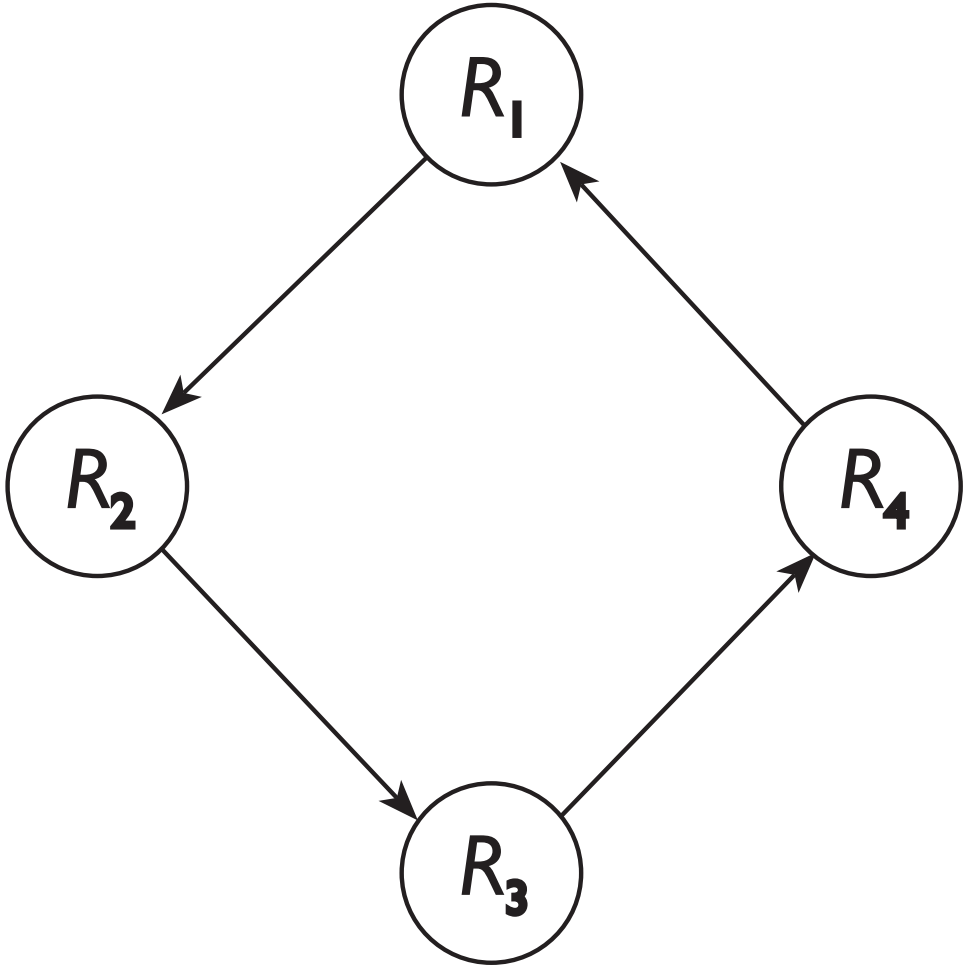
Cyclic activation graph



Active databases

- A DBMS which offers an execution engine for *Event-Condition-Action* rules (production rules) is an *active database*
- Active databases present a *reactive* behaviour (compared with the *passive* behaviour of typical DBMSs): they execute not only user transactions, but also the rules
- Rules are similar to procedures, but their execution is automatic: they permit to share a richer data semantics among all the applications accessing the database
  - "knowledge independence"
- Several research prototypes have been developed
- Most commercial systems offer this functionality, in the form of *triggers* (standardised in SQL-3)

Event-condition-action (ECA) paradigm

- Trigger are defined by a specific DDL statement (`create trigger`)
  - based on the event-condition-action paradigm:
    - event: data update, specified by `insert, delete, update`
    - condition (optional): SQL predicate
    - action: sequence of SQL statements (or a procedure in an extended SQL, like PL/SQL in Oracle)
  - intuition:
    - when the event occurs (triggering)
    - if the condition is satisfied (consideration)
    - then do the action (execution)
  - each trigger is associated with a table (target): it is activated only by events occurring on that table

Granularity and execution mode

- Granularity
  - row-level: the trigger is activated once for every tuple on which the event occurred
  - statement-level: the trigger is activated once for every SQL statement, referring to all the tuples on which the statement operated (set-oriented)
- Execution mode
  - immediate: right after (or even before) the event
  - deferred: at transaction commit

