Abstract: A formalisation of an execution model for the Front End implementation of SWORD for the DRA front end filter project RSRE 1C/6130.
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0.2 Document CrossReferences


0.3 Changes History

Issue 1.1 (18 February 1993) First draft.


Issue 2.2 Removed dependency on ICL logo font

0.4 Changes Forecast

None.
1 GENERAL

1.1 Scope

This document gives a formal specification of part of the SWORD Front End giving the high-level security properties required of both the Query Transformations of [13] and of the Front End Filter of [12]. It constitutes part of deliverable D3 of work package 1a, as given in the Phase 2 Technical Proposal, [1].

1.2 Introduction

[6] gives a formal description of the top-level architecture of the Front End Implementation of SWORD and identifies three subsystems from which the system is constructed, namely, the SSQL Transformation Processor, the TSQL database, and the Output Filter. It is the purpose of this document to give a more concrete formulation of the critical requirements on these subsystems.

The current issue gives preliminary discussion of issues in formalising the critical requirements. Some formal material is included.

2 PRELIMINARIES

The following ProofPower instructions set the context for the proof tools and set up the new theory \( fef026 \), with parent the theory \( fef029 \) in which the syntactic transformation of SSQL queries is formalised.

\[
\begin{align*}
\text{sml} & \quad \text{open \_theory "fef029";} \\
& \quad (\text{force\_delete\_theory "fef026" handle _ => ()}); \\
& \quad \text{new\_theory"fef026";} \\
& \quad \text{push\_pe "hol";} \\
\end{align*}
\]

3 REPRESENTATION OF DERIVED TABLES

The abstract formulation of the critical requirements on the subsystems of \( FE\_SWORD \) given in [6] give little insight into how the subsystems are to be constructed. Further detail on the actual data types involved is required to discuss this.

Apart from some minor and easily remedied differences of organisation, the syntax of TSQL is a subset of the syntax of SSQL. For simplicity, it has been chosen to model the TSQL abstract syntax as being identical with the SSQL syntax. The TSQL semantics may then be specified reusing most of the SSQL semantics of [2, 3, 4] by imposing a state invariant which asserts that all classification information in the state, apart from where classifications are stored as data, is fixed at the lowest classification. A formal treatment of the TSQL semantics along these lines is given in [5].

The representation of a TSQL state as an SSQL state is defined informally in [12] and formally in [8]. In the general case, an SSQL table with \( k \) columns is represented as a TSQL table with \( 1 + 3k \)
columns: the first column in the TSQL table contain the row existence classes, successive blocks of 3 columns give the classification, the dinary data and the sterling data for the corresponding SSQL column. The SSQL state also associates some ‘static’ classification information about each table, namely: its class ($TS_{class}$) and its maximum row class ($TS_{maxRow}$), and also about each column in a table, namely: its existence class ($CC_{exist}$) and the maximum and minimum classifications for the data in the column ($CS_{min}, CS_{max}$). This information is not represented in the TSQL state (as modelled here, although in practice, it will be held in a TSQL table); however, it is used in the transformations of [12] in order to optimise the representation, so that, for example, the classification column is omitted for SSQL columns for which $CS_{min} = CS_{max}$.

The management of the optimisations discussed above and of the variable scoping rules of the query language make a significant contribution to the complexity of the transformations as specified in [12]. The scoping rules also complicate the semantics of both SSQL as given in [4] and hence of TSQL. The main security-relevant mechanisms used in the transformations are therefore best understood if the optimisations, the handling of the scoping rules for the two languages, and the security checks themselves are handled separately in a formal treatment.

Most of the complexity of the TSQL and SSQL semantics is in the $SELECT$ query. Indeed, at least in TSQL, the $DELETE$, $INSERT$ and $UPDATE$ queries can be modelled as a $SELECT$ query to compute a new table followed by an assignment or a merge of the new table into an existing table.

The security checks which apply to a $SELECT$ query are best understood if we think of execution of the query as returning a derived table, which we think of as having two components: the table specification which contains static information about the table and its columns; and the list of rows comprising the table data proper. We will take a conceptual, unoptimised, view of derived tables and so use the following data types for them:

HOL Labelled Product

\begin{verbatim}
_DerColSpec_

| DCS_name | Ide LIST LIST |
| DCS_min  | Class        |
| DCS_max  | Class        |
\end{verbatim}

HOL Labelled Product

\begin{verbatim}
_DerTableSpec_

| DTS_name | Ide LIST LIST |
| DTS_maxRow | Class       |
| DTS_colSpecs | DerColSpec LIST |
\end{verbatim}

HOL Labelled Product

\begin{verbatim}
_DerTableRow_

| DTR_where | Class        |
| DTR_row   | Class        |
| DTR_cols  | (Class × Item) LIST |
\end{verbatim}

\footnote{The names used here are as used in [2].}
The information in the above is intended to be extracted from information recorded for a table in the SSQL state or computed during derivation of the table, as described in the following table:

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCS_name</td>
<td>The names by which the column may be known (computed from DirectoryS and the ColSpecs for the table initially)</td>
</tr>
<tr>
<td>DCS_min/DCS_max</td>
<td>The minimum and maximum classes for data in the column (taken from the ColSpecs for the column initially)</td>
</tr>
<tr>
<td>DTS_name</td>
<td>The names by which the table may be known (computed from DirectoryS initially)</td>
</tr>
<tr>
<td>DTS_class</td>
<td>The class of the table (computed from the TableSpec for the table initially)</td>
</tr>
<tr>
<td>DTS_maxRow</td>
<td>The maximum row existence class of the table (computed from the TableSpec for the table initially)</td>
</tr>
<tr>
<td>DTS_colSpecs</td>
<td>The column specifications for the table</td>
</tr>
<tr>
<td>DTR_where</td>
<td>The classification in this row of a WHERE clause used to construct this table. This information is only used during execution of transformed queries and by the output filter; it is not stored in the state and is taken as lattice_bottom for tables extracted directly from the state.</td>
</tr>
<tr>
<td>DTR_row</td>
<td>The existence classification of this row (taken from the SSQL state initially)</td>
</tr>
<tr>
<td>DTR_cols</td>
<td>The classification and data for each field in this row (taken from the SSQL state initially)</td>
</tr>
</tbody>
</table>

We have chosen not to include the table or column existence classes here.

