Application Controls

CSH6 Chapter 52

"Application Controls"

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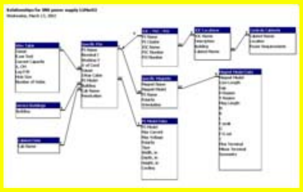
Topics

- Protection in Development
- Protecting Databases
- Protecting Batch Files
- Ensuring that Information in the System is Valid

Protection in Development

- Software Quality Assurance (QA)
  - Focuses on methods for preventing, catching and correcting errors in source code and other operational instructions
- Application Controls
  - Specific subset of methods for preventing data corruption in production systems
- Databases
  - Primary mechanism for storing and manipulating data in today's systems
- Batch vs Online
  - Live interaction (online)
  - Automated processing (batch)



Types of Data Corruption

- Physical
  - Caused by hardware failures
  - Errors do not correlate with (respect)
    - ✓ Applications
    - ✓ Files / datasets / databases
    - ✓ Why not?
- Logical
  - Caused by software failures
  - Errors *may* correlate with
    - ✓ Applications
    - ✓ Files / datasets / databases
  - Why only "may"?

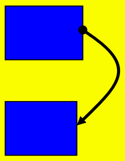
DBMS Controls

- Referential Integrity
- Uniqueness Constraints
- Locking
- Transaction Controls
- Database Recovery

For those who have completed IS240, this section should be a review.

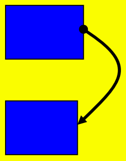
Referential Integrity

- In designing databases, may stipulate that certain records may not exist without pre-existing indexes
- E.g., cannot normally enter
  - ***Order-detail*** without entering ***order-header***
  - ***Prescription data without entering***
    - ✓ Patient data
    - ✓ Doctor data
    - ✓ Pharmacist data
    - ✓ Drug data
    - ✓ Admission data



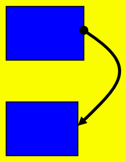
Referential Integrity (cont'd)

- ➢ DBMS will prevent deletion of records when others are *dependent* on them
- ➢ E.g.,
  - ❑ Cannot delete ***order-header*** if there are orders with the order-number of that header
  - ❑ Cannot delete ***patient-master*** record if there are admission records for that patient



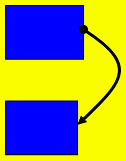
DBMS Controls

- ➢ Referential Integrity
- ➢ Uniqueness Constraints
- ➢ Locking
- ➢ Transaction Controls
- ➢ Database Recovery



Uniqueness Constraints

- ➢ In relational DBMS (RDBMS), every record in a table (dataset) must be unique
  - ❑ If there is no natural ***key*** or ***index*** field (or combination of fields) that guarantees uniqueness, can create one automatically
- ➢ DBMS can enforce uniqueness of specific fields in records using the ***unique key*** characteristic
- ➢ E.g.,
  - ❑ Order-number
  - ❑ Patient-ID
  - ❑ Student-ID….



DBMS Controls

- ➢ Referential Integrity
- ➢ Uniqueness Constraints
- ➢ Locking
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- ➢ Database Recovery

Locking

- ➢ Concurrency Control
- ➢ Basic Concepts of Locking
- ➢ Serializable Transactions
- ➢ Deadlock (Deadly Embrace)
- ➢ Locking Strategies

Concurrency Control

- ➢ Multi-Step Transactions
- ➢ Resource Locking
- ➢ Consistent Transactions
- ➢ Transaction Isolation Level
- ➢ Cursor Type

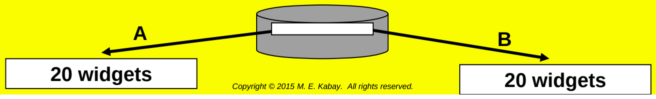
Multi-Step Transactions Are Fragile

- Think about order-entry system
- Create order-header
  - ❑Includes *total* of cost of line-items (details)
    - ✓Updated at END of detail data entry
- Begin entering line-items
  - ❑Enter 3 records … *have not yet finished*
  - ❑System crashes
- What is the value in the order-header's *total* field?

