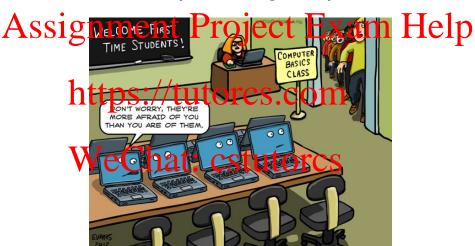


Week 8 – Query Processing and Optimisation





Housekeeping

Assignment Peroject Exame Help

- The submission deadline is 23:59, Oct 11, 2022.
- This assignment must be done individually (no group work).

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Housekeeping

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- 2 All he tabs an Oct 3 (Monday, public holiday) in Week 9 will be moved to the same verues on Oct 10 (Monday) in Week 19.



Housekeeping

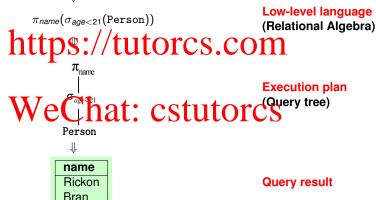
Assignment Peroject Exame Help

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- This assignment must be done individually (no group work).
- 2 All hetabs an Oct 3 (Monday, public holiday) in Week 9 will be moved to the same vehicles on Oct 10 (Monday) in Week 19.
- 3 Lab 8 is optional (no associated with any assessment items)
 - We will open a separate sign-up page on Wattle at 12pm Oct 6.
 - ptional labs will be scheduled from Oct 11 to Oct 14.
 - Four options are available
 - (1) Database Programming with Java
 - (2) Database Programming with Python
 - (3) Database Exercises on IMDB
 - (4) Database Security (SQL Injection)



Query Processing – Example

Assignment Project Estam Help





From SQL to RA Expressions

Assidents (mather first) plast Name and Exam Help Courses (crsNr, title, unit)

SELECT lastName, result, title

http:// Students.mathr=Exams.mathr And

Exams.crsNr=Courses.crsNr AND result < 1.3;



From SQL to RA Expressions

Assimulation first plast Name and Exam Help Courses (crsNr, title, unit)

SELECT lastName, result, title

http://www.coursesom

THERE STUDENTS, mathr=Exams, mathr AND

Exams.crsNr=Courses.crsNr AND result < 1.3;

- RA Expressions:

 Trast terre, recell title Ground 1. ((Souther to Julen C. rhan) = Exams. matn. Exams)
 - $\bowtie_{\sigma_{\mathtt{Exams.}\mathit{crsNr}=\mathtt{Courses.}\mathit{crsNr}}} \mathtt{Courses}))$
 - $\sigma_{\text{lastName, result, title}}(\sigma_{\text{result}} \le 1.3(\sigma_{\text{EXAMS. crsNr}=\text{Courses. crsNr}}(\sigma_{\text{Students. matNr}}(\text{Students} \times \text{Exams} \times \text{Courses}))))$
 - 3 $\pi_{lastName, result, title}$ ((Students ⋈_{Students.matNr=Exams.matNr} ($\sigma_{result \le 1.3}$ (Exams))) ⋈_{Exams.crsNr=Courses.crsNr} Courses)
 - **4**) . . .



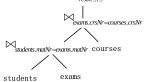
From RA Expressions to Query Trees

Assignation can be presented as a query tree: Help

- internal nodes represent the intermediate result;
- the root node represents the resulting relation.
- Example:

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 Ν εχαμες Cron t sees (Cron t sees)

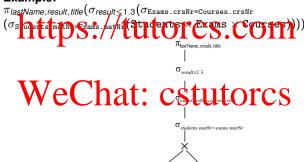




Query Tree Example

ASSI Schild nodes must be executed by the transfer of the policy of the

Example:

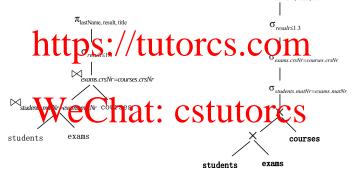


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Equivalent Query Trees (Query Optimisation)

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ASSIGNMENT Project Exame Help additional annotation at each node indicating:

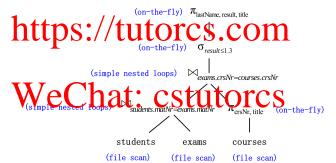
(1) the access method to use for each table, and











Note: Pipelined evaluation may have significant saving on I/O cost, while materialized evaluation can avoid repeated computations.



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- This is determined by the query optimiser using a variety of algorithms (Fat: there is no true optimal solution in general)
- Realistically, we cannot expect to always find the best plan, but we expect to consistently find a plan that is good.



Assignment to the period of the property of the period of

- This is determined by the query optimiser using a variety of algorithms (Fat: there is no true optimal solution in general)
- Realistically, we cannot expect to always find the best plan, but we expect to consistently find a plan that is good.
- The variance of different execution pans for the same query may different considerably (e.g., seconds vs. hours vs. days):
 - different but equivalent RA expressions;
 - different algorithms for each RA operator.



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Assessing ideas of algorithms as defor Reperators Exam Help selection: If there is no index we have to scan the table. Otherwise, we scan the indexes to retrieve matching tuples and apply remaining

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selection conditions to further restrict the tuples.



Assessing ideas of algorithms is of or RA energions Exam Help selection: If there is no index we have to scan the table. Otherwise, we scan the indexes to retrieve matching tuples and apply remaining selection conditions to further restrict the tuples.

Projection retrieves a subserver ettributes from each tuple of the table (similar to selection). If requiring duplicate elimination, then we have to do sorting additionally (expensive part!)



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• Join: We may use nested loops join, or sort-merge join, hash joins,

WeChat: cstutorcs

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> ction retrieves a tubser of attributes from each tuple of the table Sinhilar to selection). If requiring duplicate elimination, then we have to do sorting additionally (expensive part!)

- Join: We may use nested loops join, or sort-merge join, hash joins,
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- Aggregation operators use temporary counters in main memory when retrieving tuples.



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• Join: We may use nested loops join, or sort-merge join, hash joins,

Group by and order by are typically implemented using sorting.