Triggers in Oracle, syntax

`create trigger` *TriggerName*
Mode Event {`,` *Event*}
`on` *TargetTable*
[[`referencing` *Reference*]
[`for each row`]
[`when` *SQLPredicate*]]
PL/SQLBlock

- *Mode:* `before` or `after`
- *Event:* `insert, update, delete`
- `for each row` specifies the granularity
- *Reference:* permits to introduce variable names (only for row-level triggers):

  `old as` *OldVariable* | `new as` *NewVariable*

Example: automatic reorder management

1. event:

   `update(QtyAvbl)` in Warehouse

2. condition: the new available quantity is less than the (new) reorder quantity:

   `new.QtyAvbl < new.QtyReord`

3. action:

   if there are no pending order for the part, issue a new order

Active rule

```
create trigger Reorder
after update of QtyAvbl on Warehouse
when (new.QtyAvbl < new.QtyLimit)
for each row
  declare
    X number;
  begin
    select count(*) into X
    from PendingOrders
    where Part = new.Part;
    if X = 0
    then
      insert into PendingOrders
      values (new.Part, new.QtyReord, sysdate);
    end if;
  end;
```

Application execution

```
update Warehouse
  set QtyAvbl = QtyAvbl - 50
  where Part = 4
```

Part	QtyAvbl	QtyLimit	QtyReord
4	100	80	50

Trigger execution

event : **`update(QtyAvbl) on Warehouse`**

condition : TRUE

action : **`insert into PendingOrders values (new.Part, new.QtyReord, sysdate)`**

Part	QtyReord	Date
4	50	10-10-00

Triggers in Oracle, semantics

- *Immediate* execution mode (both for `after` and `before`)
- Execution schedule:
  - `before statement` triggers
  - for each tuple on which the event occurred:
    - `before row` triggers
    - operation
    - `after row` triggers
  - `after statement` triggers
- If an error is detected, everything is undone
- No explicit user-defined priorities
- At most 32 triggers can be activated *in cascade*

Triggers in DB2, syntax

```
create trigger TriggerName
  Mode Event on TargetTable
  [referencing Reference]
  for each Level
   [when (SQLPredicate)]
    SQLProceduralStatement
```

- *Mode:* `before` or `after`
- *Event:* `insert, update, delete`
- `for each` *Level* specifies the granularity, `row` or `statement`
- *Reference:* permits to define variable names (depending on rule granularity):

```
        old as OldTupleVar | new as NewTupleVar
old_table as OldTableVar | new_table as NewTableVar
```

Triggers in DB2, semantics

- *Immediate* execution mode (both for `after` and `before`)
- `before` triggers cannot modify the database, except to introduce changes on the update introduced by the event (thus, they cannot trigger other rules)
- If an error occurs, everything is undone (executed transaction and triggers)
- No priorities among triggers (order defined by the system)
- Interaction with reactions to violations of referential integrity constraints
- At most 16 triggers *in cascade*

Example of trigger in DB2

```
foreign key (Supplier)
    references Distributor
    on delete set null

create trigger SoleSupplier
    before update of Supplier on Part
    referencing new as N
    for each row
    when (N.Supplier is not null)
    signal sqlstate '70005' ('Cannot change supplier')

create trigger AuditPart
    after update on Part
    referencing old_table as OT
    for each statement
    insert into Audit
    values(user, current_date, (select count(*) from OT))
```

Extensions (usually not available)

