B561 Advanced Database Concepts
Assignment 2
Fall 2022

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September 23, 2022

1. Translating SQL queries with query predicates and subquery expressions into safe TRC

1. • Consider the query '*Find the bno and title of each book that was bought by exactly one student.*' This query can be expressed as the SQL query

   Solution:

   $\{(b.bno, b.title) \mid Book(b) \wedge \exists s \in Student(Buys(s.sid, b.bno)) \wedge \forall s1 \in Student \forall s2 \in Student(Buys(s1.sid, b.bno) \wedge Buys(s2.sid, b.bno) \rightarrow (s1 = s2)\}$

2. • Consider the query '*Find each pair* (m, b) *where* m *is a major and* b *is the bno of a book bought by a student who has major* m *and such that the price of* b *is the lowest among the set of books bought by students with major* m.'

   Solution:

   $\{(m.major, b.bno) \mid Major(m) \wedge Book(b) \wedge \exists t \in Buys(b.bno = t.bno \wedge \exists hm \in hasMajor(t.sid = hm.sid \wedge hm.major = m.major)) \wedge \neg \exists t \in Buys \neg \exists b1 \in Books(t.bno = b1.bno \wedge hasMajor(t.sid, m.major) \wedge b1.price < b.price)\}$

2. Expressing queries in (Extended) Safe TRC and Pure SQL with and without subquery expressions

3. Consider the query '*Find the bno and title of each book that is bought by a student who is (strictly) younger than each student who majors in Chemistry and who also bought that book.*'

   (a) • Express this query in Safe TRC (i.e, with quantifiers '*exists*' or '$\forall$').

   Solution:

   $\{(b.bno, b.title) \mid Book(b) \wedge \exists t1 \in Buys(b.bno = t1.bno \wedge \exists s1 \in Student \exists s2 \in Student(s1.sid = t1.sid \wedge s1.birthyear > s2.birthyear \wedge \exists t2 \in Buys(t2.sid = s2.sid \wedge \exists hm \in hasMajor(hm.sid = t2.sid \wedge hm.major = `Chemistry'))))\}$

   (b) • Express this query in Extended Safe TRC (i.e, with subquery expressions).
   Solution:

   $\{(b.bno, b.title) \mid Book(b) \wedge exists(1 \mid Buys(t1) \wedge t1.bno = b.bno \wedge exists(1 \mid Student(s1) \wedge Student(s2) \wedge s1.sid = t1.sid \wedge s1.birthyear > s2.birthyear \wedge exists(1 \mid Buys(t2) \wedge t2.sid = s2.sid \wedge exists(1 \mid hasMajor(hm) \wedge hm.sid = t2.sid \wedge hm.major = `Chemistry'))))\}$

4. Consider the query '*Find each student-book pair* (s, b) *where* s *is the sid of a student who majors in CS and who bought each book that costs no more than book* b.'

   (a) • Express this query in Extended Safe TRC (i.e, with subquery expressions).

   Solution:

   $\{(s.sid, b.bno) \mid Student(s) \wedge Book(b) \wedge exists(1 \mid hasMajor(hm) \wedge hm.major = `CS' \wedge hm.sid = s.sid \wedge notexists(1 \mid Book(b1) \wedge$

$b1.price \leq b.price \wedge notexists(1 \mid Buys(t) \wedge t1.bno = b1.bno \wedge t1.sid = s.sid)))\}$

5. Consider the query '*Find the sid and name of each student who bought all-but-one book that cost strictly more than $30.*'

   (a) • Express this query in Safe TRC (i.e, with quantifiers '$exists$' or '$\forall$').

