DÉVELOPPEMENT DE SYSTÈMES CRITIQUES AVEC LA MÉTHODE EVENT-B

LA VALIDATION D'UN MODÈLE EVENT-B AVEC PROB

🎓 3A cursus ingénieurs - Mention Sciences du Logiciel
🏛 CentraleSupelec - Université Paris-Saclay - 2024/2025

Idir AIT SADOUNE
idir.aitsadoune@centralesupelec.fr ✉

OUTLINE

- Introduction
- Model-checking
- Model-checking with ProB plugin
- Conclusion about ProB plugin

Back to the begin - Back to the outline

OUTLINE

- Introduction
- Model-checking
- Model-checking with ProB plugin
- Conclusion about ProB plugin

Back to the begin - Back to the outline

THE PROOF WITH ATELIER-B

- There are two main proof activities in the **Event-B** method :
  1. the proof of consistency used to show that the events of a machine preserve the invariant,
  2. the proof of refinement used to show that one machine is a valid refinement of another.

THE PROOF WITH ATELIER-B

- There are two main proof activities in the **Event-B** method :
  1. the proof of consistency used to show that the events of a machine preserve the invariant,
  2. the proof of refinement used to show that one machine is a valid refinement of another.

- In the **Rodin platform**, proof activities are supported by tools, such as the **Atelier-B plugin**.

THE PROOF WITH ATELIER-B

- There are two main proof activities in the **Event-B** method :
  1. the proof of consistency used to show that the events of a machine preserve the invariant,
  2. the proof of refinement used to show that one machine is a valid refinement of another.

- In the **Rodin platform**, proof activities are supported by tools, such as the **Atelier-B plugin**.
  - ➠ the **Rodin platform** generates the list of proof obligations (**PO**)

THE PROOF WITH ATELIER-B

- There are two main proof activities in the **Event-B** method :
  1. the proof of consistency used to show that the events of a machine preserve the invariant,
  2. the proof of refinement used to show that one machine is a valid refinement of another.

- In the **Rodin platform**, proof activities are supported by tools, such as the **Atelier-B plugin**.
  - ➠ the **Rodin platform** generates the list of proof obligations (**PO**)
  - ➠ the **Atelier-B plugin** is an automatic prover

THE PROOF WITH ATELIER-B

- There are two main proof activities in the **Event-B** method :
  1. the proof of consistency used to show that the events of a machine preserve the invariant,
  2. the proof of refinement used to show that one machine is a valid refinement of another.

- In the **Rodin platform**, proof activities are supported by tools, such as the **Atelier-B plugin**.
  - ➠ the **Rodin platform** generates the list of proof obligations (**PO**)
  - ➠ the **Atelier-B plugin** is an automatic prover

- In some cases, the most complex **POs** are not proved automatically and *must be proved interactively*.

HISTORY OF FORMAL VERIFICATION METHODS

Before...

- Software code was sequential
- Properties were expressed in First-Order Predicate Logic
- Theorem provers $\longrightarrow$ partial/total correctness
- Hardly automated $\longrightarrow$ semi-decidable (e.g. B/Event-B Method)

HISTORY OF FORMAL VERIFICATION METHODS

Before…

- Software code was sequential
- Properties were expressed in First-Order Predicate Logic
- Theorem provers → partial/total correctness
- Hardly automated → semi-decidable (e.g. B/Event-B Method)

After 80's

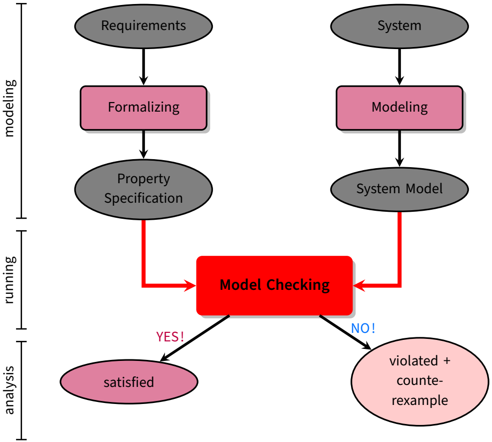
- Software is concurrent and reactive
- Properties are expressed in Temporal Logic
- Solving accurate properties like safety, liveness, fairness…
- Push-Button → decidable (e.g. Model Checking)

