Access Control Models, with Applications to Robotics

The European Robotics Forum

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Agenda

- Motivation
- Types of Access Control
- Discretionary Access Control
- Role Based Access Control
- Mandatory Access Control
- Appendix
  - MAC Variants
  - Clark-Wilson Model for Integrity Preservation

Motivation 1

- Application of IT, especially robotics, meant to increase efficiency of repetitive tasks →
  - cost reduction,
  - quality increase

  → competitive advantage
- Robotics is challenging here for
  - being highly distributed
  - involving lots of sensors and actors
  - collaborating or even cooperating with humans → security and safety risks

Motivation 2

- Security is an enabler for safety via classical goals:
  - confidentiality $\rightarrow$ encryption ✓
  - integrity $\rightarrow$ checksums ✓
  - availability $\rightarrow$ redundancy ✓
- But equally important are:
  - non-repudiation $\rightarrow$ secure logging (robot "black-box", block-chain?, ...)
  - authenticity $\rightarrow$ digital signatures (can be expensive and hard to maintain practically), ... ✓
  - authorization $\rightarrow$ many possibilities $\Rightarrow$ this talk
- Security models: technical and organizational procedures for authorization $\neq$ authentication
  - Authentication: proof of a claimed identity ($\neq$ identification $=$ determination of an unknown identity)
  - Authorization: verification of rights that are assigned to a certain identity, whose verification/determination is a separate issue!

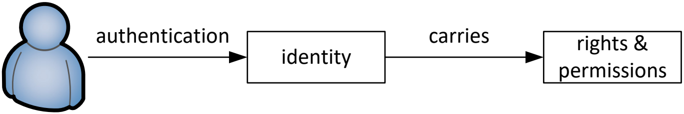
- Security models of different kind were developed in the 1970s and applied ever since then.
- Internal and external attacks lead to:
  - Loss of data and information (deletion, copying, ...)
  - Data manipulation (updates on database records, sending malicious commands to robots ...)
- Complex security rules are inevitable
- Access control systems for large distributed systems are mandatory

Motivation 4

- Access to resources (data, information, sensors, actors, ...) must be constrained/controlled.
  - Not everybody must be allowed to do everything. There are defined rules.
  - Dependent on time, context, privileges, ...
  - Goal in industrial production is the protection of integrity (other businesses may care more for confidentiality).

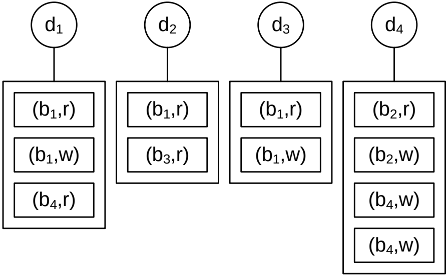
- Multi-user environments
  - Changing users, where user $\in$ {sensor, actor, human operator, ...}
  - Rights/roles of users may change
  - restrict information flow (no information leakage or injection of commands)
  - Access to common resources (e.g., sensor, actor, but also project directories, ...)

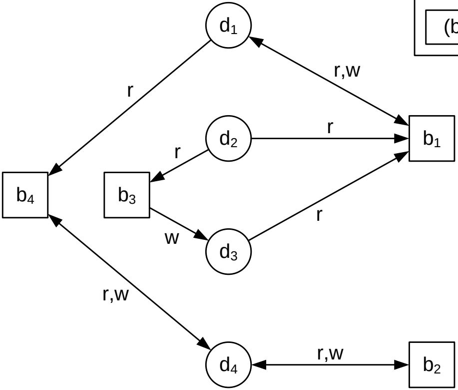
- DAC (User-definable access control) is also called identity based access control (IBAC).
- System consists of
  - Subjects (users , processes, groups)
  - Objects (devices, files, physical objects, ...)
  - Subjects and objects carry unique IDs.
- Owner defines rights on her/his objects.
  - Positive (permissions) and negative (restrictions) rights are possible.
  - Each object has exactly one owner.
  - The owner of an object may change.
  - Rights on an object are granted individually.
- Rights are maintained (enforced) via
  - access control list (ACL)
  - access matrices (rarely used)



- Subjects can grant rights to other subjects.
  - User A calls program B (both are subjects!)
  - Program B inherits the rights of user A.
  - Program B is also an object (a file in general).