Concurrency Causes New Problems

E.g., The Lost Update Problem:

- User A reads inventory: finds 20 widgets.
- User B reads inventory: also finds 20 widgets.
- User A subtracts 10 widgets from 20, writes total ____ widgets back into inventory
- User B subtracts 5 widgets from ____, writes total ____ widgets back into inventory
- But actually, there are only ____ widgets left in the real inventory



Atomic Transactions

- We want to complete
  - ❑*All* the steps of a transaction or
  - ❑*None* of the steps
- ATOMIC
  - ❑Greek "a" for "not" & "tomos" for "cut"
  - ❑Thus "atomic" means "can not be cut."
- We mark *atomic transactions* with boundaries
  - ❑Start transaction
  - ❑Commit transaction
- If necessary, can reverse steps taken
  - ❑Rollback transaction

Resource Locking

- Basic Concepts of Locking
- Lock Terminology
- Serializable Transactions
- Deadlocks
- Optimistic vs Pessimistic Locking
- Declaring Lock Characteristics

Basic Concepts of Locking

- Locking is used in *inter-process communication* (IPC)
- A lock is a form of *semaphore* (signal)
- Locks allow processes to
  - ❑Coordinate their access to resources
  - ❑Prevent inconsistencies
- In DBMS, primarily used to *serialize* data access
  - ❑One process gets control of data at a time

Lock Terminology

- Implicit vs explicit
  - ❑Automatic locks placed by DBMS: implicit
  - ❑Programmatically ordered: explicit
- Lock *granularity*
  - ❑Large: database, dataset
  - ❑Fine: records
- *Exclusive* vs *shared* locks
  - ❑Exclusive:
    - ✓One process READ/WRITE
    - ✓No other processes allowed at all
  - ❑Shared:
    - ✓One process has R/W
    - ✓Other processes can only READ

Conditional vs Unconditional Locking

- *Conditional* locking
  - ❑Process 1 locks resource A
  - ❑Process 2 locks resource A
    - ✓Receives error condition
    - ✓Lock fails and process 2 continues
- *Unconditional* locking
  - ❑Process 1 locks resource A
  - ❑Process 2 locks resource A
    - ✓Does not receive a condition report
    - ✓Process 2 waits in suspense (hangs) until lock is granted

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Serializable Transactions

- Prevent transactions affecting same records from overlapping
- Two-phase locking
  - ❑Can accumulate locks
  - ❑But once any lock is released, cannot get more until all are released
  - ❑Defines growing phase and shrinking phase
- More restrictive (and more common) strategy
  - ❑No locks released until COMMIT or ROLLBACK

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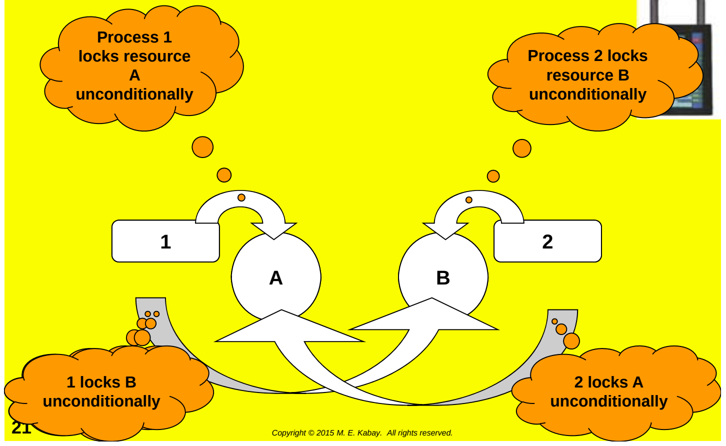
Deadlock (Deadly Embrace)


Process 1 locks resource A unconditionally
Process 2 locks resource B unconditionally
1
2
A
B
1 locks B unconditionally
2 locks A unconditionally

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Preventing Deadlocks

- Deadlock is example of a *race condition*
  - ❑Will not necessarily occur
  - ❑Occurs by chance when specific events happen at specific time
- Always ensure that processes in applications
  - ❑LOCK RESOURCES IN SAME ORDER
  - ❑UNLOCK RESOURCES IN REVERSE ORDER
- Apply these principles to example on previous slide to see how they absolutely prevent deadlock

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Pessimistic Locking Strategy

- Assume collisions will occur and prevent conflicts
  - ❑Lock records
  - ❑Process transaction
  - ❑Release locks
- But very dangerous for performance if processing involves human interaction
  - ❑Not controllable
  - ❑Operator can leave resources locked and hang system
    - ✓Operator could go to lunch!

