Database Experiment 2

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Environment

```
$ mysql --version
mysql  Ver 14.14 Distrib 5.7.28, for Linux (x86_64) using  EditLine wrapper
```

Process

1. Define Tables

The first step to creating tables is creating a database:

```
create database Experiment; use Experiment;
```

Now we can create tables. Constraints are left for later parts.

```
create table Employee (name char(30),ID int,age tinyint,salary int,departmentID int);
create table Department (name char(30),ID int,headID int);
create table Project (name char(50),ID int,departmentID int);
create table Job (employeeID int,projectID int,workTime double);
```

Check table definitions with the command:

```
describe Employee; describe Department; describe Project; describe Job;
```

Then we fill the tables with some sample data:

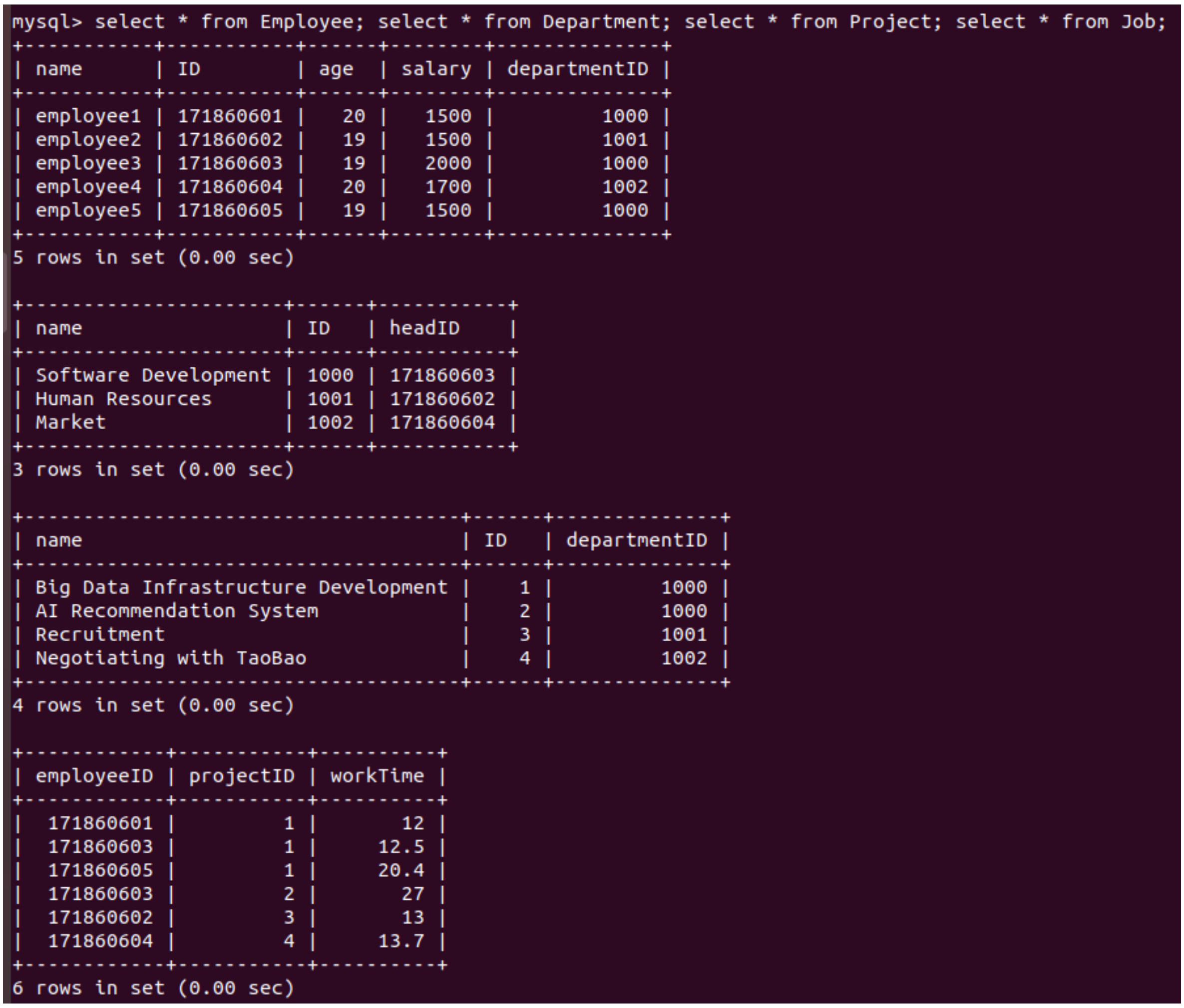
```
insert into Employee (name,ID,age,salary,departmentID) values
('employee1',171860601,20,1500,1000),
('employee2',171860602,19,1500,1001),
('employee3',171860603,19,2000,1000),
('employee4',171860604,20,1700,1002),
('employee5',171860605,19,1500,1000);

insert into Department (name,ID,headID) values
('Software Development',1000,171860603),
('Human Resources',1001,171860602),
('Market',1002,171860604);

insert into Project (name,ID,departmentID) values
('Big Data Infrastructure Development',1,1000),
('AI Recommendation System',2,1000),
('Recruitment',3,1001),
('Negotiating with TaoBao',4,1002);
```

```
insert into Job (employeeID,projectID,workTime) values
(171860601,1,12),
(171860603,1,12.5),
(171860605,1,20.4),
(171860603,2,27),
(171860602,3,13),
(171860604,4,13.7);
```

