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The Rodin Platform for Incremental Modelling in Event-B

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www.deploy-project.eu

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Outline

- Complex Systems Modelling in Event-B
- Interplay of proof and modelling
- Worked example: Access to secure building
- Tool Animation
- Conclusion

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Design of complex systems

- Need for rigorous modelling
- The main purpose of modelling is reasoning
  - to improve our understanding of the system
  - to clarify assumptions about the system
  - to increase quality of system model
- Need for refinement
  - Too many details to address final system directly

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Reasoning about complex systems

- Requires rigorous reasoning
  - Formal notation
  - Formal reasoning
- This is offered by formal proof
  - Why prove?
    - To incrementally improve a model
    - To take advantage of failing proofs
  - What to prove?
    - Proof obligations associated with each model

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List of core Event-B proof obligations

- Feasibility of events
- Invariant preservation by events
- Refinement of events
- Introduction of new events
- Convergence of events
- Enabledness of events

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Example of an Event-B machine

invariants

$inv1 : auth \in User \leftrightarrow Room$

$inv2 : in \in User \nrightarrow Room$

$inv3 : in \subseteq auth$

event *enter*

any

u, r

when

$grd1 : u \notin \mathrm{dom}(in)$

$grd2 : u \mapsto r \in auth$

then

$act1 : in := in \cup \{u \mapsto r\}$

end

parameters

guards

actions

Invariant properties:

- *inv1* : A user is authorised to be in certain rooms
- *inv2* : A user can be at most in one room
- *inv3* : A user can only be in rooms where he is authorised to be

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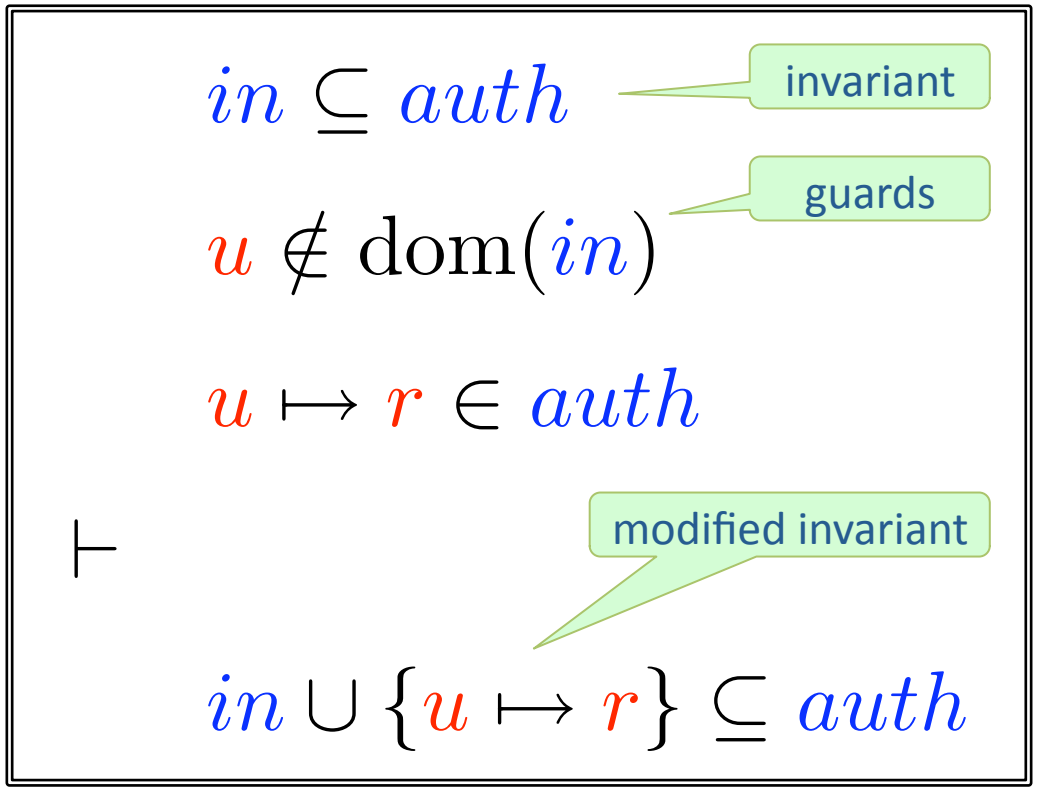
Preservation of $in \subseteq auth$ by event *enter*

- Proof obligation:



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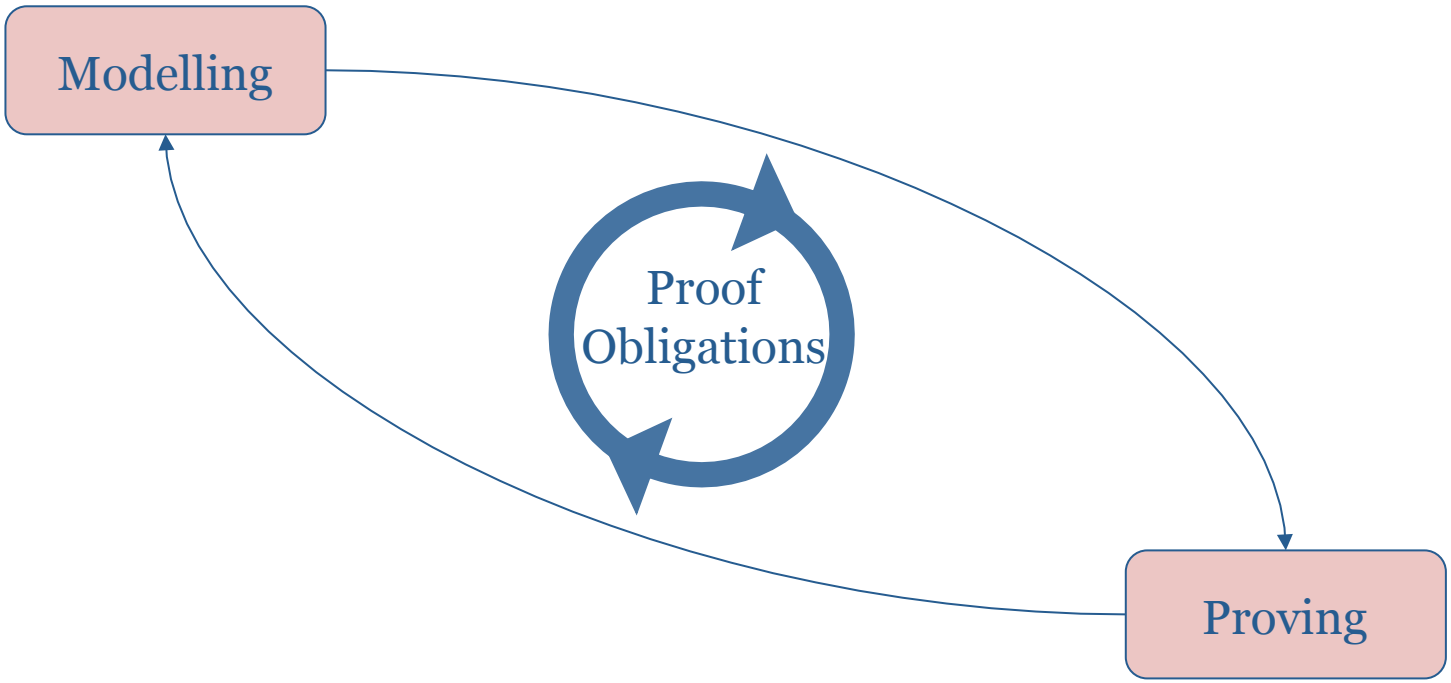
Use of proof obligations for modelling

- Modelling is an incremental activity



- Proof obligations are automatically generated

Creating a model incrementally

- What does this mean?
- We do not demonstrate the actual tool "Rodin"
  - But focus on essential features
  - Removed everything that could distract
- Aim:
  - To illustrate method and tool
  - Not to get distracted by features of the Rodin tool
- By way of an example
  - Access to a secure building

