Database Management Systems

(COP 5725)

Fall 2021

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Exam 1 Solutions

Name:	
UFID:	
Email Address:	

Pledge (Must be signed according to UF Honor Code)

On my honor, I have neither given nor received unauthorized aid in doing this assignment.

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Signature

For scoring use only:

	Maximum	Received
Question 1	40	
Question 2	10	
Question 3	15	
Question 4	35	
Total	100	

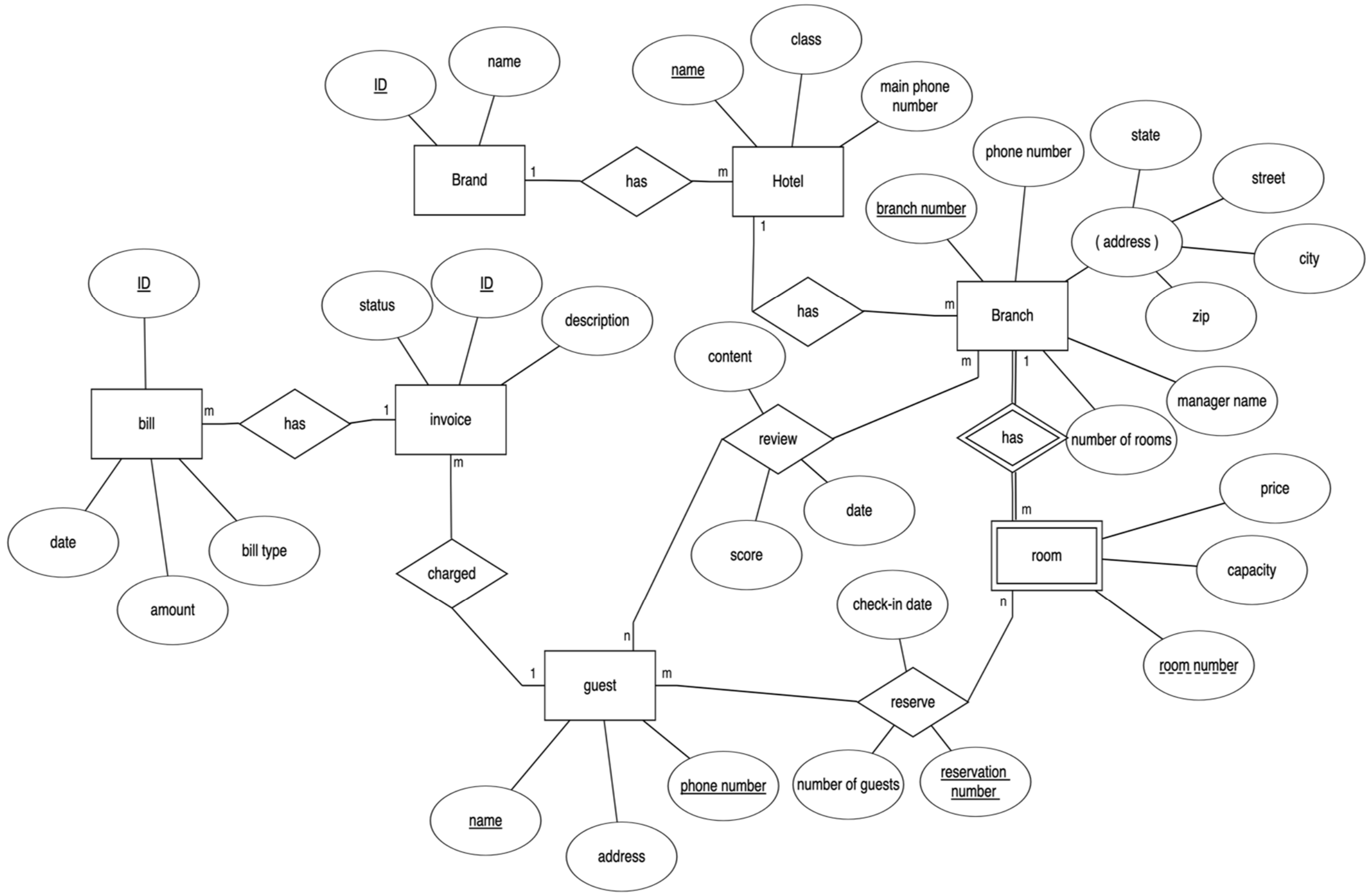
Question 1 (Entity-Relationship Model) [40 points]

