Transactions & recovery

CMT220
Databases & Modelling

Cardiff School of **Computer Science & Informatics**
http://www.cs.cf.ac.uk

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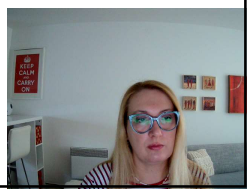
Lecture

- in the previous lecture we learned about database integrity
- database integrity is paramount and DBMS often include the ability to handle transactions to maintain the integrity of data
- in this lecture we introduce the concept of transaction as a basic unit of consistent and reliable computing in database systems
- we will also learn about the capability of a database to recover from various types of failures



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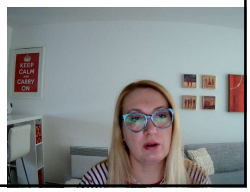
Transactions

- a transaction is an action, or a series of actions, carried out by a single user or an application program, which reads or updates the contents of a database
- a transaction is a logical unit of work that transforms the database from one consistent state to another consistent state
- transactions are the units of:
  - recovery
  - consistency
  - integrity



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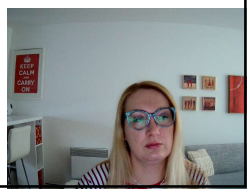
ACID properties

- a transaction must satisfy the ACID properties:
  - **A**tomicity
  - **C**onsistency
  - **I**solation
  - **D**urability



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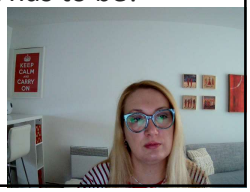
ACID properties

- atomicity
  - transactions do not have parts
  - transactions cannot be executed partially
- consistency
  - transactions take the database from one consistent state into another
  - note: midway through a transaction the database might not be consistent, but at the and it has to be!



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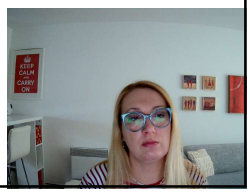
ACID properties

- isolation
  - the effects of a transaction are not visible to other transactions until it has completed
- durability
  - once a transaction is completed, its updates survive, even if there is a subsequent system crash



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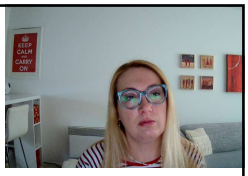
Example



- transaction: "transfer £50 from account A to account B"

1. read(A)
2. A = A – 50
3. write(A)
4. read(B)
5. B = B + 50
6. write(B)

- atomicity: should not take money from A without giving it to B
- consistency: no money lost or gained overall
- isolation: other queries should not see A or B change until completion
- durability: the money does not go back to A

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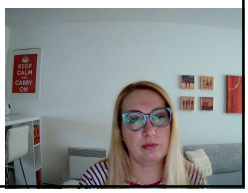
Transaction manager

- transaction manager enforces the ACID properties
  - it schedules the operations of transactions
  - `COMMIT` and `ROLLBACK` are used to ensure atomicity
  - locks or timestamps are used to ensure consistency and isolation for concurrent transactions
  - a log is kept to ensure durability in the event of system failure



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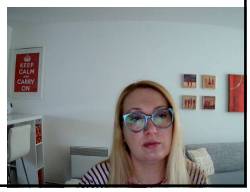
COMMIT and ROLLBACK

- `COMMIT` signals the successful end of a transaction
  - any changes made by the transaction are saved
  - these changes become visible to other transactions
- `ROLLBACK` signals the unsuccessful end of a transaction
  - any changes made by the transaction are undone
  - as if the transaction never occurred



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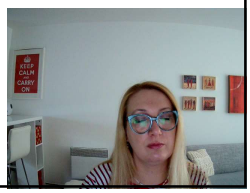
Recovery

- in theory, transactions should be durable
- ... but in practice we cannot always prevent all types of failures, e.g.
  - system crash
  - power failure
  - disk crash
  - user mistake
  - sabotage
  - natural disaster



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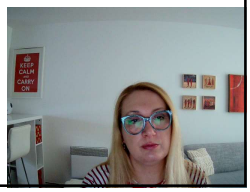
Transaction log

- transaction log records details of all transactions
  - any changes transactions make to the database
  - how to undo these changes
  - when transactions complete and how
- the log is stored on disk, not in memory
  - if the system crashes, then the log is preserved
- write ahead log rule
  - the entry in the log must be recorded before COMMIT



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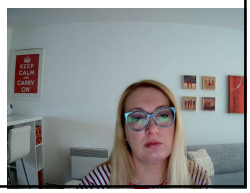
System failures

- a system failure affects all running transactions
  - software crash
  - power failure
- the physical media (disks) are not damaged
- at various times a DBMS takes a checkpoint
  - all committed transactions are written to disk
  - a record is made (on disk) of the transactions that are currently running



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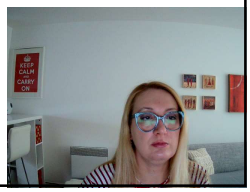
System recovery