DO NOT LOCK AROUND HUMAN INTERVENTION!

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Optimistic Locking Strategy

- Assume collisions will be rare and recover if they happen
  - ❑Read original data records
  - ❑Process transaction using buffers
  - ❑Lock original data records
  - ❑Check to see if original data have changed
    - ✓If no change, commit transaction & unlock
    - ✓If change, unlock & start over

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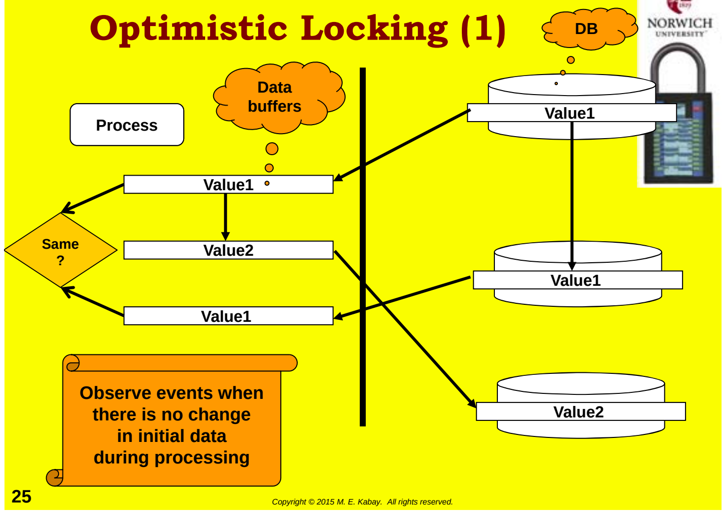
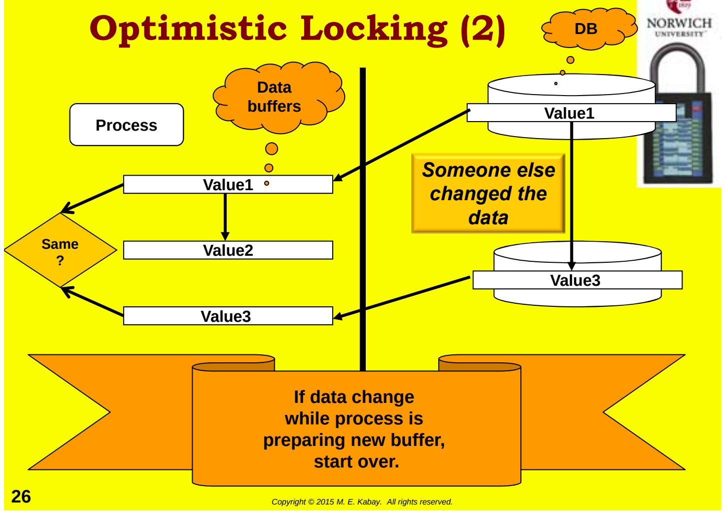
Optimistic Locking (1)


DB
Data buffers
Process
Value1
Value1
Same ?
Value2
Value1
Value1
Value2
Observe events when there is no change in initial data during processing

Optimistic Locking (2)


DB
Data buffers
Process
Value1
Value1
Someone else changed the data
Same ?
Value2
Value3
Value3
If data change while process is preparing new buffer, start over.