OUTLINE

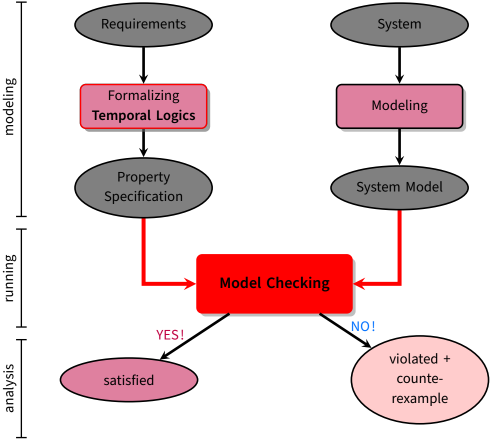
- Introduction
- Model-checking
- Model-checking with ProB plugin
- Conclusion about ProB plugin

Back to the begin - Back to the outline

PRINCIPLE OF MODEL-CHECKING



PRINCIPLE OF MODEL-CHECKING



CentraleSupélec

PROPOSITIONAL LOGIC

$$\phi \quad ::= \quad true \quad \mid \quad a \quad \mid \quad \phi \quad \wedge \quad \phi \quad \mid \quad \neg\, \phi$$

where $a \in AP$

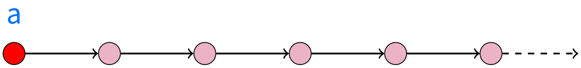
PROPOSITIONAL LINEAR TEMPORAL LOGIC

$$\phi \quad ::= \quad true \quad \mid \quad a \quad \mid \quad \phi \quad \wedge \quad \phi \quad \mid \quad \neg\,\phi \quad \mid \quad \bigcirc\,\phi$$

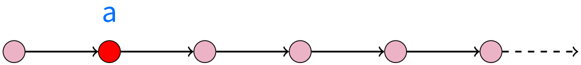
where $a \in AP$

$\bigcirc$
(next)

$\sigma \models a$



$\sigma \models \bigcirc\, a$



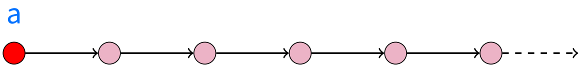
PROPOSITIONAL LINEAR TEMPORAL LOGIC

$$\phi \quad ::= \quad true \quad | \quad a \quad | \quad \phi \quad \wedge \quad \phi \quad | \quad \neg\,\phi \quad | \quad \bigcirc\,\phi \quad | \quad \Box\,\phi$$

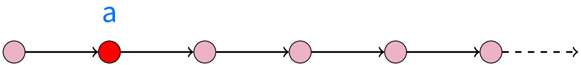
where $a \in AP$

$\bigcirc$ (next) $\quad$ $\Box$ (always)

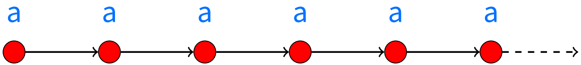
$\sigma \models a$



$\sigma \models \bigcirc\, a$



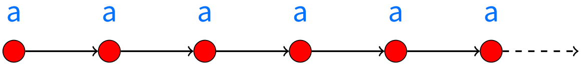
$\sigma \models \Box\, a$



LTL : DERIVED TEMPORAL OPERATORS

$\Box\phi$
(always)

$\sigma \models \Box\, a$

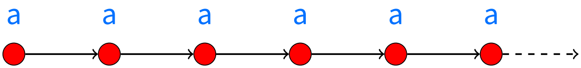


LTL : DERIVED TEMPORAL OPERATORS

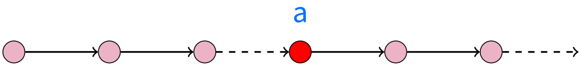
$\Box\phi$
(always)