- any transaction that was running at the time of failure needs to be undone and restarted
- any transaction that committed since the last checkpoint needs to be redone



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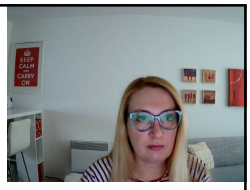
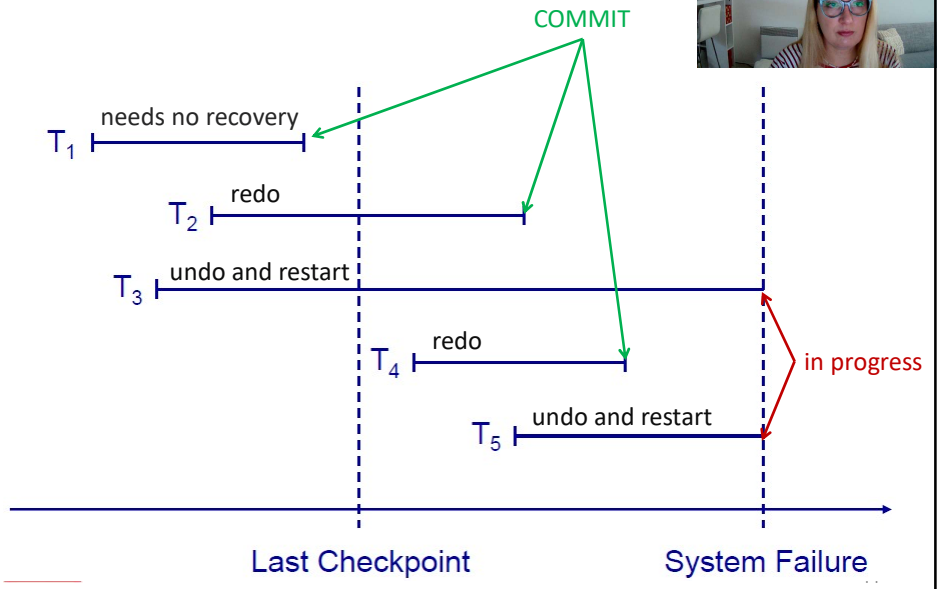
Types of transactions





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Transaction recovery

- two lists of transaction
  1. UNDO: all transaction that were in progress at the last checkpoint
  2. REDO: empty list
- for each entry in the log (at the last checkpoint) do:
  - if a BEGIN TRANSACTION entry is found for transaction T, then add T to UNDO
  - if a COMMIT entry if found for T, then move T from UNDO to REDO

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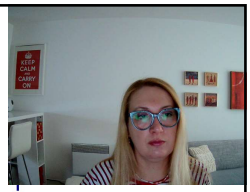
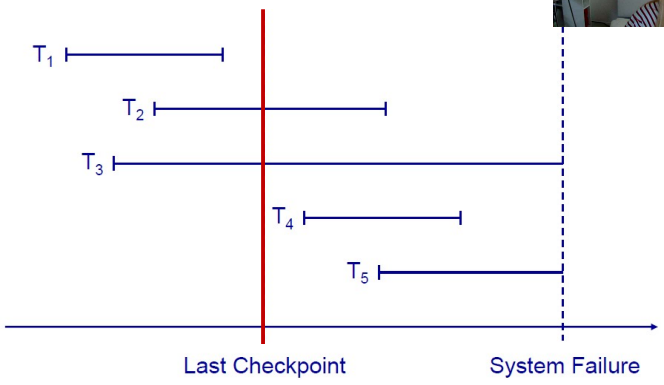
Transaction recovery





- UNDO: T_2, T_3
- REDO:
- active transactions: T_2, T_3
- add them to UNDO

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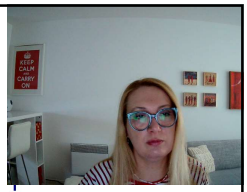
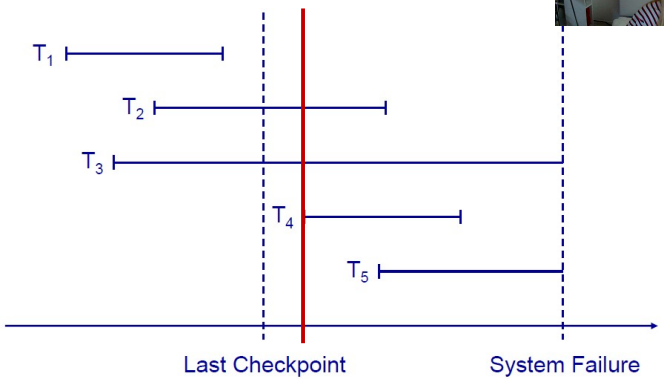
Transaction recovery





