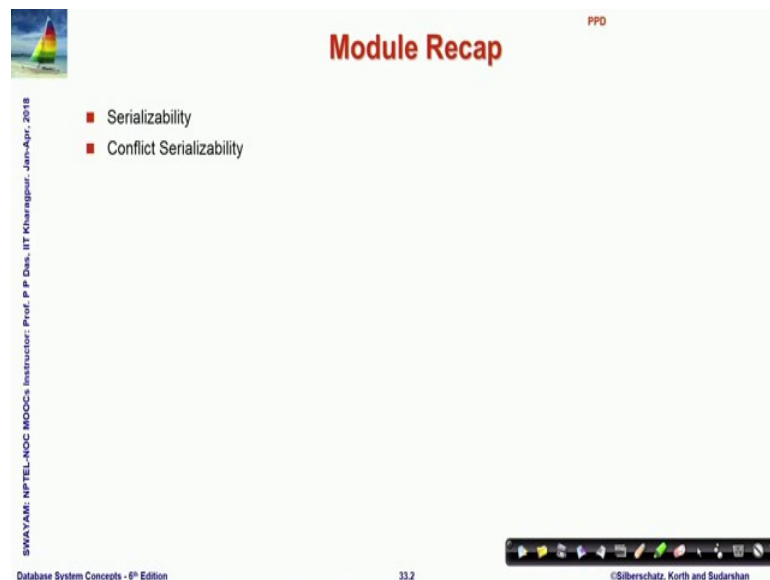


Database Management System
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Indian Institute of Technology, Kharagpur

Lecture – 33
Transactions/3 : Recoverability

Welcome to module 33 of Database Management Systems. This is on transactions again there is a third and closing module on transactions and, we will discuss recoverability issues and some more of the serializability issues in this module.

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The slide is titled "Module Recap" in red text. It features a small sailboat icon in the top left corner. Below the title, there is a list of topics: "Serializability" and "Conflict Serializability", each preceded by a red square bullet point. The slide is part of a presentation, as indicated by the navigation bar at the bottom. The navigation bar includes icons for back, forward, and other navigation functions. The slide number "33.2" is visible in the bottom center. The footer text "Database System Concepts - 6th Edition" and "©Silberschatz, Korth and Sudarshan" are also present.

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Module Recap

- Serializability
- Conflict Serializability

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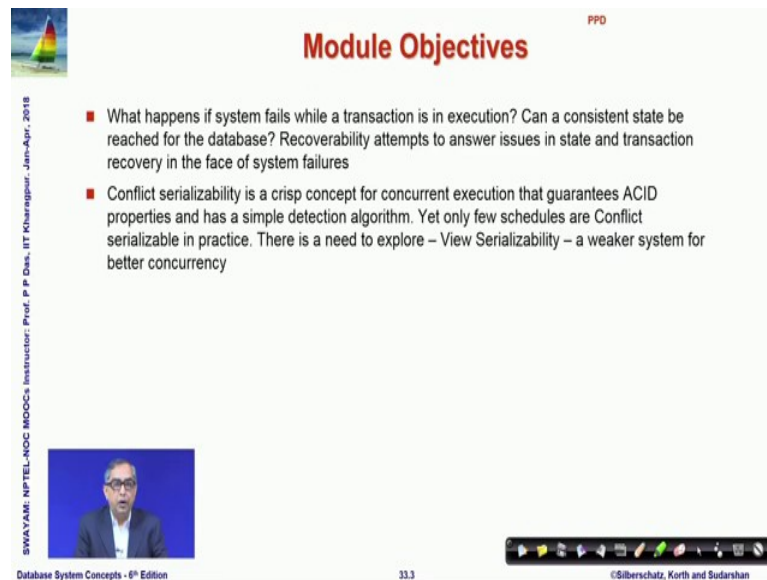
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In the last module we have talked at length about serializability and specifically, we looked at what is known as conflict serializability and the algorithm to detect that. ah

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The slide is titled "Module Objectives" in red text. It contains two bullet points, each preceded by a red square icon. The first bullet point discusses system failure and recovery, while the second discusses conflict serializability and its relationship to ACID properties and view serializability. On the left side, there is a vertical text string "SWAYAM: NPTEL-NOC MOOCs Instructor: Prof. P P Das, IIT Khargpur, Jan-Apr, 2018" and a small video feed of the instructor. At the bottom, there is a footer with "Database System Concepts - 6th Edition", the slide number "33.3", and the copyright notice "©Silberschatz, Korth and Sudarshan".

Module Objectives

- What happens if system fails while a transaction is in execution? Can a consistent state be reached for the database? Recoverability attempts to answer issues in state and transaction recovery in the face of system failures
- Conflict serializability is a crisp concept for concurrent execution that guarantees ACID properties and has a simple detection algorithm. Yet only few schedules are Conflict serializable in practice. There is a need to explore – View Serializability – a weaker system for better concurrency

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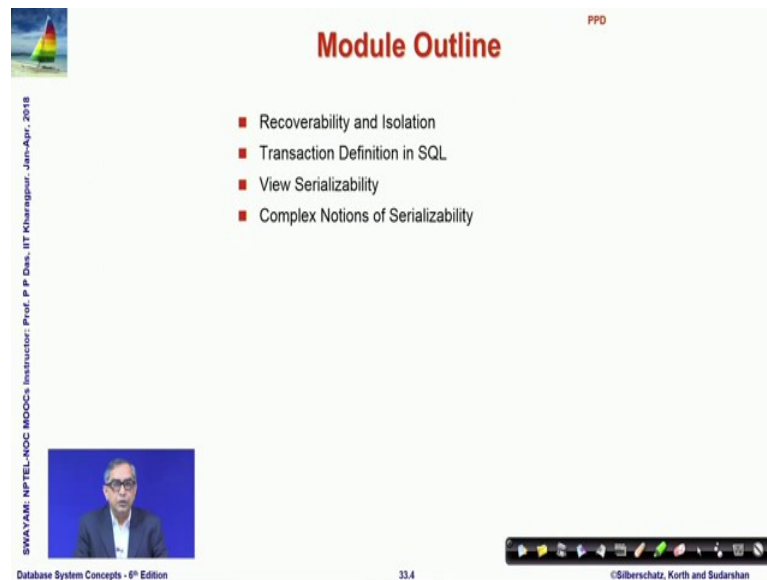
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Now, we would bring in another perspective is if while a transaction is in execution what if the system would fail, the failure may be due to hardware software, various different reasons power outage, disk crash and so on. So, why when that happens the database is likely to come into an inconsistent state. So, we would like to discuss how to recover from that inconsistent state and bring it back to a consistent state.

We would also look at that going forward from conflict serializability, what are the other notions of serializability, that can be used to serialize transactions and we will look at a weaker definition of serializability known as view serializability, which can serialize more schedules than what conflict serializability can give us.