4 EXAMPLES

Before discussing the use of the above representation of a derived table within the formal framework, it may be helpful to consider some examples of the transformation of SSQL queries into TSQL. For the examples which follow, the main part of the transformation algorithm is defined in the description of tuple_list_make_outer in [13].

Example 1 The basic principle of operation of the Front End implementation of SWORD is apparent from the treatment of the simplest form of SELECT query:

SSQL Example

```
| SELECT * FROM table |
```
In essence, this is transformed into a single TSQL query (with no check query) of the form\(^2\):

```
TSQL Example
SELECT cc, rc, col1_s, col1_d, col1_c, ...
FROM table_t
WHERE cc DOM rc
```

where \(table_t\) is the TSQL table implementing \(table\), \(cc\) is a constant classification equal to the clearance of the client, \(rc\) is the column containing the row classes, and the \(col_l_k\) are the columns containing the classes, sterling data and dinary data for the (SSQL) columns of \(table\). Viewed conceptually as a derived table in the above sense, the result of this TSQL query represents the entirety of all rows in \(table\) whose existence the client is cleared to know, together with a column of where clause classes all equal to the clearance of the client. Filtering such a derived table amounts, in effect, to removing all rows whose class is not dominated by the client clearance and overwriting with a dummy value the data in all fields where the field classification is not dominated by the client clearance. Since, in this case, all of the classification information in the derived table is taken directly from the database (and so may be assumed to be correct), the result of this filtering removes all information content which the client is not cleared to see\(^3\).

**Example 2** For a more complex SSQL query, classifications in the derived table which represents its output are computed during execution of the TSQL query. For example, consider:

```
SSQL Example
SELECT col2 + col3 FROM table WHERE col1 < col2
```

Here, in each row, computation of the \(WHERE\) clause reveals information about values in the first two fields of the row. Again there is no check query and the transformed query might have the form:

```
TSQL Example
SELECT col1_c LUB col2_c, rc, col2_s + col3_s, col2_c LUB col3_c
FROM table_t
WHERE (col1_s < col2_s OR NOT cc DOM (col1_c LUB col2_c)) AND cc DOM rc
```

Here, the classification associated by the transformations with each computed data value \(col2_s + col3_s\) in each row is the least upper bound of the classifications for \(col2\) and \(col3\) in that row, since the result of the addition reveals information about both of its operands.

Note that in the derived table passed to the filter, rows for which either the SSQL \(WHERE\) clause is true or the client is not cleared to compute the \(WHERE\) clause are included. I.e. the transformed query takes the \(WHERE\) clause as \textit{true} for rows where the \(WHERE\) clause computation is a possible covert channel. From the security point of view the \(WHERE\) clause could equally well be taken as \textit{false} for such rows, however, part of the desired filter functionality is to inform the client when such rows have been detected. What the filter then does is to issue a “may-not-be-complete” message and to delete the offending rows.

\(^2\)In fact, the optimised query may omit some of the expressions in the select-list. In this case, \(cc\) would certainly be omitted, since there is no \(WHERE\) clause.

\(^3\)In the current specifications [12, 13], the transformations add the \(WHERE\) clause as shown in the example and the filter does not need to eliminate rows whose existence the client is not cleared to know, since there will not be any. However, the row existence column is passed into the filter, since it comprises part of the output returned to the client (as is the class of the \(WHERE\) clause).
Example 3  In the above examples, there is no need for a check query since the data query can include all the information required for the filter to eliminate possible covert channels. The check query becomes necessary when the query includes a GROUP BY clause, e.g. consider the following query:

SSQL Example

```sql
SELECT col1, COUNT (*) FROM table WHERE col2 > 0 GROUP BY col1
```

This is intended to return a table showing, for each value of `col1` appearing in `table` in a row having a positive `col2` value, the number of rows having that `col1` value and a positive `col2` value.

The query must not be allowed to reveal information about rows whose `col1` value the client is not cleared to see. This will result in a check query as follows:

TSQL Example

```sql
SELECT TRUE
FROM table
WHERE cc DOM rc AND col2 > 0 AND NOT cc DOM col1_c
```

Thus the check query will return a row for each row in `table` whose existence the client is cleared to know, whose `col2` value is such that the row would be included in the counts to be made by the data query and whose `col1` value the client is not cleared to know. If there are any such rows the data query should not be allowed to proceed.

Example 4  The above examples involve selection from a single table. Selection from (the cartesian product of) several tables follows similar lines except that the row existence classes must be combined to give the existence class for the derived table. For example, consider:

SSQL Example

```sql
SELECT * FROM tableA, tableB
```

This is transformed into the following query, which is similar to the selection from a single table but with the existence class in each row of the cartesian product taken to be the least upper bound of the existence classes of the two rows it is formed from.

TSQL Example

```sql
SELECT cc, rcA LUB rcB, colA1_s, colA1_d, colA1_c, ..., colB1_s, colB1_d, colB1_c, ...
FROM tableA_t, tableB_t,
WHERE cc DOM (rcA LUB rcB)
```

Discussion  In fact, the above examples display most of the security relevant features of the transformations, with the following exceptions:

1. The more complex variants of a single select query, e.g. the HAVING clause.

2. More complex cases of the computation of the classification of the result of an expression. Example 2 above shows one of the simpler cases, where for each row, the expression `col2 + col3` is assigned a classification which is the least upper bound of the classifications of `col2` and `col3` in that row). In other examples, e.g., the and and or expression forms, the result classification used depends on the actual values of (some of) the operands as well as on the classifications associated with them.
3. The details of the mapping of the SSQL name space onto the TSQL name space.

4. The handling of nested SELECT queries and the management of the scope of the name spaces within them.

The formal treatment in this document and in [10] is intended to address all of these issues, however the treatment of naming issues is somewhat simplified, bringing out the semantic issues but not all the syntactic ones.

