Concurrency Control

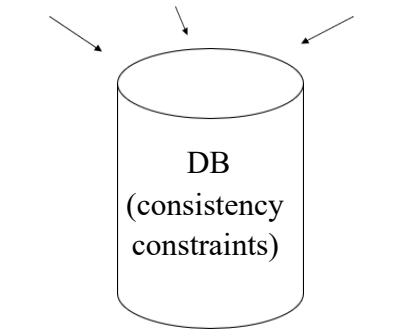
- Schedule
- Conflict Serializable Schedule
- Two phase locking
- Warning Protocol
- Validation

Week15_Course

Database System_Concurrency Control part1

Schedule

Concurrency Control



How to prevent harmful interference between transactions?

=> **scheduling techniques** based on
- locks
- timestamps and validation

Correctness depends on scheduling of transactions

A schedule

- Chronological (possibly interleaving) order in which actions of transactions are executed

- A correct schedule is equivalent to executing transactions one-at-a-time in some order

T1	T2	T3
Write (A)	Write (B)	Write (C)
Write (B)	Write (C)	Write (A)
Write (D)	Write (D)	

Example:

Constraint: A=B

T1:	T2:
Read(A)	Read(A)
A ← A+100	A ← A×2
Write(A)	Write(A)
Read(B)	Read(B)
B ← B+100	B ← B×2
Write(B)	Write(B)

Schedule A

T1	T2
Read(A); A ← A+100;	
Write(A);	
Read(B); B ← B+100;	
Write(B);	
	Read(A);A ← A×2;
	Write(A);
	Read(B);B ← B×2;
	Write(B);

OK

S_A=r1(A)w1(A) r1(B)w1(B)r2(A)w2(A)r2(B)w2(B)

A	B
25	25
125	
	125
250	
	250
250	250

Schedule B

T1	T2
	Read(A);A ← A×2;
	Write(A);
	Read(B);B ← B×2;
	Write(B);
Read(A); A ← A+100;	
Write(A);	
Read(B); B ← B+100;	
Write(B);	

OK

A	B
25	25
50	
	50
150	
	150
150	150

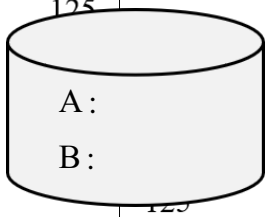
Schedule C

T1	T2
Read(A); A ← A+100	
Write(A);	
	Read(A);A ← A×2;
	Write(A);
Read(B); B ← B+100;	
Write(B);	
	Read(B);B ← B×2;
	Write(B);

OK

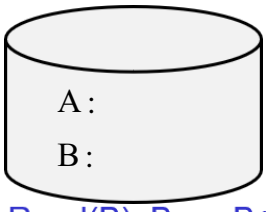
Sc=r1(A)w1(A)r2(A)w2(A)r1(B)w1(B)r2(B)w2(B)

A	B
25	25
125	
	125
	250
250	250



Schedule D

T1	T2
Read(A); A ← A+100;	
Write(A);	
	Read(A);A ← A×2;
	Write(A);
	Read(B);B ← B×2;
	Write(B);
Read(B); B ← B+100;	
Write(B);	



Constraint violation!

A	B
25	25
125	
250	
	50
	150
250	150

Schedule E

Same as Schedule D but with new T2'

T1	T2'
Read(A); A ← A+100;	
Write(A);	
	Read(A);A ← A×1;
	Write(A);
	Read(B);B ← B×1;
	Write(B);
Read(B); B ← B+100;	
Write(B);	

A	B
25	25
125	
125	
	25
	125
125	125

- Want schedules that are "good", regardless of
  - initial state (<–> "good" in *any* DB state) and
  - transaction semantics
- Only look at order of READs and WRITEs
  - Note: transactions see values in buffers, not on disk

  => this time ignore INPUT/OUTPUTs

Example: Sa (Schedule a) =

r1(A)w1(A)r1(B)w1(B) r2(A)w2(A) r2(B)w2(B)

T1 T2

Scheduling Transactions: Definitions

- *Serial schedule:* no concurrency
  - Does not interleave the actions of different transactions.
- *Equivalent schedules*: same result on any DB state
  - For any database state, the effect (on the set of objects in the database) of executing the first schedule is identical to the effect of executing the second schedule.
- *Serializable schedule*: equivalent to a serial schedule
  - A schedule that is equivalent to *some* serial execution of the transactions.

