

Below are all benchmark queries Q1 to Q6 and their corresponding DataLog formulation, SQL queries before and after AQIT transformation

- **Query Q1** finds when and on what machines, the pressure readings of class A were higher than *@thA* from its expected value:

Original query Q1 in SQL is translated to DQ1 in DataLog

| | |
|-------------------------------------|-----------------------------|
| Q1 | DQ1(m,bt,et)← |
| 1 SELECT va.m, va.bt, va.et | measuresA(m,s,bt,et,mv) AND |
| 2 FROM measures A va, sensor s | sensor(m,s,_,_,ev,_,_) AND |
| 3 WHERE va.m = s.m AND va.s=s.s AND | v1 = ev + @thA AND |
| 4 va.mv > s.ev + @thA | mv > v1 |

Since the DataLog query DQ1 exposes *idx(measuresA.mv)* already. Therefore, AQIT will not transform DQ1. Finally, it returns Q1 unchanged.

| | |
|-------------------|------------------|
| 1 The same as DQ1 | 1 The same as Q1 |
|-------------------|------------------|

- **Query Q2** identifies abnormal behaviors based on absolute deviations: When and for what machines did the pressure reading of class B deviate more than *@thB* from its expected value? AQIT translates the query into the following SQL query T2:

| | |
|-------------------------------------|-----------------------------|
| Q2 | DQ2(m,bt,et)← |
| 1 SELECT vb.m, vb.bt, vb.et | measuresB(m,s,bt,et,mv) AND |
| 2 FROM measuresB vb, sensor s | sensor(m,s,_,_,ev,_,_) AND |
| 3 WHERE vb.m = s.m AND vb.s=s.s AND | v1 = mv - ev AND |
| 4 abs(vb.mv - s.ev) > @thB | v2 = abs(v1) AND |
| 5 | v2 > @thB |

AQIT transforms the DataLog query DQ2 into TDQ2 exposing *idx(measuresB.mv)*. Finally, it translates TDQ2 to T2 in SQL

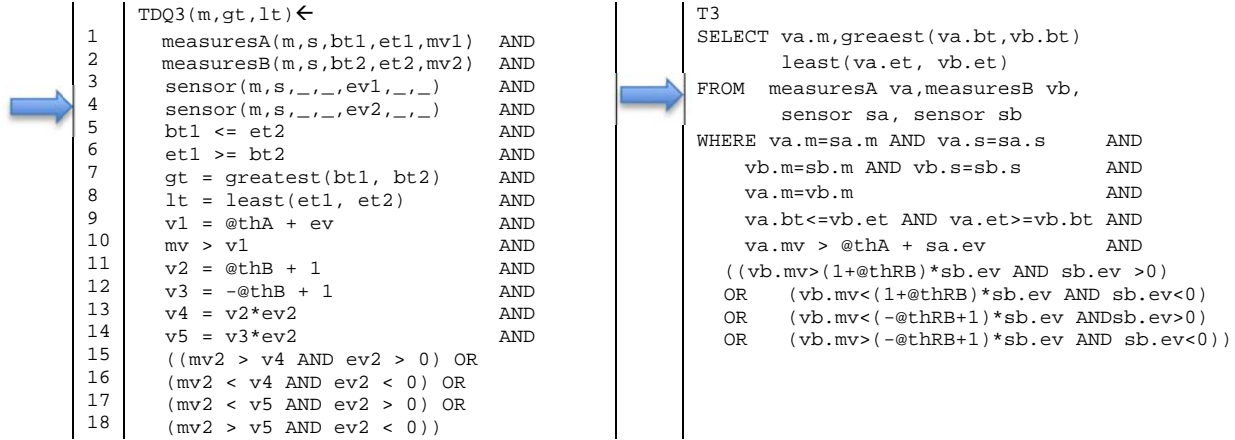
| | |
|-------------------------------|-------------------------------------|
| TDQ2(m,bt,et)← | T3 |
| 1 measuresB(m,s,bt,et,mv) AND | SELECT vb.m, vb.bt, vb.et |
| 2 sensor(m,s,_,_,ev,_,_) AND | FROM measuresB vb, sensor s |
| 3 v1 = @thB + ev AND | WHERE vb.m = s.m AND va.s = s.s AND |
| 4 v2 = - @thB + ev AND | (vb.mv > @thB + s.ev OR |
| 5 (mv > v1 OR mv < v2) | vb.mv < - @thB + s.ev) |

- **Query Q3** identifies two different abnormal behaviors of the same machine at the same time based on two different measurement classes: When and for which machines were the pressure readings of class A higher than *@thA* from its expected value at the same time as the pressure reading of class B were deviating *@thRB* % from its expected value? After the AQIT transformation Q3 becomes T3:

Original query Q3 in SQL is translated to DQ3 in DataLog

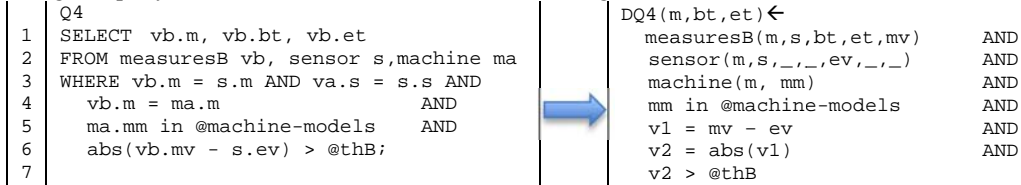
| | |
|--------------------------------------|--------------------------------|
| Q3 | DQ3(m,gt,lt)← |
| 1 SELECT va.m, greaest(va.bt, vb.bt) | measuresA(m,s,bt1,et1,mv1) AND |
| 2 least(va.et, vb.et) | measuresB(m,s,bt2,et2,mv2) AND |
| 3 FROM measuresA va, measuresB vb, | sensor(m,s,_,_,ev1,_,_) AND |
| 4 sensor sa, sensor sb | sensor(m,s,_,_,ev2,_,_) AND |
| 5 WHERE va.m=sa.m AND va.s=sa.s AND | bt1 <= et2 AND |
| 6 vb.m=sb.m AND vb.s=sb.s AND | et1 >= bt2 AND |
| 7 va.m=vb.m AND | gt = greatest(bt1, bt2) AND |
| 8 va.bt<=vb.et AND va.et>=vb.bt AND | lt = least(et1, et2) AND |
| 9 va.mv - sa.ev > @thA AND | v2 = mv - ev AND |
| 10 abs((vb.mv - sb.ev)/sb.ev)>@thRB | v2 > @thA AND |
| 11 | v3 = mv2 - ev2 AND |
| 12 | v4 = v3 / ev2 AND |
| | v5 = abs(v4) AND |
| | v5 > @thB |

AQIT transforms the DataLog query DQ3 into TDQ3 exposing *idx(measuresB.mv)* and *idx(measuresA.mv)*. Finally, it translates TDQ3 to T4 in SQL

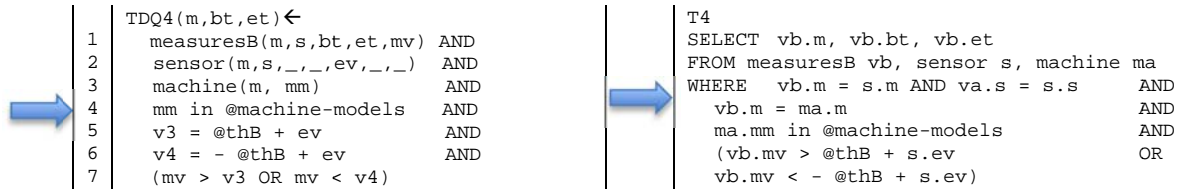


- **Query Q4** identifies when were the pressure readings of class B deviating more than $@thB$ for the machines in the list *machine-models*? Here, if a query spans many machine models the impact of AQIT should decrease since many different index keys are accessed. We thus varied the size of *@machine-models*.

Original query Q4 in SQL is translated to DQ4 in DataLog

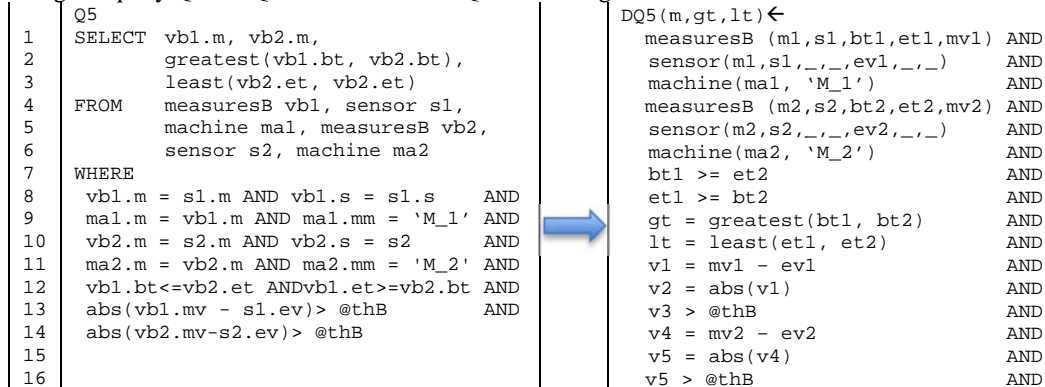


AQIT transforms the DataLog query DQ4 into TDQ4 exposing *idx(measuresB.mv)*. Finally, it translates TDQ4 to T4 in SQL



- **Query Q5** identifies when the pressure reading of class B deviates more than $@thB$ for two specific machine models using a temporal join. The query involves numerical expressions over two indexed variables, which are both exposed by AQIT.