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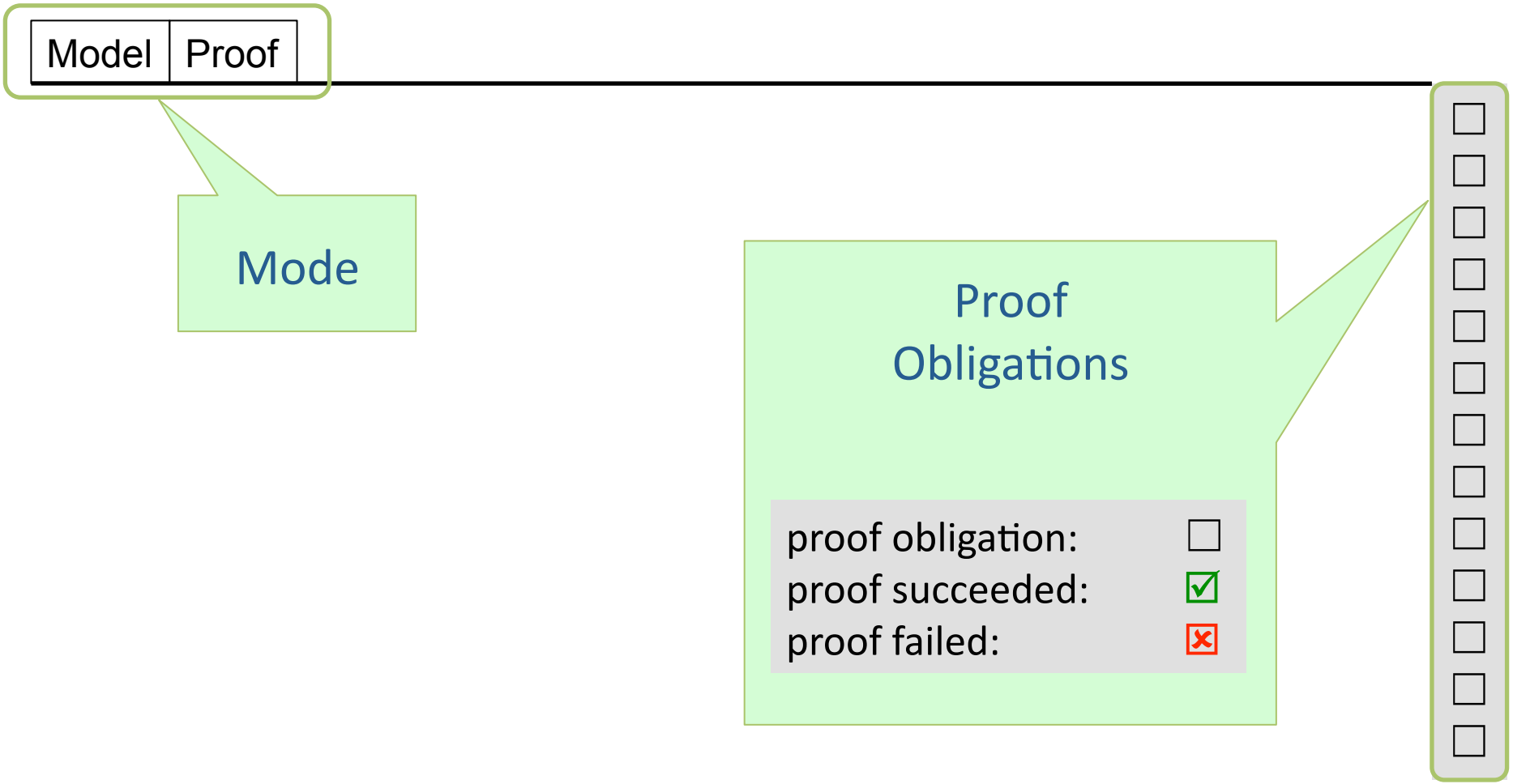
Description of the secure access model

- Abstract model
  - *Users*, *Rooms*
  - Entering/leaving rooms; adding/removing authorisations
- Refined model
  - *Tokens*
  - Data-refinement of abstract model
- The model itself is not of importance
  - But the way we create it is important