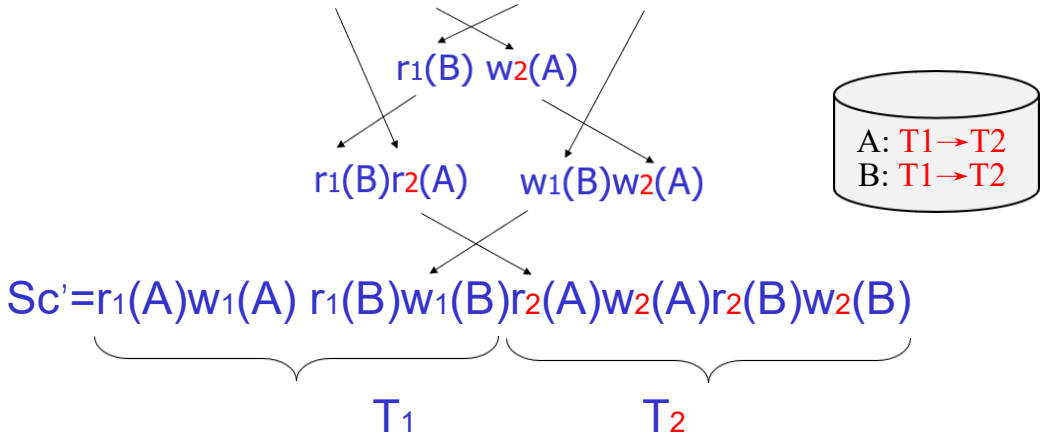
  (Note: If each transaction preserves consistency, every serializable schedule preserves consistency.)

Serial Schedule

- A schedule is **serial**, if actions of transactions are not interleaved
  - e.g., (T1, T2) or (T2, T1)
  - A serial schedule obviously maintains consistency (assuming correctness of individual transactions)
- Could we reorder a schedule into an equivalent serial schedule?
  - Actions **conflict**, if swapping them may change the meaning of a schedule:
    - any two actions of a single transaction
    - two actions on a common DB element A, one of which is WRITE(A)

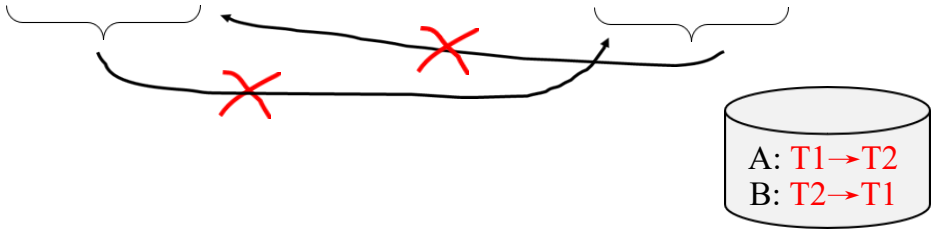
Example: (of swapping non-conflicting actions)

$Sc=r_1(A)w_1(A)r_2(A)w_2(A)r_1(B)w_1(B)r_2(B)w_2(B)$



However, for Sd:

$Sd=r_1(A)w_1(A)r_2(A)w_2(A)r_2(B)w_2(B)r_1(B)w_1(B)$



- Sd cannot be rearranged into a serial schedule
  - ⇨ Sd is not "equivalent" to any serial schedule
  - ⇨ Sd is "bad"

Summary

- Schedule
- Serial Schedule

多选题 1分

互动交流一 一不定项选择题

以下哪一种写法表示的是事务的调度（Schedule）？

A T1 = R1(C) R1(A) W1(C) R1(B) W1(D) W1(B) R1(A)

B S1= W3(A) R1(B) R2(A) R4(D) W1(B) R4(A) W2(B) W1(D) R4(B)

C T2 = R1(C) W1(D) W1(B)　T3 = R2(A) W2(D) W2(B)

D S2= W3(A) R1(B) W1(D) W1(B) R2(A) W2(B)R4(D) R4(A) R4(B)

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多选题 1分

互动交流二

以下哪一个调度是串行调度（Serial Schedule）？

A T1 = R1(C) R1(A) W1(C) R1(B) W1(D) W1(B) R1(A)

B S1= W3(A) R1(B) R2(A) R4(D) W1(B) R4(A) W2(B) W1(D) R4(B)

C T2 = R1(C) W1(D) W1(B)　T23= R2(A) W2(D) W2(B)

D S2= W3(A) R1(B) W1(D) W1(B) R2(A) W2(B) R4(D) R4(A) R4(B)

