Enforcing Agile Access Control Policies in Relational Databases using Views

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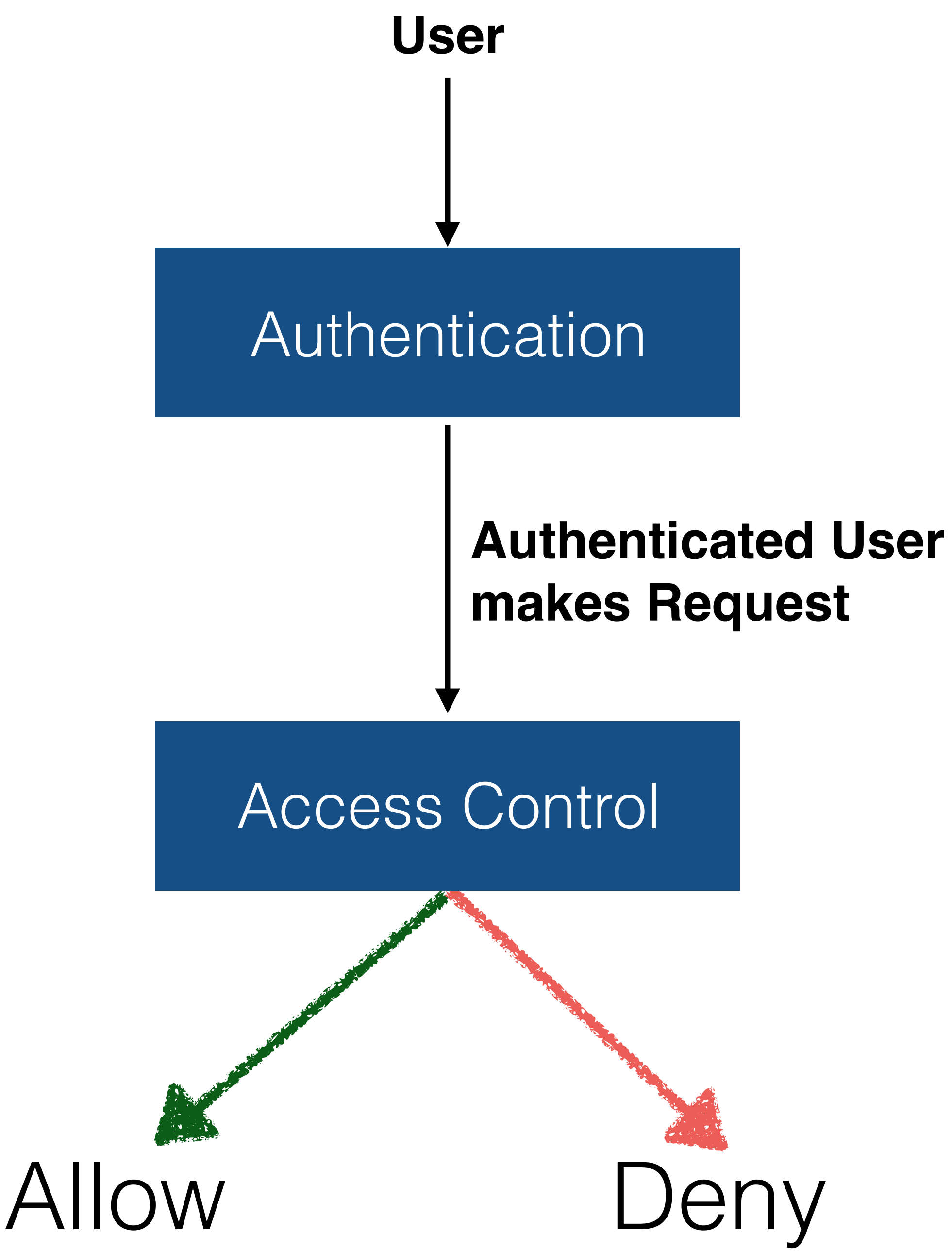
Databases and Data Protection

- Databases store **valuable** and **sensitive** information
- 7 out of 10 top security threats involve databases [2]
- Deploy data protection mechanisms: authentication, access control, encryption…