Design an Entity-Relationship diagram by considering the requirements listed below. That means that you have to identify suitable entity sets, relationship sets, attributes, keys of entity sets (if not specified), and so on. Further, add the cardinalities (1:1, 1:m, m:1, m:n) to the relationship sets (by using the notations of ERDPlus) and write down your assumptions regarding the cardinalities if there could be a doubt.

(a) [20 points] Design an ER diagram for the following hotel management system.

- A brand of hotels (brand in short) can own many hotels, and a hotel has many branches.
- A brand has a unique ID and a name. A hotel has a name, a hotel class, and a phone number.
- A branch of hotels (branch in short) has an address, a phone number, a branch number, a number of rooms, and a manager's name.
- The address includes street, city, state, and zip code.
- A branch has many rooms, and a room has a room number, a price, and a capacity.
- A guest can reserve a room. A guest has a name, an address, and a phone number.
- When a reservation is made, the check-in date, the number of guests, and the reservation number are stored.
- Guests can review the branch where they stay, and each review has a score, a contents, and a date.
- When a guest leaves a branch, an invoice is charged to the guest.
- The status, an ID, and the description of an invoice are stored.
- An invoice can have many bills that have an ID, bill type, amount, and date.

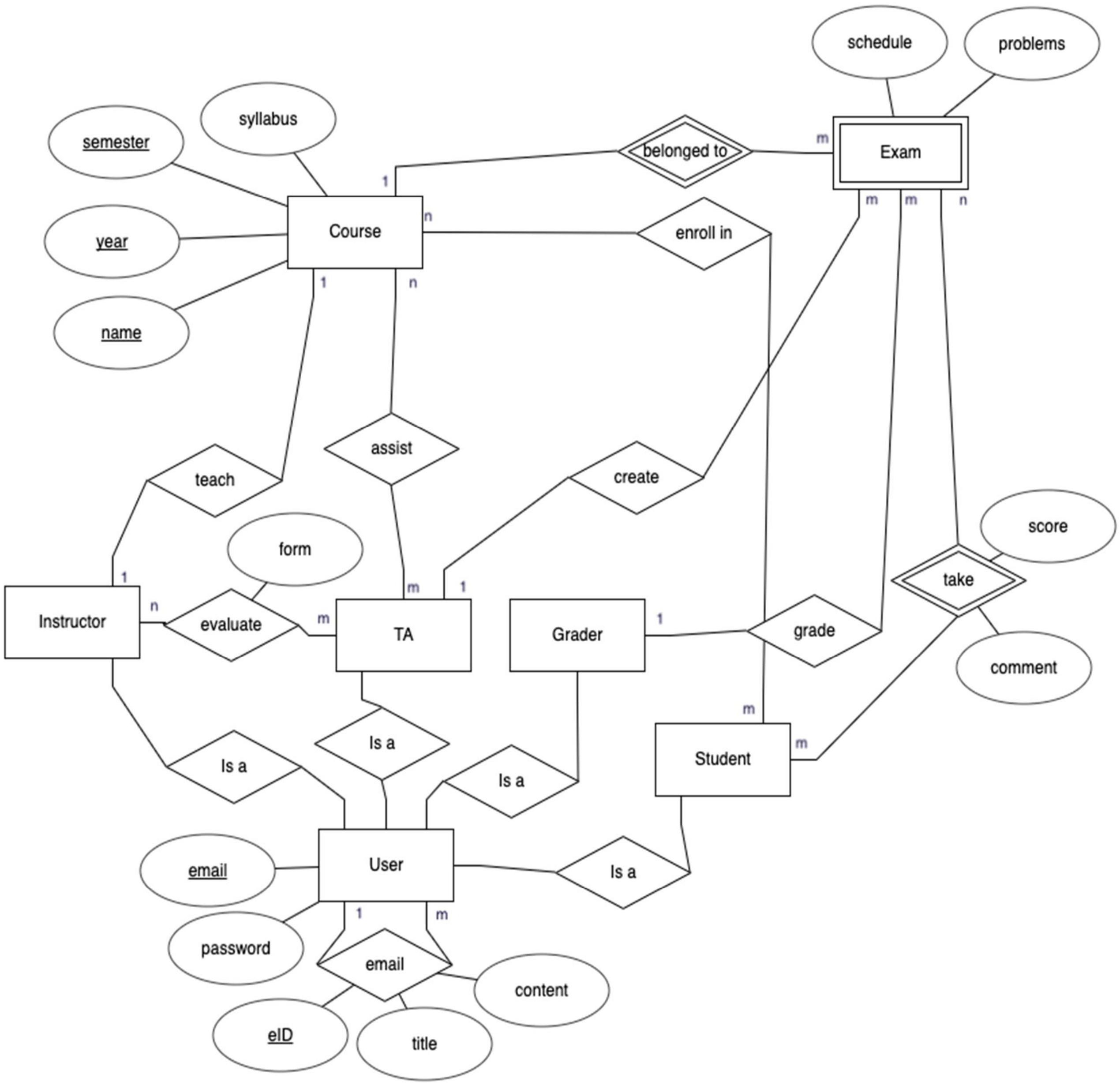
Create your diagram using ERDPlus. When you are finished, export it as an image, and upload it below.