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Module Outline

- Recoverability and Isolation
- Transaction Definition in SQL
- View Serializability
- Complex Notions of Serializability

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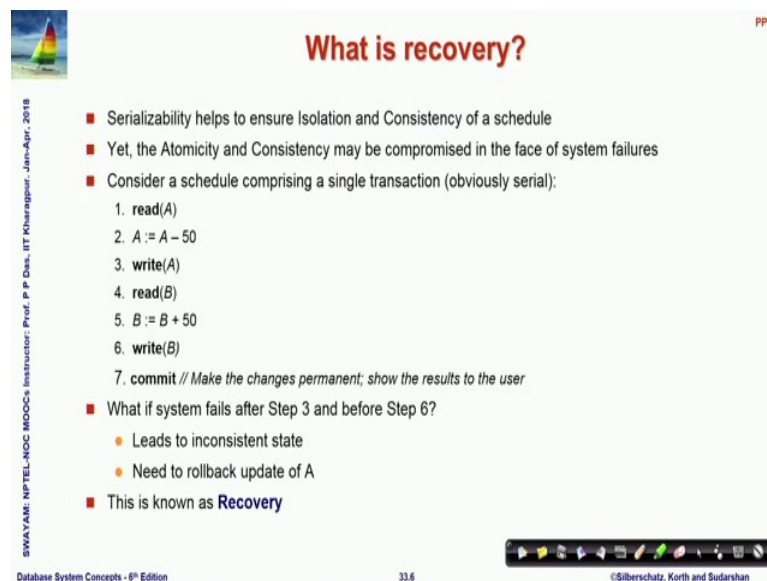
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So, these are the topics to discuss and we start with recoverability and isolation.

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What is recovery?

- Serializability helps to ensure Isolation and Consistency of a schedule
- Yet, the Atomicity and Consistency may be compromised in the face of system failures
- Consider a schedule comprising a single transaction (obviously serial):
 1. `read(A)`
 2. `A := A - 50`
 3. `write(A)`
 4. `read(B)`
 5. `B := B + 50`
 6. `write(B)`
 7. `commit` // Make the changes permanent; show the results to the user
- What if system fails after Step 3 and before Step 6?
 - Leads to inconsistent state
 - Need to rollback update of A
- This is known as **Recovery**

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So, what we have done is we have seen the serializability help us, if we think in terms of the acid properties that we started by defining as the desirable properties of the transactions, we have seen that the serializability significantly helps us to achieve isolation and consistency of a schedule, yet the atomicity and consistency may be compromised, if there is a system failure.

So, we had talked about this example a bit earlier again let us take a look. So, this is a transaction where an amount of 50 dollar is being transferred from account A to account B. So, he first read debit and then write on account A and then read credit and write to account B and we have added a 7th instruction, which is commit and I will talk more about that in this module which makes that changes to A and B permanent and shows a result to the user as well.

Now, what happens if the system fails between step 3 and after step 3 when A has been written and between before step 4 step 6 when B has finally, been written. So, naturally 50 dollars will simply disappear because what has been debited from A and will be available to be seen in account A will the corresponding credit will not be visible.

So, this leads to inconsistent state and to handle that what we need to do is to roll back the transaction, which means that we need to undo the changes that we have already done. So, we have to again go back to account A and write a new value which was the earlier value the value before the debit had happened. And this process of restoring the consistency back to the database is known as the recovery process.

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Recoverable Schedules


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- **Recoverable schedule**
 - If a transaction T_j reads a data item previously written by a transaction T_i , then the commit operation of T_i must appear before the commit operation of T_j .
- The following schedule is not recoverable if T_2 commits immediately after the read(A) operation

T_1	T_2
read (A)	
write (A)	
	read (A)
	commit
read (B)	

- If T_1 should abort, T_2 would have read (and possibly shown to the user) an inconsistent database state. Hence, database must ensure that schedules are recoverable





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So, we say that a so, let us define a schedule to be recoverable if a transaction T_j reads A data previously written by a transaction T_i , then the commit operation of T_i must appear before the commit operation of T_j , if that happens then that is the earlier transaction which has written the data and T_j the later transaction which is reading the data the

earlier transaction has to commit that is make the changes permanent in the database before T_j actually reads it. If that happens, then we say that that schedule is a recoverable schedule.

So, consider a following schedule of transactions T_8 and T_9 where T_8 has read and written A, but has not committed; that means, some more tasks in T_8 are still pending it has not finished, but T_9 then reads A which is a in terms of serializability it is fine, but then T_9 commits and then T_8 is again trying to read B the continues. So, what happens is what if the transaction will fail the transaction T_9 will fail immediately after the read operation.

So, what will happen I am sorry, if T_8 aborts in between, then what will happen that T_9 would have read because, say in read B or of T_8 T_8 aborts that it fails, then T_9 has already read the intermediate value of A and has committed which means it is possibly shown it to the user, but T_8 since it has aborted sent it has failed, it has to be rolled back and the original value of A will be rolled back which is different from what has already been shown to the user and he will reach an inconsistent state.

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Cascading Rollbacks

■ **Cascading rollback** – a single transaction failure leads to a series of transaction rollbacks. Consider the following schedule where none of the transactions has yet committed (so the schedule is recoverable)

T_{10}	T_{11}	T_{12}
read (A)		
read (B)		
write (A)		
	read (A)	
	write (A)	
		read (A)
abort		

■ If T_{10} fails, T_{11} and T_{12} must also be rolled back

■ Can lead to the undoing of a significant amount of work

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So, this is an example of a schedule which is not recoverable. Now let us also observe that a single transaction failure not only means that one transaction needs to be rolled back, but it could have a cascading effect, that is a series of transaction may require a rollback. So, here is an example of T_{10} , T_{11} and T_{12} . So, T_{10} reads A and B and writes A

and then T_{11} reads and writes A and T_{12} reads A and at that time if T_{10} fails if that aborts, then naturally it is not enough to simply roll back T_{10} because, if we roll back T_{10} , then we the value of a goes back to the original and T_{11} would have a wrong value which T_{10} had written, but has now been undone has now been rolled back.

So, it means that T_{11} will also have to be rolled back. Similarly if that is rolled back then naturally T_{12} also have to be rolled back and so on and when this rolling back goes from one transaction to the other we say this is the cascading roll back. And this can lead to a significant amount of work.

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Cascadeless Schedules

- **Cascadeless schedules** — for each pair of transactions T_i and T_j such that T_j reads a data item previously written by T_i , the commit operation of T_i appears before the read operation of T_j .
- Every cascadeless schedule is also recoverable
- It is desirable to restrict the schedules to those that are cascadeless
- Example of a schedule that is NOT cascadeless

T_{10}	T_{11}	T_{12}
read (A)		
read (B)		
write (A)		
	read (A)	
	write (A)	
abort		read (A)

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So, what we would prefer is if we could have schedules where such cascading roll back is not required. So, and there is a there is a condition through which you can achieve that. So, if we have a pair of transaction T_i and T_j . So, that T_j reads A data item previously written by T_i , then the commit operation of T_i has to happen before the read operation of T_j which means that said in other words that T_j should read only read values which are already committed and not read intermediate temporary values of other transactions.

So, every cascable schedule is also recoverable because, you can individually recover that and it is desirable to restrict schedules to those which are cascade less as far as possible, we will see that in non not all cases that is possible, but if it is possible you would like schedules which are cascade less. So, that covered a rollback work the extra

work can be minimized. So, here is an example which we had just seen which is not a cascadable schedule.

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Recoverable Schedules: Example

■ Irrecoverable Schedule

T1	T1's Buffer	T2	T2's Buffer	Database
				A = 5000
R(A);	A = 5000			A = 5000
A = A - 1000;	A = 4000			A = 5000
W(A);	A = 4000			A = 4000
		R(A);	A = 4000	A = 4000
		A = A + 500;	A = 4500	A = 4000
		W(A);	A = 4500	A = 4500
		Commit;		
Failure Point				
Commit;				

Source: <https://www.geeksforgeeks.org/dbs-recoverability-of->

So, wait for word let us take a couple of examples of very similar transactions and, we would see when their schedules are irrecoverable, when their cascaded recovery is possible cascaded rollback is possible and, when cascade less rollback is possible. So, if you so, here what I have done is I have shown here the 2 transactions T_1 and T_2 . And this is what transaction T_1 is doing and we assume that in the in the database the initial value of a is 5000.

