Validating SGAC Access Control Policies with Alloy and ProB

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SHERBROOKE

Motivation

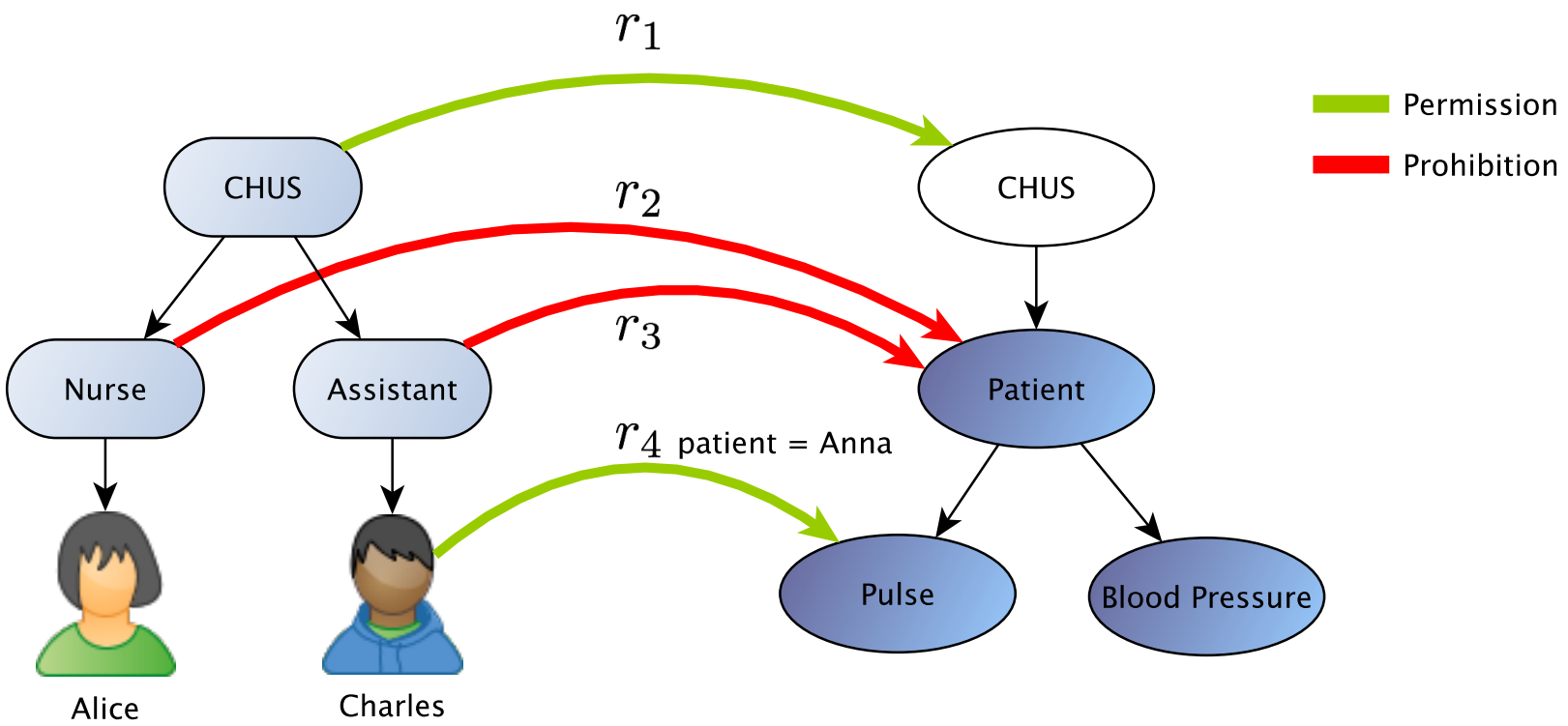
- Consent Management in Electronic Health Records
- Hospital of Université de Sherbrooke (CHUS) in Québec, Canada.
- Two major stakes in access control (healthcare) :

  1) patient privacy $\rightarrow$ consent
  2) patient safety $\rightarrow$???????

Presentation of SGAC

- SGAC = Automated Consent Management System
- Designed to meet CHUS requirements
- Features:
  - hierarchy among users;
  - hierarchy among data;
  - explicit prohibitions;
  - automated conflict resolutions.