(b) [20 points] Design an ER diagram for the following Online Class Management System.

- There are four types of users: Students, TAs, graders, and instructors.
- Every user is identified by an email and has a password.
- An instructor can teach one course in the semester.
- Each course has a year, a semester, a syllabus, and a name.
- Students enroll in courses. TAs assist courses and create multiple exams which belong to courses.
- The exam has a schedule and problems.
- Students take exams. When the Grader grades an exam, a score is stored.
- Graders leave comments when they grade exams. Score and comments can be seen by the student.
- The instructors evaluate TAs, and an evaluation form is created.
- Users can write an email, which is identified by an eID, to other users, and it contains the title and content.

Create your diagram using [ERDPlus](). When you are finished, export it as an image, and upload it below.


schedule
problems
syllabus
semester
belonged to
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1
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year
Course
enroll in
1
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name
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create
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Grader
1
grade
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Student
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1
m
password
email
content
eID
title

Question 2 (Relational Algebra) [10 points]

Provide brief answers to the following questions.

(a) [4 points] Explore whether the following statements are true or false. Give reasons for your assessments.

a. [2 points] $\pi_A(R \cap S) = \pi_A(R) \cap \pi_A(S)$, where A is a common attribute of R and S.

This statement is false. Assume we have $R(A, B) = \{(1, 2)\}$ and $S(A, B) = \{(1, 3)\}$. Then $\pi_A(R \cap S) = \emptyset$ but $\pi_A(R) \cap \pi_A(S) = \{(1)\}$.

b. [2 points] $\sigma_F(R ⟗ S) = \sigma_F(R) ⟗ S$, where F is a condition that only contains attributes of R as well as constants.

This statement is false.
Assume we have $R(A, B) = \{(1, 2), (3, 3)\}$ and $S(B, C) = \{(2, 2)\}$.
Then,
$\sigma_{A=3}(R ⟗ S) = \sigma_{A=3}(\{(1,2,2), (3,3,null)\}) = \{(3,3,null)\}$ and
$\sigma_{A=3}(R) ⟗ S = \{(3,3)\} ⟗ S = \{(3,3,null), (null,2,2)\}$

(b) [3 points] The Cartesian Product is one of the five basic Relational Algebra operators. The *Division* (*Quotient*) operator is a derived Relational Algebra operator. Is the statement "*The Division operator is the opposite of the Cartesian Product operator*" correct or incorrect? In other words, if R and S are two relations and $T = R \times S$ holds, are then $T \div S = R$ and $T \div R = S$? Please argue in either direction.

