SQL:
Data Definition Language

CSC343 Introduction to Databases
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Table attributes have types

• When creating a table, you must define the type of each attribute.
• Analogous to declaring a variable’s type in a program. Eg, “int num;” in Java or C.
• Some programming languages don’t require type declarations. Eg, Python.
• Pros and cons?
• Why are type declarations required in SQL?
Built-in types

- **CHAR (n)**: fixed-length string of n characters. Padded with blanks if necessary.
- **VARCHAR (n)**: variable-length string of up to n characters.
- **TEXT**: variable-length, unlimited. Not in the SQL standard, but psql and others support it.
- **INT** = **INTEGER**
- **FLOAT** = **REAL**
- **BOOLEAN**
- **DATE; TIME; TIMESTAMP** (date plus time)
Values for these types

- **Strings**: 'Shakespeare''s Sonnets'
  Must surround with single quotes.
- **INT**: 37
- **FLOAT**: 1.49, 37.96e2
- **BOOLEAN**: TRUE, FALSE
- **DATE**: '2011-09-22'
- **TIME**: '15:00:02', '15:00:02.5'
- **TIMESTAMP**: 'Jan-12-2011 10:25'
And much more

- These are all defined in the SQL standard.
- There is much more, e.g.,
  - specifying the precision of numeric types
  - other formats for data values
  - more types
- For what psql supports, see chapter 8 of the documentation.
User-defined types

• Defined in terms of a built-in type.
• You make it more specific by defining constraints (and perhaps a default value).
• Example:

```sql
create domain Grade as int
  default null
  check (value>=0 and value <=100);
create domain Campus as varchar(4)
  default 'StG'
  check (value in ("StG','UTM','UTSC'");
```
Semantics of type constraints

• Constraints on a type are checked every time a value is assigned to an attribute of that type.
• You can use these to create a powerful type system.
Semantics of default values

- The default value for a type is used when no value has been specified.
- Useful! You can run a query and insert the resulting tuples into a relation -- even if the query does not give values for all attributes.
- Table attributes can also have default values.
- The difference:
  - attribute default: for that one attribute in that one table
  - type default: for every attribute defined to be of that type
Keys and Foreign Keys
Key constraints

• Declaring that a set of one or more attributes are the **PRIMARY KEY** for a relation means:
  • they form a key (unique and no subset is)
  • their values will never be null (you don’t need to separately declare that)

• Big hint to the DBMS: optimize for searches by this set of attributes!

• Every table must have 0 or 1 primary key.
  • A table can have no primary key, but in practise, every table should have one. Why?
  • You cannot declare more than one primary key.
Declaring primary keys

• For a single-attribute key, can be part of the attribute definition.

```sql
create table Blah (  
    ID integer primary key,  
    name varchar(25))
```

• Or can be at the end of the table definition. (This is the only way for multi-attribute keys.) The brackets are required.

```sql
create table Blah (  
    ID integer,  
    name varchar(25),  
    primary key (ID))
```
Uniqueness constraints

- Declaring that a set of one or more attributes is **UNIQUE** for a relation means:
  - they form a key (unique and no subset is)
  - their values *can* be null; if they mustn’t, you need to separately declare that

- You can declare more than one set of attributes to be **UNIQUE**.
Declaring UNIQUE

• If only one attribute is involved, can be part of the attribute definition.
  create table Blah (  
    ID integer unique,  
    name varchar(25));

• Or can be at the end of the table definition. (This is the only way if multiple attributes are involved.) The brackets are required.
  create table Blah (  
    ID integer,  
    name varchar(25),  
    unique (ID));
We saw earlier how nulls affect “unique”

- For uniqueness constraints, no two nulls are considered equal.

- E.g., consider:
  ```sql
  create table Testunique (
    first varchar(25),
    last varchar(25),
    unique(first, last)
  )
  ```

- This would prevent two insertions of ('Yijun', 'Xi')

- But it would allow two insertions of (null, 'Schoeler')

This can’t occur with a primary key. Why not?
Foreign key constraints

• Eg in table Took:
  \[\text{foreign key (sID) references Student}\]

• Means that attribute sID in this table is a foreign key that references the primary key of table Student.
  • Every value for sID in this table must actually occur in the Student table.