5 EXECUTION MODEL (PART 1)

In order to simplify the handling both of nested SELECTs and of name space management, it is proposed to use a model of the TSQL execution mechanism in which the essence of the SELECT functionality is separated out. To do this, we restrict attention to transitions of the underlying DBMS whose effect can be viewed as having been obtained by the following steps:

1. Represent the visible state of the database as a list of derived tables, \( dtl \);

2. Perform some computation on \( dtl \) resulting in a new derived table, \( dt \);

3. Either filter \( dt \) to create the output for the client (SELECT query), or use \( dt \) and other information from the query to update the database (other queries).

Here, step 1 is intended to involve a fixed mapping on database states dependent on the SSQL database structure. The main security property enforced by step 1 is the removal of tables which the client is not cleared to see (cf. [13], in which such tables are not entered into the global symbol table).

In step 3, the filtering for the output from the SELECT queries is to be carried out by using the filter specified in [7]. The other sorts of query are to be processed on the assumption that \( dt \) encodes information about the modifications to be made to the table named in the query.

Step 2 is where the main security features of the transformations[13] are modelled. In particular, by bounding the class of computations permitted in this step, we can formalise the intuitions behind the clearances which are assigned by the transformations to the fields of derived tables.

The three-stage model of TSQL execution may be viewed as an alternative description of the function \( TSQLtf \) of [5], which reveals the semantic issues but ignores syntactic ones. It may be formalised as follows:
HOL Constant

\[ EM : (State_t \rightarrow \text{DerTable LIST}) \rightarrow (Query \rightarrow (\text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors})) \rightarrow (Query \times (\text{DerTable} \times \text{Errors}) \times State_t \rightarrow State_t \times \text{ANSWER}) \rightarrow (Query, State_t) \ \text{DBMS\_TYPE} \]

\forall \ \text{view, compile, act, query, st} \cdot \\
EM \ \text{view} \ \text{compile} \ \text{act} \ (\text{query, st}) \\
= \ \text{let compute} = \text{compile query} \\
\text{in let viewed} = \text{view st} \\
\text{in let computed} = \text{compute viewed} \\
\text{in} \ \text{act} \ (\text{query, computed, st})

Here the components, \text{view, compile and act} of the model represent the three stages as follows:

1. \text{view} represents the state of the database as a list of derived tables;
2. \text{compile} compiles a query to give the derived-table-forming function it computes;
3. \text{act} either updates the state or delivers an answer according to the type of \text{query} and the derived table computed by the compiled query.

6 REPRESENTING SSQL AND TSQL STATES AS DERIVED TABLES

This section describes how SSQL and TSQL states are viewed as lists of derived tables. A fairly explicit algorithm is specified for the SSQL states. The view for the TSQL states is then loosely specified in terms of the SSQL formulation.

The classification of a derived table in an SSQL state will be the least upper bound of the corresponding table classification and ‘containing directory’ classifications in the SSQL state.

6.1 Interpreting a State as a List of Tables

Obtain a list of pairs of directory name and directory from a state together with the upper bound of the clearances for the directory.

HOL Constant

\[ \text{StateDirs : State} \rightarrow (\text{Class} \times \text{Ide LIST} \times \text{Directory}) \ \text{LIST} \]

\forall s \cdot \text{Elems} \ (\text{StateDirs} \ s) \\
= \ \{ (c, (i, d)) \mid (i, d) \in \text{repState} \ s \} \land c = (\text{Dir\_exist} \ d \ \text{lub} \text{Dir\_class} \ d) \}
Lemma 1

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Obtain a list of pairs of table name and table from a directory.

HOL Constant

\[
\text{DirTables} : \text{Directory} \rightarrow (\text{Ide} \times \text{TableSpec}) \text{ LIST}
\]

\[
\forall d \bullet \text{Elems} (\text{DirTables} d) = \text{Dir\_tables} d
\]

Obtain a list of quadruples of class, directory name, table name and table from a state. This involves propagating the classes and directory names obtained for each directory \text{StateDirs} into the information returned for each table.

HOL Constant

\[
\text{StateTables} : \text{State} \rightarrow (\text{Class} \times \text{Ide \ LIST} \times \text{Ide} \times \text{TableSpec}) \text{ LIST}
\]

\[
\forall s \bullet \text{StateTables} s =
\]

\[
\text{let } (\text{cl}, \text{ildl}) = \text{Split(StateDirs s)}
\]

\[
\text{in let } (\text{il}, \text{dl}) = \text{Split ildl}
\]

\[
\text{in let } (\text{itll}) = (\text{Map DirTables dl})
\]

\[
\text{in let } f c i \text{ it} = (c, i, \text{it})
\]

\[
\text{in let } g (c, i, \text{its}) = \text{Map } (f c i) \text{ its}
\]

\[
\text{in let } h \text{ cl is itss} = \text{Map } g (\text{Combine cl } (\text{Combine is itss}))
\]

\[
\text{in Flat } (h \text{ cl ill itll})
\]

6.2 Mapping SSQL Tables to Derived Tables

First, obtain the static column information for a derived table from a \text{ColSpec}.

HOL Constant

\[
\text{ColSpec}_d : (\text{Ide \ LIST} \times \text{Ide} \times \text{TableSpec}) \rightarrow \text{ColSpec} \rightarrow \text{DerColSpec}
\]

\[
\forall d\_name \ t\_name \ t \ cs \bullet \text{ColSpec}_d (d\_name, t\_name, t) \ cs =
\]

\[
\text{let } cc = (\text{TS\_cons } t) \odot (\text{CS\_consGroup } cs)
\]

\[
\text{in let } tc\_name = \text{Cons } t\_name[\text{CS\_ide } cs]
\]

\[
\text{in } \text{MkDerColSpec }
\]

\[
[[\text{CS\_ide } cs]; \text{tc\_name}; d\_name \wedge tc\_name]
\]

\[
(\text{CS\_min } cs)
\]

\[
(\text{CS\_max } cs)
\]

Obtain the static table information for a derived table from a \text{TableSpec}.
HOL Constant

\[ \text{TableSpec}_{d} : (\text{Class} \times \text{Ide~LIST} \times \text{Ide} \times \text{TableSpec}) \rightarrow \text{DerTableSpec} \]

\[ \forall c~d~_name~t~_name~t \bullet \text{TableSpec}_{d} (c, d~_name, t~_name, t) = \]
\[ \text{MkDerTableSpec} \]
\[ \left[ \left[ t~_name \right] ; d~_name \right] \cap \left[ t~_name \right] \]
\[ (\text{TS} \cdot \text{maxRow}~t) \]
\[ (\text{RelList}(\text{Squash}\{(n, cs) \mid \exists cs' \in \text{TS} \cdot \text{colspe}c\) ~t \]
\[ \wedge cs = \text{ColSpec}_{d} (d~_name, t~_name, t) \hspace{0.5cm} cs' \wedge n = \text{CS} \cdot \text{posn}~cs' \}) \]

Obtain the information in a derived table row from a \text{TableSpec}, a \text{Row} and a classification. The where clause class is set to bottom since no where clause has been evaluated for the row.