This statement is correct.
Consider the following tables *R, S,* and *T* given as

R	*C*
	4
	8

S	*D*
	3
	1
	7

T	*C*	*D*
	4	3
	4	1
	4	7
	8	3
	8	1
	8	7

Obviously, $T = R \times S$ holds. *All* tuples of R are concatenated with *all* tuples of S.
Therefore, we obtain

$T \div S = R$ *and* $T \div R = S$

(c) [3 points] Consider the following relations R and Q:

```
R | X |  Y
-----------
  | 1 | 'A'
  | 2 | 'B'
  | 3 | 'C'

Q | X |  Y
-----------
  | 2 | 'D'
  | 3 | 'C'
  | 4 | 'B'
```

Write a Relational Algebra query (hint: you can write a multi-step query) that uses the relations R and Q and creates the following new relation S:

```
S |  X1  |  Y  |  X2
-------------------------
  |  1   | 'A' | NULL
  |  2   | 'B' | NULL
  |  3   | 'C' |  3
  | NULL | 'D' |  2
```

$\rho_{R1(X1,Y)}(R)$

$\rho_{R2(X2,Y)}\left(\sigma_{X<4}(Q)\right)$

$S \leftarrow R1 ⟗ R2$

Question 3 (Relational Algebra) [15 points]

Provide brief answers to the following questions.

(a) [8 points] Let *R*(*A, B, C*), *S*(*B, D*), and *T*(*A, C*) be relations such that *R* has *r* tuples, *S* has *s* tuples, and *T* has *t* tuples with *r* > 0, *s* > 0, and *t* > 0. The attributes *A*, *B, C,* and *D* are supposed to have the same numerical data type. Consider the given Relational Algebra expressions and determine the *minimum* number and the *maximum* number of possible tuples of each result relation. Explain your answers.

a. [2 points] $\pi_{A,C}(R) \cap T$

The *minimum* number of possible tuples in the result is 0. This is the case when there are no common tuples in both relations. The *maximum* number of possible tuples in the result is min(*r*, *s*) since it is either *r* if $\pi_{A,C}(R) \subseteq T$ or *t* if $\pi_{A,C}(R) \supset T$.

b. [2 points] $R \bowtie_{R.B=S.B} S$

The *minimum* number of possible tuples in the result is 0. This is the case if every number of *B* in *R* is different from every number of *B* in *S*. The *maximum* number of possible tuples in the result is *r**s*. This is the case if all numbers in *R.B* and in *S.B* are the same. Then each tuple in *R* will be combined with each tuple in *S*.

c. [4 points] $\pi_B(\pi_B(R) \cup \pi_B(S))$ (For this question, also consider two other *possible* numbers of tuples beside the *minimum* and *maximum* number of tuples.)

The *minimum* number of possible tuples in the result is 1. This is the case if all numbers in *R.B* and in *S.B* are the same.

The *possible* number of tuples in the result is as follows.

Case 1: When *R.B* contains all values of *S.B* ($R.B \supseteq S.B$), then the possible number of tuples is *r*.

Case 2: When *S.B* contains all values of *R.B* ($S.B \supseteq R.B$), then the possible number of tuples is *s*.

Case 3: When *S.B* and *R.B* do not have any values in common ($R.B \cap S.B = \emptyset$), then the possible number of tuples is *r*+*s*. It is the *maximum* number of tuples.

Case 4: When some values of *R.B* and *S.B* are the same ($R.B - S.B \neq \emptyset \wedge S.B - R.B \neq \emptyset \wedge R.B \cap S.B \neq \emptyset$), then the possible number of tuples is *r*+*s* - $|R.B \cap S.B|$.