Optimistic vs Pessimistic Strategies

- Optimistic locking *advantages*
  - Does not lock resources around human intervention
  - Appropriate for Web / Internet transactions
  - Especially important if lock granularity is large (e.g., entire DB or entire tables)
- Optimistic locking *disadvantages*
  - If specific resource is in high demand (much *contention* for specific records) then can cause repeated access (*thrashing*)
  - Can degrade individual and system performance

Declaring Lock Characteristics

- Older programs often used specific calls to locking routines
  - E.g., “DBLOCK”
  - Passed parameters to set exact type of lock
    - ✓Conditional or not, granularity etc.
- Modern programming using DBMS uses transaction markers
  - BEGIN, COMMIT, ROLLBACK
  - Allows global definition of locking strategy
  - DBMS handles details
  - Can thus change locking globally without reprogramming

DBMS Controls

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- Transaction Controls
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ACID Transactions

- Transactions sometimes described as ideally *ACID*
  - *Atomic*: all changes in the multi-step transaction are committed or none is
  - *Consistent*: all records involved in the transaction are changed or none is
  - *Isolated*: concurrency does not harm integrity
  - *Durable*: not reversible once committed except through normal transaction processing of a new transaction

Consistency

- Statement-level consistency
  - If change is supposed to apply to group of records, then no changes to any of those records will be permitted until all records have been changed
- Transaction-level consistency
  - Same principle applied to multiple steps
  - Not always easy to achieve
  - If locking applied around very long processes, will see performance / throughput degradation for other users
  - May want to limit long updates to batch processing during off-hours

Transaction Isolation Level

- Can have difficulties / inconsistencies when concurrent processes access intermediate results during transactions
- *Dirty read*: access a record changed by another process but not yet committed
- *Nonrepeatable* read: some other process has altered the original record (e.g., during optimistic locking)
- *Phantom* read: a new movie by George Lucas – NO NO – means new records inserted or deleted since last read

ANSI SQL Isolation Levels

- Can specify degree of protection desired

ANSI SQL		Isolation Level			
		Read Uncommitted	Read Committed	Repeatable Read	Serializable
Problem Type	Dirty Read	Y	N	N	N
	Nonrepeatable Read	Y	Y	N	N
	Phantom Read	Y	Y	Y	N

DBMS Controls

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Database Recovery

- Transactions
- Application Logging
- Transactions and Log Files
- Backups & Log Files
- Recovery from Backups
- Recovery from Log Files

Transactions

- What are *transactions*?
- Why should we care if a transaction were interrupted by a DBMS failure or a system failure?

CLASS DISCUSSION

Application Logging

- Benefits of logging
  - Audit trail for security / investigations
  - Performance data
  - Debugging
- What might a logging process write into the log file when a process is
  - *Adding* a record?
  - *Changing* a record?
  - *Deleting* a record?

CLASS DISCUSSION

Transactions and Log Files

- Why would it matter to anyone that a log file keep a *distinction* among different types of transactions?
- How does a log file mark *completion* of an atomic transaction?

CLASS DISCUSSION

Backups & Log Files

Distinguish among the following types of backups:

- ***System*** **vs** ***application***
- ***Full*** **(everything)**
- ***Differential*** **(*****aka*** **"Partial") (everything changed since last full)**
- ***Incremental*** **(everything changed since last incremental) (aka "Partial")**
- ***Delta*** **(only changed data) (aka "Partial")**
- ***Log files*** **(only the** ***information about the changes*****)**

Backup Types

File	SUN	MON	TUE	WED	THU	FRI	SAT
A	🟩	🟥	🟩	🟥	🟥	🟩	🟥
B	🟩	🟩	🟥	🟩	🟥	🟩	🟥
C	🟩	🟩	🟩	🟩	🟥	🟥	🟥
D	🟩	🟩	🟩	🟥	🟥	🟥	🟩
E	🟩	🟩	🟩	🟩	🟩	🟥	🟩

Backup Type	SUN	MON	TUE	WED	THU	FRI	SAT
FULL	ABCDE	ABCDE	ABCDE	ABCDE	ABCDE	ABCDE	ABCDE
DIFFERENTIAL		A	AB	ABD	ABCD	ABCDE	ABCDE
INCREMENTAL		A	B	AD	ABCD	CDE	ABC
DELTA (records)		A'	B'	A'D'	A'B'C'D'	C'D'E'	A'B'C'

Do not use the term "partial backup."