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Week15_Course

Database System_Concurrency Control part2

Conflict Serializable Schedule

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Concurrency Control

- Schedule
- Conflict Serializable Schedule
- Two phase locking
- Warning Protocol
- Validation

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Concepts

Transaction: sequence of $r_i(x)$, $w_i(x)$ actions

Conflicting actions: $r_h(A)$ $w_h(A)$ $w_h(A)$
$w_k(A)$ $r_k(A)$ $w_k(A)$

If schedule S contains conflicting actions
…, $p_h(A)$, …, $q_k(A)$, ... [i.e., one of p, q is w],
transaction T_h must precede T_k in a corresponding serial schedule. Denote this by $T_h \rightarrow T_k$

Returning to Sc

$Sc=r_1(A)w_1(A)r_2(A)w_2(A)r_1(B)w_1(B)r_2(B)w_2(B)$

$T_1 \rightarrow T_2$ $T_1 \rightarrow T_2$

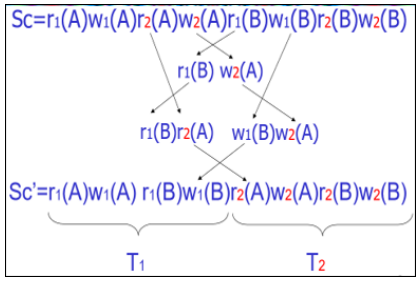
No cycles $\Rightarrow$ Sc is "equivalent" to a serial schedule (in this case T_1,T_2)

Definition

S1, S2 are **conflict equivalent** schedules

if S1 can be transformed into S2 by a series of swaps on non-conflicting actions.

(=> effect of both S1 and S2 on the DB is the same)



A schedule is **conflict serializable** if it is conflict equivalent to some serial schedule.

Definition

A schedule is **conflict serializable** if it is conflict equivalent to some serial schedule.

NB: Conflict serializability is a sufficient (but not a necessary) condition for serializability (equivalence to some serial schedule)

Easier to enforce than serializability, therefore generally assured by commercial systems

Precedence graph P(S) (S is schedule)

Nodes: transactions T1, T2, ... in S
Arcs: Ti → Tj for i ≠ j whenever
- pi(A), qj(A) are conflicting actions in S,
(same element A, at least one of actions is a write)
- action pi(A) precedes qj(A) in S

- What is P(S) for
S = w3(A) w2(C) r1(A) w1(B) r1(C) w2(A) r4(A) w4(D)
- Is S serializable?

Exercise:

- What is P(S) for
S = $w_3(A)$ $w_2(C)$ $r_1(A)$ $w_1(B)$ $r_1(C)$ $w_2(A)$ $r_4(A)$ $w_4(D)$

- Is S serializable?

Lemma Let S_1, S_2 be schedules for the same set of transactions

S_1, S_2 conflict equivalent $\Rightarrow P(S_1)=P(S_2)$

Proof:

Assume $P(S_1) \neq P(S_2)$

$\Rightarrow \exists\ T_i$: $T_i \rightarrow T_j$ in $P(S_1)$ and not in $P(S_2)$

$\Rightarrow S_1 = \ldots p_i(A) \ldots q_j(A) \ldots$

$S_2 = \ldots q_j(A) \ldots p_i(A) \ldots$

p_i, q_j conflict

$\Rightarrow S_1, S_2$ not conflict equivalent

Note: $P(S_1)=P(S_2) \not\Rightarrow S_1, S_2$ conflict equivalent

Counter example:

$S_1 = w_1(A)\ r_2(A)\ w_2(B)\ r_1(B)$

$S_2 = r_2(A)\ w_1(A)\ r_1(B)\ w_2(B)$

Theorem I

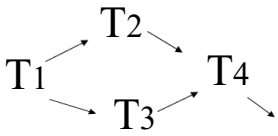
$P(S_1)$ acyclic $\Longleftrightarrow$ S_1 conflict serializable

($\Leftarrow$) Assume S_1 is conflict serializable
$\Rightarrow$ $\exists$ serial S_s: S_s, S_1 conflict equivalent
$\Rightarrow$ $P(S_s) = P(S_1)$ [<– Lemma]
$\Rightarrow$ $P(S_1)$ acyclic since $P(S_s)$ is acyclic

Theorem (cont.)