- Aggregation operators use temporary counters in main memory when retrieving tuples.
- Set operators can use the same approach as projection to eliminate duplicates.



Estimating Query Costs - Example

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Estimating Query Costs - Example

A SSWhich moving got a non-Universe for an experience of its actors playing an agent? p $\pi_{title, production.year}(\sigma_{role.description='agent'}(BOLE \bowtie ACTOR_AWARD \bowtie (AWARD - \sigma_{award.country='USA'}(AWARD))))$

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Estimating Query Costs - Example



AWARD





Size of Relations

Assignmentz Project Exam Help

• Let *n* denote the average number of tuples in *r*, and ℓ_i the the average space (e.g., in bits) for attribute A_i .

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Size of Relations

Assignment-Project-Exam Help

• Let n denote the average number of tuples in r, and ℓ_j the the average space (e.g., in bits) for attribute A_j .

- Then, $n \cdot \sum_{i=1}^{k} \ell_i$ is the size of the relation r.
- We use this formula to assign sizes to leaf nodes in the query tree.



Assignmenta Paroject Exama Help

varchar(20))

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Assignment Project Exam Help

varchar(20))

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Assignment Project Exam Help

varchar(20))

Estimate the average number of tuples as 15.

Estimate the average space to Cattributes.



Assignment Project Fx3, md Help

varchar(20))

- Estimate the average number of tuples as 15.

 Estimate the average space to Cattributes.
 - Award_name: 8 · 20 = 160 bits (the mean length is 20);
- Institution: 8,30 = 240 bits (the mean length is 30);

 Award_country: 8 · 10 = 80 bits (the mean length is 10)



Assignment Project Exam Help

varchar(20))

- Estimate the average number of tuples as 15.

 Lettrace the average space to Cattribucs. Om
 - Award_name: $8 \cdot 20 = 160$ bits (the mean length is 20);
- Institution: 8:30 = 240 bits (the mean length is 30);

 Award-country: 8:10 = 80 bits (the mean length is 10).
- The average size of a tuple is 160 + 80 + 240 = 480 bits.



Assignment Project Fx3, md Help

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 Award-country: 8:10 = 80 bits (the mean length is 10).
- The average size of a tuple is 160 + 80 + 240 = 480 bits.
- The average size of a relation is estimated to be $15 \cdot 480 = 7,200$ bits.



Assignment variation reaction reaction. Help Role_description:varchar(100), Credits:varchar(40))

https://tutorcs.com



Assignment variation reaction reaction. Help Role_description:varchar(100), Credits:varchar(40))

Estimate the average number of tuples as 500.

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Assignment value of the property of the proper

• Estimate the average number of tuples as 500.

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Assignment value of the confidence of the confid

Estimate the average number of tuples as 500.

nestmaesthe average space to attributes 1111

- Id: $8 \cdot 8 = 64$ bits (as the domain is char(8));
- Title: $8 \cdot 25 = 200$ bits (the mean length is 25);
- Production year: 13 bits (as the domain is number(4));
 Role description: 8 59 400 bits (the mean length is 50);
 - Credits: $8 \cdot 20 = 160$ bits (the mean length is 20).



Assignment value of the confidence of the confid

Estimate the average number of tuples as 500.

PEstimate the average space to attributes ()

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 Role-description: 8 59 400 bits (the mean length is 50);
 - Credits: $8 \cdot 20 = 160$ bits (the mean length is 20).
- The average size of a tuple is 64 + 200 + 13 + 400 + 160 = 837 bits



Assignment variation reaction reaction. Help Role_description:varchar(100), Credits:varchar(40))

Estimate the average number of tuples as 500.

nEstimates the average space to cats lbutes of m

- $d: 8 \cdot 8 = 64$ bits (as the domain is char(8));
- Title: $8 \cdot 25 = 200$ bits (the mean length is 25);
- Production year: 13 bits (as the domain is number(4));
 Role-description: 8 50 400 bits (the mean length is 50);
 - Credits: $8 \cdot 20 = 160$ bits (the mean length is 20).
- The average size of a tuple is 64 + 200 + 13 + 400 + 160 = 837 bits
- The average size of a relation is to be $500 \cdot 837 = 418,500$ bits



Assignment in the control of the con

Year_of_award:number(4),Category:varchar(100),Result:varchar(20))

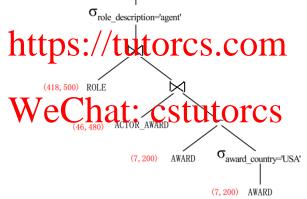
- Estimate the average number of tuples as 40

 Estimates he average specificate bues 0 111
 - Title: 200 bits (as before);
 - Production_year: 13 bits (as before);
 - Role_description: 400 bits (as before);
- Afard hame: 160 bits (at before); (Communication of the sound of the s
 - Category: $8 \cdot 40 = 320$ bits (the mean length is 40);
 - Result: $8 \cdot 7 = 56$ bits (the mean length is 7).
- The average size of a tuple is 200 + 13 + 400 + 160 + 13 + 320 + 56 = 1,162 bits.
- The average size of a relation is $40 \cdot 1162 = 46,480$ bits.



Estimating Query Costs - Example (Query Tree)

Assignment Project Exam Help





Size of Selection Node

Assignment nProjects Examilelp

Scan the relation one tuple after another (if there is no index);

Check for each tuple, whether the condition a is catisfied or not;

• Keep exactly those tuples satisfying φ .



Size of Selection Node

Assignment nProjects Examilelp

- Scan the relation one tuple after another (if there is no index);
- Check for each tuple, whether the condition a is satisfied or not;
- Keep exactly those tuples satisfying φ .
- Let s be the size of its single relevant node.
- The Size Calculation Castutores

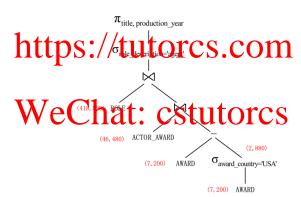
 $a_{\varphi}\cdot s$,

where a_{φ} is the average percentage of tuples satisfying φ .



Estimating Query Costs - Example (Selection)

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Size of Difference Node

Assignment Project Exam Help

- Let s_1 and s_2 be the sizes of the two relevant nodes.
- Again, we need to condider the probability that tuples occur in both relations.