HOL Constant

\[ \text{TableRow}_{d} : \text{TableSpec} \rightarrow \text{Row} \rightarrow \text{DerTableRow} \]

\[ \forall t~r \bullet \text{TableRow}_{d}~t~r = \]
\[ \text{let}~f = \lambda~d \bullet (\text{Dat} \cdot \text{class}~d, \text{Dat} \cdot \text{item}~d) \]
\[ \text{in} \]
\[ \text{MkDerTableRow} \]
\[ \text{lattice} \cdot \text{bottom} \]
\[ (\text{R} \cdot \text{exist}~r) \]
\[ (\text{RelList}(\text{Squash}) \]
\[ \{(n, ic) | n \in \text{Dom} (\text{R} \cdot \text{data}~r) \wedge ic = f((\text{R} \cdot \text{data}~r) \circ n)\}) \]

Now obtain the derived table from a \text{TableSpec} and a classification.

HOL Constant

\[ \text{Table}_{d} : (\text{Class} \times \text{Ide~LIST} \times \text{Ide} \times \text{TableSpec}) \rightarrow \text{DerTable} \]

\[ \forall c~d~_name~t~_name~t \bullet \text{Table}_{d} (c, d~_name, t~_name, t) = \]
\[ \text{MkDerTable} \]
\[ (\text{TableSpec}_{d} (c, d~_name, t~_name, t)) \]
\[ (\text{Map} (\text{TableRow}_{d}~t) \circ (\text{TS} \cdot \text{rows}~t)) \]

6.3 Viewing an SSQl State as a List of Derived Tables

Finally the mapping from an SSQl \text{State} : \text{Exp} to a list of derived tables.

HOL Constant

\[ \text{View}_{s} : \text{State} \rightarrow \text{DerTable~LIST} \]

\[ \forall s \bullet \text{View}_{s}~s = \text{Map} \text{Table}_{d} (\text{StateTables}~s) \]
6.4 Viewing a TSQL State as a List of Derived Tables

The view of a TSQL state is obtained using the view function for SSQQL and the representation function of [8].

HOL Constant

\[
\text{View}_t : \text{State}_t \rightarrow \text{DerTable LIST}
\]

\[
\forall s_t \bullet \forall s_s \bullet s_t = \text{reprState} s_s \Rightarrow \text{View}_t s_t = \text{View}_s s_s
\]

Note that the consistency of the above implicit definition requires that any two SSQQL states which are identified by reprState must be the same when viewed as lists of derived tables.

7 ACTION FUNCTION

A derived table is flattened into a list of data tuples using the following function:

HOL Constant

\[
\text{GiveData} : \text{DerTable} \rightarrow \text{Data LIST LIST}
\]

\[
\forall dt \bullet \text{GiveData } dt = \text{Flat}
\]

\[
\text{in let } \text{class\_item } c = \text{ValuedItemItem( MkValuedItem } \text{sterling ( ClassVal } c) \text{)}
\]

\[
\text{in let } \text{item\_data } i = \text{MkData } \text{lattice\_bottom } i
\]

\[
\text{in let } \text{class\_data } c = \text{item\_data } (\text{class\_item } c)
\]

\[
\text{in let } \text{cell\_cols } (c, i) = [\text{class\_data } c; \text{item\_data } i]
\]

\[
\text{in let } \text{row\_data } r
\]

\[
\text{in } \text{Map row\_data}(\text{DT\_rows } dt)
\]

The following, which is intended to determine whether or not a query is a SELECT query might be moved to an earlier document, I think:

HOL Constant

\[
\text{is\_select} : \text{Query} \rightarrow \text{BOOL}
\]

\[
\forall q \bullet \text{is\_select } q \Leftrightarrow \exists t \bullet q = \text{select } t
\]

We do not yet have a specification of any of the database update operations and so the update function must be supplied as a parameter to the function defining the action of the system:
Lemma 1

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HOL Constant

\[
\text{Act}_t : (\text{Query} \times (\text{DerTable} \times \text{Errors}) \times \text{State}_t \rightarrow \text{State}_t) \\
\rightarrow \text{Query} \times (\text{DerTable} \times \text{Errors}) \times \text{State}_t \rightarrow \text{State}_t \times \text{ANSWER}
\]

\[
\forall \text{upd; query; dt; errs; st} \\
\text{Act}_t \ \text{upd} \ (\text{query}, (\text{dt}, \text{errs}), \text{st}) \\
= \text{if } \neg\text{errs} = [] \text{ then } (\text{st}, ([], \text{errs})) \\
\text{else if } \text{is_select query} \\
\text{then } (\text{st}, (\text{GiveData dt, errs})) \\
\text{else } (\text{upd} \ (\text{query}, (\text{dt}, \text{errs}), \text{st}), ([], []))
\]

8 CRITICAL PROPERTIES

We can now attempt to state critical requirements on the main subsystems of the architectural model of [6] by attempting to bound the allowable untrusted queries which are executed. Since we are currently only concerned with the SELECT query, only condition subsys_secureE from [6] is relevant.

First of all, we need to specify an analogue of hide for derived tables in order to state the information flow constraints which apply to computations on them.