$\Diamond\phi \equiv \neg\Box\neg\phi$
(eventually)

$\sigma \models \Box\, a$



$\sigma \models \Diamond\, a$



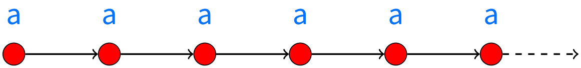
LTL : DERIVED TEMPORAL OPERATORS

$\Box\phi$ (always)

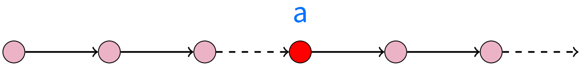
$\Diamond\phi \equiv \neg\Box\neg\phi$ (eventually)

$\Diamond\Box\phi$ (persistence)

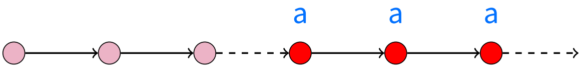
$\sigma \models \Box\, a$



$\sigma \models \Diamond\, a$



$\sigma \models \Diamond\Box\, a$



LTL : DERIVED TEMPORAL OPERATORS

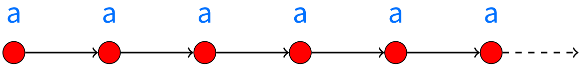
$\Box\phi$ (always)

$\Diamond\phi \equiv \neg\Box\neg\phi$ (eventually)

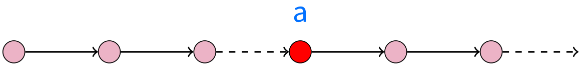
$\Diamond\Box\phi$ (persistence)

$\Box\Diamond\phi \equiv \neg\Diamond\Box\neg\phi$ (infinitely many)

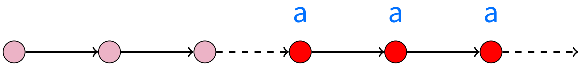
$\sigma \models \Box\, a$



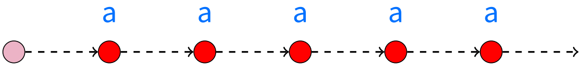
$\sigma \models \Diamond\, a$



$\sigma \models \Diamond\Box\, a$



$\sigma \models \Box\Diamond\, a$



$\{\, i \mid a \in \sigma(i) \,\}$ is infinite

EXAMPLE OF TEMPORAL PROPERTIES

- **Safety** :
  - mutual exclusion : $\square\neg(crit_1 \wedge crit_2)$
  - elevator : $\square(moving \Rightarrow doors_{closed})$
  - traffic light : $\square(yellow \Rightarrow \bigcirc red)$

EXAMPLE OF TEMPORAL PROPERTIES

- **Safety** :
  - mutual exclusion : $\Box\neg(crit_1 \wedge crit_2)$
  - elevator : $\Box(moving \Rightarrow doors_{closed})$
  - traffic light : $\Box(yellow \Rightarrow \bigcirc red)$
- **Liveness** :
  - progress : $\Diamond\, progress$
  - response : $\Box(try\_to\_send \Rightarrow \Diamond delivered)$
  - termination : $\Diamond\Box\, terminated$

EXAMPLE OF TEMPORAL PROPERTIES

- **Safety** : nuclear plant
  - cooling : $\Box\neg(temp_{high} \wedge cooling_{low})$
  - alarm : $\Box(temp_{high} \Rightarrow alarm)$
  - saving : $\Box(temp_{high} \Rightarrow \bigcirc react_{low})$

CentraleSupélec

EXAMPLE OF TEMPORAL PROPERTIES

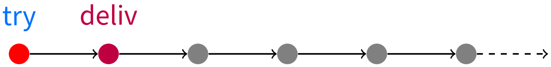
- **Safety** : nuclear plant
  - cooling : $\Box\neg(temp_{high} \wedge cooling_{low})$
  - alarm : $\Box(temp_{high} \Rightarrow alarm)$
  - saving : $\Box(temp_{high} \Rightarrow \bigcirc react_{low})$