• Requirements:
  • Must be declared either primary key or unique in the “home” table.
Declaring foreign keys

• Again, declare with the attribute (only possible if just a single attribute is involved) or as a separate table element.

• Can reference attribute(s) that are not the primary key as long as they are unique; just name them.

```sql
create table People (  
    SIN integer primary key,  
    name text,  
    OHIP text unique);  
create table Volunteers (  
    email text primary key,  
    OHIPnum text references People(OHIP));
```
Enforcing foreign-key constraints

• Suppose there is a foreign-key constraint from relation R to relation S.

• When must the DBMS ensure that:
  • the referenced attributes are PRIMARY KEY or UNIQUE?
  • the values actually exist?

• What could cause a violation?

• You get to define what the DBMS should do.

• This is called specifying a “reaction policy.”
Other Constraints and Assertions
"check" constraints

• We’ve seen a check clause on a user-defined domain:
  
  ```sql
  create domain Grade as smallint
  default null
  check (value>=0 and value <=100);
  ```

• You can also define a check constraint
  
  • on an attribute
  
  • on the tuples of a relation
  
  • across relations
Attribute-based “check” constraints

• Defined with a single attribute and constrain its value (in every tuple).
• Can only refer to that attribute.
• Can include a subquery.
• Example:
  ```sql
  create table Student (
    sID integer,
    program varchar(5) check
      (program in (select post from P)),
    firstName varchar(15) not null, ...);
  ```
• Condition can be anything that could go in a WHERE clause.
When they are checked

• Only when a tuple is inserted into that relation, or its value for that attribute is updated.

• If a change somewhere else violates the constraint, the DBMS will not notice. E.g.,
  • If a student’s program changes to something not in table P, we get an error.
  • But if table P drops a program that some student has, there is no error.
“not null” constraints

• You can declare that an attribute of a table is NOT NULL.

```sql
create table Course(
    cNum integer,
    name varchar(40) not null,
    dept Department,
    wr boolean,
    primary key (cNum, dept));
```

• In practise, many attributes should be not null.

• This is a very specific kind of attribute-based constraint.
Tuple-based “check” constraints

• Defined as a separate element of the table schema, so can refer to any attributes of the table.

• Again, condition can be anything that could go in a WHERE clause, and can include a subquery.

• Example:

```sql
create table Student (
    sID integer,
    age integer, year integer,
    college varchar(4),
    check (year = age - 18),
    check college in
    (select name from Colleges));
```
When they are checked

• Only when a tuple is inserted into that relation, or updated.

• Again, if a change somewhere else violates the constraint, the DBMS will not notice.
How nulls affect “check” constraints

• A check constraint only fails if it evaluates to false.
• It is not picky like a WHERE condition.
• E.g.: `check (age > 0)`

<table>
<thead>
<tr>
<th>age</th>
<th>Value of condition</th>
<th>CHECK outcome</th>
<th>WHERE outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>TRUE</td>
<td>pass</td>
<td>pass</td>
</tr>
<tr>
<td>-5</td>
<td>FALSE</td>
<td>fail</td>
<td>fail</td>
</tr>
<tr>
<td>NULL</td>
<td>unknown</td>
<td>pass</td>
<td>fail</td>
</tr>
</tbody>
</table>
Example

• Suppose you created this table:

```sql
create table Frequencies(
    word varchar(10),
    num integer,
    check (num > 5));
```

• It would allow you to insert (`'hello'`, `null`) since `null` passes the constraint `check (num > 5)`.

• If you need to prevent that, use a “not null” constraint.

```sql
create table Frequencies(
    word varchar(10),
    num integer not null,
    check (num > 5));
```
Naming your constraints

- If you name your constraint, you will get more helpful error messages.

- This can be done with any of the types of constraint we’ve seen.