Check with the command:

```
select * from Employee; select * from Department; select * from Project; select
* from Job;
```

This is the screen-capture of the tables after data is inserted:



```
mysql> select * from Employee; select * from Department; select * from Project; select * from Job;
+-----------+-----------+------+--------+--------------+
| name      | ID        | age  | salary | departmentID |
+-----------+-----------+------+--------+--------------+
| employee1 | 171860601 |   20 |   1500 |         1000 |
| employee2 | 171860602 |   19 |   1500 |         1001 |
| employee3 | 171860603 |   19 |   2000 |         1000 |
| employee4 | 171860604 |   20 |   1700 |         1002 |
| employee5 | 171860605 |   19 |   1500 |         1000 |
+-----------+-----------+------+--------+--------------+
5 rows in set (0.00 sec)

+----------------------+------+-----------+
| name                 | ID   | headID    |
+----------------------+------+-----------+
| Software Development | 1000 | 171860603 |
| Human Resources      | 1001 | 171860602 |
| Market               | 1002 | 171860604 |
+----------------------+------+-----------+
3 rows in set (0.00 sec)

+-------------------------------------+------+--------------+
| name                                | ID   | departmentID |
+-------------------------------------+------+--------------+
| Big Data Infrastructure Development |    1 |         1000 |
| AI Recommendation System            |    2 |         1000 |
| Recruitment                         |    3 |         1001 |
| Negotiating with TaoBao             |    4 |         1002 |
+-------------------------------------+------+--------------+
4 rows in set (0.00 sec)

+------------+-----------+----------+
| employeeID | projectID | workTime |
+------------+-----------+----------+
|  171860601 |         1 |       12 |
|  171860603 |         1 |     12.5 |
|  171860605 |         1 |     20.4 |
|  171860603 |         2 |       27 |
|  171860602 |         3 |       13 |
|  171860604 |         4 |     13.7 |
+------------+-----------+----------+
6 rows in set (0.00 sec)
```

2. Adding Constraints

2.1 Primary Key

After analyzing the relations between the three entities `Department`, `Employee`, and `Project`, I found three weak assumptions:

1. Every employee can only be in one department.
2. Every department can only have one head.
3. Every project can only belong to one department.

In reality, these assumptions do not hold, especially in start-up companies. This is issued as a problem.

The assumption are considered as weak because they can be solved by setting multiple primary keys, but that raises new problems.

For example, we could set the primary key for `Employee` as `ID-departmentID`, and now an employee can have multiple entries belonging to different departments. But we have to make sure that the name, age and salary are the same for the same Employee(ID).

A better way would be to split the Employee table into two sub-tables.

There is the same problem for `Department` and `Project`.

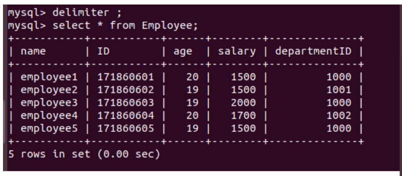
Since I can't split these tables due to homework requirements(the best solution), and I want my table to be more realistic, two options remain:

1. Assuming that everything is valid and do nothing.
2. Add triggers to fix things for the same ID.

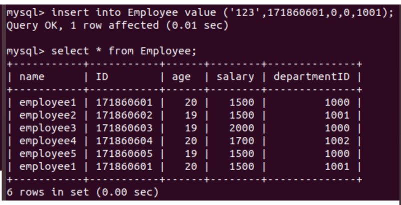
To make this analysis meaningful, I choose option 2.

```
alter table Employee add primary key (ID,departmentID);
alter table Department add primary key (ID,headID);
alter table Project add primary key (ID,departmentID);
alter table Job add primary key (employeeID,projectID);

delimiter //
create trigger EmployeeCheck before insert on Employee
for each row
begin
    if exists (select * from Employee where ID = new.ID) then set
    new.name = (select distinct name from Employee where ID = new.ID),
    new.age = (select distinct age from Employee where ID = new.ID),
    new.salary = (select distinct salary from Employee where ID = new.ID);
    end if;
end; //
delimiter ;

delimiter //
create trigger DepartmentCheck before insert on Department
for each row
begin
    if exists (select * from Department where ID = new.ID) then set
    new.name = (select distinct name from Department where ID = new.ID);
    end if;
end; //
delimiter ;

delimiter //
create trigger ProjectCheck before insert on Project
for each row
begin
    if exists (select * from Project where ID = new.ID) then set
    new.name = (select distinct name from Project where ID = new.ID);
    end if;
end; //
delimiter ;
```