- **Liveness** : nuclear plant
  - reactivity : $\Box\Diamond\, react_{high}$
  - temperature : $\Box(react_{low} \Rightarrow \Diamond temp_{low})$

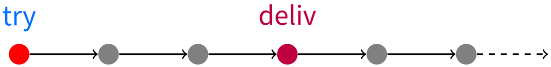
LTL : UNTIL OPERATOR

$$\phi \quad ::= \quad true \quad | \quad a \quad | \quad \phi \quad \wedge \quad \phi \quad | \quad \neg\,\phi \quad | \quad \bigcirc\ \phi \quad | \quad \Box\,\phi$$

$try \Rightarrow \bigcirc deliv$



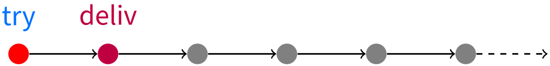
$try \Rightarrow \Diamond deliv$



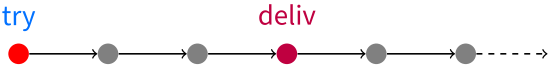
LTL : UNTIL OPERATOR

$$\phi \quad ::= \quad true \quad | \quad a \quad | \quad \phi \quad \wedge \quad \phi \quad | \quad \neg\,\phi \quad | \quad \bigcirc\,\phi \quad | \quad \Box\,\phi \quad | \quad \phi \quad \bigcup \quad \phi$$

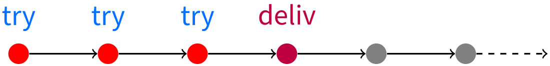
$try \Rightarrow \bigcirc deliv$



$try \Rightarrow \lozenge deliv$



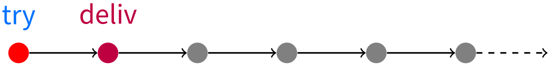
$try \bigcup deliv$



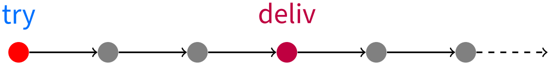
LTL : UNTIL OPERATOR

$$\phi \quad ::= \quad true \quad | \quad a \quad | \quad \phi \;\wedge\; \phi \quad | \quad \neg\,\phi \quad | \quad \bigcirc\,\phi \quad | \quad \Box\,\phi \quad | \quad \phi \bigcup \phi$$

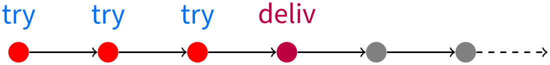
$try \Rightarrow \bigcirc deliv$



$try \Rightarrow \Diamond deliv$



$try \bigcup deliv$

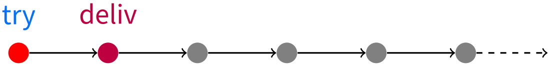


$$\Diamond\,\phi \;\equiv\; \textbf{true} \;\cup\; \phi$$

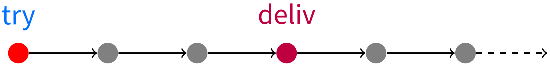
LTL : UNTIL OPERATOR

$$\phi \ ::= \ true \ | \ a \ | \ \phi \wedge \phi \ | \ \neg \phi \ | \ \bigcirc \phi \ \cancel{| \ \Box \phi} \ | \ \phi \bigcup \phi$$

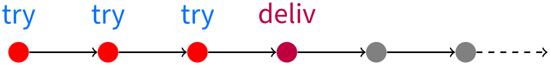
$try \Rightarrow \bigcirc deliv$



$try \Rightarrow \Diamond deliv$

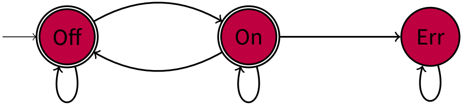


$try \bigcup deliv$

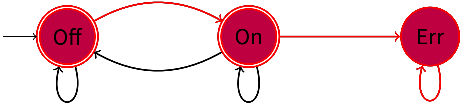


$\Diamond \phi \equiv$ **true** $\cup \ \phi$ and $\Box \phi \equiv \neg \Diamond \neg \phi$