So, what will happen is read here and this value is a different A this is in the buffer or the memory of T_1 transaction, where A becomes 5000, then you subtract 1000 and then you write back the moment you write back in the database in between the value in the database is not changing, it is only that value is only in the buffer and, when you write back the value in the database has changed.

And then transaction T_2 reads that value. So, in its local buffer A becomes 4000 it increments by 500 and then writes it back and when that happens, then in the database also the value has changed to 4500 and then T_2 commits and at this point let us assume that there was if there was a failure. So, this is the point where there was a failure there were other instructions in T 1 as well which is not of our interest right now, and then T_1 would have committed, but what happens if the failure happens at this point naturally the

T₁ needs to roll back T₁ needs to undo this and set the this value 5000 back into the database.

But that would mean that what T₂ has committed T₂ has already committed this value 4500 in the database and therefore, that has been probably been used in other places and shown to the user that will create an inconsistency in the database. So, these are this is a schedule of T₁ and T₂ which cannot be recovered from. So, let us and so what it has what has been violated that T₂ has actually read A value which was in transit and, then it has already committed based on that read value.

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Recoverable Schedules: Example

■ Recoverable Schedule without cascading rollback

T1	T1's Buffer	T2	T2's Buffer	Database
				A = 5000
R(A);	A = 5000			A = 5000
A = A - 1000;	A = 4000			A = 5000
W(A);	A = 4000			A = 4000
Commit;				
		R(A);	A = 4000	A = 4000
		A = A + 500;	A = 4500	A = 4000
		W(A);	A = 4500	A = 4500
		Commit;		

Source: <https://www.geeksforgeeks.org/databases-recoverability-of/>

Now, let us look into the next. So, what has been done here that all the changes are the same, but the only point that we have done is we have changed the point where the commit happens again still the T₂ is reading the same value in our in a and is making the updates 4500, but the commit happens at a later point of time after the commit of this transaction T₁ has taken place.

So, this is recoverable, but if we want to recover T₁ naturally; that means, that for T₁ to be recovered, I also need to recover T₂ because T₂ is used a value which is not going to be the value in after the rollback of T₁ has happened T₂ has used 4000, but after the rollback the value in the database will be back to 5000. So, it is the rollback is required for T₁ as well as in T₂. So, this is a case of cascaded cascading roll back that has

happened. So, some more work is being done and that has happened because T₂ now here the rollback is possible because T₂ is committing after T₁.

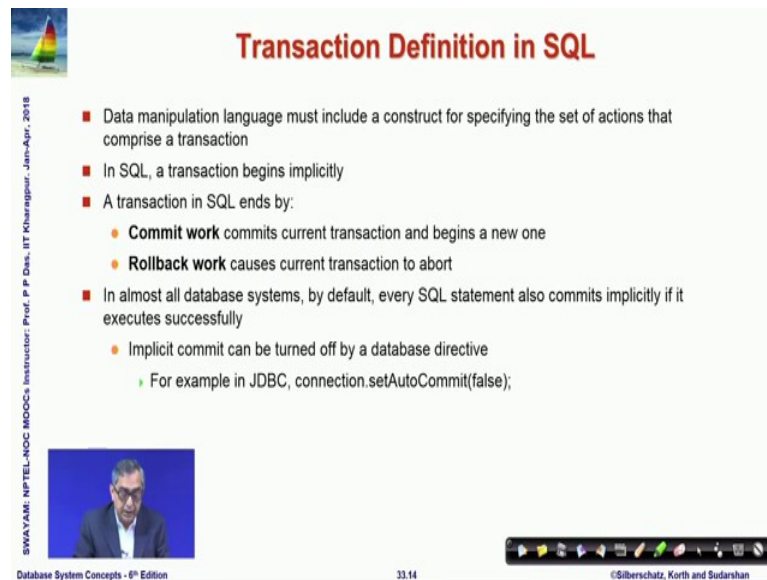
So, the transaction it is reading from it is actually committing the changes after that source transaction has committed. So, that satisfies the condition of recoverable schedule. So, you are able to recover, but it still required the cascading because T₁ had read A value in here of A which was not yet committed. So, if we would have committed that, then we would have been able to actually create a schedule which is cascade less as we see in the next slide.

So, now I what the change that has happened is a commit is done, right after writing the value of A and T₂ reads that only after that commit has happened, earlier it was reading before that commit has happened. So, once T₂ reads it after this commit. So, if there is some there is some requirement of if there is some situation of rollback, then only T₁ needs to be rolled back and T₂ does not need to be a rollback because, it has used a value which is already committed.

So, this is the basic through the example you can clearly see, what is how the rollback can happen and in a later module, we will discuss the processes of how to do this kind of rollback the cascading and non cascading both kinds and show how to go ahead with that, but now for now what we learned is schedules need to be recoverable and, preferably cascade less rollback recovery schedules are preferred in case of database transactions.

Now, let us move on and talk little bit about what is available in SQL language in terms of handling transactions.

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Transaction Definition in SQL

- Data manipulation language must include a construct for specifying the set of actions that comprise a transaction
- In SQL, a transaction begins implicitly
- A transaction in SQL ends by:
 - **Commit work** commits current transaction and begins a new one
 - **Rollback work** causes current transaction to abort
- In almost all database systems, by default, every SQL statement also commits implicitly if it executes successfully
 - Implicit commit can be turned off by a database directive
 - ▶ For example in JDBC, `connection.setAutoCommit(false);`

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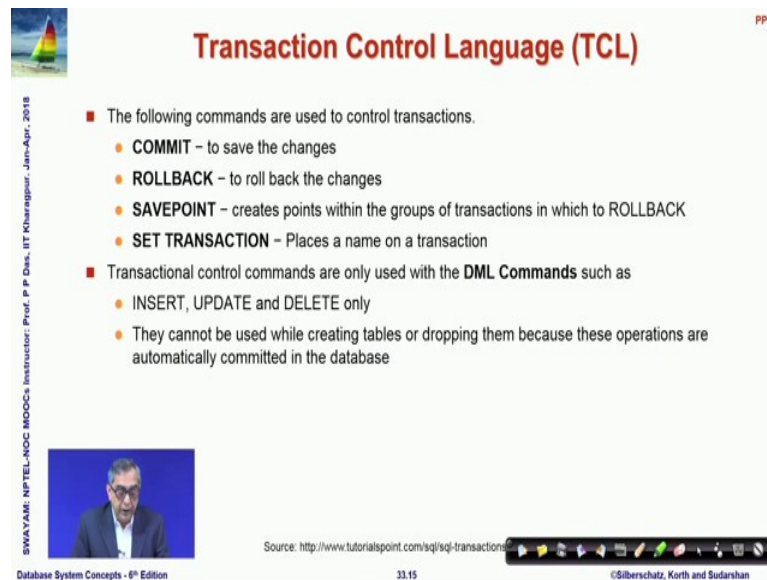
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So, SQL we have seen the kind of DDL data definition and data manipulation language paths and those were discussed in terms of our interactive session as well. As a part of data manipulation it is also possible to specify certain specific transaction events. So, a transaction in SQL typically begins implicitly and, it ends by a commit work which says that let us, you commit the current transaction that is make all the changes permanent, in the database make it visible to the user and begin a new work, or it could roll back the transaction which means that all the changes that you had done are rolled back and the transaction basically aborts.