Size of Difference Node

Assignment Project Exam Help

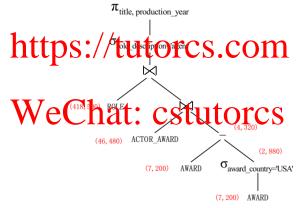
- Let s_1 and s_2 be the sizes of the two relevant nodes.
- Again, we need to confider the probability that tuples occur in both relations.
- The size of a difference node is WeChat: estutiones

where (1 - p) is the probability that tuples from s_1 does not occur in s_2 .



Estimating Query Costs - Example (Difference)

Since 40% of the movie awards from the USA, it is probability of arrayard to SS be SUS awards 1.4. We have C(I,p) = 7,200 C(I,0.1) = 4,120.





Size of Natural Join Node

Assignment Project Exam Help Leter and s₂ be the sizes of the two relevant nodes, and r₁ and r₂ be the

size of a tuple in these two nodes. $\frac{s_1}{r_1}$ and $\frac{s_2}{r_2}$ are the estimated number of tuples in these two hodes. COM



Size of Natural Join Node

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tuples in these two hodes utores.com

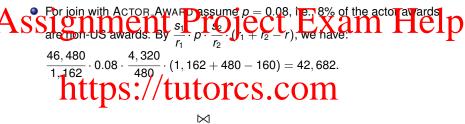
The size of a natural join node is

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where r is the size of a tuple over the **common attributes**, and p is the **matching probability** (for any tuple of the first relevant node to match with any tuples in the second relevant relation). Note that $r_1 + r_2 - r$ is the size of a tuple after the natural join operation.



Estimating Query Costs - Example (Natural Join)







Estimating Query Costs - Example (Natural Join)

Assignment si Project, Exam Help

 $\frac{418,500}{837} \cdot 0.002 \cdot \frac{42,682}{1,482} \cdot (837 + 1,482 - 200 - 400 - 13) = 49,133.$

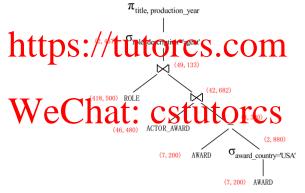
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Estimating Query Costs - Example (Selection)

For selection $\sigma_{\text{role description}}$ assume $a_{\text{c}} = 0.05$ (i.e., non-US awards for possible are 56). Her ce, we have C is = 0.05X40181 2,457 C p





Size of Projection Node

Assignment: Project Exam Help Project each tuple to the attributes in {A1,..., An}

Eliminate duplicates (Note: SQL does not eliminate tuples unless

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Size of Projection Node

Assignment: Project Exam Help Project each tuple to the attributes in {A₁,..., A_n}

Eliminate duplicates (Note: SQL does not eliminate tuples unless DISTINCT is used).

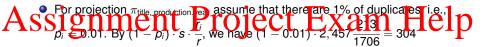
number n of tuples and its average size r of a tuple.

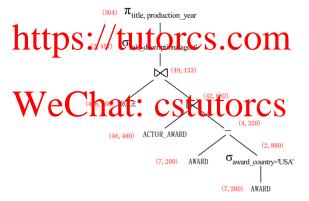
• The size of a projection node
$$\pi_{A_1,...,A_n}$$
 is WeChat: $\underset{(1-p_i)\cdot s\cdot \frac{1}{r}}{\text{extractor}}$.

where r_i is the average size of a tuple over $\{A_1, \ldots, A_n\}$, and p_i is the probability that two tuples coincide on A_1, \ldots, A_n (i.e., the same values on all attributes A_1, \ldots, A_n).



Estimating Query Costs - Example (Projection)



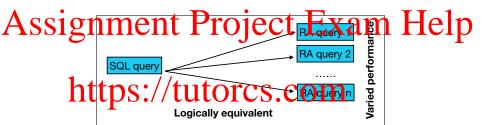




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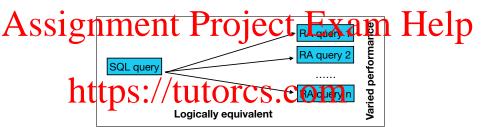
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$$a^{2}-b^{2} = ab-b^{2}$$
Wechat: $a^{2}b$ $a^{2}b$ $a^{2}b$





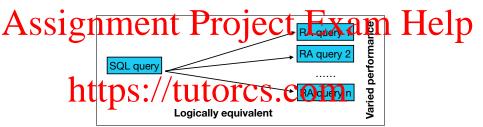
Which FA query should be chosen for a given SQL query?





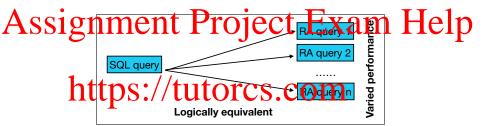
• Which FA query should be chosen for a given SQL query?





• Which FA query should be chosen for a given SQL query?
• Who choose? Query optimise!





- Which FA query should be chosen for a given SQL query?
 Who choose? Query optimise!
 - How to choose?



- Which FA query should be chosen for a given SQL query?
 Who choose? Query optimise!
 - How to choose?
 - Semantic query optimisation
 - Rule-based optimisation
 - Cost-based optimisation



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Assignment is estimated by a second of the control of the control

Semantic query optimisation

Use 10 Sation specific enactic Snovie 10 10 tansform a query into the one with a lower cost (they return the same answer).



Assignment is estimated by a series optimisation approaches:

- Semantic query optimisation
- The che with a lower cost (they return the same answer).
- Rule-based query optimisation

Use he iristic rules to transferm a relational algebra expression into an equivalent one with a possibly lower cost.



Assignment is a sit code Gener Examing Help optimisation approaches:

Semantic query, optimisation

Use the phastip of specific enactic should go to transform a query into the one with a lower cost (they return the same answer).

Rule-based query optimisation

Use he iristic rules to transferm a relational algebra expression into an equivalent one with a possibly lower cost.

Cost-based query optimisation

Use a cost model to estimate the costs of plans, and then select the most cost-effective plan. This will not be assessed in our course.