- Representation as
  - Graph
  - ACL
  - access matrix



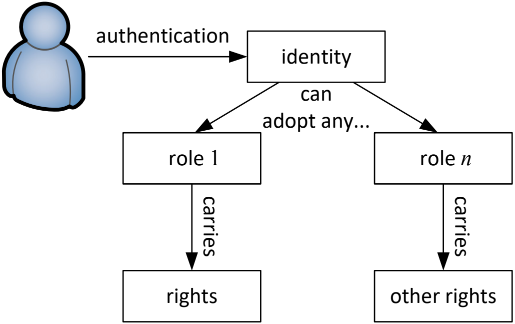


M	d_1	d_2	d_3	d_4
b_1	r,w	r	r	
b_2				r,w
b_3		r	w	
b_4	r			r,w

Discretionary Access Control (DAC) 4

- DAC is implemented in many operating systems.
- (One) problem due to exclusive use of DAC
  - Login-passwords (or hash values thereof) are stored in a file owned by the administrator.
  - Users cannot access that file (otherwise, a user could modify another user's password).
  - If a user wishes to change her/his password, access to the file is required.
- Solution (least privilege)
  - User is temporarily elevated to the administrative role (in the background), so that access to the password file becomes possible. This happens transparently for the user.
  - A pure use of DAC would otherwise require the administrator's intervention to change a password (as this is the owner of the password file).

- Role Based Access Control was first proposed in 1992 by D. F. Ferraiolo and D. R. Kuhn.
- A role (user role, function) defines
  - Duties (specialized sensors, specialized actors, ...)
  - Rights (access to local resources, sensors, physical parts, ...)
- Users adopt and may switch roles ← multiple access credentials

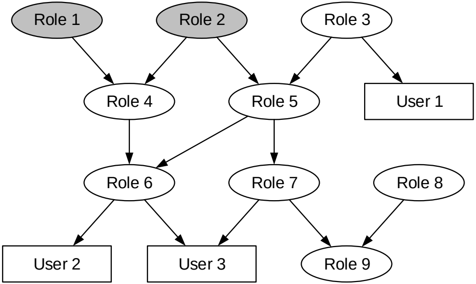


- The assignment of subjects to roles enables:
  - Easy administration (few roles instead of having to adapt many users)
  - Assignment of minimal privileges to fulfil duties (Need-to-Know-Principle).
  - Change of roles (owner of a part may change along a production line)
  - Separation-of-duty principle (e.g., robot must not take commands from sensors not carrying the proper role).
- Roles can inherit from one another.
  - Rights can be inherited (also restricted), e.g., main vs. deputy, ...
  - Complex interdependencies (hierarchies) are easy to model (e.g., worker $<$ supervisor $<$ chief of production).
  - Multiple inheritance possible.
- Popular to grant rights in complex systems.
  - Hospital (doctor, department head, nurse, patient, ...)
  - University (principal, institute head, coordinators, ...)
  - Enterprise (executive board, manager, employee, ...)

Ellipses: Roles

grey ellipses: abstract roles (no physical role representative)

Rectangles: users



In a robotic system, e.g.,

- sensor $<$ emergency sensor (could overrule the "normal sensor")
- robot operator $<$ robot programmer $<$ process administrator