   Solution:

   $\{(s.sname, s.sname \mid Student(s) \wedge \exists b1 \in Book(\neg\exists t1 \in Buys(t1.sid = s.sid \wedge b1.bno = t1.bno) \wedge \neg\exists b2 \in Book(b2.bno \neq b1.bno \wedge b2.price \geq 30 \wedge \neg\exists t2 \in Buys((t2.sid = s.sid) \rightarrow (b2.bno = t2.bno))) \wedge b1.price \geq 30)\}$

3. Expressing queries in Relational Algebra and RA SQL

10. Reconsider the query in Problem 1 '*Find the bno and title of each book that was bought by exactly one student.*'

    (a) • Express this query in Relational Algebra in standard notation.

    Solution:

    $\{ \pi_{B.bno,B.title}(B) - \pi_{B_1.bno,B_1.title}(B_1 \bowtie_{B_1.bno=T_1.bno} (T_1 \bowtie_{T_1.bno=T_2.bno \wedge T1.sid \neq T_2.sid} T_2)) \}$

11. Reconsider the query in Problem 2 '*Find each pair (m, b) where m is a major and b is the bno of a book bought by a student who has major m and such that the price of b is the lowest among the set of books bought by students with major m.*'

    (a) • Express this query in Relational Algebra in standard notation.

    Solution:

$\{ \pi_{hM.major,T.bno}(hM \bowtie_{T.sid=hM.sid} (T \bowtie_{T.bno=B.bno} B)) -$
$\pi_{hM.major,T.bno}(hM \bowtie_{T.sid=hM.sid} (T \bowtie_{T.bno=B.bno} (B \bowtie_{hM.major=hM_1.major}$
$(hM_1 \bowtie_{T_1.sid=hM_1.sid} (T_1 \bowtie_{T_1.bno=B_1.bno \wedge B.price>B_1.price} (B_1))))))$
$\}$

12. Reconsider the query in Problem 3 '*Find the bno and title of each book that is bought by a student who is (strictly) younger than each student who majors in Chemistry and who also bought that book.*'

    (a) • Express this query in Relational Algebra in standard notation.

    Solution:

    $\pi_{bno,title}(Book_{\bowtie_{b.bno=t1.bno}} Buys_{1\bowtie_{t1.sid=s1.sid}} Student_{1\bowtie_{s1.birthyear>s2.birthyear}}$
    $Student_{2\bowtie_{s2.sid=t2.sid}} Buys_{2\bowtie_{hm.sid=t2.sid \wedge \sigma_{major='Chemistry'}}} hasMajor)$

13. Reconsider the query in Problem 4 '*Find each student-book pair (s, b) where s is the sid of a student who majors in CS and who bought each book that costs no more than book b.*'

    (a) • Express this query in Relational Algebra in standard notation.

    Solution:

    $\pi_{sid,bno}(Student \bowtie Book_{\bowtie_{hm.sid=s.sid \wedge hm.major='CS'}} hasMajor) - \pi_{sid,bno}(Student_{\bowtie}$
    $Book_{\bowtie_{hm.sid=s.sid \wedge hm.major='CS'}} hasMajor \cap$
    $\pi_{sid,bno}(Student \bowtie Book_{\bowtie_{hm.sid=s.sid \wedge hm.major='CS'}} hasMajor_{\bowtie}$
    $Book_{\bowtie_{hm.sid=s.sid \wedge hm.major='CS'}} hasMajor_{\bowtie b1.price<=b.price} Book_{1\bowtie_{t1.sid=s.bno \wedge t1.bno=b1.bno}} Buys)$

14. Reconsider the query in Problem 5 '*Find the sid and name of each student who bought all-but-one book that cost strictly more than \$30.*'

    (a) • Express this query in Relational Algebra in standard notation.

    Solution:

    $1 - \pi_{sid}(Student)_{\bowtie t1.sid=s.sid} Buys_{\bowtie t.bno \neq b.bno \wedge b.price>30} Books$

4. Expressing constraints using Relational Algebra

19. • Among the books that cite a book, there are books that cite the same set of other books.