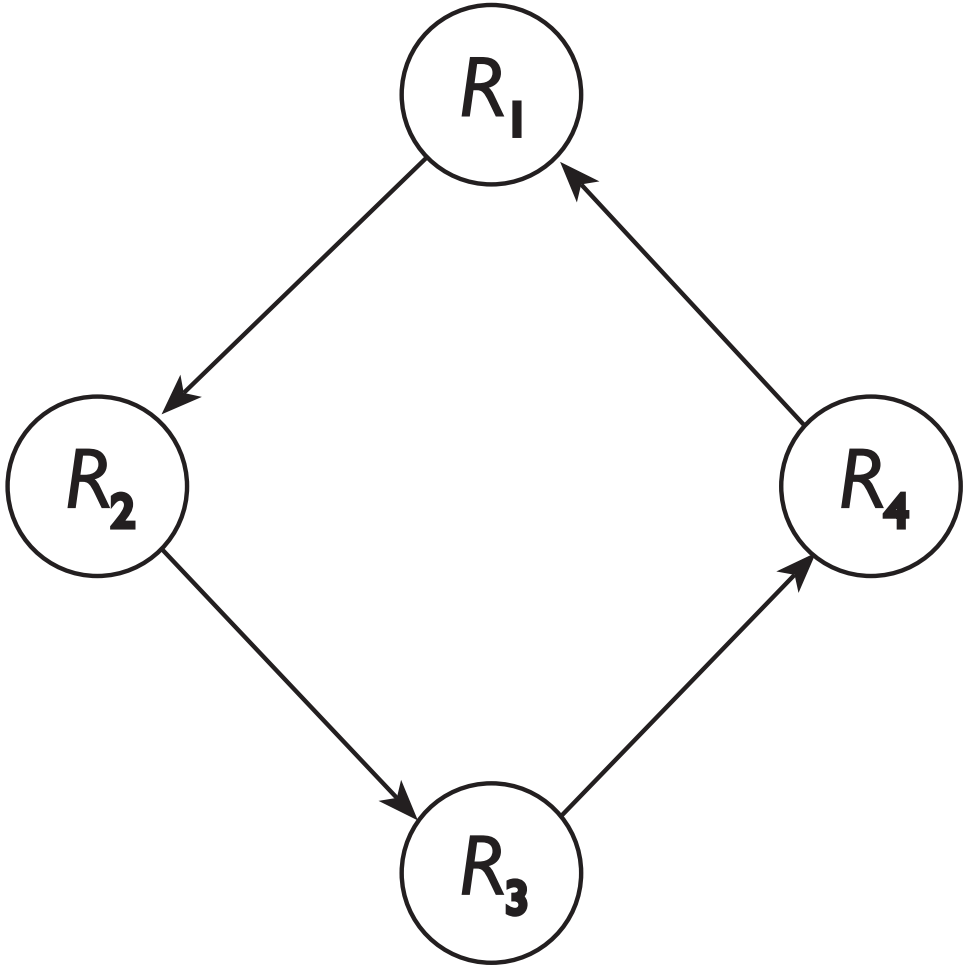
- Temporal events (even periodic) or “user-defined”
- Boolean combinations of events
- `instead of`: clause: it is not executed the operation that triggered the event, but another one in its place
- “Detached” execution mode: a separate transaction is started to manage the triggers
- Explicit user-defined priorities
- Rule sets, that can be made activated and deactivated with a single command

Properties of active rules

- Termination (fundamental property)
- Confluence
- Identical observable behaviour

- Termination is assessed studying rule interaction
- An important conceptual tool is the triggering graph
  - acyclicity of the triggering graph guarantees that the triggers cannot exhibit an infinite cascading execution
  - cycles in the triggering graph identify possible sources of non-termination

Cyclic activation graph



Applications of active databases

- Internal services
  - checking and maintenance of integrity constraints
  - replication
  - view management
    - materialised views: update propagation
    - virtual views: query rewriting
- External services
  - description of the dynamics (behaviour) of the database

Referential integrity management

- An exemplary active rule application

- The constraint is first expressed as an SQL predicate
  - the negation of the predicate becomes the rule condition
- The events that can introduce constraint violations are identified and monitored by active rules
- The rule actions represent the (arbitrary) integrity maintenance policy that the designer considers appropriate

Example of referential integrity management by active rules

- Integrity constraint

```
exists (select * from Department
        where DeptName = Employee.Dept)
```

- Condition:

```
not exists (select * from Department
            where DeptName = Employee.Dept)
```

- Events:
  - insert into Employee
  - delete from Department
  - update to Employee.Dept
  - update to Department.DeptName

Example of referential integrity management by active rules

- First active rule (of four):

```
create trigger DeptRef1
after insert on Employee
for each row
when (not exists
  (select * from Department
   where DeptName = New.Dept))
signal sqlstate '70006' (’employee without department');
```

Business rules

- Business rules express the strategy of a company in pursuing its objectives
- Active rules are the most flexible and powerful tool to implement business rules in information systems
- For instance, business rule "*an employee must not have a salary greater than that of the manager of the department to which he or she belongs*":

```
create trigger ExcessiveSalary
after update on Salary of Employee
for each row
when New.Salary > select Salary from Employee
                  where EmpNum in
                    (select Director from Department
                     where DeptNum = New.DeptNum)
then signal sqlstate '70005' ('Salary too high')
```