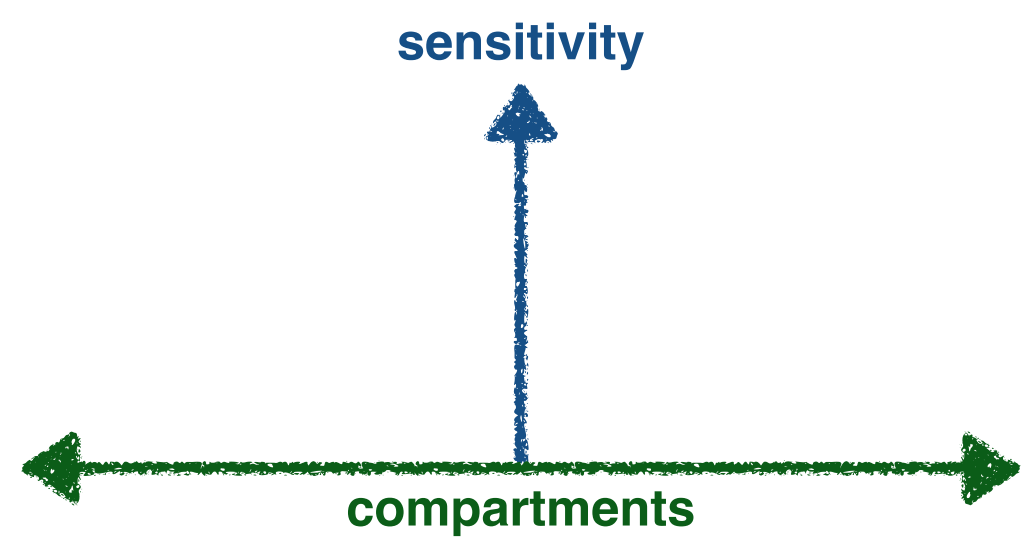
Databases and Access Control

- Access control applies to **authenticated users**
- Access control preserve **confidentiality** and **integrity**
- Most current access control workflows rely on individuals to **manually implement policy models** using access control mechanisms
- Access Control rules specified by a specific **policy**



Use Case: Multilevel Security for Relational Databases

- Implements the **need-to-know principle**
- Based on security **lattice** introduced by Bell and LaPadula
- Enforcement through two **properties**:
  - Simple security property
  - Star property
- **Static user privileges are not appropriate**:
  - Update of policy is error-prone
  - No dynamic evolution (mutual exclusion)