Semantic Query Optimisation

SEIGN: Ment Project Exam Help Person(id, first_name, last_name, year_born)

MOVIE(title, production_year, country, run_time, major_genre)

WRITER(id, title, production_year, credits) where

DIS PERSTUTIONES.COM title, production_year] ⊆ MOVIE [title, production_year]

List the ids of the writers who have written movies produced in 2000. **VeChat: CSTUTOTCS**

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Semantic Query Optimisation

gament Project Exam Help

PERSON(id, first_name, last_name, year_born)

MOVIE(title, production_year, country, run_time, major_genre)

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lois PERSULTORCS.COM title, production_year] ⊆ MOVIE [title, production_year]

List the ids of the writers who have written movies produced in 2000.

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 $\pi_{id}\sigma_{production_year=2000}(WRITER \bowtie PERSON)$

 $\pi_{id}\sigma_{production_year=2000}(WRITER \bowtie MOVIE)$



Semantic Query Optimisation

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List the ids of the writers who have written movies produced in 2000.

Weinat estutore
π_{id}σ_{production.year=2000} (WRITER ΣPERSON Σ MOVIE

 $\pi_{id}\sigma_{production_year=2000}(WRITER \bowtie PERSON)$

 $\pi_{id}\sigma_{production_year=2000}(WRITER \bowtie MOVIE)$

 $\pi_{id}\sigma_{production_vear=2000}WRITER \leftarrow the optimised RA$



Assignment Particular Execution performance.

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Assargement Project Example 19 heuristic rules that typically improve the execution performance.

• Key ideas: apply the most restrictive operation before other operations, which tall the transfer of the state of the sta



Assirgment Project Favoring Help heuristic rules that typically improve the execution performance.

- Key ideas: apply the most restrictive operation before other operations, which tall the transfer of the state of the sta
 - Push-down selection:

Apply as early as possible to reduce the number of tuples; WeChat: cstutorcs



Assaire The Divinish ton Pranticing the Categories Transporting Help heuristic rules that typically improve the execution performance.

- Key ideas: apply the most restrictive operation before other operations, which can reduce the size printer mediate results
 - Push-down selection:

Apply as early as possible to reduce the number of tuples;

Apply as early as possible to reduce the number of attribu

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Rule-based Query Optimisation

Assaire The Divinish ton Pranticing the Categories Transporting Help heuristic rules that typically improve the execution performance.

- Key ideas: apply the most restrictive operation before other operations, which can reduce the size printer mediate results
 - Push-down selection:

Apply as early as possible to reduce the number of tuples;

Apply as early as possible to reduce the number of attributes.



Rule-based Query Optimisation

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- Key ideas: apply the most restrictive operation before other operations, which can reduce the size printer mediate results
 - Push-down selection:

Apply as early as possible to reduce the number of tuples;

Apply as early as possible to reduce the number of attributes.

 But we must ensure that the resulting query tree gives the same result as the original query tree, i.e., the equivalence of RA expressions.



Assignment Project Exam Help Merging RA operators.

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Assignment Project Exam Help

```
• \sigma_{\varphi}(\sigma_{\psi}(R)) \equiv \sigma_{\varphi \wedge \psi}(R);

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• \sigma_{\varphi}(R_1 \times R_2) \equiv R_1 \bowtie_{\varphi} R_2;
```



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Assign they be executed in Open Project Exam Help

 $\sigma_{\textit{CourseNo}='\textit{COMP2400'}}(\sigma_{\textit{UID}=111}(\textit{STUDY})) \quad \text{v.s. } \sigma_{(\textit{Course}='\textit{COMP2400'}) \land (\textit{UID}=111)}(\textit{STUDY})$

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111	CUN2/02	120
333	B VS V2014	130

UID CourseNo Hours

111 COMP2400 120

111 BUSN2011 110

111 ECON2102 120

STUDY									
UID	CourseNo	Hours							
111	COMP2400	120							

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STUDY										
<u>UID</u>	<u>CourseNo</u>	Hours								
111	COMP2400	120								
222	COMP2400	115								
333	STAT2001	120								
111	BUSN2011	110								
111	ECON2102	120								
333	BUSN2011	130								

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(without any intermediate relation)

STUDY								
UID	<u>CourseNo</u>	Hours						
111	COMP2400	120						



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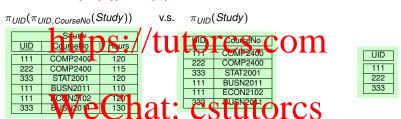
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	STUDY				
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111	COMP2400	120			
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111	BUSN2011	110			
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Assignment Project Exam Help

• $\sigma_{\varphi}(R_1 \times R_2) \equiv R_1 \bowtie_{\varphi} R_2$

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Assignment Project Exam Help

• $\sigma_{\varphi}(R_1 \times R_2) \equiv R_1 \bowtie_{\varphi} R_2$ $\sigma_{Course.No=Enrol.CoureNo}(Course \times Enrol)$

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Assignment Project Exam Help

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ŀ	BUSN2011	Management Accounting	6		222	COMP2400	2016 S1	active	
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Assignment Project Exam Help

• $\sigma_{\varphi}(R_1 \times R_2) \equiv R_1 \bowtie_{\varphi} R_2$ $\sigma_{Course.No=Enrol.CoureNo}(Course \times Enrol)$

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COMP2400	Relational Databases	6	111	COMP2400	2016 S2	active
BUSN2011	Management Accounting	6	111	BUSN2011	2016 S1	active
BUSN2011	Management Accounting	6	222	COMP2400	2016 S1	active
BUSN2011	Management Accounting	6	111	COMP2400	2016 S2	active



Assignment Project Exam Help

• $\sigma_{\varphi}(R_1 \times R_2) \equiv R_1 \bowtie_{\varphi} R_2$ • $\sigma_{Course.No=Enrol.CoureNo}(Course \times Enrol)$

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222	COMP2400	2016 S1	active
111	COMP2400	2016 S2	active

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Ī	COMP2400	Relational Databases	6	111	BUSN2011	2016 S1	active
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	COMP2400	Relational Databases	6	111	COMP2400	2016 S2	active
	BUSN2011	Management Accounting	6	111	BUSN2011	2016 S1	active
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Assignment Project Exam Help