HOL Constant

\[
\text{HideDerTableRow} : \text{Class} \rightarrow \text{DerTableRow} \rightarrow \text{DerTableRow}
\]

\[
\forall \text{cc r} \bullet \text{HideDerTableRow cc r} \\
= \text{let } d = \text{ValuedItemItem}(\text{MkValuedItem sterling dummyVal}) \\
\text{in let } hc (c, i) = \text{if } \text{cc dominates c then } (c, i) \text{ else } (c, d) \\
\text{in } \text{MkDerTableRow} \\
(DTR_{where r}) \\
(DTR_{row r}) \\
(Map hc (DTR_{cols r}))
\]

Note that in the following, rows which the client is not cleared to evaluate the WHERE clause are left in. Although such rows are eliminated by the Output Filter they may occur as intermediate results in the table computations of [10], e.g., in inner SELECTs.

HOL Constant

\[
\text{HideDerTableData} : \text{Class} \rightarrow \text{DerTableRow LIST} \rightarrow \text{DerTableRow LIST}
\]

\[
\forall \text{cc rs} \bullet \text{HideDerTableData cc rs} \\
= \text{let } okr = \{r|\text{cc dominates DTR_row r}\} \\
\text{in } \text{Map (HideDerTableRow cc) (rs | okr)}
\]
Lemma 1  
An Execution Model for SWORD

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Date: 5 June 2016

**HOL Constant**

**HideDerTable**: \( \text{Class} \rightarrow \text{DerTable} \rightarrow \text{DerTable} \)

\[
\forall cc \ t \cdot \text{HideDerTable} cc t = \text{MkDerTable} (DT_{\text{spec}} t) (\text{HideDerTableData} cc (DT_{\text{rows}} t))
\]

Given a function, \( f \), on lists of derived tables, let us say that the **risk inputs** of \( f \) at a given class, \( c \) are those inputs for which \( f \) reveals information which should not be visible at class \( c \):

**HOL Constant**

**RiskInputs**: \( \text{Class} \rightarrow (\text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}) \rightarrow (\text{DerTable LIST} \ P) \)

\[
\forall c \ f \cdot 
\text{RiskInputs} c f = \left\{ ts \mid \exists ts_0 \ , 
\begin{array}{ll}
\text{Map} (\text{HideDerTable} c) ts_0 = \text{Map} (\text{HideDerTable} c) ts \\
\land (\neg \text{HideDerTable} c (\text{Fst} (f ts_0)) = \text{HideDerTable} c (\text{Fst} (f ts)) \\
\lor \neg \text{Snd} (f ts_0) = \text{Snd} (f ts)) \right\}
\]

We can now assert the critical requirements on the **SELECT** query processing (corresponding to subsys_secureE of [6]), using the following auxiliary:

**HOL Constant**

**ConditionE**: 

\[
\left( \text{Query} \rightarrow (\text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}) \right) \\
\rightarrow \text{Class} \\
\rightarrow (\left( \text{Query} \times (\text{Query} + \text{ONE}) \times \text{PARS} \right) + \text{Errors}) \ P
\]

\[
\forall \text{compile cc} \cdot 
\text{ConditionE} \ \text{compile cc} = \\
\left\{ \text{stp_res} \mid \text{isError} \text{stp_res} \lor \\
\text{let} (dq, ocq, pars) = \text{destVal stp_res} \\
\text{in let dcomp = compile dq} \\
\text{in} \forall ri \cdot ri \in \text{RiskInputs cc dcomp} \\
\Rightarrow \text{IsL ocq} \\
\land \text{is_select(OutL ocq)} \\
\land \text{let ccomp = compile (OutL ocq)} \\
\text{in} \neg DT_{\text{rows}}(\text{Fst} (ccomp ri)) = [] \\
\lor \neg \text{Snd} (ccomp ri) = [] \right\}
\]
Lemma 1

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HOL Constant

\[
\text{STP\_secure\_E} : \quad (\text{Query} \rightarrow (\text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}))
\]
\[
\rightarrow \quad (\text{Query}, \text{'PARS}) \text{ STP\_TYPE} \quad \mathbb{P}
\]

\[
\forall \text{compile} \bullet
\]
\[
\text{STP\_secure\_E} \text{ compile}
\]
\[
= \quad \{ \text{stp} \mid \forall \ q \ c \bullet \text{stp}(q, c) \in \text{ConditionE compile c}\}
\]

(and similarly, presumably for the other 4 conditions from [6], although something would need to be said about the details of \textit{upd}).

We can now instantiate the generic formulation of the execution model to the particular view and action functions of the previous sections.

HOL Constant

\[
\text{EM}_1 : \quad (\text{Query} \rightarrow (\text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}))
\]
\[
\rightarrow \quad (\text{Query} \times (\text{DerTable} \times \text{Errors}) \times \text{State}_t \rightarrow \text{State}_t)
\]
\[
\rightarrow \quad (\text{Query}, \text{State}_t) \text{ DBMS\_TYPE}
\]

\[
\forall \text{ compile upd} \bullet
\]
\[
\text{EM}_1 \text{ compile upd}
\]
\[
= \quad \text{EM View}_t \text{ compile (Act}_t \text{ upd)}
\]

A compiler and associated database update operation are correct with respect to the TSQL semantics if the above construction implements the TSQL semantics as specified by \textit{TSQLtf} in [5].

HOL Constant

\[
\text{Correct\_Compile} : \quad ((\text{Query} \rightarrow (\text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}))
\]
\[
\times \quad (\text{Query} \times (\text{DerTable} \times \text{Errors}) \times \text{State}_t \rightarrow \text{State}_t)) \quad \mathbb{P}
\]

\[
\text{Correct\_Compile} = \{(\text{compile, upd}) \mid \text{EM}_1 \text{ compile upd} = \text{TSQLtf}\}
\]

To relate the three-stage model of TSQL execution to the actual system constructed from the TSQL transition function, filter of SSQL transformation processor of [5, 7, 9], it is conjectured in [11], conjecture \textit{EM\_SecureE}, that if a compiler and associated database update operation satisfy the above correctness criterion, and if the SSQL Query Transformation Processor lies in the set \textit{STP\_secure\_E} determined by the compiler, then the system components satisfy property E of [6] with respect to the representation.