Focus on three modelling scenarios

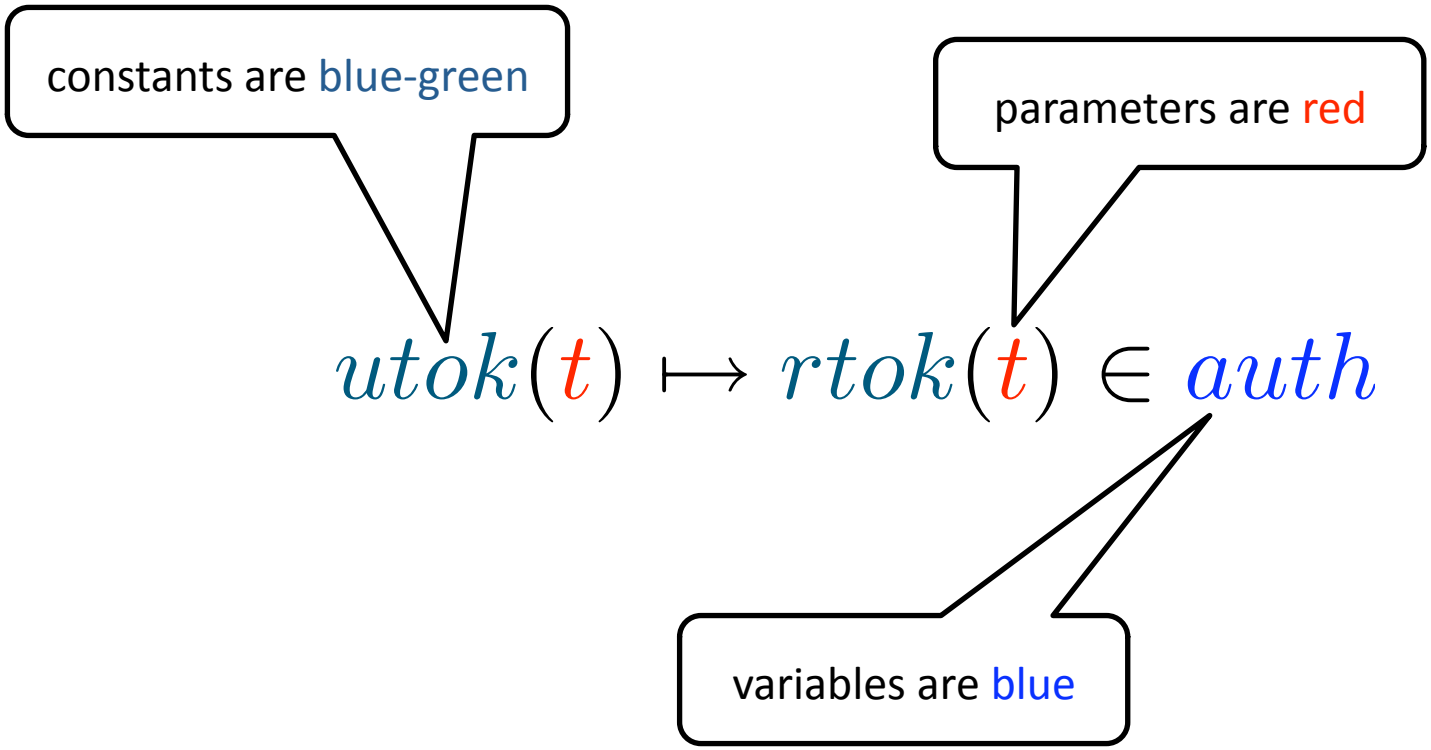
- Adding events
  1. Reasoning about guards and invariants
- Refining an event
  2. Reasoning about parameters
  3. Reasoning about guards and invariants

Layout of the modelling canvas



Colouring conventions for formulas

Model | Proof



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Creation of the **abstract model**

Model | Proof

Summary:

- Variables: *in*, *auth*
- Events:
  - *enter* – enter building
  - *leave* – leave building
  - *addAuth* – add authorisation
  - *remAuth* – remove authorisation

Location and authorisation of users

Model | Proof

invariants

$inv1 : auth \in User \leftrightarrow Room$

$inv2 : in \in User \nrightarrow Room$

$inv3 : in \subseteq auth$

Location and authorisation of users

Model | Proof

invariants

$inv1 : auth \in User \leftrightarrow Room$

$inv2 : in \in User \nrightarrow Room$

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initialisation

$act1 : in := \emptyset$

$act2 : auth := \emptyset$

Location and authorisation of users

Model | Proof

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Location and authorisation of users

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$inv1 : auth \in User \leftrightarrow Room$

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$inv3 : in \subseteq auth$

initialisation

$act1 : in := \emptyset$

$act2 : auth := \emptyset$

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Entering a room

Model | Proof

event $enter$
  any
    u, r
  when
    $grd1 : u \notin \mathrm{dom}(in)$
    $grd2 : u \mapsto r \in auth$
  then
    $act1 : in := in \cup \{u \mapsto r\}$
  end

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Entering a room

Model | Proof

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Proof obligation:

Preservation of invariant *inv3*

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Entering a room

Model | Proof

Preservation of invariant *inv3*

$in \subseteq auth$

$u \notin \mathrm{dom}(in)$

$u \mapsto r \in auth$

$\vdash$

$in \cup \{u \mapsto r\} \subseteq auth$

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  end

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Leaving a room

Model | Proof

event $leave$
  any
    u
  when
    $grd1 : u \in \mathrm{dom}(in)$
  then
    $act1 : in := \{u\} \lhd in$
  end