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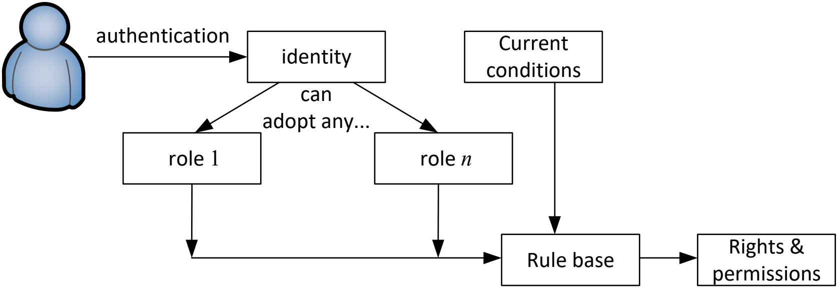
- Mandatory access control is in the literature also called rule-based access control.
- Decisions are made according to a central and mandatory rule base.
- Rules may specify:
  - Times (access permitted only during work hours)
  - Number of accesses (say, a file can be opened at most 100 times per day)
  - Attributes (ownership, security clearance, ...)
  - Statistical patterns (normal vs. irregular user behavior)
  - Age of objects (e.g., within the last n time units)

- Objects/Subjects get attributes assigned (MAC labels).
  - Security clearance (example: unclassified, ..., top secret)
  - Keywords (example: adminstration, production planning, ...)
  - resource type $\rightarrow$ resource-based access control
  - current role $\rightarrow$ combination with RBAC

- roughly comparable to a combination and refinement of DAC and RBAC



- very flexible, yet (for that reason) also very complex
- Object access constrained by rules (e.g., no use of certain sensors, actors, . . .)
- Popular in file system right management (Linux, AppArmor, various firewalls, . . .)

Comparative summary

- DAC: identity $\rightarrow$ rights and permissions
- RBAC: identity $\rightarrow$ role $\rightarrow$ rights and permissions
- MAC:
    1. identity $\rightarrow$ role
    2. role $+$ current system conditions $\rightarrow$ rights and permissions
- most other schemes: ... viewable as special cases or particular refinements of MAC for certain application contexts

Take-Home Message

- Recommendation: do not rely on "standard" security mechanisms too much (don't just use a password, plan for a highly diverse and changing environment in future)
- Determine the attributes, resources, ... general factors... that determine permissions and prohibitions
- Anticipate changes in future and adapt your access control to be flexibel for that → rule-based access control is often efficient to maintain, update and adapt
- Also check out other (more advanced) access control models: policy-based, attribute-based, risk-level determined, Brewer-Nash (Chinese-Wall), Bell-LaPadula, Clark-Wilson (← used in many databases) ...

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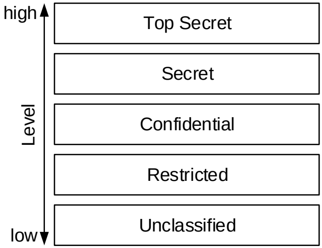
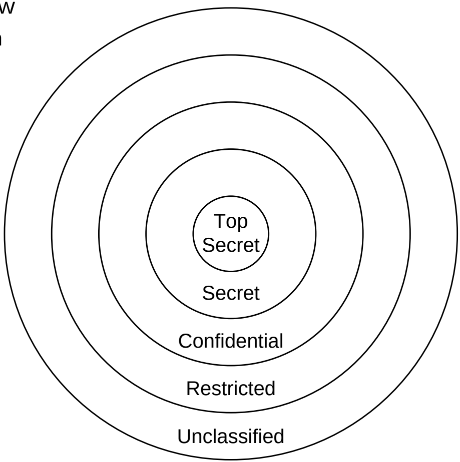
Questions?