Recovery from Log Files

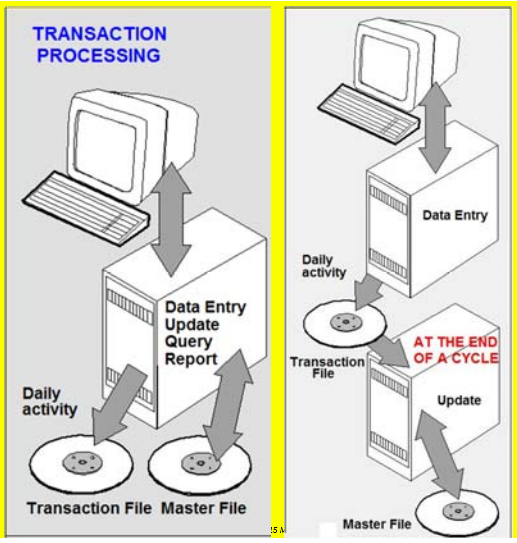
- ***Roll-backward*** **recovery**
  - Use log file to identify interrupted (incomplete) transactions using *checkpoints*
    - ✓Look for *start marker* without *end marker*
  - Remove all changes that are part of those incomplete transactions
- ***Roll-forward*** **recovery**
  - Start with valid backup
  - Use log file to re-apply all completed transactions
  - Leave out the incomplete transactions

Which kind of recovery is faster?

Protecting Batch Files

- Batch processing as defined in *Computer Desktop Encyclopedia*:
- (1) Performing a particular operation automatically on a group of files all at once rather than manually opening, editing and saving one file at a time. For example, graphics software that converts a selection of images from one format to another would be a batch processing utility.
- (2) Processing a group of transactions at one time. Transactions are collected and processed against the master files (master files updated) at the end of the day or some other time period. Contrast with transaction processing.

Batch Processing (2)



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Batch Processing (3)

- Normal batch processing automatically keeps original files as default backups
- Process master file + transaction file(s)
  - ❑Copy unchanged records into new file
  - ❑Copy modified records from transactions
  - ❑Don’t copy deleted records
- End up with
  - ❑Original master file
  - ❑New master file
  - ❑Transaction (activity) files
- Typically keep several generations of masters

Assuring that Information in the System is Valid

- Validation Controls: catching data input errors
  - ❑Check digits in input stream
  - ❑Hash totals
  - ❑Digital signatures
  - ❑Range checks
  - ❑Table lookups (including combinations)
- Diagnostic Utilities: catching data corruption or tampering
  - ❑Edit checks
  - ❑Business rules
  - ❑Exception reports
  - ❑Statistical Quality Control (SQC) methods (anomaly detection)

Review Questions (1)

1. Distinguish between SQA and application controls.
2. Why should we pay attention to applications when planning our security procedures?
3. Why are databases of such concern in application security discussions?
4. Name and distinguish between the two fundamental types of data corruption (by cause).
5. Explain the concept of *referential integrity* using examples.
6. How do DBMSs enforce uniqueness constraints?

Review Questions (2)

7. Why do concurrently-accessed databases require *locking strategies*?
8. What’s a *transaction*?
9. What is meant by *atomic* transactions?
10. How is a transaction marked in a log file?
11. Which has finer granularity, locking an entire dataset or locking a set of records?
12. Distinguish between *exclusive* and *shared* locks.
13. Distinguish between *conditional* and *unconditional* locks.
14. What’s a deadlock and how can you prevent it?

Review Questions (3)

15. Distinguish between *pessimistic* and *optimistic* locking strategies.
16. What does *ACID* mean in discussions of transactions? Explain each of the components.
17. Why do production applications normally include log files as part of their design?
18. Explain how *roll-backward* recovery works.
19. Explain how *roll-forward* recovery works.
20. Discuss the security features of batch processing.
21. Explain how applying each of the validation controls described in slide 45 could help check the validity of stored information in a database.