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Leaving a room

Model | Proof

event $leave$
  any
    u
  when
    $grd1 : u \in \mathrm{dom}(in)$
  then
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  end

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Leaving a room

Model | Proof

event $leave$
  any
    u
  when
    $grd1 : u \in \mathrm{dom}(in)$
  then
    $act1 : in := \{u\} \lhd in$
  end

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Adding an authorisation

Model | Proof

event $addAuth$
  any
    u, r
  when
    $grd1 : u \in User$
    $grd2 : r \in Room$
  then
    $act1 : auth := auth \cup \{u \mapsto r\}$
  end

Adding an authorisation

Model | Proof

event $addAuth$
  any
    u, r
  when
    $grd1 : u \in User$
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Removing an authorisation

Model | Proof

event $remAuth$
  any
    u, r
  when
    $grd1 : u \in User$
    $grd2 : r \in Room$
  then
    $act1 : auth := auth \setminus \{u \mapsto r\}$
  end

Removing an authorisation

Model | Proof

event $remAuth$
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    u, r
  when
    $grd1 : u \in User$
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Removing an authorisation

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Proof obligation:

Preservation of invariant *inv3*

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Removing an authorisation

Model | Proof

Preservation of invariant *inv3*

$in \subseteq auth$

$u \in User$

$r \in Room$

$\vdash$

$in \subseteq auth \setminus \{u \mapsto r\}$

Possible remedies:

- Modify action:
  → Remove user *u* from building
- Modify guard:
  → Require user *u* not in building
- Modify guard:
  → Require user *u* not in room *r*

$u \mapsto r \notin in$

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Removing an authorisation

Model | Proof

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Removing an authorisation

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Removing an authorisation

Model | Proof

Preservation of invariant *inv3*

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$u \mapsto r \notin in$

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$in \subseteq auth \setminus \{u \mapsto r\}$

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Removing an authorisation

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$in \subseteq auth \setminus \{u \mapsto r\}$

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Creation of the **refined model**

Model | Proof

Summary:

- Variables: *tok*, *auth*
- Events:
  - *enter* – enter building
  - other events not shown

Replacing Users and Rooms by Tokens

Model | Proof

axioms

$axm1 : utok \in Token \rightarrow User$

$axm2 : rtok \in Token \rightarrow Room$

Abstract model of a record type with two fields *utok* and *rtok*

Replacing Users and Rooms by Tokens

Model | Proof

invariants

$$inv4 \ : \ \forall\, u, r \cdot \\ u \mapsto r \in in \\ \Leftrightarrow \\ \exists\, t \cdot t \in tok \ \wedge \ u = utok(t) \ \wedge \ r = rtok(t)$$

Using some set-theoretic notation of Event-B *inv4* can be stated more concisely:

$$in = utok^{-1} \, ; (tok \lhd rtok)$$

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Replacing Users and Rooms by Tokens

Model | Proof

invariants

$inv4 : in = utok^{-1} ; (tok \lhd rtok)$

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Replacing Users and Rooms by Tokens

Model | Proof

invariants

$inv4 : in = utok^{-1} ; (tok \lhd rtok)$

initialisation

$act1 : tok := \emptyset$

$act2 : auth := \emptyset$

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Replacing Users and Rooms by Tokens

Model | Proof

invariants

$inv4 : in = utok^{-1} ; (tok \lhd rtok)$

initialisation

$act1 : tok := \emptyset$

$act2 : auth := \emptyset$

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Replacing Users and Rooms by Tokens

Model | Proof

invariants

$inv4 : in = utok^{-1} ; (tok \lhd rtok)$

initialisation

$act1 : tok := \emptyset$

$act2 : auth := \emptyset$

Entering a room (refined model)

Model | Proof

event *enter*
  any
    t
  when
    $grd1 : t \notin tok$
    $grd2 : utok(t) \mapsto rtok(t) \in auth$
  then
    $act1 : tok := tok \cup \{t\}$
  end

abstract event *enter*
  any
    u, r
  when
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    $grd2 : u \mapsto r \in auth$
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Model | Proof

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  any
    t
  when
    $grd1 : t \notin tok$
    $grd2 : utok(t) \mapsto rtok(t) \in auth$
  then
    $act1 : tok := tok \cup \{t\}$
  end

abstract event *enter*
  any
    u, r
  when
    $grd1 : u \notin \mathrm{dom}(in)$

$r\}$

Proof obligation:

Strengthening of guard *grd2*

Entering a room (refined model)