$P(S_1)$ acyclic $\Longleftrightarrow$ S_1 conflict serializable

($\Rightarrow$) Assume $P(S_1)$ is acyclic



Transform S_1 as follows:

(1) Take T1 to be transaction with no incoming arcs
(2) Move all T1 actions to the front

S_1 = …… $q_j(X)$ …… $p_1(A)$ …

(3) we now have S_1 = < T1 actions ><... rest ...>
(4) repeat above steps to serialize rest!

Example of Theorem Application

For each of the following schedules, answer the questions below:

S_b= W3(**A**)R1(**B**)R2(**A**)R1(**D**)W1(**B**)R4(A)W2(**B**)R4(**D**)R3(**D**)R4(**B**)

(a) What is the precedence graph for the schedule S_b?

(b) Is the schedule conflict serializable? If so, show all equivalent serial transaction orders. If not, describe why not.

Summary

- Schedule, Serial Schedule
- Conflict Serializable Schedule
- Precedence Graph P(S)
- P(S_1) acyclic $\Longleftrightarrow$ S_1 conflict serializable

多选题 1分

互动交流一 —不定项选择题

以下哪一个调度可以保证数据库的一致性?

A
T1: A=A+100, B=B-100
T2: A=1.06*A, B=1.06*B

B
T1: A=A+100, B=B-100
T2: A=1.06*A, B=1.06*B

C
T1: B=B-100 ,A=A+100
T2: B=1.06*B , A=1.06*A,

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多选题 1分

互动交流二 —不定项选择题

以下调度的哪个部分应该在优先图中出现?

S= W3(A) R1(B) R2(A) R1(D) R2(B) W4(A) R1(A)

A T3 → T2 → T4 → T1

B T1 → T2 → T4

C T1 → T3

提交

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Week15_Course

Database System
Concurrency Control part3

Two phase locking

Concurrency Control

- Schedule
- Conflict Serializable Schedule
- Two phase locking
- Warning Protocol
- Validation

How to enforce serializable schedules?

Option 1: (Optimistic strategy)

Run system, recording P(S); At end of day, check P(S) for cycles, and declare if execution was good

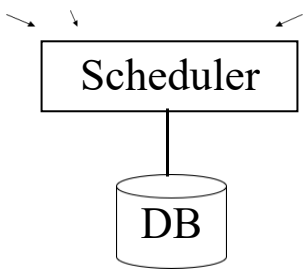
Option 2: (Pessimistic strategy)

Prevent occurrence of cycles in P(S)

How to enforce serializable schedules?

Option 2: (Pessimistic strategy)

Prevent occurrence of cycles in P(S)



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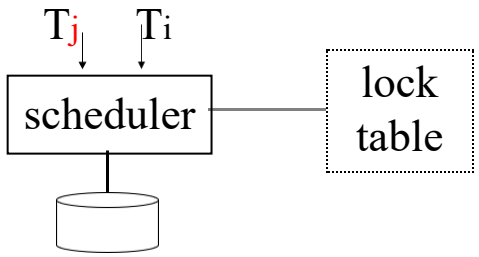
A locking protocol

Two new actions:

lock (exclusive): $l_j(A)$

unlock: $u_j(A)$



Rule #1: Well-formed transactions

T_i: ⋯ $l_i(A)$ ⋯ $p_i(A)$ ⋯ $u_i(A)$ ...

- Lock elements (A) before accessing them
  (pi is a read or a write)
- Eventually, release the locks ($u_i(A)$)

Rule #2 Legal scheduler

$$S = \cdots\cdots l_i(A) \cdots\cdots u_i(A) \cdots\cdots$$

$$\longleftrightarrow$$

$$\text{no } l_j(A) \text{ for } i \neq j$$

- At most one transaction T_i can hold a lock on any element A

Exercise:

- What schedules are legal?
  What transactions are well-formed?

S1 = $l_1(A)l_1(B)r_1(A)w_1(B)l_2(B)u_1(A)u_1(B)$
$r_2(B)w_2(B)u_2(B)l_3(B)r_3(B)u_3(B)$

S2 = $l_1(A)r_1(A)w_1(B)u_1(A)u_1(B)$
$l_2(B)r_2(B)w_2(B)l_3(B)r_3(B)u_3(B)$

S3 = $l_1(A)r_1(A)u_1(A)l_1(B)w_1(B)u_1(B)$
$l_2(B)r_2(B)w_2(B)u_2(B)l_3(B)r_3(B)u_3(B)$

Schedule F (with simple locking)

T1	T2	A	B
		25	25
l_1(A);Read(A)			
A:=A+100;Write(A);u_1(A)		125	
	l_2(A);Read(A)		
	A:=Ax2;Write(A); u_2(A)	250	
	l_2(B); Read(B)		
	B:=Bx2;Write(B); u_2(B)		50
l_1(B); Read(B)			
B:=B+100;Write(B); u_1(B)			150
	Constraint violation!	250	150

Simple-minded locking not sufficient to ensure serializability (i.e., correctness)!