So, in almost all systems by default every SQL statement commits implicitly and, if it has been able to execute successfully, otherwise it rolls back and this implicit commit can be controlled also, it can be in different system there are different ways to control that and say that I do not want implicit commit I would only want commit to be done explicitly.

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Transaction Control Language (TCL)

- The following commands are used to control transactions.
 - **COMMIT** – to save the changes
 - **ROLLBACK** – to roll back the changes
 - **SAVEPOINT** – creates points within the groups of transactions in which to ROLLBACK
 - **SET TRANSACTION** – Places a name on a transaction
- Transactional control commands are only used with the **DML Commands** such as
 - INSERT, UPDATE and DELETE only
 - They cannot be used while creating tables or dropping them because these operations are automatically committed in the database

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Source: <http://www.tutorialspoint.com/sql/sql-transactions>

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So, for that purpose a part of SQL called the transaction control language has different instructions commit to save the changes roll back to roll back, the changes undo the changes and also to do some do, it in some controlled way by defining savepoint and you can also set the a particular name to a transaction and it is behavior.

So, let us look at examples for doing that soon and these TCL commands are used with specific DML commands they are meaningful in terms of insert update and delete only for example, if you are creating a database or you are doing a select to data retrieval, then these instructions have no role in those transactions.

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TCL: COMMIT Command

- The COMMIT is the transactional command used to save changes invoked by a transaction to the database
- The COMMIT saves all the transactions to the database since the last COMMIT or ROLLBACK command
- The syntax for the COMMIT command is as follows:
 - SQL> DELETE FROM Customers WHERE AGE = 25;
 - SQL> COMMIT;

Before DELETE

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
2	Khilan	25	Delhi	1500
3	kaushik	23	Kota	2000
4	Chaitali	25	Mumbai	6500
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

After DELETE

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
3	kaushik	23	Kota	2000
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

SQL> SELECT * FROM Customers;

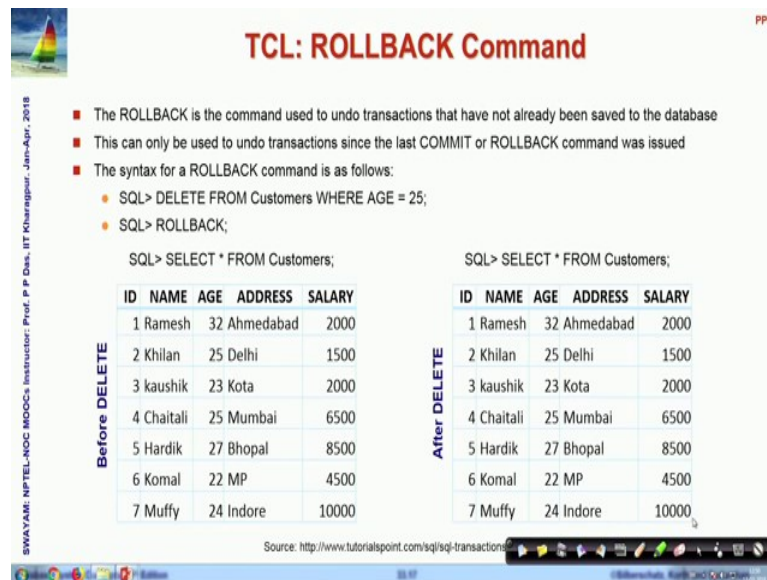
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So, **COMMIT** is a transaction command which is used to save changes and make them permanent based on what has been invoked. So, here you see the example of a customer database and, what I am showing is if you this is the initial state of that table and, before any value has been deleted and if you do select star from customers these 7 records is what you get to see, in view of that you do a delete and then you commit the delete.

So, we say that I have deleted and make that deletion permanent. So, deleting based on age. So, this record is supposed to be get deleted and this record is supposed to get deleted and, after I have done the commit then again if I do the same data retrieval. And now I get to see 5 records only the 2 record number 2 and record number 4 have been permanently deleted. So, this is the way you can explicitly do commit and make the changes permanent.

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TCL: ROLLBACK Command

- The ROLLBACK is the command used to undo transactions that have not already been saved to the database
- This can only be used to undo transactions since the last COMMIT or ROLLBACK command was issued
- The syntax for a ROLLBACK command is as follows:
 - SQL> DELETE FROM Customers WHERE AGE = 25;
 - SQL> ROLLBACK;

SQL> SELECT * FROM Customers;

Before DELETE

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
2	Khilan	25	Delhi	1500
3	kaushik	23	Kota	2000
4	Chaitali	25	Mumbai	6500
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

SQL> SELECT * FROM Customers;

After DELETE

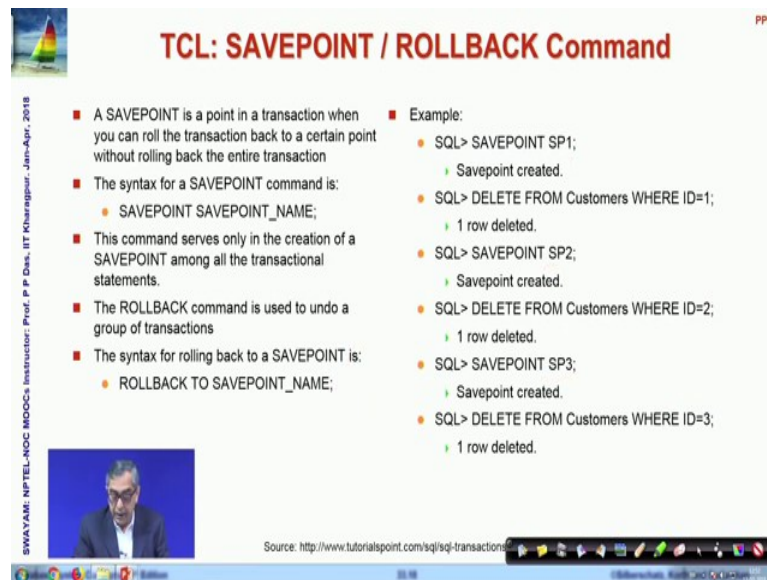
ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
2	Khilan	25	Delhi	1500
3	kaushik	23	Kota	2000
4	Chaitali	25	Mumbai	6500
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

Source: <http://www.tutorialspoint.com/sql/sql-transactions>

In terms of rollback it is a command which is used to undo transactions that is the changes that have already not been saved to the database you can roll back.

So, you can roll back or undo transactions only back up in history up to the last commit, or the last rollback command was issued on this. So, again looking at the same example this is the initial state and, then you did a delete as we did last time. So, these 2 records are to be deleted, but then instead of commit we have given a rollback. So, as you give rollback these deletion operations get undone. So, these two records are again back to the table and so, after the rollback if I again do the select I will get to see the 2 records back in my list. So, this is the purpose of the rollback command.