Example


r_1
r_2
r_3
r_4 patient = Anna
Permission
Prohibition
CHUS
CHUS
Nurse
Assistant
Patient
Pulse
Blood Pressure
Alice
Charles

Conflict Resolution Strategy

r_a has precedence over r_b iff:

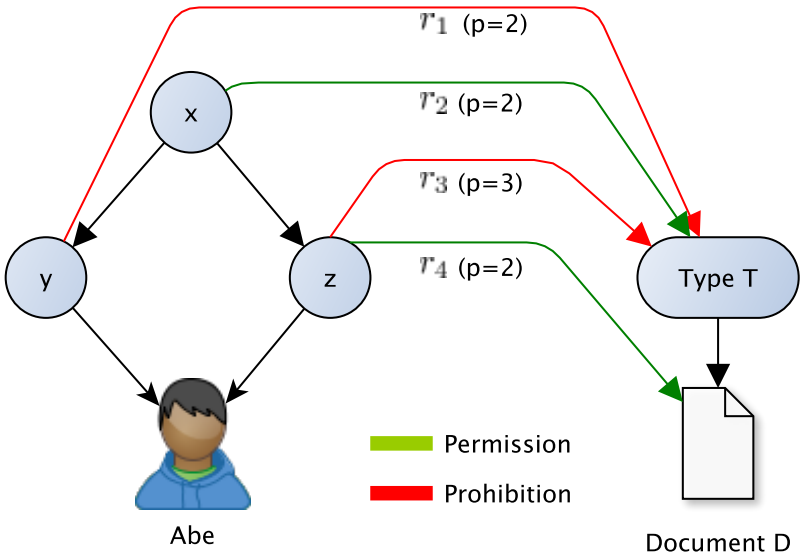
1. r_a's priority value is lower;
   ex: r_2 has precedence over r_3.

or

2. same priority and
   r_a's subject is more specific;
   ex: r_1 has precedence over r_2.

or

3. same priority and
   incomparable subjects,
   and $r_a.m = - \; r_b.m = +$.
   ex: r_1 has precedence over r_4.



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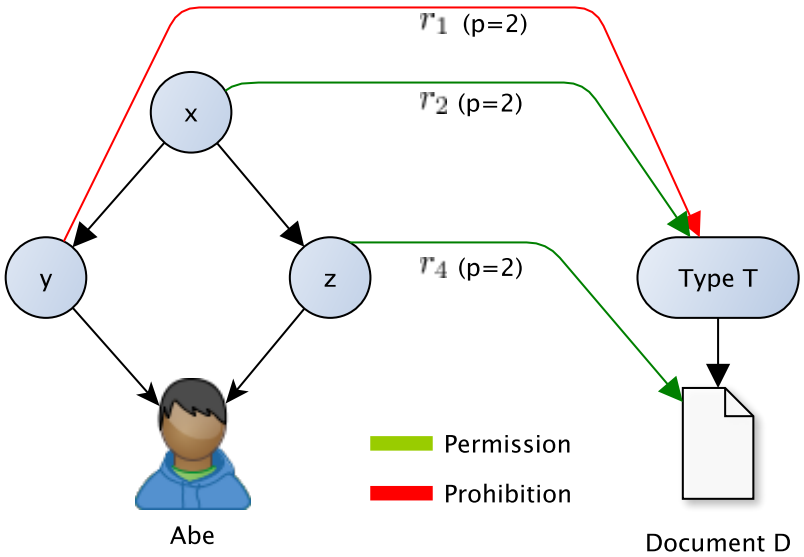

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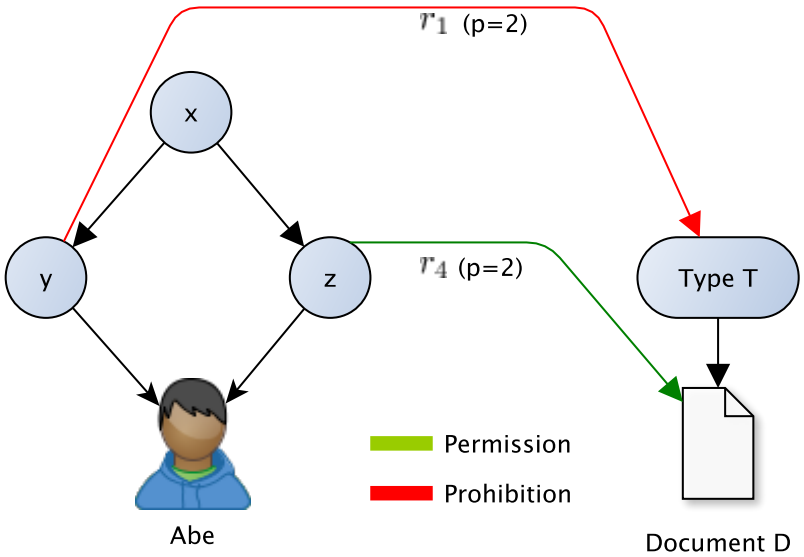