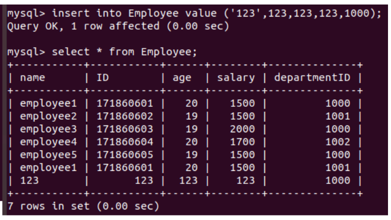
To prove that it works:



```
mysql> delimiter ;
mysql> select * from Employee;
+-----------+-----------+------+--------+--------------+
| name      | ID        | age  | salary | departmentID |
+-----------+-----------+------+--------+--------------+
| employee1 | 171860601 |   20 |   1500 |         1000 |
| employee2 | 171860602 |   19 |   1500 |         1001 |
| employee3 | 171860603 |   19 |   2000 |         1000 |
| employee4 | 171860604 |   20 |   1700 |         1002 |
| employee5 | 171860605 |   19 |   1500 |         1000 |
+-----------+-----------+------+--------+--------------+
5 rows in set (0.00 sec)
```



```
mysql> insert into Employee value ('123',171860601,0,0,1001);
Query OK, 1 row affected (0.01 sec)

mysql> select * from Employee;
+-----------+-----------+------+--------+--------------+
| name      | ID        | age  | salary | departmentID |
+-----------+-----------+------+--------+--------------+
| employee1 | 171860601 |   20 |   1500 |         1000 |
| employee2 | 171860602 |   19 |   1500 |         1001 |
| employee3 | 171860603 |   19 |   2000 |         1000 |
| employee4 | 171860604 |   20 |   1700 |         1002 |
| employee5 | 171860605 |   19 |   1500 |         1000 |
| employee1 | 171860601 |   20 |   1500 |         1001 |
+-----------+-----------+------+--------+--------------+
6 rows in set (0.00 sec)
```



```
mysql> insert into Employee value ('123',123,123,123,1000);
Query OK, 1 row affected (0.00 sec)

mysql> select * from Employee;
+-----------+-----------+------+--------+--------------+
| name      | ID        | age  | salary | departmentID |
+-----------+-----------+------+--------+--------------+
| employee1 | 171860601 |   20 |   1500 |         1000 |
| employee2 | 171860602 |   19 |   1500 |         1001 |
| employee3 | 171860603 |   19 |   2000 |         1000 |
| employee4 | 171860604 |   20 |   1700 |         1002 |
| employee5 | 171860605 |   19 |   1500 |         1000 |
| employee1 | 171860601 |   20 |   1500 |         1001 |
| 123       |       123 |  123 |    123 |         1000 |
+-----------+-----------+------+--------+--------------+
7 rows in set (0.00 sec)
```

2.2 Not Null

Every field is to set `NOT NULL`.

```
alter table Employee modify name char(30) not null, modify age tinyint not null,
modify salary int not null;
alter table Department modify name char(30) not null;
alter table Project modify name char(50) not null;
alter table Job modify workTime double not null;
[describe Employee; describe Department; describe Project; describe Job;]
```

2.3 Foreign Key

Employee(departmentID) references Department(ID); Department(headID) references Employee(ID); Project(departmentID) references Department(ID); Job(employeeID) references Employee(ID); Job(projectID) references Project(ID).

Since `update` should be synchronized and `delete` should be restricted, the clause `on update cascade on delete restrict` is added for all foreign key constraints.

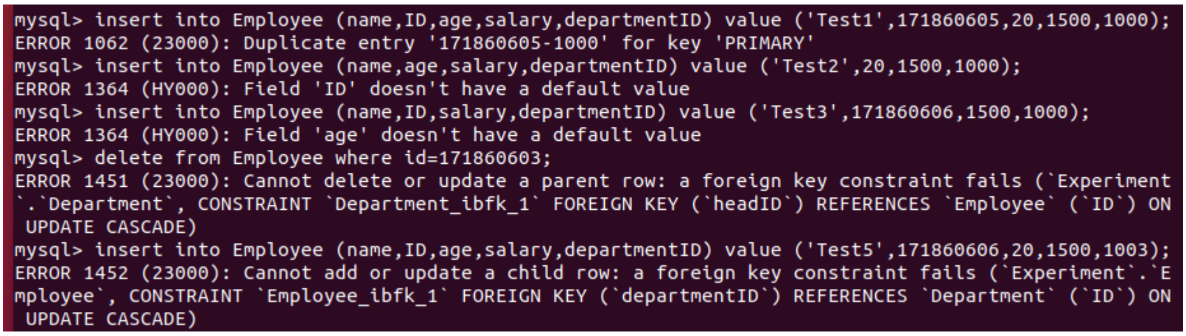
```
alter table Employee add foreign key (departmentID) references Department (ID)
on update cascade on delete restrict;
alter table Department add foreign key (headID) references Employee (ID) on
update cascade on delete restrict;
alter table Project add foreign key (departmentID) references Department (ID) on
update cascade on delete restrict;
alter table Job add foreign key (employeeID) references Employee (ID) on update
cascade on delete restrict;
alter table Job add foreign key (projectID) references Project (ID) on update
cascade on delete restrict;
```