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TCL: SAVEPOINT / ROLLBACK Command

- A SAVEPOINT is a point in a transaction when you can roll the transaction back to a certain point without rolling back the entire transaction
- The syntax for a SAVEPOINT command is:
 - SAVEPOINT SAVEPOINT_NAME;
- This command serves only in the creation of a SAVEPOINT among all the transactional statements.
- The ROLLBACK command is used to undo a group of transactions
- The syntax for rolling back to a SAVEPOINT is:
 - ROLLBACK TO SAVEPOINT_NAME;

Example:

- SQL> SAVEPOINT SP1;
Savepoint created.
- SQL> DELETE FROM Customers WHERE ID=1;
1 row deleted.
- SQL> SAVEPOINT SP2;
Savepoint created.
- SQL> DELETE FROM Customers WHERE ID=2;
1 row deleted.
- SQL> SAVEPOINT SP3;
Savepoint created.
- SQL> DELETE FROM Customers WHERE ID=3;
1 row deleted.

Source: <http://www.tutorialspoint.com/sql/sql-transactions.htm>

Now, you can a transactions often could be long. So, within the transaction you may want to mark certain points. So, that in case you roll back or you need to roll back, you can roll back to that particular point and those points are in the transaction are known as the **SAVEPOINT**. So, this is the format use a save point and give it a name and, then later on you can use those save points for your purpose of rollback.

So, you are again if you are doing a rollback, then you instead of just doing rollback, you now use the save point ID that you had used in naming that particular point up to which you want to roll back and, do a rollback and that will happen only up to that point. So, let us look at an example so, here it is a series of instructions in a in a DML transaction. So, I initially set SP one as a save point that is I may want to roll back to the beginning, when I delete one record say ID 1. So, 1 record gets deleted, then I again save another save point another save point SP 2 this was SP 1 and, then delete a second record another save point delete another record.

So, now I have a control to undo at this point have a control to undo to 3 points for example, if I do a rollback to SP 3 I will roll back to this point, where only this record will be deletion of this record will be undone, but the first 2 records will still look show as deleted, but if I roll back to save point SP 2, then 2 records ID 2 and ID 3 that were deleted their deletion will be undone and only 1 deletion will look up. Similarly if I roll back to SP 1, it will show that no deletion as it all happened.

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TCL: SAVEPOINT / ROLLBACK Command

- Three records deleted
- Undo the deletion of first two
- SQL> ROLLBACK TO SP2;
 - Rollback complete

SQL> SAVEPOINT SP1;
SQL> DELETE FROM Customers WHERE ID=1;
SQL> SAVEPOINT SP2;
SQL> DELETE FROM Customers WHERE ID=2;
SQL> SAVEPOINT SP3;
SQL> DELETE FROM Customers WHERE ID=3;

SQL> SELECT * FROM Customers;

At the beginning

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
2	Khilan	25	Delhi	1500
3	kaushik	23	Kota	2000
4	Chaitali	25	Mumbai	6500
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

SQL> SELECT * FROM Customers;

After ROLLBACK

ID	NAME	AGE	ADDRESS	SALARY
2	Khilan	25	Delhi	1500
3	kaushik	23	Kota	2000
4	Chaitali	25	Mumbai	6500
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

Source: <http://www.tutorialspoint.com/sql/sql-transactions>

So, if I do that on the this is the initial state on the left to the initial state of the database 3 records have been deleted and, then I do undo off the first deletion of the first 2 and I roll back to SP 2.

So, then when I undo the deletion of the last 2 records, then the what I see is the records which are marked as ID 2 and ID 3, which were done after SP 2 was marked which were deleted after SP 2 are marked, they are back into the table whereas, the deletion of SP 1 is still in effect and therefore, deletion that was none after SP 1 that is of record ID 1 is still missing and in this way you can control and roll back to any specific point in a database in a database transaction.

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TCL: RELEASE SAVEPOINT Command

- The RELEASE SAVEPOINT command is used to remove a SAVEPOINT that you have created
- The syntax for a RELEASE SAVEPOINT command is as follows:
 - RELEASE SAVEPOINT SAVEPOINT_NAME;
- Once a SAVEPOINT has been released, you can no longer use the ROLLBACK command to undo transactions performed since the last SAVEPOINT

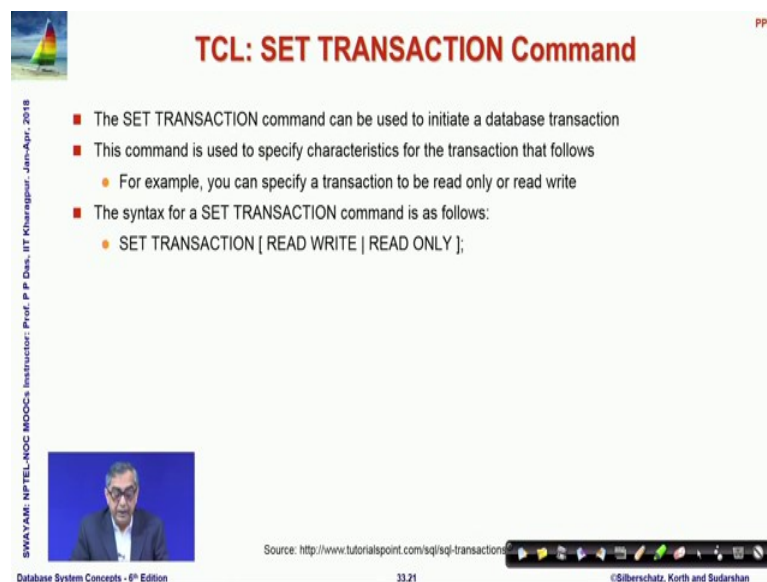
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Source: <http://www.tutorialspoint.com/sql/sql-transactions>

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You can once you have marked a safe point you can also, release the safe point that is you can choose to forget that safe point. Once a safe point has been released you cannot roll back to that safe point naturally.

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TCL: SET TRANSACTION Command

- The SET TRANSACTION command can be used to initiate a database transaction
- This command is used to specify characteristics for the transaction that follows
 - For example, you can specify a transaction to be read only or read write
- The syntax for a SET TRANSACTION command is as follows:
 - SET TRANSACTION [READ WRITE | READ ONLY];

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Source: <http://www.tutorialspoint.com/sql/sql-transactions>

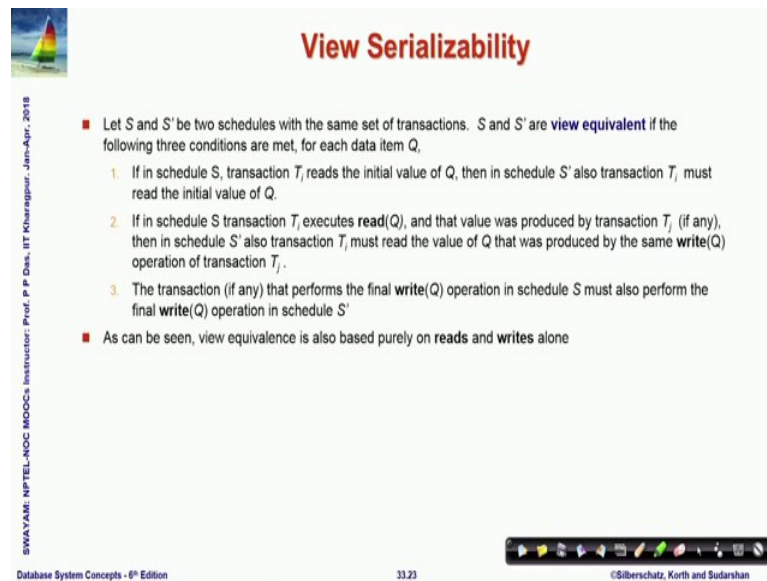
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You can use **SET TRANSACTION** command to initiate a database transaction also and, it is typically used to specify the characteristics of the transaction, particularly if you want to say whether a transaction is a read only transaction or a read write transaction,

then you can do it in this way, you can say set transaction and give a read or write flag read or write or read only flag for that.