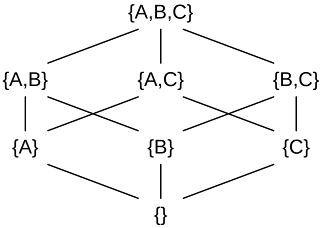
- multi level security – MLS
  - Simplest variants (1970s)
  - Classify data in terms of security levels
  - Limitation of information flow
  - Vertical classification of data
  - Example: Biba-Model

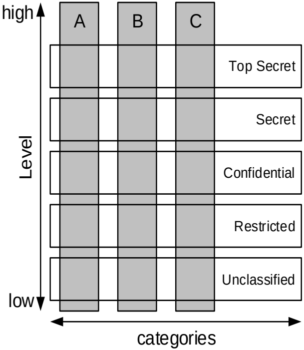




- Multilateral security models
  - A.k.a. rule based security models
  - More complex than multi-level security models
  - Use vertical and horizontal classification
  - Example: Bell-LaPadula-Model

Subset-relations among categories induces a lattice





Clark-Wilson – Basics

- Developed in 1987 by David Clark and David Wilson.
- Multilateral security model
- Goal is the protection of integrity (integrity policy)
- Strongly different to the Bell-LaPadula- and Biba model.
- The model uses transactions as basic operations.
- The CW model is – in principle – implemented in every database management system (DBMS).
  - Assumption: DBMS supports transactions
  - Examples: Oracle, MySQL, MS SQL, ...
- All subsequent explanations will refer to DBMS.

- Constrained Data Items – *CDI*
  CDIs are data entities that are subject to integrity conditions.

  Examples:
  - Foreign key entries
  - Not-null conditions (columns)
  - Tables or columns protected by stored procedures

- Unconstrained Data Items – *UDI*
  UDIs are arbitrarily malleable data entities.

  Examples:
  - Database records without integrity constraints
  - Intermediate results

Clark-Wilson – Components 2

- Integrity Constraints – *IC*
  ICs define conditions under which *CDIs* are considered as valid.

  Examples:
  - Foreign key value (referred record must exist in the other table)
  - Not-null conditions

- Integrity Verification Procedures – *IVP*
  IVPs are programs that check integrity. Violations of constraints initiate a rollback.

  Examples:
  - Parts of a DBMS that enforce constraints
  - INSERT/UPDATE/DELETE stored procedures

- Transformation Procedures – *TP*
  TPs are programs that modify *CDIs* while retaining the integrity

  Examples:
  - INSERT/UPDATE/DELETE commands
  - Transactions (set of INSERT/UPDATE/DELETE commands)
  - Stored procedures

- Certified Relation – *C*
  $C \subseteq TP \times CDI$
  The relation defines which *TPs* may modify which *CDIs*.

  Examples:
  - Write protection of tables ($TP =$ INSERT, $CDI =$ affected table)
  - Protection against unknown stored procedures.

Clark-Wilson – Components 4

- Users – U
  U represent instances using the system.

- Allowed – A
  $A \subseteq U \times TP \times CDI$
  Is a relation that defines which user can run which TP on which $CDIs$.
  A is often maintained as a separate table inside the DBMS and is under extra protection.

  Examples:
  - User "A" may access table "Mitarbeiter" using the TP UPDATE.
  - User may read and write booking records.

- Certification rules
  - CR 1 (Integrity protection)
    The *IVPs* must assure that all *CDIs* remain in a consistent state at all times
  - CR 2 (Transaction execution)
    TPs modify *CDIs* from one consistent state into another consistent state.
  - CR 3 (Separation of duties)
    The relation A must satisfy the separation-of-duty-principle. For example, a cashier must not update the table with the booking records
  - CR 4 (Recovery after failure)
    TPs must log their activities in an (append-only) file.
  - CR 5 (Correct insert of data)
    TPs that process *UDIs* must convert these into valid *CDIs* or otherwise do nothing.

- Enforcement Rules
  - ER 1 (Write-protected areas)
    TP t can operate on *CDI* c only if $(t, c) \in C$.
  - ER 2 (Access rules)
    A user u can access *CDI* c via *TP* t only if this is permited by A, i.e., $(u, t, c) \in A$
  - ER 3 (User login)
    Users must be authenticated before they can run any *TPs*.
  - ER 4 (Privilege escalation)
    A user who can modify relation C (or parts of it) must not gain rights to run any affected *TPs*. Thus, nobody can grant additional rights to her/himself.