• $\sigma_{\varphi}(R_1 \times R_2) \equiv R_1 \bowtie_{\varphi} R_2$ Course $\bowtie_{Course.N_0 = Enrol.CourseN_0}$ Enrol

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ľ	COMP2400	Relational Databases	6		222	COMP2400	2016 S1	active
ı	BUSN2011	Management Accounting	6		111	COMP2400	2016 S2	active



Assignment Project Exam Help

• $\sigma_{\varphi}(R_1 \times R_2) \equiv R_1 \bowtie_{\varphi} R_2$ $Course \bowtie_{Course,No=Enrol,Course,No} Enrol$

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BUSN2011	Management Accounting	6		111	COMP2400	2016 S2	Г

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No	Cname	Unit	StudentID	CourseNo	Semester	Status
COMP2400	Relational Databases	6	222	COMP2400	2016 S1	active
COMP2400	Relational Databases	6	111	COMP2400	2016 S2	active
BUSN2011	Management Accounting	6	111	BUSN2011	2016 S1	active

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Assignment Project Exam Help

- $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ; • $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ; • $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_2 ;
- $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition contains attributes not in X, where X_i contains attributes both in R_i and X, and one both in R_i and R_i :
- $\pi_X(R_1 \bowtie R_2) \equiv \pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2)$, if the join condition involves only attributes in X, where X_i contains attributes both in R_i and X, and ones both in R_1 and R_2 ;



Assignment Project Exam Help

• $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ; $\sigma_{Cname='ManagementAccounting'}(Course \bowtie Enrol)$

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• $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ; $\sigma_{Cname='ManagementAccounting'}(Course \bowtie Enrol)$

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BUSN2011	Management Accounting	6		222	COMP2400	2016 S1	active
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Assignment Project Exam Help

• $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ; $\sigma_{Cname='ManagementAccounting'}(Course \bowtie Enrol)$

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COMP2400	Relational Databases	6	111	BUSN2011	2016 S1	active
BUSN2011	Management Accounting	6	222	COMP2400	2016 S1	active
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• $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ; $\sigma_{Cname='ManagementAccounting'}(Course \bowtie Enrol)$

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COMP2400	Relational Databases	6		111	BUSN2011	2016 S1	active
BUSN2011	Management Accounting	6		222	COMP2400	2016 S1	active
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COMP2400	nelational	Palabases	7	6	222	2016 S1	active
COMP2400	Relational	Databases		6	111	2016 S2	active
BUSN2011	Managemen	t Accounting		6	111	2016 S1	active

CourseNoNo	Cname	Unit	StudentID	Semester	Status
BUSN2011	Management Accounting	6	111	2016 S1	active



Assignments Project je Exam Help

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• \sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2, if \varphi contains only attributes in R_1;
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Assignments: Project je Exam Help

- $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ;
- $\sigma_{Cname=ManagementAccounting'}(Course) \bowtie Enrol$





Assignments: Project je Exam Help

- $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ;
 - $\sigma_{Cname="ManagementAccounting"}(Course) \bowtie Enrol$



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Assignments: Project je Exam Help

- $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ;
- $\sigma_{Cname='ManagementAccounting'}(Course) \bowtie Enrol$



CourseNo Cname Unit
COMP2400 Relational Databases 6
BUSN2011 Management Accounting 6

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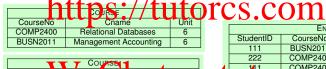


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Rule-based Optimisation

Assignments: Project je Exam Help

- $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv \sigma_{\varphi}(R_1) \bowtie R_2$, if φ contains only attributes in R_1 ;
 - $\sigma_{Cname=\text{'Management}Accounting'}(Course) \bowtie Enrol$



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StudentID	CourseNo	Semester	Status											
111	BUSN2011	2016 S1	active											
222	COMP2400	2016 S1	active											
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CourseNo	Cname	Unit	StudentID	Semester	Status
BUSN2011	Management Accounting	6	111	2016 S1	active



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Assignment Project Exam Help $\pi_{X}(R_1 \bowtie R_2) \equiv \pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2)$, if the join condition involves only attributes in X, how could we derive X_1 and X_2 ?

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 $\pi_{CourseNo,Cname,StudentID}(Course \bowtie Enrol)$

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COMP2400	Relational	Databases	6		111	2016 S2	active
BUSN2011	Managemen	t Accounting	6		111	2016 S1	active



Assignment Project Exam Help $\pi_{x_1(R_1)\bowtie R_2)}$ = $\pi_{x_1(R_1)\bowtie \pi_{x_2}(R_2)}$, if the join condition involves only

attributes in X, how could we derive X_1 and X_2 ?

 $\pi_{CourseNo,Cname,StudentID}(Course \bowtie Enrol)$

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111	BUSN2011	2016 S1	active
222	COMP2400	2016 S1	active
111	COMP2400	2016 S2	active

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COMP2400	Relational [Databases	6	111	2016 S2	active
BUSN2011	Management	Accounting	6	111	2016 S1	active

CourseNo	Cname	StudentID
COMP2400	Relational Databases	222
COMP2400	Relational Databases	111
BUSN2011	Management Accounting	111



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Assignment Project Exam Help $\pi_{\chi}(R_1 \bowtie R_2) \equiv \pi_{\chi_1}(R_1) \bowtie \pi_{\chi_2}(R_2)$, if the join condition involves only attributes in X, how could we derive X_1 and X_2 ?

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Assignment Project Exam Help attributes in <math>X, how could we derive X_1 and X_2 ?

 $\pi_{\textit{CourseNo},\textit{Cname}}(\textit{Course}) \bowtie \pi_{\textit{CourseNo},\textit{StudentID}}(\textit{Enrol})$

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 $\pi_{\textit{CourseNo},\textit{Cname}}(\textit{Course}) \bowtie \pi_{\textit{CourseNo},\textit{StudentID}}(\textit{Enrol})$

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CourseNo	Cname	Unit		
COMP2400	Relational Databases	6		
BUSN2011	Management Accounting	6		





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CourseNo	Cname	Unit		
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BUSN2011	Management Accounting	a 6	1	

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BUSN2011	Management Accounting

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COMP2400	Relational Databases	6		222	COMP2400	2016 S1	active
BUSN2011	Management Accounting	6		111	COMP2400	2016 S2	active

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CourseNo	Cname	Unit		111	BUSN2011	2016 S1	active
COMP2400	Relational Databases	6		222	COMP2400	2016 S1	active
BUSN2011	Management Accounting	6		111	COMP2400	2016 S2	active

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COMP2400	Relational Databases							
BUSN2011 Management Accounting								







attributes in X, how could we derive X_1 and X_2 ?