PROPERTIES OF A TRACE



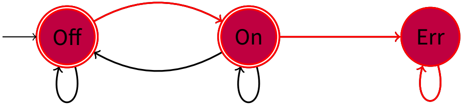
PROPERTIES OF A TRACE



have a path $\pi = Off\, On\, Err\, Err\, Err \ldots = Off\, On\, Err^{\omega}$

- $\pi \models Off$

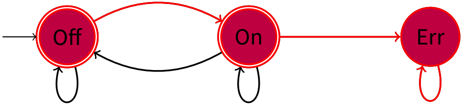
PROPERTIES OF A TRACE



have a path $\pi = Off\,On\,Err\,Err\,Err\,\ldots = Off\,On\,Err^{\omega}$

- $\pi \vDash Off$, but $\pi \nvDash On$

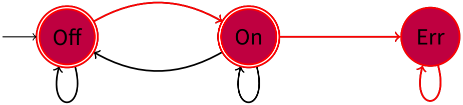
PROPERTIES OF A TRACE



have a path $\pi = Off\, On\, Err\, Err\, Err \ldots = Off\, On\, Err^{\omega}$

- $\pi \models Off$, but $\pi \not\models On$, so $\pi \models \neg On$

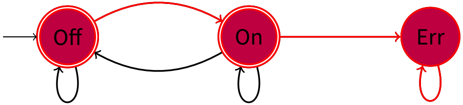
PROPERTIES OF A TRACE



have a path $\pi = Off\, On\, Err\, Err\, Err \ldots = Off\, On\, Err^{\omega}$

- $\pi \models Off$, but $\pi \not\models On$, so $\pi \models \neg On$
- $\pi \models \bigcirc On$

PROPERTIES OF A TRACE

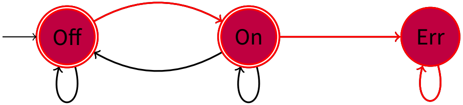


have a path $\pi = Off\,On\,Err\,Err\,Err\ldots = Off\,On\,Err^{\omega}$

- $\pi \models Off$, but $\pi \not\models On$, so $\pi \models \neg On$
- $\pi \models \bigcirc On$
- $\pi \models \bigcirc\bigcirc Err$

CentraleSupélec

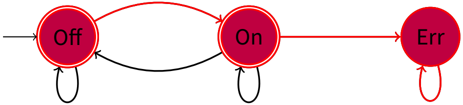
PROPERTIES OF A TRACE



have a path $\pi = Off\, On\, Err\, Err\, Err \ldots = Off\, On\, Err^\omega$

- $\pi \models Off$, but $\pi \not\models On$, so $\pi \models \neg On$
- $\pi \models \bigcirc On$
- $\pi \models \bigcirc \bigcirc Err$
- $\pi \models (Off \vee On) \cup Err$

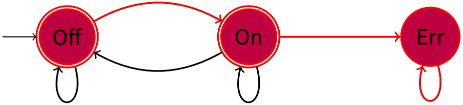
PROPERTIES OF A TRACE



have a path $\pi = Off\, On\, Err\, Err\, Err \ldots = Off\, On\, Err^{\omega}$

- $\pi \models Off,$ but $\pi \not\models On,$ so $\pi \models \neg On$
- $\pi \models \bigcirc On$
- $\pi \models \bigcirc \bigcirc Err$
- $\pi \models (Off \vee On) \cup Err$
- $\pi \models \Box(Err \Rightarrow \bigcirc Err)$