    Solution:

    $\{\ \pi_{c_1.bno1}(\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2}(\sigma_{c_1.bno2=c_2.bno2}(C_1 \times C_2))$
    $\cap\ \pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2}(\sigma_{c_1.bno1\neq c_2.bno1}(C_1 \times C_2))$
    $\cap \pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2}(\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2}(C_1 \times C_2) -$

    $\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2}$
    $(\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2}$
    $(\sigma_{c_1.bno1=c_3.bno1}(C_1 \times C_2 \times C_3)) \cap$
    $\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2}$
    $(\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2}(C_1 \times C_2 \times C_3) -$
    $\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2}$
    $(\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2,c_4.bno1,c_4.bno2}$
    $(\sigma_{c_2.bno1=c_4.bno1}(C_1 \times C_2 \times C_3 \times C_4)) \cap$
    $\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2,c_4.bno1,c_4.bno2}(\sigma_{c_3.bno2=c_4.bno2}(C_1 \times$
    $C_2 \times C_3 \times C_4))))))) \cap$
    $\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2}(\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2}(C_1 \times C_2) -$
    $\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2bno2}(\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2}$
    $(\sigma_{c_2.bno1=c_3.bno1}(C_1 \times C_2 \times C_3)) \cap$
    $\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2}$
    $(\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2}(C_1 \times C_2 \times C_3) -$
    $\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2}$
    $(\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2,c_4.bno1,c_4.bno2}$
    $(\sigma_{c_1.bno1=c_4.bno1}(C_1 \times C_2 \times C_3 \times C_4)) \cap$
    $\pi_{c_1.bno1,c_1.bno2,c_2.bno1,c_2.bno2,c_3.bno1,c_3.bno2,c_4.bno1,c_4.bno2}(\sigma_{c_3.bno2=c_4.bno2}(C_1 \times$
    $C_2 \times C_3 \times C_4)))))))) \neq \emptyset\ \}$

20. • Some student who majors only bought books that where bought by students who major in Math.

    Solution:

    $\pi_{h.sid}(\pi_{h.sid,h.major}(hasMajor) -$

$\pi_{h.sid,h.major}(\pi_{h.sid,h.major,b.sid,b,bno}(\sigma_{b.sid=h.sid}(hasMajor \times buys)) \cap$

$\pi_{h.sid,h.major,b.sid,b.bno}(\pi_{h.sid,h.major,b.sid,b.bno}(hasMajor \times buys) -$
$\pi_{h.sid,h.major,b.sid,b.bno}(\sigma_{h_1.sid<>h.sid \wedge b_1.sid=h_1.sid \wedge h_1.major=\texttt{Math}}(hasMajor \times$
$buys \times hasMajor_1 \times buys_1))))) \neq \emptyset$

21. • There are pairs of majors that have no common students who have those majors.

    Solution:

    $\pi_{m_1.major,m_2.major}(\pi_{m_1.major,m_2.major}(\sigma_{m_1.major \neq m_2.major}(major_1 \times$
    $major_2)) \cap$
    $\pi_{m_1.major,m_2.major}(\pi_{m_1.major,m_2.major}(major_1 \times major_2) -$
    $\pi_{m_1.major,m_2.major}(\pi_{m_1.major,m_2.major,h_1.major}(\sigma_{h_1.major=m_1.major}(major_1 \times$
    $major_2 \times hasMajor_1)) \cap$
    $\pi_{m_1.major,m_2.major,h_1.major}(\sigma_{h_2.major=m_2.majorandh_1.sid=h2.sid}(h_1.major=m_1.major}(major_1 \times$
    $major_2 \times hasMajor_1 \times hasMajor_2))))) \neq \emptyset$

22. • Attribute 'sid' in the relation hasMajor is a foreign key referencing the primary key 'sid' in the relation Student

    Solution:

    $\pi_{h.sid}(\pi_{h.sid}(hasMajor) - \pi_{h.sid}(\sigma_{h.sid=s.sid}(hasMajor \times student))) =$
    $\emptyset$