(b) [4 points] Let two relations R and S be given as follows.

R	a	b
	A	15
	B	20
	C	30

S	b	c
	20	D
	20	E
	10	F

Determine *three* ***different*** Relational Algebra expressions that create the following new relation (each answer should use different operations):

T	a	b
	B	20

First expression: $\rho_T(\sigma_{a=B}(R))$
Second expression: $\rho_T(\pi_{a,b}(R \bowtie S))$
Third expression: $\rho_T(R \ltimes S)$
Possible expression: $\rho_T(R - (R \triangleright S))$

(c) [3 points] Given two relations R and S as well as the following two Relational Algebra expressions.

Expression A: $R \bowtie S$ Expression B: $R \bowtie_{R.b=S.b} S$

What is the difference of the result of the two expressions and how will the results look like for each expression with the following relation instances for R and S?

R	a	b
	A	15
	B	20
	C	30

S	b	c
	20	D
	20	E
	10	F

Difference: The number of attributes in the result is different. The result of a theta join keeps every attribute that both relation schemas have. A natural join removes duplicate attributes.

$R \bowtie S$

R⋈S	a	b	c
	B	20	D
	B	20	E

$R \bowtie_{R.b=S.b} S$

$R\bowtie_{R.b=S.b}S$	a	R.b	c	S.b
	B	20	D	20
	B	20	E	20

Question 4 [35 points]

Consider the following relation schemas for a football management system. The primary keys are underlined.

```
Player(pID, name, age, mainPosition, nationID)
Coach(cID, name, age, duty, isRetired:Boolean, nationID)
Team(tID, name, staffNumber:number, foundationDate:date, lID, rival)
PlayerHistory(pID, tID, salary:number, year)
CoachHistory(cID, tID, salary:number, year)
League(lID, name, nationID, totalPlayersNumber:number)
Nation(nID, name)
```

Note the following characterization of foreign keys:

```
Player[nationID] ⊆ Nation[nID]
Coach[nationID] ⊆ Nation[nID]
League[nationID] ⊆ Nation[nID]
Team[rival] ⊆ Team[tID]
Team[lID] ⊆ League[lID]
PlayerHistory[tID] ⊆ Team[tID]
CoachHistory[tID] ⊆ team[tID]
PlayerHistory[pID] ⊆ Player[pID]
CoachHistory[cID] ⊆ Coach[cID]
```

Write Relational Algebra expressions for the following queries.

(a) [5 points] Find the names of players who have only played for the teams ever managed by the coach “Klopp”. (Assume there is only one coach named “Klopp”.)

$\rho_{Klopp}\ (\sigma_{name="Klopp"}\ (Coach))$

$\rho_{KloppTeamsID}\ (\pi_{tID}\ (\text{Klopp} \bowtie_{Klopp.cID=CoachHistory.cID}\ \text{CoachHistory}\ ))$

$\rho_{OtherTeamsID}\ (\pi_{tID}(Team) - \ KloppTeamsID)$

$\rho_{PlayersOfOtherTeams}\ (\pi_{pID}(PlayerHistory\ \bowtie\ OtherTeamsID))$

$\rho_{PlayersEverNoTeams}\ (\pi_{pID}(Player) - \pi_{pID}(PlayerHistory))$

$$\pi_{name}\big((\pi_{pID}(Player) - PlayersOfOtherTeams - PlayersEverNoTeams\big) \bowtie Player)$$

(b) [5 points] Find the names of coaches who have managed only "PL" teams in their career. ("PL" is the name of a league, and it is unique.)

$\rho_{PL}(\pi_{lID}(\sigma_{name="PL"}(League))$

$\rho_{PLTeams}(\pi_{tID}(Team \bowtie PL))$

$\rho_{CoachOtherLeaguesTeams}\ (\pi_{cID}\ (CoachHistory \rhd PLTeams))$

$\pi_{name}((\pi_{cID}(Coach) - CoachOtherLeaguesTeams) \bowtie Coach)$

(c) [5 points] Find the names of players who have ever played with "Messi" and "Ronaldo".