3. Testing

As a **TDD** fan, this part is especially important for me. Since the four tables are somewhat identical, I am only testing the `Employee` table. The tests can be divided into three equivalent classes consistent with the constraints added above:

1. Primary key constraints
    1. Duplicate
    2. Missing
2. Not null key constraints
    1. Missing (only valid using `ID` that doesn't already exist in the table due to the trigger I added)
3. Foreign key constraints
    1. Delete
    2. Insert with non-existent foreign key

```
insert into Employee (name,ID,age,salary,departmentID) value
('Test1',171860605,20,1500,1000);
insert into Employee (name,age,salary,departmentID) value
('Test2',20,1500,1000);
insert into Employee (name,ID,salary,departmentID) value
('Test3',171860606,1500,1000);
delete from Employee where id=171860603;
insert into Employee (name,ID,age,salary,departmentID) value
('Test5',171860606,20,1500,1003);
```



```
mysql> insert into Employee (name,ID,age,salary,departmentID) value ('Test1',171860605,20,1500,1000);
ERROR 1062 (23000): Duplicate entry '171860605-1000' for key 'PRIMARY'
mysql> insert into Employee (name,age,salary,departmentID) value ('Test2',20,1500,1000);
ERROR 1364 (HY000): Field 'ID' doesn't have a default value
mysql> insert into Employee (name,ID,salary,departmentID) value ('Test3',171860606,1500,1000);
ERROR 1364 (HY000): Field 'age' doesn't have a default value
mysql> delete from Employee where id=171860603;
ERROR 1451 (23000): Cannot delete or update a parent row: a foreign key constraint fails (`Experiment
`.`Department`, CONSTRAINT `Department_ibfk_1` FOREIGN KEY (`headID`) REFERENCES `Employee` (`ID`) ON
 UPDATE CASCADE)
mysql> insert into Employee (name,ID,age,salary,departmentID) value ('Test5',171860606,20,1500,1003);
ERROR 1452 (23000): Cannot add or update a child row: a foreign key constraint fails (`Experiment`.`E
mployee`, CONSTRAINT `Employee_ibfk_1` FOREIGN KEY (`departmentID`) REFERENCES `Department` (`ID`) ON
 UPDATE CASCADE)
```

4. Triggers

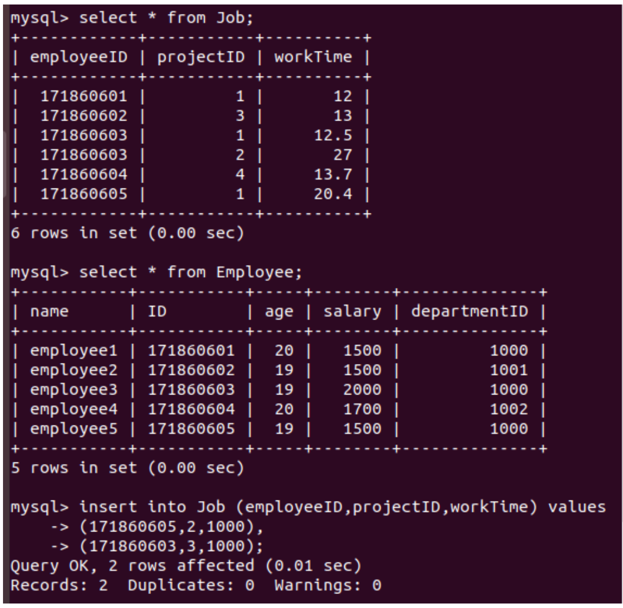
Nothing much to say about this part.

4.a WorkTimeCheck

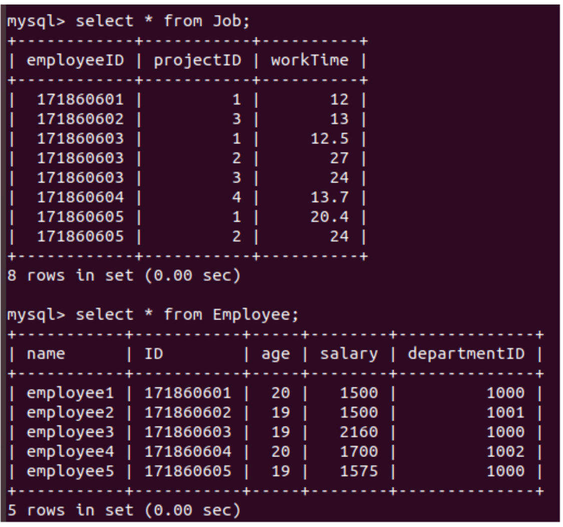
```
delimiter //
create trigger workTimeCheck before insert on Job
for each row
begin
    if new.worktime > 24 then set new.worktime = 24;
    end if;
end; //
delimiter ;
```