Connections between the above notions and the critical properties for the SWORD system as a whole are formalised and discussed in [11].

9 CLOSING DOWN

The following \textit{ProofPower} instruction restores the previous proof context.
\texttt{pop\_pc();}
10 THE THEORY fef026

10.1 Parents  

fef029

10.2 Children  

fef031 fef032

10.3 Constants

DCS\_max $\text{DerColSpec} \rightarrow \text{Class}$  
DCS\_min $\text{DerColSpec} \rightarrow \text{Class}$  
DCS\_name $\text{DerColSpec} \rightarrow \text{Col \ LIST}$  
MkDerColSpec \hspace{1em} \text{Col \ LIST} \rightarrow \text{Class} \rightarrow \text{Class} \rightarrow \text{DerColSpec}$  
DTS\_colSpecs $\text{DerTableSpec} \rightarrow \text{DerColSpec \ LIST}$  
DTS\_maxRow $\text{DerTableSpec} \rightarrow \text{Class}$  
DTS\_name $\text{DerTableSpec} \rightarrow \text{Col \ LIST}$  
MkDerTableSpec $\text{Col \ LIST} \rightarrow \text{Class} \rightarrow \text{DerColSpec \ LIST} \rightarrow \text{DerTableSpec}$  
DTR\_cols $\text{DerTableRow} \rightarrow (\text{Class} \times \text{ValuedItem OPT}) \ LIST$  
DTR\_row $\text{DerTableRow} \rightarrow \text{Class}$  
DTR\_where $\text{DerTableRow} \rightarrow \text{Class}$  
MkDerTableRow

\hspace{1em} \text{Class}  
\hspace{3em} \rightarrow \text{Class}$  
\hspace{3em} \rightarrow (\text{Class} \times \text{ValuedItem OPT}) \ LIST$  
\hspace{3em} \rightarrow \text{DerTableRow}$  
DT\_rows $\text{DerTable} \rightarrow \text{DerTableRow \ LIST}$  
DT\_spec $\text{DerTable} \rightarrow \text{DerTableSpec}$  
MkDerTable $\text{DerTableSpec} \rightarrow \text{DerTableRow \ LIST} \rightarrow \text{DerTable}$  
EM $\hspace{1em} (\text{State}_t \rightarrow \text{DerTable \ LIST})$  
\hspace{3em} \rightarrow (\text{Query} \rightarrow \text{DerTable \ LIST} \rightarrow \text{DerTable} \times \text{Errors})$  
\hspace{3em} \rightarrow (\text{Query} \times (\text{DerTable} \times \text{Errors}) \times \text{State}_t$  
\hspace{3em} \rightarrow \text{State}_t \times \text{ANSWER})$  
\hspace{3em} \rightarrow \text{tf}_t$  
StateDirs $\text{State} \rightarrow (\text{Class} \times \text{Col} \times \text{Directory}) \ LIST$  
DirTables $\text{Directory} \rightarrow (\text{Op} \times \text{TableSpec}) \ LIST$  
StateTables $\text{State} \rightarrow (\text{Class} \times \text{Col} \times \text{Op} \times \text{TableSpec}) \ LIST$  
ColSpec\_d $\text{Col} \times \text{Op} \times \text{TableSpec} \rightarrow \text{ColSpec} \rightarrow \text{DerColSpec}$  
TableSpec\_d $\text{Class} \times \text{Col} \times \text{Op} \times \text{TableSpec} \rightarrow \text{DerTableSpec}$  
TableRow\_d $\text{TableSpec} \rightarrow \text{Row} \rightarrow \text{DerTableRow}$  
Table\_d $\text{Class} \times \text{Col} \times \text{Op} \times \text{TableSpec} \rightarrow \text{DerTable}$  
Views $\text{State} \rightarrow \text{DerTable \ LIST}$  
View\_t $\text{State}_t \rightarrow \text{DerTable \ LIST}$  
GiveData $\text{DerTable} \rightarrow \text{Select}$
Lemma 1
An Execution Model for SWORD

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is_select

\( \text{Act}_t \) \( : (\text{Query} \times (\text{DerTable} \times \text{Errors}) \times \text{State}_t \rightarrow \text{State}_t) \)
\( \rightarrow \text{Query} \times (\text{DerTable} \times \text{Errors}) \times \text{State}_t \)
\( \rightarrow \text{State}_t \times \text{ANSWER} \)

\text{HideDerTableRow}

\( : \text{Class} \rightarrow \text{DerTableRow} \rightarrow \text{DerTableRow} \)

\text{HideDerTableData}

\( : \text{Class} \rightarrow \text{DerTableRow LIST} \rightarrow \text{DerTableRow LIST} \)

\text{RiskInputs}

\( : \text{Class} \rightarrow (\text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}) \rightarrow \text{DerTable LIST} \)

\text{ConditionE}

\( : (\text{Query} \rightarrow \text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}) \rightarrow \text{Class} \rightarrow (\text{Query} \times \text{Query OPT} \times \text{\textquote{PARS}}) \rightarrow \text{RESULT} \)

\text{STP_secure_E}

\( : (\text{Query} \rightarrow \text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}) \rightarrow (\text{Query}, \text{\textquote{PARS}}) \rightarrow \text{STP_TYPE} \)

\text{EM1}

\( : (\text{Query} \rightarrow \text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}) \rightarrow (\text{Query} \times (\text{DerTable} \times \text{Errors}) \times \text{State}_t \rightarrow \text{State}_t \rightarrow \text{tf}_t \)

\text{Correct.Compile}

\( : (\text{Query} \rightarrow \text{DerTable LIST} \rightarrow \text{DerTable} \times \text{Errors}) \leftrightarrow (\text{Query} \times (\text{DerTable} \times \text{Errors}) \times \text{State}_t \rightarrow \text{State}_t \)

10.4 Types

\text{DerColSpec}

\text{DerTableSpec}

\text{DerTableRow}

\text{DerTable}

10.5 Definitions

\text{DerColSpec}
\( \vdash \exists f \bullet \text{TypeDefn} (\lambda x \bullet \text{true}) f \)