–> More advanced protocol known as "two phase locking"

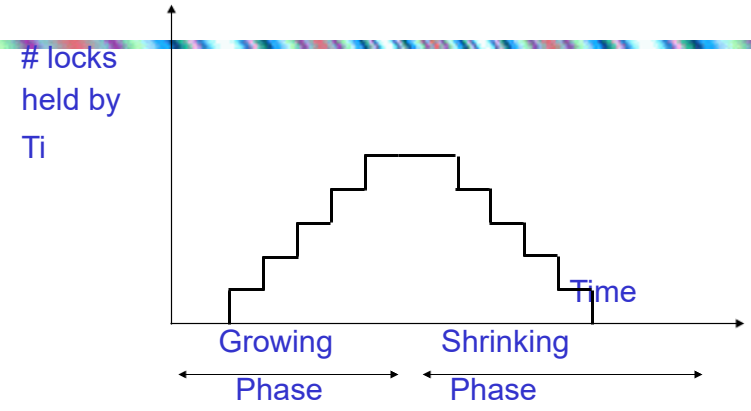
Rule #3 Two phase locking (2PL)

for transactions

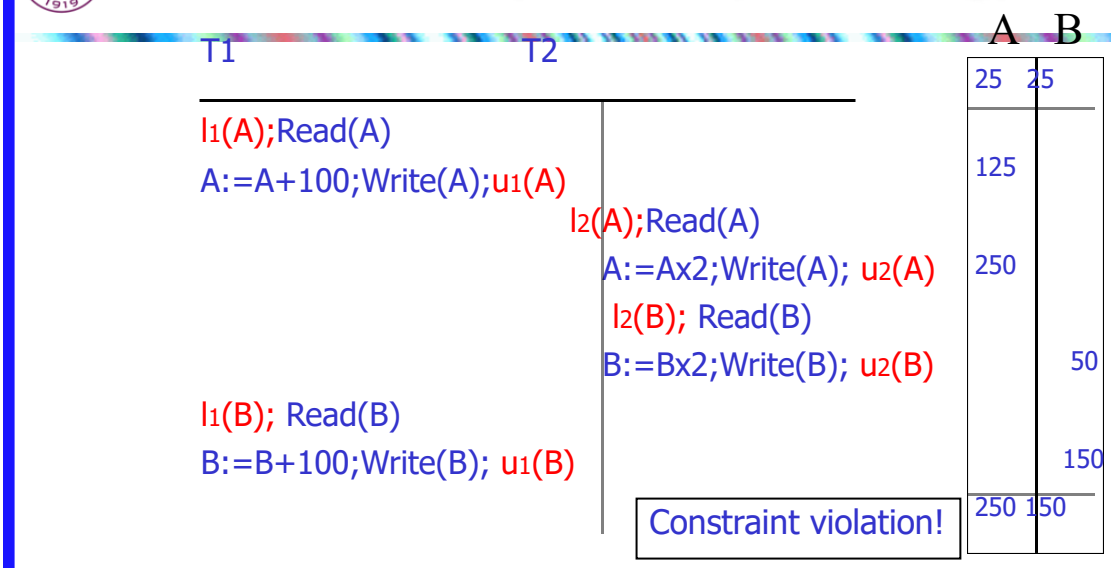
T_i = ……. $l_i(A)$ ……... $u_i(A)$ ……...