Model | Proof

Strengthening of guard *grd2*

$t \notin tok$

$utok(t) \mapsto rtok(t) \in auth$

$\vdash$

$u \mapsto r \in auth$

Must relate *t* to *u* and *r*

Choose witnesses for *u* and *r*:

$u = utok(t)$

$r = rtok(t)$

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Entering a room (refined model)

Model | Proof

event *enter*
  any
    t
  when
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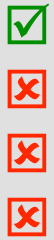

Entering a room (refined model)

Model | Proof

event *enter*
  any
    t
  when
    $grd1 : t \notin tok$
    $grd2 : utok(t) \mapsto rtok(t) \in auth$
  with
    $u \mid u = utok(t)$
    $r \mid r = rtok(t)$
  then
    $act1 : tok := tok \cup \{t\}$
  end

abstract event *enter*
  any
    u, r
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  end

Entering a room (refined model)

Model | Proof

Strengthening of guard *grd2*

$t \notin tok$

$utok(t) \mapsto rtok(t) \in auth$

$\vdash$

$utok(t) \mapsto rtok(t) \in auth$

Entering a room (refined model)

Model	Proof

Strengthening of guard *grd2*

$$t \notin tok$$

$$utok(t) \mapsto rtok(t) \in auth$$

$\vdash$

$$utok(t) \mapsto rtok(t) \in auth$$

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Proof obligation:

Strengthening of guard *grd1*

Entering a room (refined model)

Model | Proof

event *enter*
  any
    t
  when
    $grd1 : t \notin tok$
    $grd2 : utok(t) \mapsto rtok(t) \in auth$
  with
    $u \mid u = utok(t)$
    $r \mid r = rtok(t)$
  then
    $act1 : tok := tok \cup \{t\}$
  end

abstract event *enter*
  any
    u, r
  when
    $grd1 : u \notin \mathrm{dom}(in)$
    $grd2 : u \mapsto r \in aut$
  then
    c ... }
  end

Proof obligation:

Strengthening of guard *grd1*

Entering a room (refined model)

Model | Proof

Strengthening of guard *grd1*

$in = utok^{-1} ; (tok \lhd rtok)$

$t \notin tok$

$utok(t) \mapsto rtok(t) \in auth$

$\vdash$

$utok(t) \notin \mathrm{dom}(in)$

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Entering a room (refined model)

Model | Proof

Strengthening of guard *grd1*

$in = utok^{-1} ; (tok \lhd rtok)$

$t \notin tok$

$utok(t) \mapsto rtok(t) \in auth$

$\vdash$

$utok(t) \notin \mathrm{dom}(utok^{-1} ; (tok \lhd rtok))$

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Entering a room (refined model)

Model | Proof

Strengthening of guard *grd1*

$$in = utok^{-1} ; (tok \lhd rtok)$$

$$t \notin tok$$

$$utok(t) \mapsto rtok(t) \in auth$$

$\vdash$

$$utok(t) \notin \mathrm{dom}((utok^{-1} \rhd tok) ; rtok)$$

rtok is total

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Entering a room (refined model)

Model | Proof

Strengthening of guard *grd1*

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$\vdash$

$utok(t) \notin \mathrm{dom}(utok^{-1} \rhd tok)$

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Entering a room (refined model)

Model | Proof

Strengthening of guard *grd1*

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$t \notin tok$

$utok(t) \mapsto rtok(t) \in auth$

$\vdash$

$utok(t) \notin utok[tok]$

Guard

$t \notin tok$

is too weak.

$utok(t) \notin utok[tok]$

is a better choice for guard *grd1*

Entering a room (refined model)

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- Interplay of proof and modelling
- Worked example: Access to secure building
- Tool Animation
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Conclusion

- Close relationship between modelling and proving
- Proof can give hints for improvements of model
- Incremental modelling based on heuristics
  - As opposed to refinement based on proof
- There was no time to show
  - finding invariants by inspection of proofs
  - modifying an abstract model to improve a refinement

Community

- Web:
  - www.event-b.org
  - wiki.event-b.org

- Credits

  Jean-Raymond Abrial, Jens Bendisposto, Michael Butler, Dominique Cansell, Mathieu Clabaut, Kriangsak Damchoom, Fabian Fritz, Thai Son Hoang, Sonja Holl, Cliff Jones, Thierry Lecomte, Michael Leuschel, Farhad Mehta, Christophe Métayer, Renato Silva, Colin Snook, François Terrier, Laurent Voisin, . . .