Let us quickly take a look at a different form of serializability besides the conflict serializability is called view serializability.

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View Serializability

- Let S and S' be two schedules with the same set of transactions. S and S' are **view equivalent** if the following three conditions are met, for each data item Q ,
 1. If in schedule S , transaction T_i reads the initial value of Q , then in schedule S' also transaction T_i must read the initial value of Q .
 2. If in schedule S transaction T_i executes $\text{read}(Q)$, and that value was produced by transaction T_j (if any), then in schedule S' also transaction T_i must read the value of Q that was produced by the same $\text{write}(Q)$ operation of transaction T_j .
 3. The transaction (if any) that performs the final $\text{write}(Q)$ operation in schedule S must also perform the final $\text{write}(Q)$ operation in schedule S' .
- As can be seen, view equivalence is also based purely on reads and writes alone

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So, in terms of view serializability we again define what is known as when are 2 transactions defined to be view equivalent, earlier you remember we define 2 schedules to be conflict equivalent, now we are defining view equivalent. So, there are 3 conditions the conditions are simple what conditions say is a to try a schedules are view equivalent, if the transaction the initial value that a transaction reads is same in both these schedules, for every transaction the initial value that it reads must be the same between the 2 schedules.


Similarly, the third condition says that the final write that is done, final value that it writes every transaction writes in both the schedules must be the same the same writes should operate. And the second conditions is a read write pair that every transaction when it performs a read on the data item, it must read from the write corresponding write in the other schedule in by the same by the transaction that which did the write.

So, I always initialize start with the same initial values for every data item in both schedules, I always read from the corresponding right in the same schedule in the 2

schedules and, I must write the final in every transaction every data item must be written in the same way in the 2 schedules.

So, this is again and the key balance is based purely on read write alone as is the case of conflict equivalence also.

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View Serializability (Cont.)

- A schedule S is **view serializable** if it is view equivalent to a serial schedule
- Every conflict serializable schedule is also view serializable
- Below is a schedule which is view-serializable but *not* conflict serializable

T_{27}	T_{28}	T_{29}
read (Q)	write (Q)	
write (Q)		
		write (Q)

- What serial schedule is above equivalent to?
 - $T_{27} \rightarrow T_{28} \rightarrow T_{29}$
 - The one read(Q) instruction reads the initial value of Q in both schedules and
 - T_{29} performs the final write of Q in both schedules
- T_{28} and T_{29} perform write(Q) operations called **blind writes**, without having performed a read(Q) operation
- Every view serializable schedule that is not conflict serializable has **blind writes**

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So, given the definition of view equivalence, we can say schedule is the view serializable, if it is view equivalent to a serial schedule earlier which said that a schedule is conflict serializable, if it is conflict equivalent to a serial schedule. Now we are defining the view serializability, with a little bit of thought you can convince yourself that every conflict serializable schedule is also view serializable, but the reverse is not true.

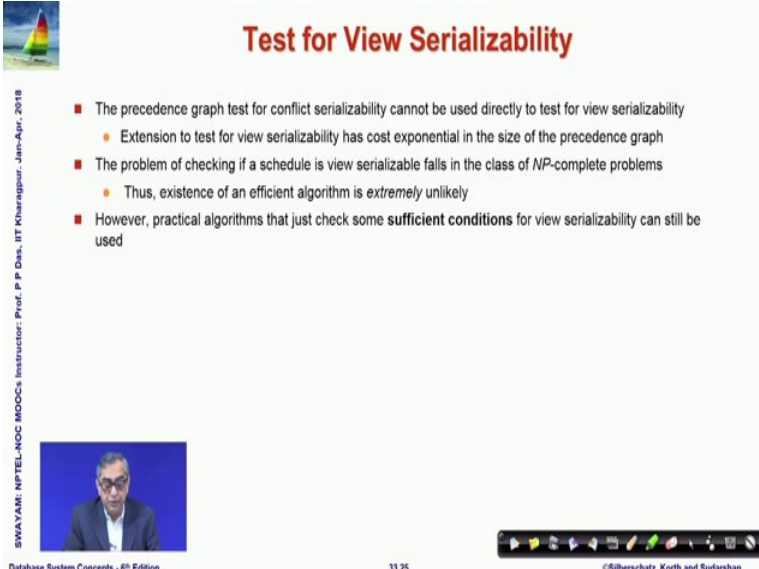
So, here is a schedule which is view serializable, but it is not conflict serializable, you know this is not conflict serializable because, certainly you cannot make it into a serial schedule make it equivalent to a serial schedule because, you cannot move this right Q above the right Q of T_{28} or of T_{29} , but you cannot move this either. So, given that but if you in terms of the view equivalence we balance, then you will say that this is equivalent to a serial schedule and what should be the serial schedule; obviously, there are 6 choices because there are 3 schedules.

So, there are 6 possible permutations which give you 6 different serial schedules and if in that so our first condition says that I must read from the same value so; obviously, T_{27} reads the initial value of Q. So, T_{27} has to be the first transaction, if the third condition says that I must do the same right T_{29} does the final write here. So, the in the serial schedule also T_{29} must be the last one. So, T_{28} has to be the middle one.

So, the serial schedule that this is equivalent to is $T_{27} T_{28} T_{29}$ and, the one reads and the other 2 writes and T_{29} performs a final write. So, you can see that this is a this is not a conflict serializable, but this is view serializable and if you note the view serializability moment, you have you view serializability and you may not have conflict serializability, then you must be having certain blind rights, these are called blind rights this is a blind right, in the sense that here you are writing the value of Q in T_{28} without having read it is current or previous value. So, you have just blindly you had just computed some value and you are writing to that.

So, if a schedule is not conflict serializable, but is view serializable it must have performed some blind rights where it has written data without actually reading it. So, this is a weaker form of serializability that is possible.

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Test for View Serializability

- The precedence graph test for conflict serializability cannot be used directly to test for view serializability
 - Extension to test for view serializability has cost exponential in the size of the precedence graph
- The problem of checking if a schedule is view serializable falls in the class of NP-complete problems
 - Thus, existence of an efficient algorithm is *extremely unlikely*
- However, practical algorithms that just check some **sufficient conditions** for view serializability can still be used

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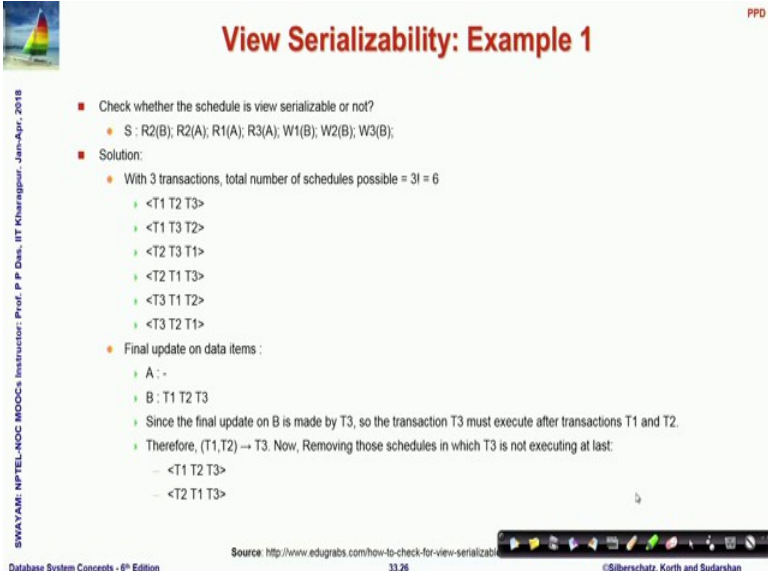
Now the question is similar to conflict serializability, where we saw that it schedule can be conflict serializable, if it is corresponding precedence graph is a cyclic. So, we would

like to extend find out similar test for view serializability, but as it turns out that trying to find out this is exponential in cost in terms of the size of the precedence graph.