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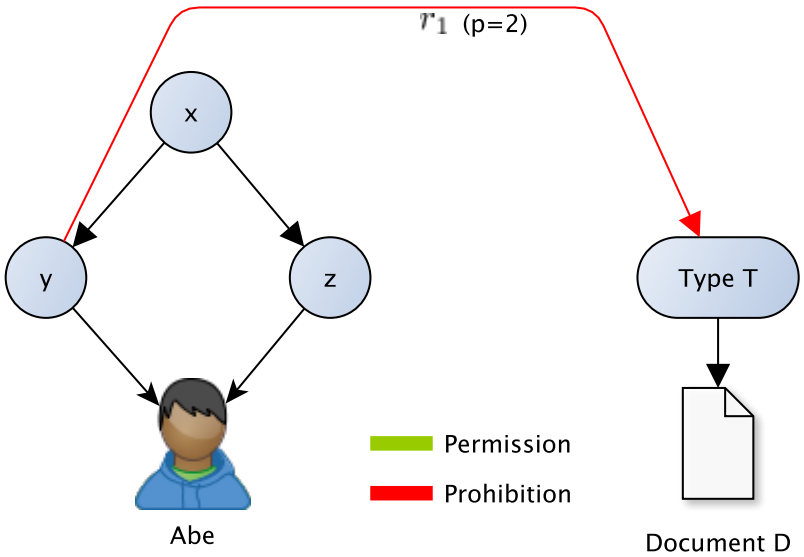