no unlocks　　no locks

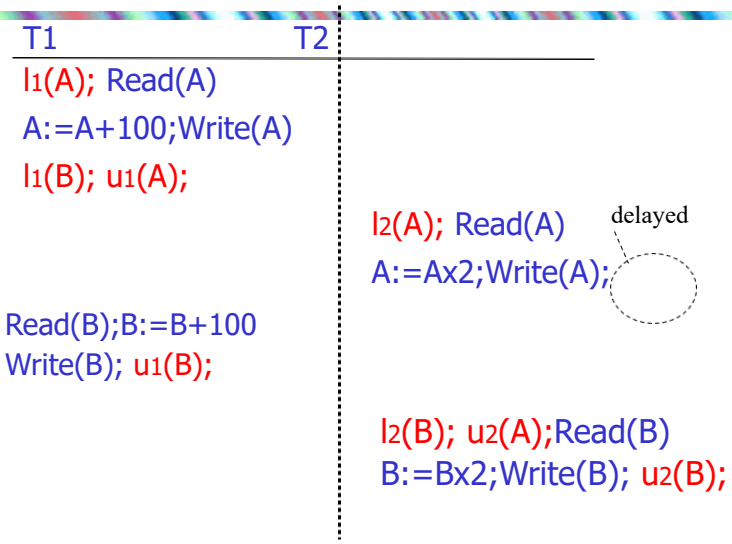
- All lock requests of a transaction have to precede its unlock requests



Schedule F (with simple locking)



Schedule G (with 2PL)

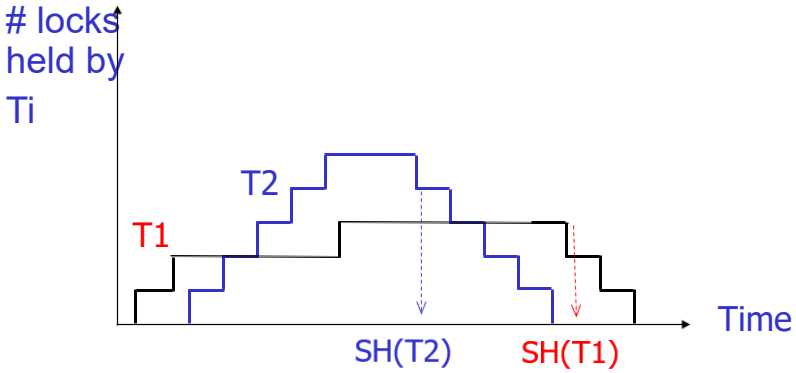


Next step:

Show that Rules #1,2,3 (2PL) $\Rightarrow$ conflict serializable schedule

To help in proof:

Definition Shrink(Ti) = SH(Ti) =first unlock action of Ti



Lemma Let S be a 2PL schedule.
Ti → Tj in P(S) ⇒ SH(Ti) $<_S$ SH(Tj)

Proof of lemma:

Ti → Tj means that

S = ... $p_i(A)$ ... $q_j(A)$ ...; p,q conflict

By rules 1,2:

S = ... $p_i(A)$ ... $u_i(A)$ ... $l_j(A)$ ... $q_j(A)$ ...

By rule 3: SH(Ti) SH(Tj)

So, SH(Ti) $<_S$ SH(Tj)

Theorem II Rules #1,2,3 (that is, 2PL) ⇒ { conflict serializable schedule

Proof: Let S be a 2PL schedule.

Assume P(S) has cycle

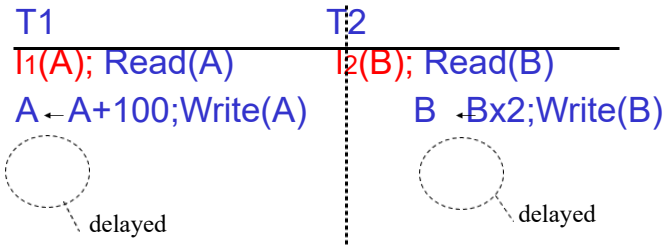
$T_1 \rightarrow T_2 \rightarrow \ldots T_n \rightarrow T_1$

By Lemma: $SH(T_1) < SH(T_2) < \ldots < SH(T_1)$

Impossible, so P(S) acyclic

⇒ S is conflict serializable (by Th. I)

Schedule H (T2 reversed)



- Neither proceeds: a **deadlock**
  - System must rollback (= abort & restart) at least one of T1, T2

死锁的预防

- 一次封锁法
  - 要求每个事务必须一次将所有要使用的数据全部加锁，否则就不能继续执行
  - 存在的问题:降低系统并发度 、难于事先精确确定封锁对象
- 顺序封锁法
  - 顺序封锁法是预先对数据对象规定一个封锁顺序，所有事务都按这个顺序实行封锁。
  - 顺序封锁法存在的问题:维护成本高、难以实现

Summary-Two phase locking

- 能够判断一个事务是否是Well-formed transactions
- 能够判断一个调度是否是Legal scheduler
- 能够判断一个事务是否满足two phase locking
- 可以在一个事务中添加加锁和解锁动作，使其满足规则1和规则3
- 对满足规则1和规则3的事务可以生成可串行化的调度

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