So, it has been proved that the of checking, whether a schedule is view serializable is in the class of NP complete problem. So, if you are good in algorithms. So, you will know what NP problems are and when are problems called NP complete, in very simple terms even if you are not familiar with that depth of algorithms, you can simply issue note that if an algorithm is NP complete, then it is extremely unlikely that there exists in efficient algorithm for.

It there exists any kind of polynomial time algorithm, it is extremely unlikely still not it is still an open problem in computer science, whether a tall polynomial algorithm exists for NP complete problems, but it is extremely unlikely that an efficient algorithm will exist, you may have some approximate algorithms which can give sufficiency conditions which can say that well if these conditions are satisfied, then necessarily a schedule is view serializable, but not a sufficient condition are not a necessary condition, that is in other words that there may be some schedules which do not satisfy the sufficient condition, but are still view serializable.

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View Serializability: Example 1

Check whether the schedule is view serializable or not?

S : R2(B); R2(A); R1(A); R3(A); W1(B); W2(B); W3(B);

Solution:

- With 3 transactions, total number of schedules possible = $3! = 6$
- <T1 T2 T3>
- <T1 T3 T2>
- <T2 T3 T1>
- <T2 T1 T3>
- <T3 T1 T2>
- <T3 T2 T1>

Final update on data items :

- A : -
- B : T1 T2 T3

Since the final update on B is made by T3, so the transaction T3 must execute after transactions T1 and T2.

Therefore, (T1,T2) → T3. Now, Removing those schedules in which T3 is not executing at last:

- <T1 T2 T3>
- <T2 T1 T3>

Source: <http://www.edugrabs.com/how-to-check-for-view-serializability/>

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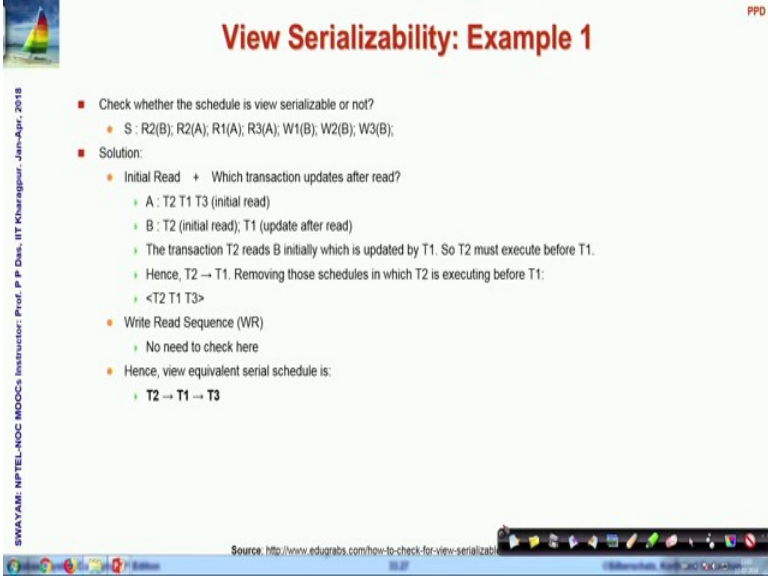
So, using view serializability have certain problems. So, here I have worked out a longer problem in terms of the view serializability to check that. So, it is kind of a brute force algorithm. So, if you see this is the schedule given there are two data items A and B and

there are 3 transactions T_1 T_2 T_3 . Since there are three transactions, then if I want to prove if it is view serializable, then what I will have to do I will have to find a one of the possible serial schedules which is view equivalent to this?

So, first I list out all the serial schedules given 3 transactions, there are 6 serial schedules and then I first start with condition three which is who is doing the last update. So, there are writes are only on B. So, and last of that are being done in all the 3 transactions. So, there is no write on A so, the list of final update on A is empty and for B the order is T_1 T_2 T_3 so, T_3 does the last.

So, it must whatever schedule this whatever serial schedule this given schedule S has to be view equivalent to must have T_3 as the last transaction to execute. So, only these two are the candidates which may be view equivalent to this schedule S.

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View Serializability: Example 1

- Check whether the schedule is view serializable or not?
 - S : R2(B); R2(A); R1(A); R3(A); W1(B); W2(B); W3(B);
- Solution:
 - Initial Read + Which transaction updates after read?
 - A : T2 T1 T3 (initial read)
 - B : T2 (initial read), T1 (update after read)
 - The transaction T2 reads B initially which is updated by T1. So T2 must execute before T1.
 - Hence, T2 → T1. Removing those schedules in which T2 is executing before T1:
 - <T2 T1 T3>
 - Write Read Sequence (WR)
 - No need to check here
 - Hence, view equivalent serial schedule is:
 - T2 → T1 → T3

Source: <http://www.edugrabs.com/how-to-check-for-view-serializability/>

So, we reduce down and now we have only to decide whether these two any of these two are view equivalent to the given schedule S. So, moving on with that now next we check condition 1 and condition 2 together.

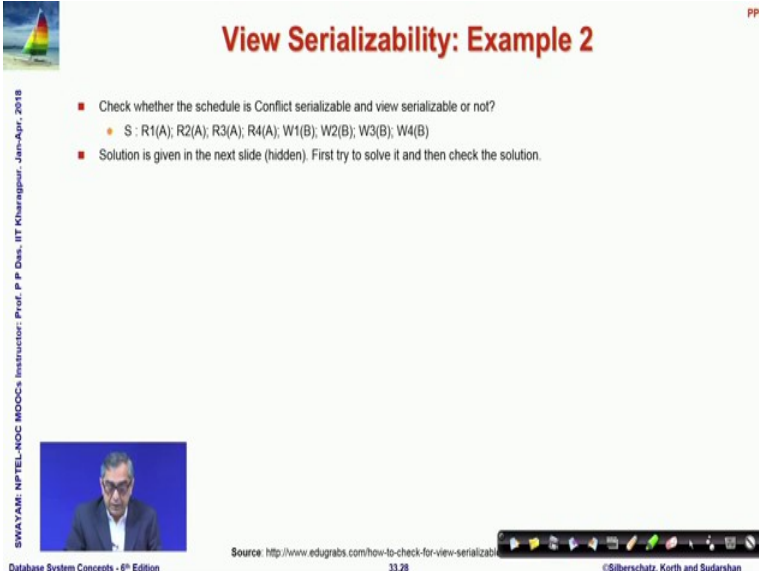
So, condition one checks that they must read the same value in both the schedule. So, we see that these are the reads that are happening on A. So, we see that on A there are reads happening, I am sorry this is these are the three that is reading A. So, it happens in the order of T_2 T_3 T_1 and T_3 .