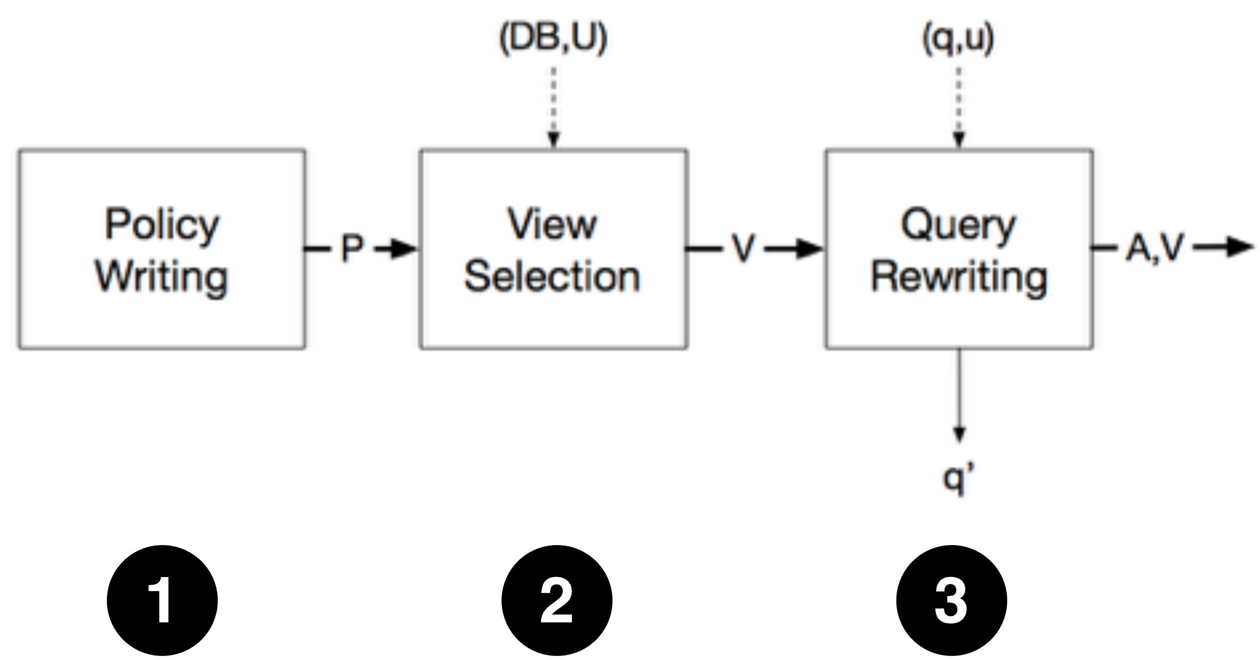


id	name	mission	destination
-	U,{Naval}	TS,{Naval}	S,{Naval}
1	Seawolf	spy	Russia
2	Roosevelt	patrol	Gulf of Aden
3	Normandy	patrol	Gulf of Oman

Example table with MLS labels

Approach to Agile Access Control Policy Enforcement

1. **Policy Writing**:
   - Define policy set **P**
   - **High-level abstraction**
2. **View Selection**:
   - Input: DB, P, U
   - **Generates** a set V reflecting P
3. **Query Rewriting**:
   - Input: DB, P, U, V, A,
   - **Rewrite query** q’ over V
   - **Update** V and A



Overview of the Approach

❶ Policy Writing

The **ASL language** is made of:

- **Predicates**: active, in, dirin, typeof (describe the users and objects)
- **Rules**: done, authorization, derivation, access control, resolution, integrity (describe the policy)

We make the following assumptions:

- **Column granularity**
- **Positive authorizations** only (no conflict resolution)

```
Require: L, DB, U
Let P = ∅
for each T ∈ DB do
    for each u ∈ U do
        if (l_{T,1} ≤ l_{u,1}) & ... & (l_{T,n} ≤ l_{u,n}) then
            add rule grant(T, u, R, SELECT) ←
              active(u, l_u) & typeof(T, l_T)
        else if (l_{T,1} ≥ l_{u,1}) & ... & (l_{T,n} ≥ l_{u,n}) then
            add rule grant(T, u, R, INSERT) ←
              active(u, l_u) & typeof(T, l_T)
        else if (l_{T,1} = l_{u,1}) & ... & (l_{T,n} = l_{u,n}) then
            add rule grant(T, u, R, UPDATE) ←
              active(u, l_u) & typeof(T, l_T)
            add rule grant(T, u, R, DELETE) ←
              active(u, l_u) & typeof(T, l_T)
        end if
    end for
end for
return P
```

Bell-LaPadula model

$$p_1 = \texttt{grant}(T, u, r, *) \leftarrow !done(T', u, *, *, *) \ \& \ \texttt{typeof}(T, A) \ \& \ \texttt{typeof}(T', B)$$

$$p_2 = \texttt{grant}(T, u, r, *) \leftarrow !done(T', u, *, *, *) \ \& \ \texttt{typeof}(T, B) \ \& \ \texttt{typeof}(T', A)$$

Chinese Wall policy

Jajodia, S., Samarati, P., & Subrahmanian, V. S.
A logical language for expressing authorizations.
IEEE Symposium on Security and Privacy, 1997