4.b SalaryIncrease

```
drop trigger salaryIncrease;
delimiter //
create trigger salaryIncrease after insert on Job
for each row
begin
    if new.employeeID in (select headID from Department) then update Employee
set salary = salary * 1.08 where Employee.ID = new.employeeID;
    else update Employee set salary = salary * 1.05 where Employee.ID =
new.employeeID;
    end if;
end; //
delimiter ;
```



```
mysql> select * from Job;
+------------+-----------+----------+
| employeeID | projectID | workTime |
+------------+-----------+----------+
|  171860601 |         1 |       12 |
|  171860602 |         3 |       13 |
|  171860603 |         1 |     12.5 |
|  171860603 |         2 |       27 |
|  171860604 |         4 |     13.7 |
|  171860605 |         1 |     20.4 |
+------------+-----------+----------+
6 rows in set (0.00 sec)

mysql> select * from Employee;
+-----------+-----------+-----+--------+--------------+
| name      | ID        | age | salary | departmentID |
+-----------+-----------+-----+--------+--------------+
| employee1 | 171860601 |  20 |   1500 |         1000 |
| employee2 | 171860602 |  19 |   1500 |         1001 |
| employee3 | 171860603 |  19 |   2000 |         1000 |
| employee4 | 171860604 |  20 |   1700 |         1002 |
| employee5 | 171860605 |  19 |   1500 |         1000 |
+-----------+-----------+-----+--------+--------------+
5 rows in set (0.00 sec)

mysql> insert into Job (employeeID,projectID,workTime) values
    -> (171860605,2,1000),
    -> (171860603,3,1000);
Query OK, 2 rows affected (0.01 sec)
Records: 2  Duplicates: 0  Warnings: 0
```



```
mysql> select * from Job;
+------------+-----------+----------+
| employeeID | projectID | workTime |
+------------+-----------+----------+
|  171860601 |         1 |       12 |
|  171860602 |         3 |       13 |
|  171860603 |         1 |     12.5 |
|  171860603 |         2 |       27 |
|  171860603 |         3 |       24 |
|  171860604 |         4 |     13.7 |
|  171860605 |         1 |     20.4 |
|  171860605 |         2 |       24 |
+------------+-----------+----------+
8 rows in set (0.00 sec)

mysql> select * from Employee;
+-----------+-----------+-----+--------+--------------+
| name      | ID        | age | salary | departmentID |
+-----------+-----------+-----+--------+--------------+
| employee1 | 171860601 |  20 |   1500 |         1000 |
| employee2 | 171860602 |  19 |   1500 |         1001 |
| employee3 | 171860603 |  19 |   2160 |         1000 |
| employee4 | 171860604 |  20 |   1700 |         1002 |
| employee5 | 171860605 |  19 |   1575 |         1000 |
+-----------+-----------+-----+--------+--------------+
5 rows in set (0.00 sec)
```

Just in case you miss it, 171860603 is in head of a department while 171860605 isn't.

5. Worker

```
create user worker; grant select on Experiment.Employee to worker; grant update (age) on Experiment.Employee to worker; exit;
```

Check the existence of `worker` and privileges via command:

```
select User from mysql.user; show grants for worker;
```