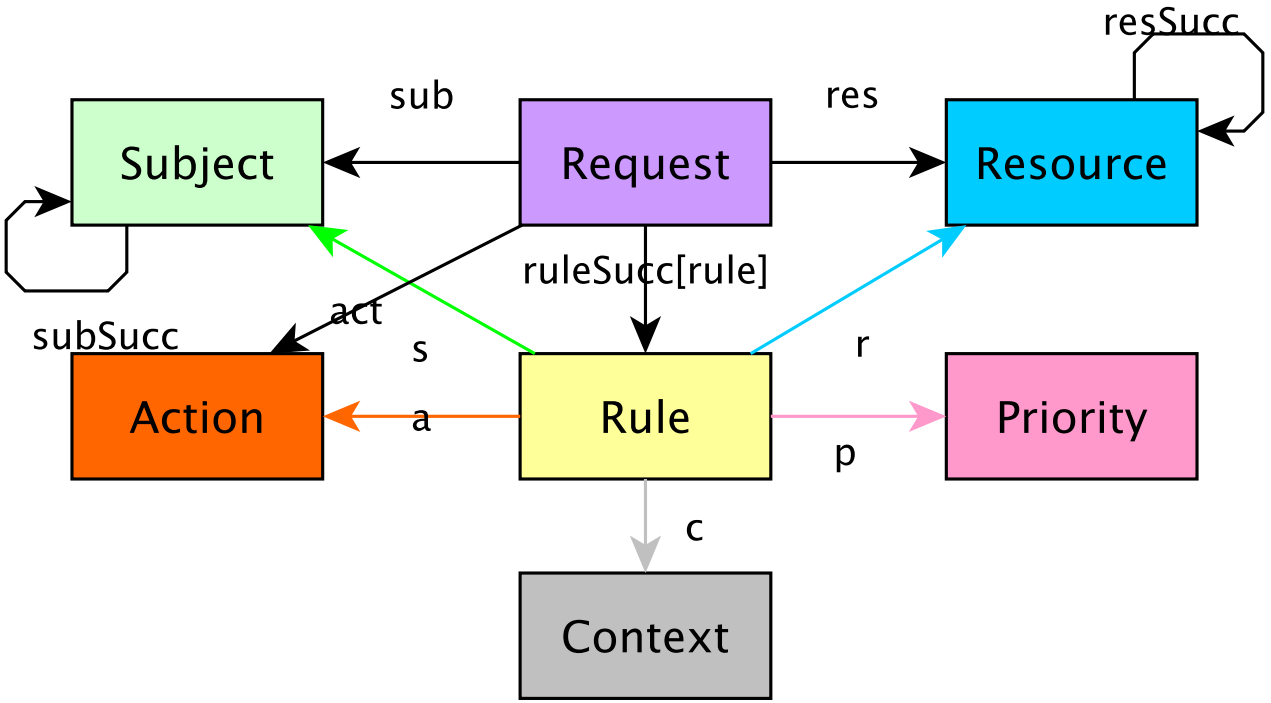
Properties

The properties we want to check are:

- access:
  can health worker W have access to the document D ?
- ineffective rule detection:
  what are the rules that are never taken into account when evaluating a request ?
- important hidden data detection:
  are there important data that are unreachable by any health worker ?
- granting context detection:
  in which contexts is a given request granted ?

Formalization

Huynh *et al.*, SGAC: A patient-centered access control method, (RCIS'16).



Rule ordering

r_a has precedence over r_b iff:

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3. same priority and incomparable subjects, and $r_a.m = - \; r_b.m = +$.
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Two steps :

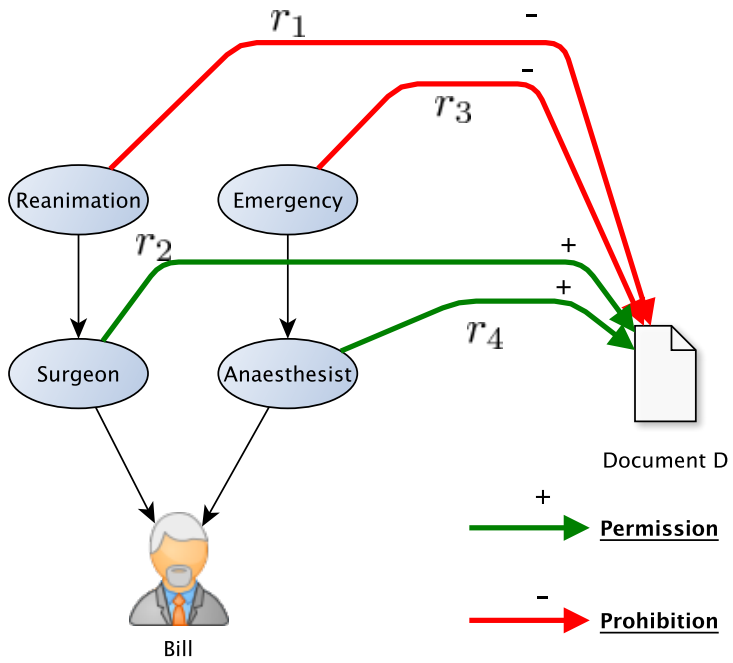
- introduction of '$\prec$': ordering with priority and subject specificity (phase 1-2);
- introduction of '$<$': final ordering (phase 3).

Why two steps?

Only maximal elements of $\prec$ must be compared with their modality.

ex: without the maximal element condition,

$r_1 < r_2$, $r_3 < r_4$, $r_2 < r_3$ and $r_4 < r_1$.



Request Evaluation

In order to evaluate a request in a given context :

1. we select all applicable rules to the request;
2. we order the applicable rules;
3. we analyse the graph made of the ordered rules : the sinks of the graph determine the result of the request.

Automated verification

We use first order logic based tools : Alloy and ProB.

Alloy

Alloy is a model finder that offers a graphical interface and evaluator that are very useful to debug and help understandings counter-examples.

ProB

ProB is a model checker and animator for the B method. Its constraint solving capability allows it to do model finding.

Let's get started : simplifications first !

In order to be able to conduct tractable verification with the tools, we have to make some adjustments:

- reduce the size of the graphs: verification is done for each patient, thus resource graph can be cut ;
- ignore the actions: the approach taken for each action is the same;
- reduce computational burden: with the current approach, a graph is built for each context+request
  $\rightarrow$ 1 request = 1 graph.

Alloy

Difficulty

Alloy cannot handle the number of requests ($|PERSON \times DOCUMENTS|$).

Solution

Explicitly define one request at a time. The others target also persons and documents but are left undetermined.

Results

Alloy can conduct the verification, but some properties cannot be directly verified.