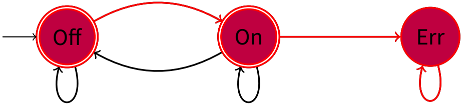
PROPERTIES OF A TRACE



have a path $\pi = Off\, On\, Err\, Err\, Err \ldots = Off\, On\, Err^{\omega}$

- $\pi \models Off,$ but $\pi \not\models On,$ so $\pi \models \neg On$
- $\pi \models \bigcirc On$
- $\pi \models \bigcirc \bigcirc Err$
- $\pi \models (Off \vee On) \cup Err$
- $\pi \models \Box(Err \Rightarrow \bigcirc Err)$
- $\pi \models \Box(Err \Rightarrow \Box Err)$

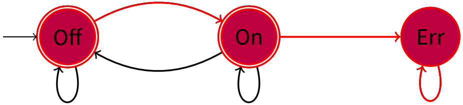
PROPERTIES OF A TRACE



have a path $\pi = Off\, On\, Err\, Err\, Err \ldots = Off\, On\, Err^{\omega}$

- $\pi \models Off$, but $\pi \not\models On$, so $\pi \models \neg On$
- $\pi \models \bigcirc On$
- $\pi \models \bigcirc \bigcirc Err$
- $\pi \models (Off \vee On) \cup Err$
- $\pi \models \square(Err \Rightarrow \bigcirc Err)$
- $\pi \models \square(Err \Rightarrow \square Err)$
- $\pi \models \lozenge\square Err$ $(persistence)$

PROPERTIES OF A TRACE

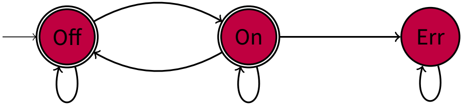


have a path $\pi = Off\, On\, Err\, Err\, Err \dots = Off\, On\, Err^{\omega}$

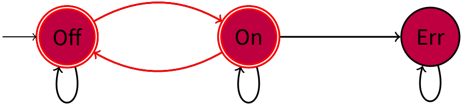
- $\pi \models Off$, but $\pi \not\models On$, so $\pi \models \neg On$
- $\pi \models \bigcirc On$
- $\pi \models \bigcirc \bigcirc Err$
- $\pi \models (Off \vee On) \cup Err$
- $\pi \models \Box(Err \Rightarrow \bigcirc Err)$
- $\pi \models \Box(Err \Rightarrow \Box Err)$
- $\pi \models \Diamond \Box Err$ $(persistence)$

$\pi \models \bigcirc \bigcirc \Box Err$

PROPERTIES OF A TRACE



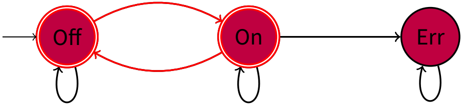
PROPERTIES OF A TRACE



have a path $\pi = Off\,On\,Off\,On\,Off\ldots = (Off\,On)^\omega$

- $\pi \overset{?}{\vDash} (Off \vee On) \cup Err$

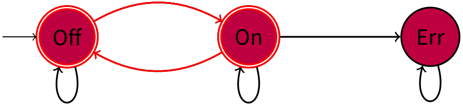
PROPERTIES OF A TRACE



have a path $\pi = Off\,On\,Off\,On\,Off \ldots = (Off\,On)^{\omega}$

- $\pi \not\models (Off \vee On) \cup Err$

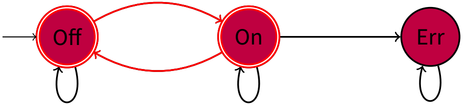
PROPERTIES OF A TRACE



have a path $\pi = Off\,On\,Off\,On\,Off\ldots = (Off\,On)^{\omega}$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \overset{?}{\models} \Diamond Err \Rightarrow ((Off \vee On) \cup Err)$

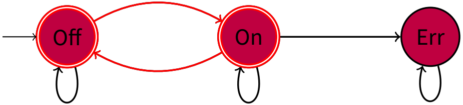
PROPERTIES OF A TRACE



have a path $\pi = Off\,On\,Off\,On\,Off\ldots = (Off\,On)^\omega$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \models \Diamond Err \Rightarrow ((Off \vee On) \cup Err)$ as $\pi \not\models \Diamond Err$