 $\pi_{CourseNo,Cname}(Course) \bowtie \pi_{CourseNo,StudentiD}(Enrol)$

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CourseNo	Cname	Unit	-
COMP2400	Relational Databases	6	2
BUSN2011	Management Accounting	6	

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222	COMP2400	2016 S1	active
111	COMP2400	2016 S2	active

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	222 COMP2400	
	111 COMP2400	

CourseNo	Cname	StudentID
COMP2400	Relational Databases	222
COMP2400	Relational Databases	111
BUSN2011	Management Accounting	111



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Assignment Project Exam Help $\pi_{X}(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie r_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

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Assignment Project Exam Help $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

 π_{Cname} , $\mathit{StudentID}$ (Course $\bowtie \mathit{Enrol}$)

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 $\pi_{Cname,StudentID}(Course \bowtie Enrol)$

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Assignment Project Exam Help $\pi_{X}(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie_{T_{X_2}}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

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CourseNo		1 Unit	TA	Student D	Courtello	Semester	Status
COMP2400	Relational Databases	6		111	BUSN2011	2016 S1	active
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COMP2400	Relational	Databases	6	111	2016 S2	active
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Assignment Push select/project Exam Help $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

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CourseNo	Chame	Unit		444
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BUSN2011	Management Ac	counting	6	111	2016 S1	active

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Relational Databases	222
Relational Databases	111
Management Accounting	111



Assignments: Project je Exam Help

 $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?



Assignments: Project; Exam Help

• $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

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CourseNo	Cname	Unit					
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Assignments: Project; Exam Help

• $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

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		Course		
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Assignments: Project je Exam Help

• $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

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StudentID	CourseNo	Semester	Status				
111	BUSN2011	2016 S1	active				
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Assignments: Project je Exam Help

• $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

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Enrol							
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Assignments: Project je Exam Help

• $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

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π _{Cname} CO R Cname Relational Managemen		: C	St	# StudentIDE StudentI 111 222	NROL S		

Is $\pi_{Cname}(Course) \bowtie \pi_{StudentID}(Enrol)$ our desired result?



Assignments: Project je Exam Help

• $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

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	Course				ENROL			
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	Cname		•	~ •	"StudentID	THOE		
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Is $\pi_{Cname}(Course) \bowtie \pi_{StudentID}(Enrol)$ our desired result?

No. $\pi_{Cname,StudentID}(Course \bowtie Enrol) \neq \pi_{Cname}(Course) \bowtie \pi_{StudentID}(Enrol)$



Signment Project before join.

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attributes outside X, how could we derive X_1 and X_2 ?

 $\pi_{Cname,StudentID}(Course \bowtie Enrol)$

 $h^{\pi_{\textit{Cname}},\textit{StudentID}}(\pi_{\textit{CourseNo},\textit{Cname}}(\textit{Course}) \bowtie \pi_{\textit{CourseNo},\textit{StudentID}}(\textit{Enrol}))$



BUSN2011

Rule-based Optimisation

• Can join be executed last? → Push select/project before join.

 $\pi_X(P_1 \bowtie P_2) = \pi_X(\pi_{X_1}(P_1) \bowtie \pi_{X_2}(P_2))$, if the join condition involves attributes outside X, how could we derive X_1 and X_2 ?

 $\pi_{Cname,StudentID}(Course \bowtie Enrol)$

 $h^{\pi_{\textit{Cname}},\textit{StudentID}}/\pi_{\textit{CourseNo},\textit{Cname}}(\textit{Course}) \bowtie \pi_{\textit{CourseNo},\textit{StudentID}}(\textit{Enrol}))$

CourseNo Cname Unit
COMP2400 Relational Databases 6

Management Accounting



• Can join be executed last? \rightarrow Push select/project before join.

attributes outside X, how could we derive X_1 and X_2 ?

 $\pi_{Cname,StudentID}(Course \bowtie Enrol)$

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 COURSE
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CourseNo
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Can join be executed last? → Push select/project before join.

attributes outside X, how could we derive X_1 and X_2 ?

 $\pi_{Cname,StudentID}(Course \bowtie Enrol)$

 $h^{\pi_{Cname.StudentID}(\pi_{CourseNo,Cname}(Course)} \bowtie \pi_{CourseNo,StudentID}(Enrol))$

COURSE StudentID

COURSE						
CourseNo	Unit					
COMP2400	Relational Databases	6				
BUSN2011	Management Accounting	6				

202					
StudentID	CourseNo	Semester	Status		
111	BUSN2011	2016 S1	active		
222	COMP2400	2016 S1	active		
111	COMP2400	2016 S2	active		

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Can join be executed last? → Push select/project before join.

attributes outside X, how could we derive X_1 and X_2 ?

 $\pi_{Cname,StudentID}(Course \bowtie Enrol)$

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COURSE StudentID

COURSE						
CourseNo			Cna	me	9	Unit
COMP2400		Relational Databases				6
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BUSN2011	Management Accounting			

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StudentID	CourseNo	Semester	Status			
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222	COMP2400	2016 S1	active			
111	COMP2400	2016 S2	active			

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attributes outside X, how could we derive X_1 and X_2 ?

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 $\pi_{Cname.StudentID}(\pi_{CaurseNo,Cname}(Course) \bowtie \pi_{CourseNo,StudentID}(Enrol))$

Cname Unit

CourseNo COMP2400 Relational Databases BUSN2011 Management Accounting

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222	COMP2400	2016 S1	active
111	COMP2400	2016 S2	active

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111	COMP2400				

CourseNo	Cname	StudentID
COMP2400	Relational Databases	222
COMP2400	Relational Databases	111
BUSN2011	Management Accounting	111



 $\bullet \ \ \, \text{Can join be executed last?} \hookrightarrow \text{Push select/project before join.}$

attributes outside X, how could we derive X_1 and X_2 ?