\text{MkDerColSpec}
\text{DCS_name}
\text{DCS_min}
\text{DCS_max}
\( \vdash \forall t x_1 x_2 x_3 \)
\( \bullet \text{DCS_name (MkDerColSpec x1 x2 x3)} = x_1 \)
\( \wedge \text{DCS_min (MkDerColSpec x1 x2 x3)} = x_2 \)
\( \wedge \text{DCS_max (MkDerColSpec x1 x2 x3)} = x_3 \)
\( \wedge \text{MkDerColSpec}
\( (\text{DCS_name t})
\( (\text{DCS_min t})
\( (\text{DCS_max t})
\) = t \)
Lemma 1

An Execution Model for SWORD

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\[ \text{DerTableSpec} \vdash \exists f \bullet \text{TypeDefn} \left( \lambda x \bullet \text{true} \right) f \]

\[ \text{MkDerTableSpec} \]

\[ \text{DTS\_name} \]

\[ \text{DTS\_maxRow} \]

\[ \text{DTS\_colSpecs} \vdash \forall t \ x1 \ x2 \ x3 \]

\[ \bullet \text{DTS\_name} \left( \text{MkDerTableSpec} \ x1 \ x2 \ x3 \right) = x1 \]

\[ \land \text{DTS\_maxRow} \left( \text{MkDerTableSpec} \ x1 \ x2 \ x3 \right) = x2 \]

\[ \land \text{DTS\_colSpecs} \left( \text{MkDerTableSpec} \ x1 \ x2 \ x3 \right) = x3 \]

\[ \land \text{MkDerTableSpec} \]

\[ \left( \text{DTS\_name} \ t \right) \]

\[ \left( \text{DTS\_maxRow} \ t \right) \]

\[ \left( \text{DTS\_colSpecs} \ t \right) \]

\[ = t \]

\[ \text{DerTableRow} \vdash \exists f \bullet \text{TypeDefn} \left( \lambda x \bullet \text{true} \right) f \]

\[ \text{MkDerTableRow} \]

\[ \text{DTR\_where} \]

\[ \text{DTR\_row} \]

\[ \text{DTR\_cols} \vdash \forall t \ x1 \ x2 \ x3 \]

\[ \bullet \text{DTR\_where} \left( \text{MkDerTableRow} \ x1 \ x2 \ x3 \right) = x1 \]

\[ \land \text{DTR\_row} \left( \text{MkDerTableRow} \ x1 \ x2 \ x3 \right) = x2 \]

\[ \land \text{DTR\_cols} \left( \text{MkDerTableRow} \ x1 \ x2 \ x3 \right) = x3 \]

\[ \land \text{MkDerTableRow} \]

\[ \left( \text{DTR\_where} \ t \right) \]

\[ \left( \text{DTR\_row} \ t \right) \]

\[ \left( \text{DTR\_cols} \ t \right) \]

\[ = t \]

\[ \text{DerTable} \vdash \exists f \bullet \text{TypeDefn} \left( \lambda x \bullet \text{true} \right) f \]

\[ \text{MkDerTable} \]

\[ \text{DT\_spec} \]

\[ \text{DT\_rows} \vdash \forall t \ x1 \ x2 \]

\[ \bullet \text{DT\_spec} \left( \text{MkDerTable} \ x1 \ x2 \right) = x1 \]

\[ \land \text{DT\_rows} \left( \text{MkDerTable} \ x1 \ x2 \right) = x2 \]

\[ \land \text{MkDerTable} \left( \text{DT\_spec} \ t \right) \left( \text{DT\_rows} \ t \right) = t \]

\[ \text{EM} \vdash \forall \text{view compile act query st} \]

\[ \bullet \text{EM} \left( \text{view compile act query st} \right) \]

\[ = \left( \text{let compute} = \text{compile query} \right) \]

\[ \text{in let viewed} = \text{view st} \]

\[ \text{in let computed} = \text{compute viewed} \]

\[ \text{in act} \left( \text{query, computed, st} \right) \]

\[ \text{StateDirs} \vdash \text{ConstSpec} \]

\[ \left( \lambda \text{StateDirs'} \right) \]

\[ \bullet \forall s \]

\[ \bullet \text{Elems} \left( \text{StateDirs'} \ s \right) \]

\[ = \left\{ \left( c, i, d \right) \mid \left( i, d \right) \in \text{repState} \ s \right\} \land c = \text{Dir\_exist} \ d \land \text{Dir\_class} \ d \} \]

\[ \text{StateDirs} \]

\[ \text{DirTables} \vdash \text{ConstSpec} \]

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Lemma 1

DRA FRONT END FILTER PROJECT

An Execution Model for SWORD

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(\lambda \text{DirTables}'
  \bullet \forall d \bullet \text{Elems} (\text{DirTables}' d) = \text{Dir\_tables} d)

DirTables

\text{StateTables} \vdash \forall s

\bullet \text{StateTables} s

= (\text{let } (cl, illdl) = \text{Split} (\text{StateDirs} s) 
  \text{ in let } ill = \text{Map} \text{ DirTables} dl 
  \text{ in let } g (c, i, its) = \text{Map} (f c i) its 
  \text{ in let } h \text{ cl is itss}

  = \text{Map}

  \text{ (Combine cl (Combine is itss))}

  \text{ in Flat} (h \text{ cl ill illl})

\text{ColSpec}_d \vdash \forall d \text{\_name} t \text{\_name} t \text{ cs}

\bullet \text{ColSpec}_d (d \text{\_name}, t \text{\_name}, t) \text{ cs}

= (\text{let } cc = \text{TS\_cons} t @ \text{CS\_consGroup} cs 
  \text{ in let } tc = [t; \text{CS\_ide} cs] 
  \text{ in MkDerColSpec}

  [[\text{CS\_ide} cs]; tc; d\text{\_name} @ tc]

  \text{ (CS\_min cs)}

  \text{ (CS\_max cs)})

\text{TableSpec}_d \vdash \forall c d \text{\_name} t \text{\_name} t

\bullet \text{TableSpec}_d (c, d \text{\_name}, t \text{\_name}, t)

= \text{MkDerTableSpec}

[[t; d\text{\_name} @ [t; t]]