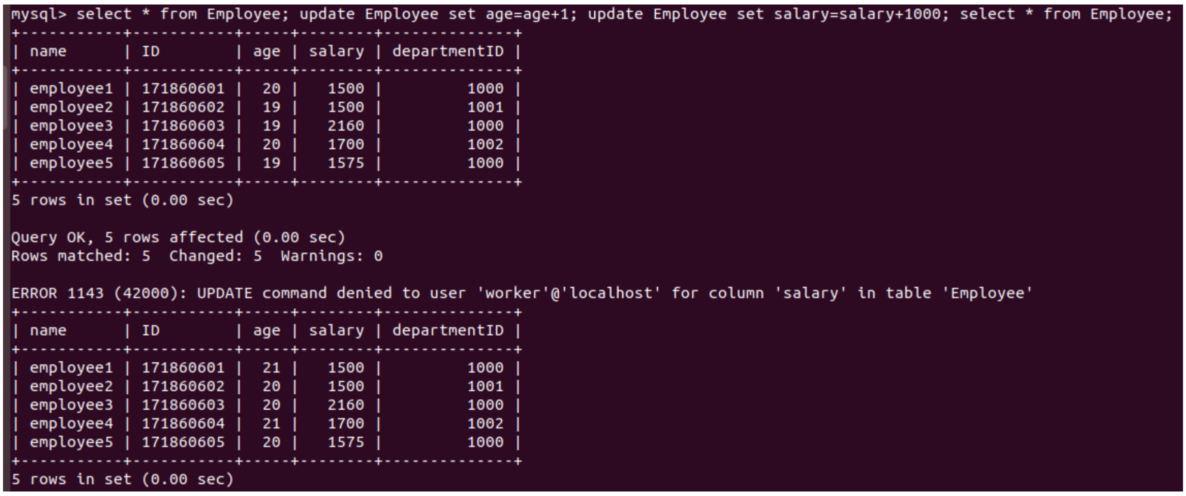
Then we try to update things using worker:

```
mysql -u worker -A Experiment
```

```
select * from Employee; update Employee set age=age+1; update Employee set salary=salary+1000; select * from Employee; exit;
```

```
sudo mysql
```

```
drop user worker;
```



```
mysql> select * from Employee; update Employee set age=age+1; update Employee set salary=salary+1000; select * from Employee;
+-----------+-----------+-----+--------+--------------+
| name      | ID        | age | salary | departmentID |
+-----------+-----------+-----+--------+--------------+
| employee1 | 171860601 |  20 |   1500 |         1000 |
| employee2 | 171860602 |  19 |   1500 |         1001 |
| employee3 | 171860603 |  19 |   2160 |         1000 |
| employee4 | 171860604 |  20 |   1700 |         1002 |
| employee5 | 171860605 |  19 |   1575 |         1000 |
+-----------+-----------+-----+--------+--------------+
5 rows in set (0.00 sec)

Query OK, 5 rows affected (0.00 sec)
Rows matched: 5  Changed: 5  Warnings: 0

ERROR 1143 (42000): UPDATE command denied to user 'worker'@'localhost' for column 'salary' in table 'Employee'
+-----------+-----------+-----+--------+--------------+
| name      | ID        | age | salary | departmentID |
+-----------+-----------+-----+--------+--------------+
| employee1 | 171860601 |  21 |   1500 |         1000 |
| employee2 | 171860602 |  20 |   1500 |         1001 |
| employee3 | 171860603 |  20 |   2160 |         1000 |
| employee4 | 171860604 |  21 |   1700 |         1002 |
| employee5 | 171860605 |  20 |   1575 |         1000 |
+-----------+-----------+-----+--------+--------------+
5 rows in set (0.00 sec)
```