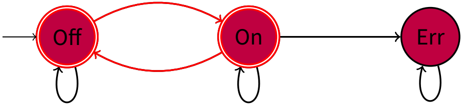
PROPERTIES OF A TRACE



have a path $\pi = Off\,On\,Off\,On\,Off \ldots = (Off\,On)^\omega$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \models \Diamond Err \Rightarrow ((Off \vee On) \cup Err)$ as $\pi \not\models \Diamond Err$
- $\pi \overset{?}{\models} \Box(On \vee Off)$

PROPERTIES OF A TRACE

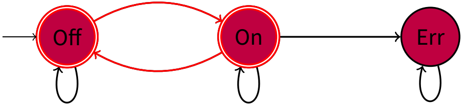


have a path $\pi = Off\,On\,Off\,On\,Off \ldots = (Off\,On)^{\omega}$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \models \lozenge Err \Rightarrow ((Off \vee On) \cup Err)$ as $\pi \not\models \lozenge Err$
- $\pi \models \square(On \vee Off)$

CentraleSupélec

PROPERTIES OF A TRACE

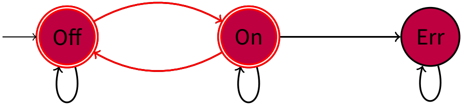


have a path $\pi = Off\, On\, Off\, On\, Off \ldots = (Off\, On)^\omega$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \models \Diamond Err \Rightarrow ((Off \vee On) \cup Err)$ as $\pi \not\models \Diamond Err$
- $\pi \models \Box(On \vee Off)$
- $\pi \overset{?}{\models} \Box\Diamond On \wedge \Box\Diamond Off$ $(infinitely\, many)$

CentraleSupélec

PROPERTIES OF A TRACE

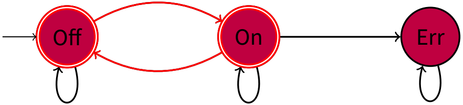


have a path $\pi = Off\,On\,Off\,On\,Off\ldots = (Off\,On)^\omega$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \models \Diamond Err \Rightarrow ((Off \vee On) \cup Err)$ as $\pi \not\models \Diamond Err$
- $\pi \models \Box(On \vee Off)$
- $\pi \models \Box\Diamond On \wedge \Box\Diamond Off$ $(infinitely\,many)$

CentraleSupélec

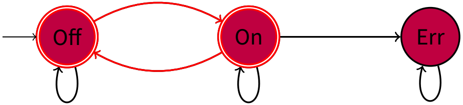
PROPERTIES OF A TRACE



have a path $\pi = Off\,On\,Off\,On\,Off\ldots = (Off\,On)^\omega$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \models \lozenge Err \Rightarrow ((Off \vee On) \cup Err)$ as $\pi \not\models \lozenge Err$
- $\pi \models \square(On \vee Off)$
- $\pi \models \square\lozenge On \wedge \square\lozenge Off$ $(infinitely\,many)$
- $\pi \overset{?}{\models} \lozenge\square On \vee \lozenge\square Off$ $(persistence)$

PROPERTIES OF A TRACE

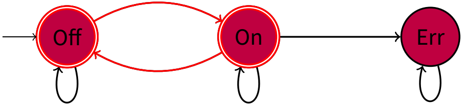


have a path $\pi = Off\,On\,Off\,On\,Off\ldots = (Off\,On)^\omega$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \models \Diamond Err \Rightarrow ((Off \vee On) \cup Err)$ as $\pi \not\models \Diamond Err$
- $\pi \models \Box(On \vee Off)$
- $\pi \models \Box\Diamond On \wedge \Box\Diamond Off$ $(infinitely\,many)$
- $\pi \not\models \Diamond\Box On \vee \Diamond\Box Off$ $(persistence)$