- Add

  ```
  constraint «name»
  ```

  before the

  ```
  check («condition»)
  ```
create domain Grade as smallint
default null
constraint gradeInRange
    check (value>=0 and value <=100));

create domain Campus as varchar(4)
    not null
constraint validCampus
    check (value in ('StG', 'UTM', 'UTSC'));

create table Offering(...
    constraint validCourseReference
    foreign key (cNum, dept) references Course);
• Order of constraints doesn’t matter, and doesn’t dictate the order in which they’re checked.
Assertions

• Check constraints apply to an attribute or table. They can’t express constraints across tables, e.g.,
  • Every loan has at least one customer, who has an account with at least $1,000.
  • For each branch, the sum of all loan amounts < the sum of all account balances.

• Assertions are schema elements at the top level, so can express cross-table constraints:
  
  \texttt{create assertion (<name>) check (<predicate>);}
Powerful but costly

• SQL has a fairly powerful syntax for expressing logical predicates, including quantification.

• Assertions are costly because
  • They have to be checked upon every database update (although a DBMS may be able to limit this).
  • Each check can be expensive.

• Testing and maintenance are also difficult.

• Assertions must be used with great care.
Triggers

• Assertions are powerful, but costly.

• Check constraints are less costly, but less powerful.

• Triggers are a compromise between these extremes:
  • They are cross-table constraints, as powerful as assertions.
  • But you control the cost by having control over when they are applied.
The basic idea

• You specify three things.

  • Event: Some type of database action, e.g.,
    after delete on Courses or
    before update of grade on Took

  • Condition: A boolean-valued expression, e.g.,
    when grade > 95

  • Action: Any SQL statements, e.g.,
    insert into Winners values (sID)
Reaction Policies
Example

• Suppose R = Took and S = Student.

• What sorts of action must simply be rejected?

• But a deletion or update with an sID that occurs in Took could be allowed ...
Possible policies

- **cascade**: propagate the change to the referring table
- **set null**: set the referring attribute(s) to null

- There are other options we won’t cover. Many DBMSs don’t support all of them.

- If you say nothing, the default is to forbid the change in the referred-to table.
Reaction policy example

- In the University schema, what should happen in these situations:
  - csc343 changes number to be 543
  - student 99132 is deleted
  - student 99132’s grade in csc148 is raised to 85.
  - csc148 is deleted
Note the asymmetry

• Suppose table R refers to table S.

• You can define “fixes” that propagate changes backwards from S to R.

• (You define them in table R because it is the table that will be affected.)

• You cannot define fixes that propagate forward from R to S.
Syntax for specifying a reaction policy

• Add your reaction policy where you specify the foreign key constraint.

• Example:
  
  ```sql
  create table Took ( 
    ... 
    foreign key (sID) references Student 
    on delete cascade 
    ... 
  );
  ```
What you can react to

- Your reaction policy can specify what to do either
  - on delete, i.e., when a deletion creates a dangling reference,
  - on update, i.e., when an update creates a dangling reference,
  - or both. Just put them one after the other.
  
  Example:
  on delete restrict on update cascade
What your reaction can be

• Your policy can specify one of these reactions (there are others):

  • restrict: Don’t allow the deletion/update.
  • cascade: Make the same deletion/update in the referring tuple.
  • set null: Set the corresponding value in the referring tuple to null.
Semantics of Deletion

• What if deleting one tuple violates a foreign key constraint, but deleting others does not?
Semantics of Deletion

• What if deleting one tuple affects the outcome for a tuple encountered later?

• To prevent such interactions, deletion proceeds in two stages:
  • Mark all tuples for which the WHERE condition is satisfied.
  • Go back and delete the marked tuples.
DDL Wrap-up
Updating the schema itself

• Alter: alter a domain or table
  alter table Course
    add column numSections integer;
  alter table Course
    drop column breadth;

• Drop: remove a domain, table, or whole schema
  drop table course;

• How is that different from this?
  delete from course;

• If you drop a table that is referenced by another table, you must specify “cascade”

• This removes all referring rows.
There’s more to DDL

• For example, you can also define:
  • indices: for making search faster (we’ll discuss these later).
  • privileges: who can do what with what parts of the database

• See csc443.