ProB

Difficulty

ProB does not manage to process and order the rules for all the requests.

Solution

Program and guide the variable calculus order.
Ex: process $\prec$ et $<$ successively and separately.

Results

ProB finally manages to order the rules, and this solution provides a way to reduce further the processing time.

ProB

Difficulty

How can we encode efficiently the properties ?

Solution

Properties are encoded into the operations of each machine. For instance, *access(req,con)*

- precondition : arguments *req* and *con* are a request and a context.
- postcondition : result of *req* within the context *con*.

Results

- Verification is done for all possible combinations;
- All properties are verified in only one run.

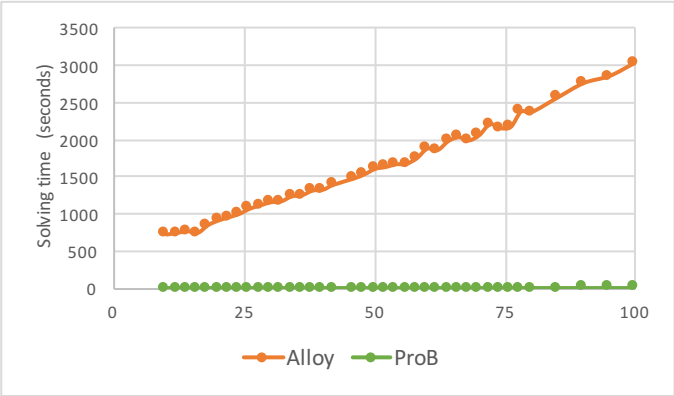
Performance Test

Process

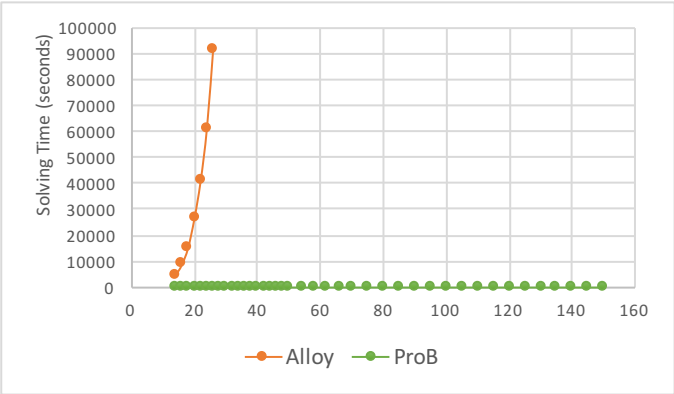
Set all parameters except one which we vary.

For each configuration (number of vertices, of rules, of contexts) :

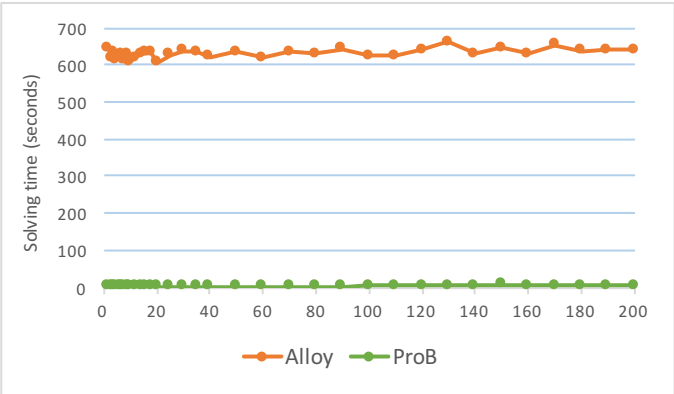
1. Generation of random graphs and random rules;
2. For each graph, random requests are picked;
3. For each request :
   - access property in random contexts;
   - detection of granting contexts;
   - detection hidden documents;
   - detection ineffective rules.



13 rules, 10 contexts :
linear processing time



100 vertices, 30 contexts :
exponential processing time



30 vertices, 12 rules :
quasi-constant processing time

Conclusion

- ProB outperforms Alloy thanks to the ability to 'program' how the computations are done
- Automated verification in real cases can be conducted (offline) with ProB
  - 300 vertices, 160 rules, 100 contexts with 200 requests in about 15 minutes with ProB
- Alloy is better than ProB in brute force in several cases, but it is insufficient here
- Need similar ability in Alloy to program the model finding
  - Integrate αRuby in Alloy

Questions

Thanks for your attention !