 $\pi_{Cname,StudentID}(Course \bowtie Enrol)$

 $17^{\pi_{Cname},StudentID}$ $\pi_{CourseNo,Cname}$ $(Course) \bowtie \pi_{CourseNo,StudentID}$ (Enrol))

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 CourseNo
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 Management Accounting
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StudentID	CourseNo	Semester	Status			
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222	COMP2400	2016 S1	active			
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COMP2400	Relational Databases	222	
COMP2400	Relational Databases	111	
BUSN2011	Management Accounting	111	

Cname	StudentID
Relational Databases	222
Relational Databases	111
Management Accounting	111



Heuristic Rules and Query Trees

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Heuristic Rules and Query Trees

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Heuristic Rules

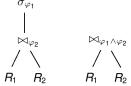
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Heuristic Rules

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Assigned the relation scholars Project Exam Help

MOVIE(title, production_year, country, run_time, major_genre)
ROLE(id, mtitle, mprod_year, description, credits)

Quent (if) Swar in tries that it posto mediting in Cruise'.

 $\pi_{\textit{title},\textit{production_},\textit{year}}(\sigma_{\textit{title}=\textit{mtitle}} \land \textit{production_},\textit{year}=\textit{mprod_},\textit{year}(\sigma_{\textit{major_},\textit{genre}='\textit{war'}} \land \textit{first_},\textit{name}='\textit{Tom'} \land \textit{last_},\textit{name}='\textit{Cruise'}(\mathsf{MOVIE} \times (\mathsf{PERSON} \bowtie \mathsf{ROLE}))))$

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Assigned the relation scholars Project Exam Help

MOVIE(title, production_year, country, run_time, major_genre)
ROLE(id, mtitle, mprod_year, description, credits)

Quent (ist) Swar in tyles that it postormed by The Cruise'.

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\pi_{title,production\_year}(\sigma_{title=mtitle} \land production\_year=mprod\_year(\sigma_{major\_genre='war'} \land first\_name='Tom' \land last\_name='Cruise'(MOVIE <math>\times (PERSON \bowtie ROLE))))
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Quision: Can we apply the following rule to optimise the query? $\sigma_{\varphi_1} \wedge \varphi_2 / R + Q_2 = P \cdot Q(R_1) \times Q_2 \cdot Q(R_2) + Q(R_2) \times Q_3 \cdot Q(R_3) \times Q_4 \cdot Q(R_4) \times Q_5 \cdot Q(R_5) \times Q_5 \cdot Q(R_$



Assiver the relation schema Project Exam Help

MOVIE(title, production_year, country, run_time, major_genre)
ROLE(id, mtitle, mprod_year, description, credits)

Quent (ist) Swar in tries that is postored by The Cruise'.

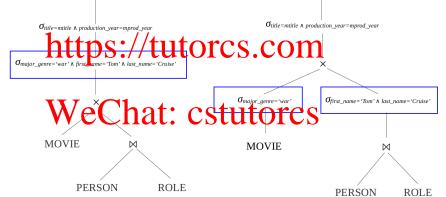
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\pi title_production_year (\sigma title=mtitle \times production_year = mprod_year (\sigma major_genre='war' \\
first_name='Tom' \last_name='Cruise' (MOVIE \times (PERSON \omega ROLE))))
```

- Quision: Can We apply the following rule to optimise the query? $\sigma_{\varphi_1} \wedge \varphi_2 / R + Q_2 = 1$ (B₁) × $G_2 + G_3 + G_4 + G_5 + G_6 + G$
- We would have

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\pi_{\textit{title},\textit{production\_year}}(\sigma_{\textit{title}=\textit{mtitle}} \land \textit{production\_year} = \textit{mprod\_year}(\sigma_{\textit{major\_genre='war'}}(\mathsf{MOVIE}) \\ \times \sigma_{\textit{first\_name='Tom'}} \land \textit{last\_name='Cruise'}(\mathsf{PERSON} \bowtie \mathsf{ROLE})))
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Assignment Project Exam Help





Assign major ma Project Exam Help

MOVIE(title, production_year, country, run_time, major_genre)
RQLE(id, mtitle, mprod_year, description, credits)

• Quentist abwar mivestila ir performed by Tom Cruise'.

 $\pi_{title,production_year}(\sigma_{title=mtitle \land production_year=mprod_year}(\sigma_{major_genre='war'}(\mathsf{MOVIE})$

× oring name= Tim \| last_name= Cruise (PERSON ⋈ ROLE)))

WELDAL CSTUTORS



PESON(id, first_name, last_name, year_born) Exam Help

MOVIE(title, production_year, country, run_time, major_genre) ROLE(id, mtitle, mprpd_year, description, credits)

list hwar mivies tia ir performed of Tom Cruise'.

 $\pi_{title,production_year}(\sigma_{title=mtitle \land production_year=mprod_year}(\sigma_{major_genre='war'}(\mathsf{MOVIE})$

 $\begin{array}{c} \times \text{ Constant Mast. name="Cruise"}(\text{PERSON} \bowtie \text{ROLE})))\\ \bullet \text{ Can we apply of (ALZAL)} \equiv CSULLOTCS \end{array}$



Assignation of the Project Exam Help

MOVIE(title, production_year, country, run_time, major_genre)
ROLE(id, mtitle, mprod_year, description, credits)

• Quell tist howar intrestua ir performed by Tom Cruise'.

 $\pi_{\textit{title},\textit{production_year}}(\sigma_{\textit{title}=\textit{mtitle} \land \textit{production_year}=\textit{mprod_year}}(\sigma_{\textit{major_genre='war'}}(\mathsf{MOVIE})$

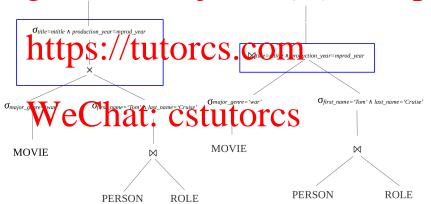
- \times Gir. Lname='Trm \last_name='Cruise'(PERSON \bowtie ROLE)))
- Can we a selve (A CA2) = 6 SUASIOTCS
- We would have

 $\pi_{\textit{title},\textit{production_year}}(\sigma_{\textit{major_genre}='\textit{war}'}(\mathsf{MOVIE})\bowtie_{\textit{title}=\textit{mtitle}\land\textit{production_year}=\textit{mprod_year}}($

 $\sigma_{\textit{first_name}='\textit{Tom}' \land \textit{last_name}='\textit{Cruise}'}(\mathsf{PERSON} \bowtie \mathsf{ROLE})))$



Assignment Project Exam Help





Assignment Project Exam Help

PERSON(id, first_name, last_name, year_born)

MOVIE(title, production_year, country, run_time, major_genre)

ROLE(id mtitle, mp/od year, description, credits).

Query: List all war movies that are performed by 'Tom Cruise'.



Assignment Project Exam Help

PERSON(id, first_name, last_name, year_born)

MOVIE(title, production_year, country, run_time, major_genre)

ROLE(id mtitle, mp/od year, description, credits).

Query: List all war movies that are performed by 'Tom Cruise'.

 $\pi_{\textit{title},\textit{production},\textit{year}}(\sigma_{\textit{major},\textit{genre}} = war'(\mathsf{MOVIE}) \bowtie_{\textit{title}} = \textit{mtitle} \land \textit{production},\textit{year} = \textit{mprod}_{\textit{year}}(\sigma_{\textit{tits}}) \land \sigma_{\textit{tits}} \land \sigma_{\textit{title}} = \sigma_{\textit{title}} \land \sigma_{\textit{title}$

• Question: Can we apply the following rule to optimise the query?

$$\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2)),$$

where X_i contains attributes both in R_i and X, and ones both in R_1 and R_2



Assigned the relation schema Project Exam Help

MOVIE(title, production_year, country, run_time, major_genre)
ROLE(id, mtitle, mprod_year, description, credits)

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Assigned the relation schema Project Exam Help

MOVIE(title, production_year, country, run_time, major_genre)
ROLE(id, mtitle, mprod_year, description, credits)

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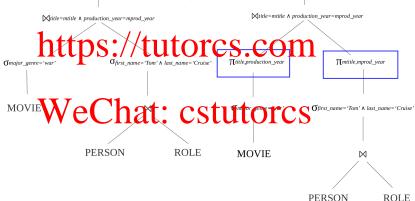
```
\pi_{title,production\_year}(\pi_{title,production\_year}(\sigma_{major\_genre='war'}(MOVIE))
\bowtie_{title=mtitle \land production\_year=mprod\_year}
```