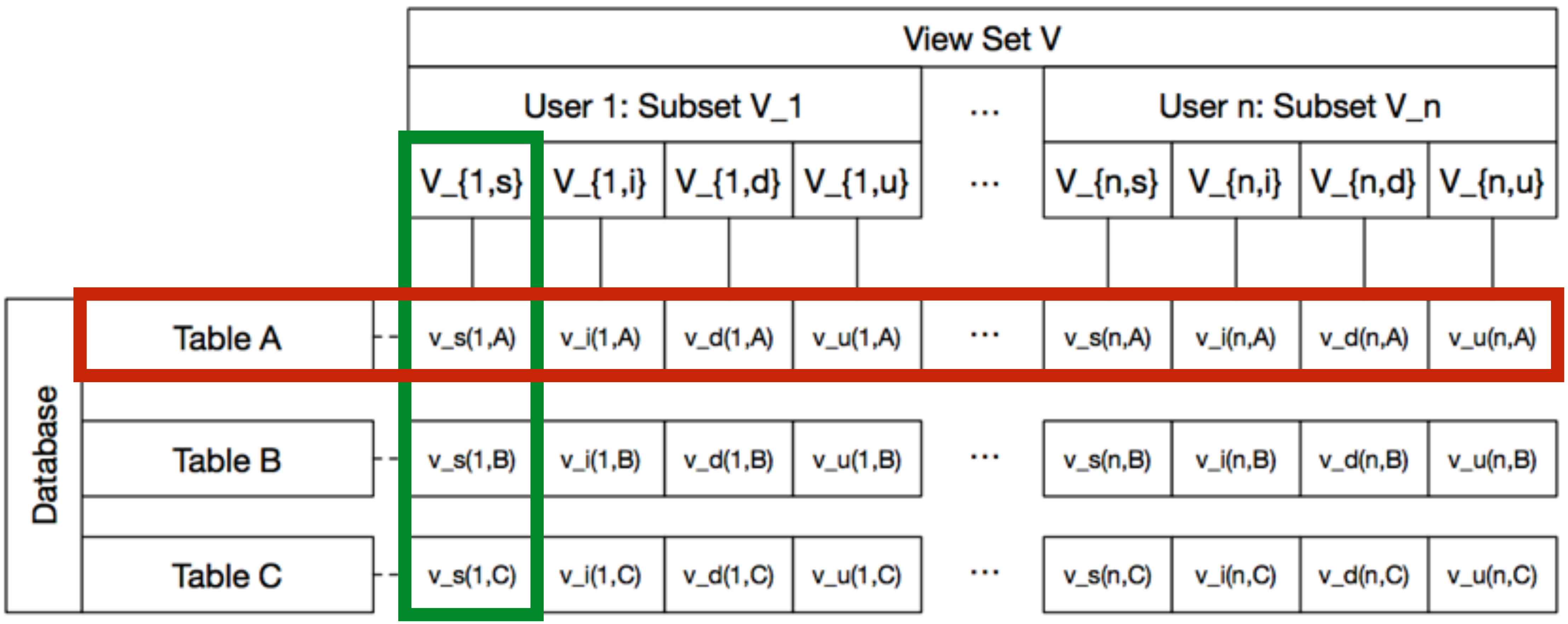
2 View Selection

- **each view corresponds to an SQL operation**: `SELECT, INSERT, DELETE,` and `UPDATE`
- a view is set for each **(user, table) pair**
- the view selection is done by considering grant, cando, and dercando **rules** and building sets `G,Gc,C,Cc,Dc`

```
Require: DB, U, P
V = V_1 ∪ ... ∪ V_|U| = ∅
for each u ∈ U do
    for each a ∈ {SELECT, INSERT, DELETE, UPDATE} do
        Create empty set V_{u,a}
        for each table T ∈ DB do
            Compute G = G(u, T, *, a)
            Compute C = C(u, T, *, a)
            Compute D = D(u, T, *, a)
            if G ∪ C ∪ D = ∅ then
                columns = ∅
                for each column c ∈ T do
                    Compute G_c = G(u, T, c, a)
                    Compute C_c = C(u, T, c, a)
                    Compute D_c = D(u, T, c, a)
                    if (G_c ∪ C_c ∪ D_c ≠ ∅) then
                        columns = columns ∪ {c}
                    end if
                end for
                v_a(u, T) = SELECT columns FROM T
            else if (G ∪ C ∪ D ≠ ∅) then
                create v_a(u, T) = SELECT * FROM T
            end if
            V_{u,a} = V_{u,a} ∪ {v}
        end for
    end for
    V_u = V_{u,s} ∪ V_{u,i} ∪ V_{u,d} ∪ V_{u,u}
end for
return V
```