Original query Q5 in SQL is translated to DQ5 in DataLog



AQIT transforms the DataLog query DQ5 into TDQ5 exposing *idx(measuresB.mv)* twice. Finally, it translates TDQ5 to T5 in SQL

```

1 TDQ5(m,gt,lt)←
2   measuresB (m1,s1,bt1,et1,mv1) AND
3   sensor(m1,s1,_,_,ev1,_,_) AND
4   machine(ma1, 'M_1') AND
5   measuresB (m2,s2,bt2,et2,mv2) AND
6   sensor(m2,s2,_,_,ev2,_,_) AND
7   machine(ma2, 'M_2') AND
8   bt1 >= et2 AND
9   et1 >= bt2 AND
10  gt = greatest(bt1, bt2) AND
11  lt = least(et1, et2) AND
12  v1 = @thB + ev1 AND
13  v2 = -@thB + ev1 AND
14  v3 = @thB + ev2 AND
15  v4 = -@thB + ev2 AND
   (mv1 > v1 OR
   mv1 < v2 OR
   mv2 > v3 OR
   mv2 < v4)

```

```

T5
SELECT vb1.m, vb2.m,
       greatest(vb1.bt, vb2.bt),
       least(vb2.et, vb2.et)
FROM   measuresB vb1,sensor s1,
       machine ma1, measuresB vb2,
       sensor s2, machine ma2
WHERE  vb1.m = s1.m AND vb1.s = s1.s AND
       ma1.m = vb1.m AND ma1.mm = 'M_1' AND
       vb2.m = s2.m AND vb2.s = s2.s AND
       ma2.m = vb2.m AND ma2.mm = 'M_2' AND
       vb1.bt<=vb2.et AND vb1.et>=vb2.bt AND
       ((vb1.mv > @thB + s1.ev) OR
        (vb1.mv < -@thB + s1.ev) OR
        (vb2.mv > @thB + s2.ev) OR
        (vb2.mv < -@thB + s2.ev))

```

- **Query Q6** is a complex query that identifies a sequence of two different abnormal behaviors of the same machine happening within a given time interval, based on two different measurement classes: On what machines the pressure readings class B were out-of-bounds more than *@thB* within 5 seconds after the pressure readings of class A were higher than *@thA* from the expected value. Here, both *idx(measuresA.mv)* and *idx(measuresB.mv)* are exposed by AQIT.

Original query Q6 in SQL is translated to DQ6 in DataLog

```

1 Q6
2 SELECT vb.m, vb.bt, vb.et
3 FROM   measuresA va, measuresB vb
4        sensor sa,sensor sb
5 WHERE  va.m = sa.m AND va.s=sa.s AND
6        vb.m = sb.m AND va.s=sb.s AND
7        va.m = vb.m AND
8        vb.bt - va.et <= 5 AND
9        va.mv - sa.ev > @thA AND
10       abs(vb.mv -sb.ev) > @thB
11

```

```

DQ6(m,bt,et)←
  measuresA(m,s,bt1,et1,mv1) AND
  measuresB(m,s,bt2,et2,mv2) AND
  sensor(m,s,_,_,ev1,_,_) AND
  sensor(m,s,_,_,ev2,_,_) AND
  v1 = bt2 - et1 AND
  v1 <= 5 AND
  v2 = mv - ev AND
  v2 > @thA AND
  v3 = mv2 -ev2 AND
  v4 = abs(v3) AND
  v4 > @thB

```

AQIT transforms the DataLog query DQ6 into TDQ6 exposing *idx(measuresA.mv)* and *idx(measuresB.mv)*. Finally, it translates TDQ6 to T6 in SQL

```

1 TDQ6(m,bt,et)←
2   measuresA(m,s,bt1,et1,mv1) AND
3   measuresB(m,s,bt2,et2,mv2) AND
4   sensor(m,s,_,_,ev1,_,_) AND
5   sensor(m,s,_,_,ev2,_,_) AND
6   v1 = bt2 - et1 AND
7   v1 <= 5 AND
8   v2 = @thA + ev AND
9   mv > v2 AND
10  v3 = @thB + ev2 AND
11  v4 = -@thB + ev2 AND
   (mv2 > v3 OR mv2 < v4)

```

```

T6
SELECT vb.m, vb.bt, vb.et
FROM   measuresA va, measuresB vb
       sensor sa,sensor sb
WHERE  va.m = sa.m AND va.s = sa.s AND
       vb.m = sb.m AND va.s = sb.s AND
       va.m = vb.m AND
       vb.bt - va.et <= 5 AND
       va.mv > @thA + sa.ev AND
       ((vb.mv > @thB + sb.ev) OR
        (vb.mv < -@thB + sb.ev))

```