```
(\pi_{\textit{mtitle}, mprod\_year}(\sigma_{\textit{first\_name}='Tom' \land last\_name='Cruise'}(\mathsf{PERSON} \bowtie \mathsf{ROLE}))))
```

We further apply some rules to optimise the query ...



Assignment Project Exam Help





Assignment Paris With 10 Tuples and 3 attributes 1 p

	1	Chingy	Right Thurr		
_	2	Scribe	Stand up		
http	C3.	Aguilera and Kim	Can't hold us down		
	34. / <i>1</i>	Livalieseence D	• Geirlg under		
	5	Justin Timberlake	Senorita		
	6	Brooke Fraser	Better		
We	71_	Black Eyed Peas	Where is the love?		
		at. Estu	lores		

- Compare two strategies of evaluating "Who is top of the pops?":
 - σ Rank=1 $(\pi$ Rank, Artist(CHARTS))
 - π Rank, Artist $(\sigma_{Rank=1}(CHARTS))$



A SSIGNING HARTS = {Rank Pytist. Song } with 10 Truples and 3 attributes 1p

	1	Chingy	Right Thurr		
_	2	Scribe	Stand up		
http	C3.	Aguilera and Kim	Can't hold us down		
	34. / <i>1</i>	Livalieseence D	• Geirlg under		
	5	Justin Timberlake	Senorita		
	6	Brooke Fraser	Better		
We	71_	Black Eyed Peas	Where is the love?		
		at. Estu	lores		

- Compare two strategies of evaluating "Who is top of the pops?":
 - σ Rank=1 $(\pi$ Rank, Artist(CHARTS))
 - π Rank, Artist (σ Rank=1 (CHARTS))

Selection before Projection is preferred.



A SSGP	ider CH	ARTS = {Rank, Atjet	with 100 tubles and	50	ttribu	tes :	2
	Rank	Artist	Song				_
	1	Chingy	Right Thurr				
1	2	Scribe	Stand up				
r	ittn	Aguilera and Kim	Cart hold is down				
-	4	Evanescence	Going under				
	5	Justin Timberlake	Senorita				
	6	Brooke Fraser	Better				
1		Black Eyed Peas	Where is the leve?				
	V V	Chat. Ca	stutulos				

- Compare two strategies of evaluating?
 - σ Rank > $10^{(\pi)}$ Rank. Artist (CHARTS))
 - π Rank, Artist $(\sigma$ Rank > 10(CHARTS))



A SSGORE	ider CH		with 100 tubles and	150	ttribu	tes:	2
~~	Rank	Artist	Song				
	1	Chingy	Right Thurr				
1	2	Scribe	Stand up				
r	1TT1	Aguilera and Kim	Card hold is down				
•	4	Evanescence	Going under				
	5	Justin Timberlake	Senorita				
	6	Brooke Fraser	Better				
1		Black Eyed Peas	Where is the leve?				
	Y V C	Chat. Ca	olulo168				

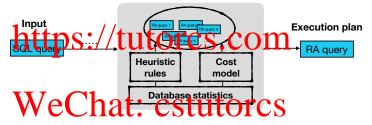
- Compare two strategies of evaluating?
 - σ Rank > 10(π Rank, Artist(CHARTS))
 - π Rank, Artist (σ Rank > 10 (CHARTS))

Projection before Selection is preferred.



Query Optimisation

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Trade-off:

Time for executing a RA query vs Time for finding a better RA query



(credit cookie) memorising vs understanding

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2006 but not whatever maths

herps: were testiconsterday

WeChat:



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