$\rho_{Messi}\ (\pi_{pID}(\sigma_{name="Messi"}\ (Player))$

$\rho_{Ronaldo}\ (\pi_{pID}(\sigma_{name="Ronaldo"}\ (Player))$

$\rho_{MessiHistory}\ \ (Messi \bowtie PlayerHistory)$

$\rho_{RonaldoHistory}\ \ (Ronaldo \bowtie PlayerHistory)$

$\rho_{PlayersWithMessi}\ (\pi_{pID}\ (MessiHistory$

$\bowtie_{MessiHistory.tID=PlayerHistory.tID \wedge MessiHistory.year=PlyaerHistory.year}\ PlayerHistory))$

$\rho_{PlayersWithRonaldo}\ (\pi_{pID}\ (RonaldoHistory$

$\bowtie_{RonaldoHistory.tID=PlayerHistory.tID \wedge RonaldoHistory.year=PlyaerHistory.year}\ PlayerHistory))$

$\pi_{name}((PlayersWithMessi \cap PlayersWithRonaldo) \bowtie Player)$

(d) [5 points] Find the names of the biggest teams (in terms of the number of staff) in the league "PL".

$\rho_{PL}(\pi_{lID}(\sigma_{name="PL"}(League))$

$\rho_{PLTeams}(\pi_{tID,name,staffNumber}(Team \bowtie PL))$

$\rho_{A}(PLTeams), \rho_{B}(PLTeams)$

$(\pi_{name}(PLTeams) - \pi_{B.name}\ (A \bowtie_{A.staffNumber > B.staffNumber} B))$

(e) [5 points] Find the names of players whose position is "ST", who are aged between 23 and 26, whose salary in 2021 is between \$3000 and \$5000, and who play in the league "LALIGA" at the moment (in 2021).

$\rho_{LALIGA}(\pi_{lID}(\sigma_{name="LALIGA"}(League))$

$\rho_{LALIGATeams}(\pi_{tID}(Team \bowtie LALIGA))$

$\rho_{tmpPlayers}\ \left(\pi_{pID,name}\left(\sigma_{(age \geq 23 \wedge age \leq 26) \wedge mainPosition="ST"}\ (Player)\right)\right)$

$\rho_{Players}\left(\pi_{pID,name,tID}\left(\sigma_{year=2021 \wedge (salary \geq 3000 \wedge salary \leq 5\ 000)}\ (tmpPlayers \bowtie PlayerHistory)\right)\right)$

$\pi_{name}(LALIGATeams \bowtie Players)$

(f) [5 points] Find the names of players who have played for all the teams where "Messi" has played.

$\rho_{Messi}\ (\pi_{pID}(\sigma_{name="Messi"}\ (Player))$

$\rho_{MessiTeams}\ \pi_{tID}\ (Messi\ \bowtie PlayerHistory)$

$\pi_{name}\big(((\pi_{pID,tID}PlayerHistory) \div MessiTeams) \bowtie Player\big)$

(g) [5 points] Find the names of players who have also played for their teams' rival team in the league "PL".

$\rho_{PL}(\pi_{lID}(\sigma_{name="PL"}(League))$

$\rho_{PLTeams}(\pi_{tID,rival}\ (Team\ \bowtie PL))$

$\rho_{PLTeamsAndPlayers}\ \pi_{pID,tID,rival}\ (PLTeams\ \bowtie PlayerHistory)$

$\rho_A(PLTeamsAndPlayers), \rho_B(PLTeamsAndPlayers)$

$\pi_{name}\ \Big(\Big(\pi_{A.pID}\ (\mathrm{A} \bowtie_{A.pID=B.pID \wedge A.rival=B.tID}\ \mathrm{B})\Big) \bowtie_{A.pID=pID}\ Player\Big)$