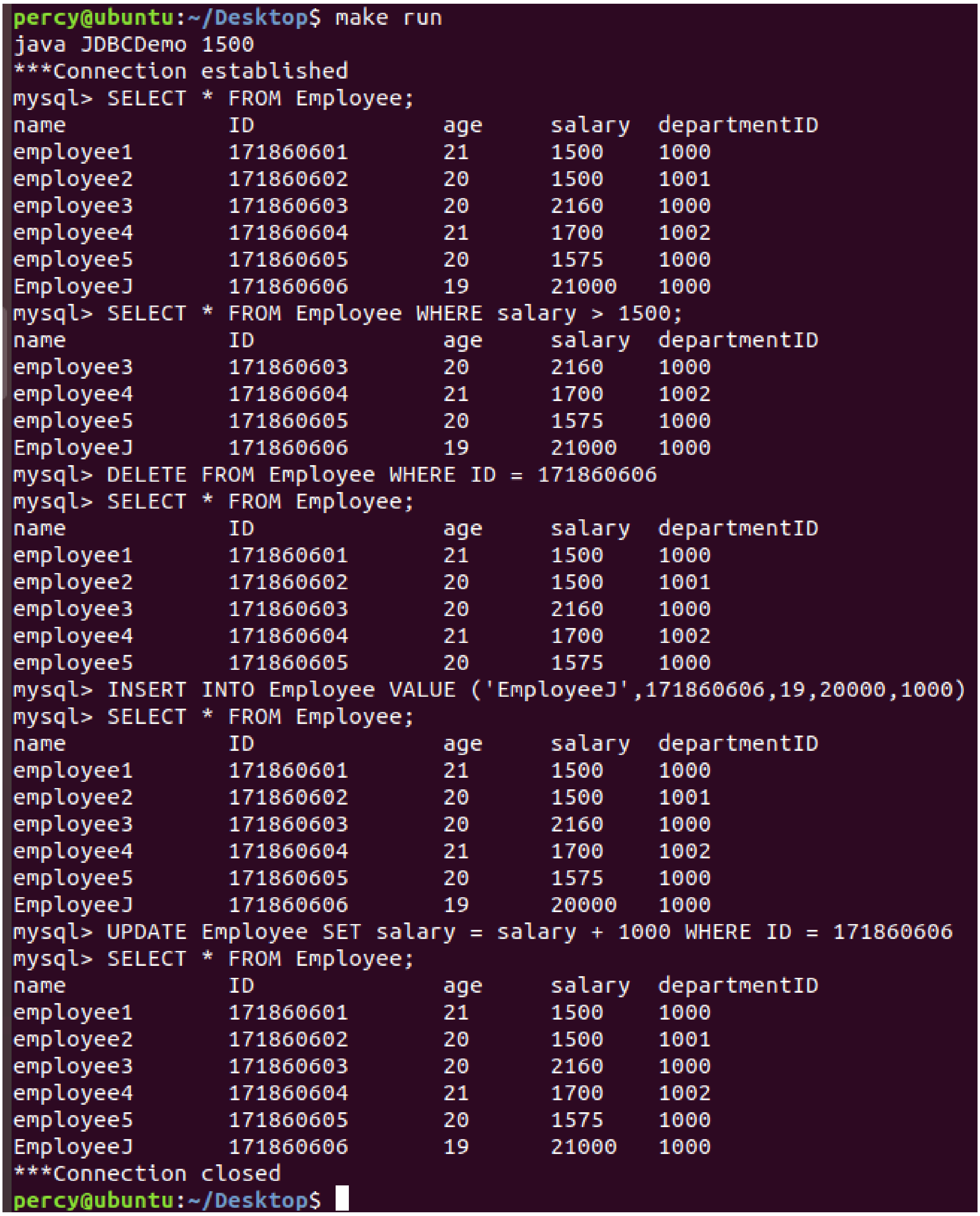
6. JDBC

I am also showing the steps for downloading and configuring `Java` and `JDBC`, since I'm not using an IDE and recording this procedure helps:

```
tar -xzvf jdk-8u221-linux-x64.tar.gz
sudo mv jdk1.8.0_221 /usr/local/java
sudo apt-get install libmysql-java
gedit ~/.bashrc
###
export JAVA_HOME=/usr/local/java
export PATH=${JAVA_HOME}/bin:${PATH}
export CLASSPATH=$CLASSPATH:/usr/share/java/mysql.jar
###
source ~/.bashrc
```

Before starting, I have to point out that I see no point in writing SQL in the command line and passing it to the Java program which then passes it onto the connection with the database. That is only adding a wrapper around `MySQL Shell`. I also have to point out that if we were to achieve functionality this way, there would be no way to use `Dynamic SQL` since everything is determined by the command line.

Thus, I have coded the `SQL` commands within the Java program, and used `Dynamic SQL` by getting a salary threshold via the command line. Since the code is not required in this report and space is limited, I am adding all my code as a separate file. Again, I'm not using and IDE so I have to add `classpaths`, compile and run Java programs manually. To make things easier, I've written a `makefile` script. Compile via `sudo make`, run via `sudo make run`.



```
percy@ubuntu:~/Desktop$ make run
java JDBCDemo 1500
***Connection established
mysql> SELECT * FROM Employee;
name            ID              age     salary  departmentID
employee1       171860601       21      1500    1000
employee2       171860602       20      1500    1001
employee3       171860603       20      2160    1000
employee4       171860604       21      1700    1002
employee5       171860605       20      1575    1000
EmployeeJ       171860606       19      21000   1000
mysql> SELECT * FROM Employee WHERE salary > 1500;
name            ID              age     salary  departmentID
employee3       171860603       20      2160    1000
employee4       171860604       21      1700    1002
employee5       171860605       20      1575    1000
EmployeeJ       171860606       19      21000   1000
mysql> DELETE FROM Employee WHERE ID = 171860606
mysql> SELECT * FROM Employee;
name            ID              age     salary  departmentID
employee1       171860601       21      1500    1000
employee2       171860602       20      1500    1001
employee3       171860603       20      2160    1000
employee4       171860604       21      1700    1002
employee5       171860605       20      1575    1000
mysql> INSERT INTO Employee VALUE ('EmployeeJ',171860606,19,20000,1000)
mysql> SELECT * FROM Employee;
name            ID              age     salary  departmentID
employee1       171860601       21      1500    1000
employee2       171860602       20      1500    1001
employee3       171860603       20      2160    1000
employee4       171860604       21      1700    1002
employee5       171860605       20      1575    1000
EmployeeJ       171860606       19      20000   1000
mysql> UPDATE Employee SET salary = salary + 1000 WHERE ID = 171860606
mysql> SELECT * FROM Employee;
name            ID              age     salary  departmentID
employee1       171860601       21      1500    1000
employee2       171860602       20      1500    1001
employee3       171860603       20      2160    1000
employee4       171860604       21      1700    1002
employee5       171860605       20      1575    1000
EmployeeJ       171860606       19      21000   1000
***Connection closed
percy@ubuntu:~/Desktop$ 
```

7. DBCP

The source code is within the attached files. Within the code you will find that I have written assignment 1 & 2. Since there is nothing to say about assignment 1, I am only introducing assignment 2 here.

The idea is simple: test query performance and connection performance separately.

Query Performance

By intuition, query performance should be roughly the same. But considering the buffer mechanisms within the database, if I were to directly test performance, the second tested connection should be faster since the results are in the buffer due to the first tested connection. So before testing them, I added a loop to execute queries and make sure that everything was in the buffer before actually testing the two connections.