So, this is what you find and in terms of B we find that transaction 2 reads B and writes it. So, it has to be in that order. So, it reads it does an initial read in terms of T_2 and, then the first right of that read value is happening in the transaction T_1 after the update of the read.

So, that means, that whatever schedule we look for in terms of view equivalence, they must have in that schedule T_1 must follow T_2 . So, T_2 must happen first because it needs to read the initial value and, then that initial value is used by then there is a right on by T_1 . So, T_2 has to come before T_1 so; that means, we are already in terms of only 2 we have seen that there are two possible candidates based on condition 3, it is $T_2 T_1 T_3$.

So, in these two we only can have this one which is satisfying the other conditions and there is no read write sequence. So, we conclude that indeed $T_2 T_1 T_3$ satisfies all the three conditions of initial read write after read and the final write conditions and therefore, this given schedule S is actually view equivalent to a serial schedule and, it is a view serial schedule and can be used safely for the transaction.

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View Serializability: Example 2

- Check whether the schedule is Conflict serializable and view serializable or not?
- S : $R_1(A); R_2(A); R_3(A); R_4(A); W_1(B); W_2(B); W_3(B); W_4(B)$
- Solution is given in the next slide (hidden). First try to solve it and then check the solution.

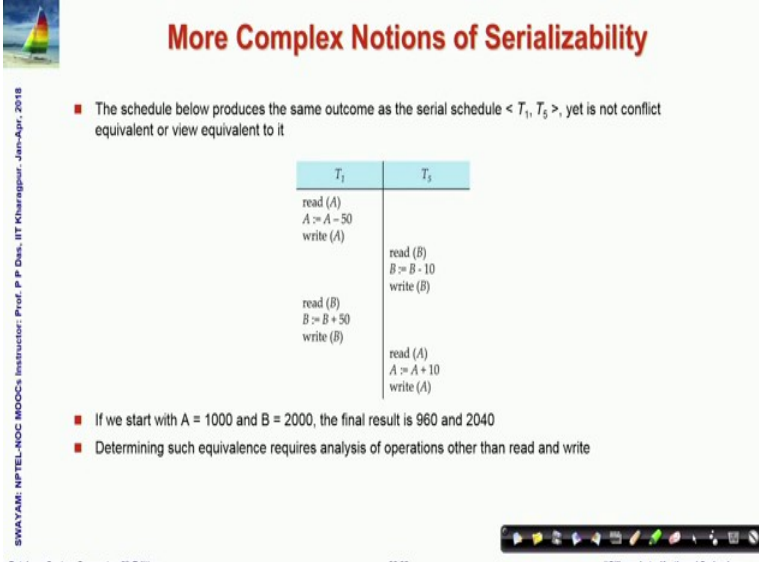
Source: <http://www.edugrabs.com/how-to-check-for-view-serializability/>

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There is another example given here, where there is there are four transactions $R_1 R_2 R_3$ and R_4 and there are 2 data items A and B and, you have to find out establish whether this is view serializable or not, I am not working out this one this is worked out in the presentation slide, but I will not show it here you are you should first try it out and, then

once you have been able to do it or you are unable to do that, then you check the solution from the presentation slide.

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More Complex Notions of Serializability

- The schedule below produces the same outcome as the serial schedule $\langle T_1, T_5 \rangle$, yet is not conflict equivalent or view equivalent to it

T_1	T_5
read (A)	
$A := A - 50$	
write (A)	
	read (B)
	$B := B - 10$
	write (B)
read (B)	
$B := B + 50$	
write (B)	
	read (A)
	$A := A + 10$
	write (A)

- If we start with $A = 1000$ and $B = 2000$, the final result is 960 and 2040
- Determining such equivalence requires analysis of operations other than read and write

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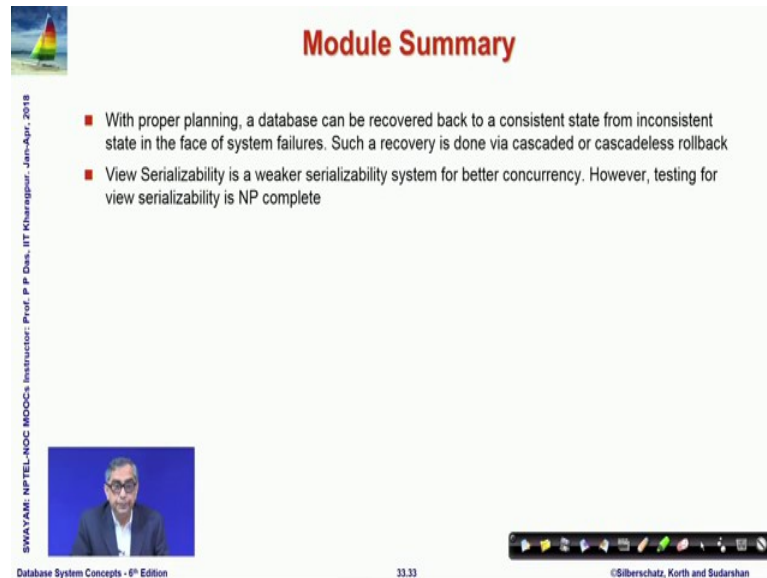
There are different other complex notions of serializability also for example, if you look at this particular schedule this actually is a serializable schedule, this is the effect that it produces will be same as the serial schedule of $T_1 T_5$, but if you go through the definitions of conflict equivalence and, view equivalence you will be able to show that this schedule is neither conflict conflict serializable nor view serializable, but yet given the particular.

So, if you just look at the read write this is not a serializable schedule in terms of conflict or view equivalence, but given the fact that it actually performs simple add subtract operations on these variables, using the properties of add subtract operations you would be able to you can actually see that this particular schedule actually is a serializable schedule and, you will get whatever initial values you start with the value that you will achieve through this schedule and the value that will achieve with the serial schedule $T_1 T_5$ are indeed same in every case.

But this is determining this requires the understanding of other instructions other operations, besides the read and write. So, this is just to show you that using the read write model and conflict and view equivalents and the only not the only ways of getting

to serializability there are more complex models, but we will not go into the depth of these complex serializability aspect.

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The slide is titled "Module Summary" in red text. It contains two bullet points, each preceded by a red square icon. The first bullet point discusses database recovery from an inconsistent state to a consistent state using cascaded or cascadeless rollback. The second bullet point discusses View Serializability as a weaker serializability system for better concurrency, noting that testing for view serializability is NP complete. The slide includes a small video inset of a man in the bottom left corner. At the bottom, there is a footer with the text "Database System Concepts - 6th Edition", the slide number "33.33", and the copyright notice "©Silberschatz, Korth and Sudarshan". A vertical text on the left side of the slide reads "SWAYAM: NPTEL-NOC MOCs Instructor: Prof. P.P. Das, IIT Kharagpur, Jan-Apr, 2018".

Module Summary

- With proper planning, a database can be recovered back to a consistent state from inconsistent state in the face of system failures. Such a recovery is done via cascaded or cascadeless rollback
- View Serializability is a weaker serializability system for better concurrency. However, testing for view serializability is NP complete

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So, we have shown that with we have shown here that with proper planning, a database can be recovered back to a consistent state from an inconsistent state, in case of system failure.

And this such a recovery can be through cascaded or cascadeless rollback and, we have also introduced a simpler model of serializability in terms of the view serializable, but testing for view serializability is np complete. So, as an effective algorithm it is not that powerful.