\text{ (TS\_maxRow t)}

\text{ (RelList}

(Squash

\{(n, cs) \mid \exists cs' \in \text{TS\_colspecs} t

\land \text{ cs}

= \text{ColSpec}_d

(d\text{\_name}, t\text{\_name}, t)

\land n = \text{CS\_posn cs'})\})

\text{TableRow}_d \vdash \forall t r

\bullet \text{TableRow}_d t r

= (\text{let } f d = (\text{Dat\_class} d, \text{Dat\_item} d) 
  \text{ in MkDerTableRow}

  \text{ lattice\_bottom}

  \text{ (R\_exist r)}

  \text{ (RelList}

  (Squash

  \{(n, ic) \mid n \in \text{Dom} (R\_data r)\})

  \text{ (\text{CS\_max cs})})

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Lemma 1 DRA FRONT END FILTER PROJECT

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∧ ic = f (R_data r ⊕ n)))

Table_d ⊢ ∀ c d_name t_name t
  • Table_d (c, d_name, t_name, t) = MkDerTable
    (TableSpec_d (c, d_name, t_name, t))
    (Map (TableRow_d t) (TS_rows t))

View_s ⊢ ∀ s • View_s s = Map Table_d (StateTables s)

View_t ⊢ ConstSpec
  (λ View'_t
    • ∀ s_t s_t
      • s_t = reprState s_s
        ⇒ View'_t s_t = View_s s_s)

GiveData ⊢ ∀ dt
  • GiveData dt = (let class_item c
    = ValuedItemItem
      (MkValuedItem sterling (ClassVal c))
    in let item_data i = MkData lattice_bottom i
    in let class_data c
      = item_data (class_item c)
    in let cell_cols (c, i)
      = [class_data c; item_data i]
    in let row_data r
      = Flat
        (Cons
          [class_data (DTR_where r);
            class_data (DTR_row r)]
        (Map cell_cols (DTR_cols r)))
    in Map row_data (DT_rows dt))

is_select ⊢ ∀ q • is_select q ⇔ (∃ i • q = select t)

Act_t ⊢ ∀ upd query dt errs st
  • Act_t upd (query, (dt, errs), st)
    = (if ¬ errs = []
      then (st, [], errs)
      else if is_select query
        then (st, GiveData dt, errs)
        else (upd (query, (dt, errs), st), [], []))

HideDerTableRow ⊢ ∀ cc r
  • HideDerTableRow cc r
    = (let d
      = ValuedItemItem
        (MkValuedItem sterling dummyVal)
      in let hc (e, r)
        = (if cc dominates c
          then (c, i)
          else (c, d))
in \(\text{MkDerTableRow}\)
\((\text{DTR} \cdot \text{where } r)\)
\((\text{DTR} \cdot \text{row } r)\)
\((\text{Map } \text{hc} (\text{DTR} \cdot \text{cols } r))\)

\(\text{HideDerTableData} \vdash \forall \text{ cc } \text{rs}\)
\(\bullet \text{HideDerTableData } \text{cc } \text{rs}\)
\(= (\text{let } \text{okr} = \{r| \text{cc dominates } \text{DTR} \cdot \text{row } r\}\)
\(\text{in } \text{Map} (\text{HideDerTableRow} \text{cc} ) (\text{rs }\uparrow \text{okr})\)

\(\text{HideDerTable} \vdash \forall \text{ cc } t\)
\(\bullet \text{HideDerTable } \text{cc } t\)
\(= \text{MkDerTable}\)
\((\text{DT} \cdot \text{spec } t)\)
\((\text{HideDerTableData} \text{cc} (\text{DT} \cdot \text{rows } t))\)

\(\text{RiskInputs} \vdash \forall \text{ c } f\)
\(\bullet \text{RiskInputs } \text{c } f\)
\(= \{ts\}
\(\exists ts_0\)
\(\bullet \text{Map} (\text{HideDerTable } \text{c} ) ts_0\)
\(= \text{Map} (\text{HideDerTable } \text{c} ) ts\)
\(\land (\neg \text{HideDerTable } \text{c} (\text{Fst } (f ts_0)))\)
\(= \text{HideDerTable } \text{c} (\text{Fst } (f ts))\)
\(\lor \neg \text{Snd } (f ts_0) = \text{Snd } (f ts))\}

\(\text{ConditionE} \vdash \forall \text{ compile } \text{cc}\)
\(\bullet \text{ConditionE } \text{compile } \text{cc}\)
\(= \{\text{stp } \text{res}\}
\\text{isError } \text{stp } \text{res}\)
\(\lor (\text{let } (\text{dq}, \text{ocq}, \text{pars}) = \text{destVal } \text{stp } \text{res}\)
\(\text{in } \text{let } \text{dcomp } = \text{compile } \text{dq}\)
\(\text{in } \forall ri\)
\(\bullet ri \in \text{RiskInputs } \text{cc } \text{dcomp}\)
\(\Rightarrow \text{IsL } \text{ocq}\)
\(\land \text{is-select } (\text{OutL } \text{ocq})\)
\(\land (\text{let } \text{ccomp } = \text{compile } (\text{OutL } \text{ocq})\)
\(\text{in } \neg \text{DT} \cdot \text{rows } (\text{Fst } (\text{ccomp } ri))\)
\(= []\)
\(\lor \neg \text{Snd } (\text{ccomp } ri) = []))\}

\(\text{STP}_\text{secure}_E \vdash \forall \text{ compile}\)
\(\bullet \text{STP}_\text{secure}_E \text{ compile}\)
\(= \{\text{stp} \lor q \bullet \text{stp } (q, c) \in \text{ConditionE } \text{compile } c\}\)

\(\text{EM1} \vdash \forall \text{ compile } \text{upd}\)
\(\bullet \text{EM1 } \text{compile } \text{upd} = \text{EM View}_t \text{ compile } (\text{Act}_t \text{ upd})\)

\(\text{Correct}_\text{Compile}\)
\(\vdash \text{Correct}_\text{Compile}\)
\(= \{(\text{compile}, \text{upd})|\text{EM1 } \text{compile } \text{upd} = \text{TSQL}_\text{lf}\}
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