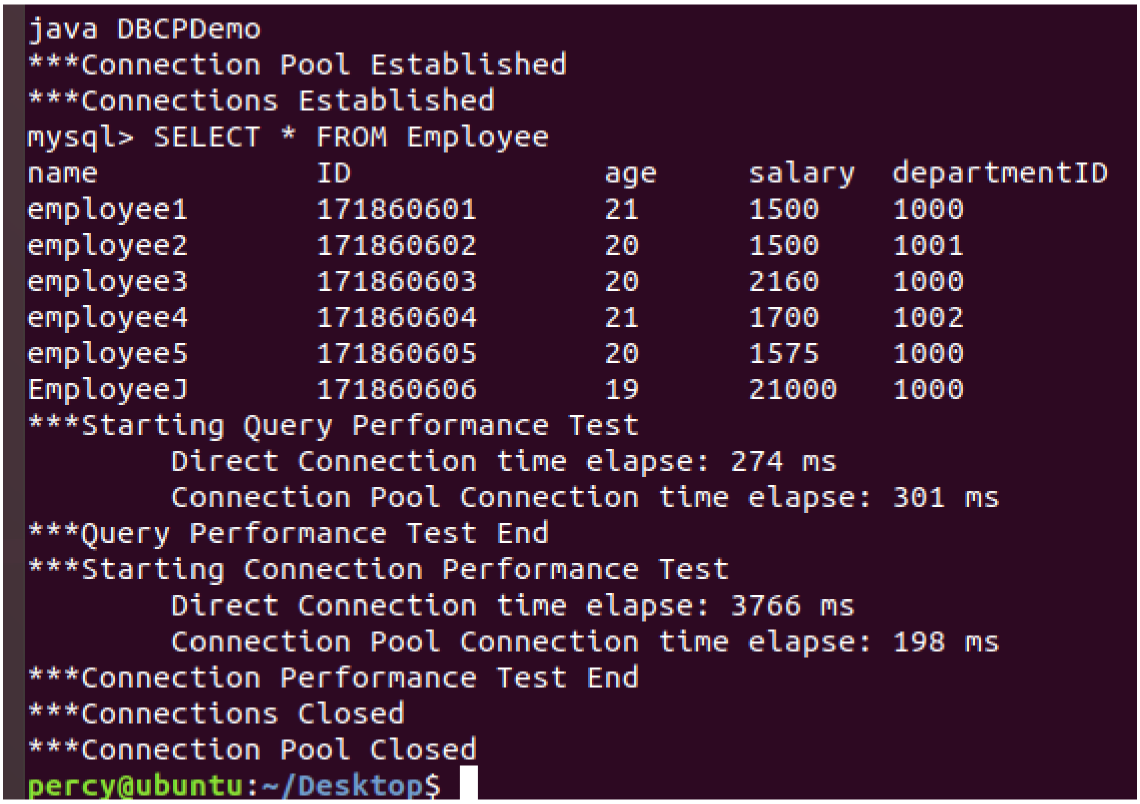
It turns out that they are roughly the same: 280 ~ 300 ms.

Connection Performance

So much can be done in this part that I was overwhelmed with what to do. So I chose the simplest approach: connect, close and reconnect. This results in dramatic performance differences, which can be considered as an upper bound for performance difference between the two connections because:

1. Direct connection has to reconnect every time.
2. Connection Pool never has to open new connections because there is always only one connection in use.

The results differ at a ratio of 20, dramatically showing the advantage of a connection pool.



```
java DBCPDemo
***Connection Pool Established
***Connections Established
mysql> SELECT * FROM Employee
name            ID              age     salary  departmentID
employee1       171860601       21      1500    1000
employee2       171860602       20      1500    1001
employee3       171860603       20      2160    1000
employee4       171860604       21      1700    1002
employee5       171860605       20      1575    1000
EmployeeJ       171860606       19      21000   1000
***Starting Query Performance Test
        Direct Connection time elapse: 274 ms
        Connection Pool Connection time elapse: 301 ms
***Query Performance Test End
***Starting Connection Performance Test
        Direct Connection time elapse: 3766 ms
        Connection Pool Connection time elapse: 198 ms
***Connection Performance Test End
***Connections Closed
***Connection Pool Closed
percy@ubuntu:~/Desktop$
```

Performance tests should actually be tested multiple times to form a sample large enough to analyze. Unfortunately, I do not have that much time, keeping the workload for this part to a minimum.

Problems and Solutions

1. Table Design

In reality, each employee can belong to multiple departments, departments can have multiple heads, projects can belong to multiple departments. So an employee shouldn't be defined singularly by the department he or she is in.

The best solution is to redesign tables, but the fix for now is using multiple primary keys and adding triggers to make sure inserting info for the same ID stays consistent.

2. Dynamic SQL

There is no way to use `Dynamic SQL` when all SQL commands are obtained via the command line.

Reference

Java1.8 API Documents

Commons-DBCP-BasicDataSource