- UNDO: T_2, T_3, T_4
- REDO:
- T_4 begins
- add it to UNDO

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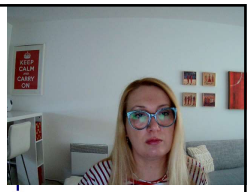
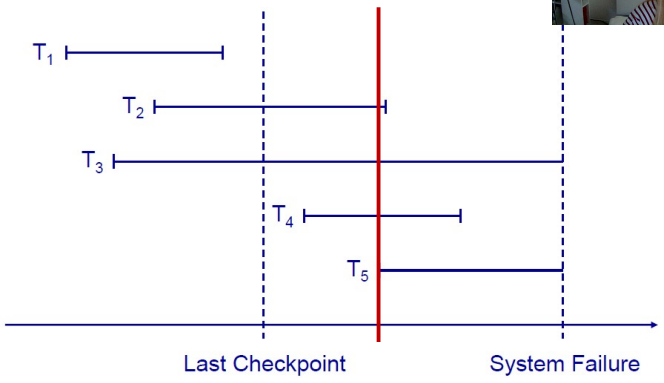
Transaction recovery





- UNDO: T_2, T_3, T_4, T_5
- REDO:
- T_5 begins
- add it to UNDO

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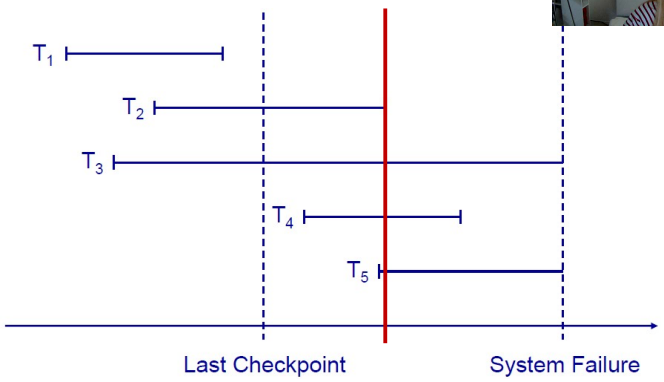
Transaction recovery



- UNDO: T_3, T_4, T_5
- REDO: T_2
- T_2 commits
- move it to REDO

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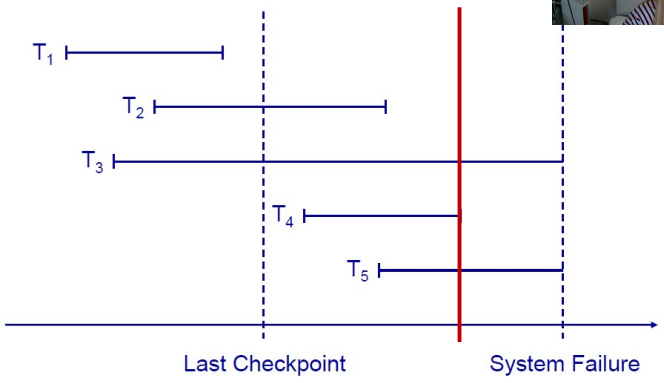
Transaction recovery



- UNDO: T_3, T_5
- REDO: T_2, T_4
- T_4 commits
- move it to REDO

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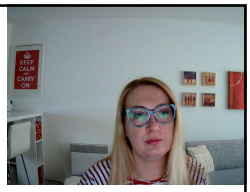
Forwards and backwards recovery



- backwards recovery
  - we need to undo some transactions
  - working backwards through the log we undo any operation by a transaction on the UNDO list
  - this returns the database to a consistent state
- forwards recovery
  - some transactions need to be redone
  - working forwards through the log we redo any operation by a transaction on the REDO list
  - this brings the database up to date

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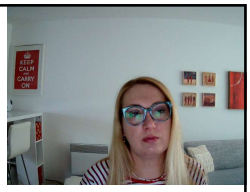
Media failures



- system failures are not too severe
  - only information since the last checkpoint is affected
  - this can be recovered from the transaction log
- media failures (e.g. disk crash) are more serious
  - the data stored on disk is damaged
  - the transaction log itself may be damaged

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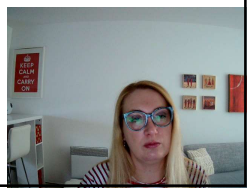
Backups

- backups are needed to recover from media failure
  - the transaction log and entire contents of the database is written to secondary storage (e.g. tape)
  - time consuming and thus often requires down time
- backup frequency
  - frequent enough to minimise information loss
  - not too frequent as to cause problems
  - daily backup (e.g. overnight) is common



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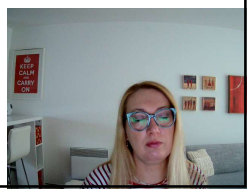
Recovery from media failure

1. use the last backup to restore the database
2. use the transaction log to redo any changes made since the last backup

- if the transaction log is damaged, we cannot do step 2
- store the transaction log and the database on separate physical devices
- this minimises the risk of losing both



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