Fig. 6. ASL View Selection algorithm

2 View Selection



Overview of the View Set

❷ View Selection

- **each view corresponds to an SQL operation**: `SELECT, INSERT, DELETE,` and `UPDATE`
- a view is set for each **(user, table) pair**
- the view selection is done by considering grant, cando, and dercando **rules** and building sets `G,Gc,C,Cc,D,Dc`

Require: DB, U, P
$V = V_1 \cup ... \cup V_{|U|} = \emptyset$
for each $u \in U$ **do**
  for each $a \in \{$SELECT, INSERT, DELETE, UPDATE$\}$ **do**
    Create empty set $V_{u,a}$
    for each table $T \in DB$ **do**
      Compute $G = G(u, T, *, a)$
      Compute $C = C(u, T, *, a)$
      Compute $D = D(u, T, *, a)$
      if $G \cup C \cup D = \emptyset$ **then**
        $columns = \emptyset$
        for each column $c \in T$ **do**
          Compute $G_c = G(u, T, c, a)$
          Compute $C_c = C(u, T, c, a)$
          Compute $D_c = D(u, T, c, a)$
          if $(G_c \cup C_c \cup D_c \neq \emptyset)$ **then**
            $columns = columns \cup \{c\}$
          end if
        end for
        $v_a(u, T)$ = SELECT $columns$ FROM T
      else if $(G \cup C \cup D \neq \emptyset)$ **then**
        create $v_a(u, T)$ = SELECT * FROM T
      end if
      $V_{u,a} = V_{u,a} \cup \{v\}$
    end for
  end for
  $V_u = V_{u,s} \cup V_{u,i} \cup V_{u,d} \cup V_{u,u}$
end for
return V

Fig. 6. ASL View Selection algorithm

❸ Query Rewriting

1. **rewrite query**: straight forward thanks to the view-table-user correspondance

2. **update view set**: update of view set is done by identifying relevant rules (using subroutine find-done) and removing views conflicting with the new accesses made in the query

3. **update past accesses**: append the accesses made in the query

```
Require: $DB$, $P$, $A$, $V$, $u$, $q$
  $q' = q$
  $A' = \emptyset$
  let $a$ be the operation of $q$
  for each table column $T.c$ mentioned in $q$ do
      if $\exists v \in V_{u,a}, T.c \subset v$ then
          rewrite $q'$ with $v.c$ instead of $T.c$
          if $v.c \neq \emptyset$ then
              $A' \leftarrow A' \cup \texttt{done}(T.c, u, R, a, t)$
          end if
      else
          return "query not compliant"
      end if
  end for
  for each $d \in A'$ do
      $\{p_j\}_j = \texttt{find-done}(P \cup A \cup A', d)$
      for each $p_j$ do
          if $p_j == \texttt{error}()$ then
              return "query not compliant"
          else if $p_j == \texttt{dercando}(T.c, s, +a)$ then
              empty c from $v \in V_{u,a}$ such that $T.c \subset v$
          else if $p_j == \texttt{do}(T.c, s, +a)$ then
              empty c from $v \in V_{u,a}$ such that $T.c \subset v$
          else if $p_j == \texttt{grant}(T.c, s, r, +a)$ then
              empty c from $v \in V_{u,a}$ such that $T.c \subset v$
          end if
      end for
  end for
  return $\{q', V', A' \cup A\}$
```

Fig. 7. ASL Query Rewriting algorithm

Conclusion

- Tractable algorithms capable of **enforcing policies** expressed using **ASL language**
  - Capable of enforcing **static access control, information flow, mutual exclusion**
  - Support for all **SQL queries** (SELECT, INSERT, DELETE, UPDATE)
- **No modification** required of:
  - Database schema
  - User queries (no need to change application code)
- Future work:
  - Implementing the technique within a database
  - Evaluate performance impact
  - Design technique allowing policy set P and view set V updates on the fly
    -> View management is main factor of complexity

Questions?

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