CentraleSupélec

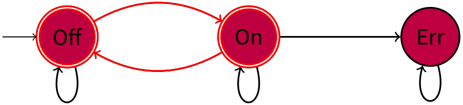
PROPERTIES OF A TRACE



have a path $\pi = Off\,On\,Off\,On\,Off\ldots = (Off\,On)^{\omega}$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \models \Diamond Err \Rightarrow ((Off \vee On) \cup Err)$ as $\pi \not\models \Diamond Err$
- $\pi \models \Box(On \vee Off)$
- $\pi \models \Box\Diamond On \wedge \Box\Diamond Off$ $(infinitely\,many)$
- $\pi \not\models \Diamond\Box On \vee \Diamond\Box Off$ $(persistence)$
- $\pi \overset{?}{\models} \Box(Off \Rightarrow \bigcirc On) \wedge \Box(On \Rightarrow \bigcirc Off)$

PROPERTIES OF A TRACE

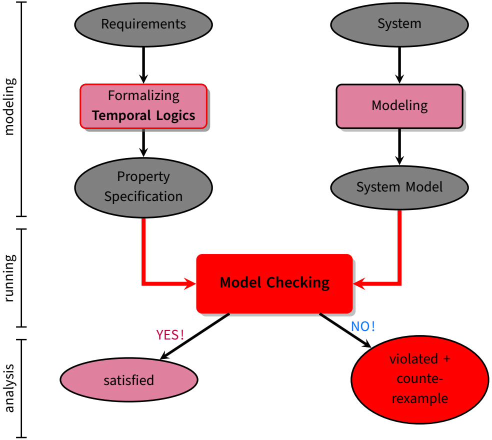


have a path $\pi = Off\,On\,Off\,On\,Off\ldots = (Off\,On)^{\omega}$

- $\pi \not\models (Off \vee On) \cup Err$
- $\pi \models \Diamond Err \Rightarrow ((Off \vee On) \cup Err)$ as $\pi \not\models \Diamond Err$
- $\pi \models \Box(On \vee Off)$
- $\pi \models \Box\Diamond On \wedge \Box\Diamond Off$ $(infinitely\,many)$
- $\pi \not\models \Diamond\Box On \vee \Diamond\Box Off$ $(persistence)$
- $\pi \models \Box(Off \Rightarrow \bigcirc On) \wedge \Box(On \Rightarrow \bigcirc Off)$

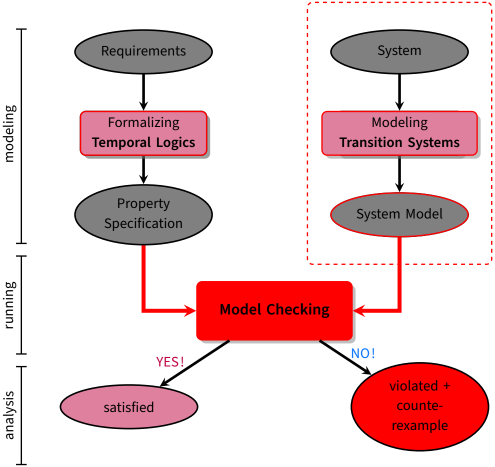
CentraleSupélec

SYSTEM MODELING



CentraleSupélec

SYSTEM MODELING



TRANSITION SYSTEMS

- model to describe the behaviour of systems
- **digraphs** where nodes represent states, and edges represent transitions
- states
  - the current colour of a traffic light : red, green, orange.
- transitions ("state change")
  - a switch from one colour to another

TRANSITION SYSTEMS

- model to describe the behaviour of systems
- **digraphs** where nodes represent states, and edges represent transitions
- states
  - the current colour of a traffic light : red, green, orange.
  - **software :** the current values of all program variables + the program counter
- transitions ("state change")
  - a switch from one colour to another
  - **software :** the execution of a program statement

TRANSITION SYSTEMS

- model to describe the behaviour of systems

- **digraphs** where nodes represent states, and edges represent transitions

- states
  - the current colour of a traffic light : red, green, orange.
  - **software :** the current values of all program variables + the program counter
  - **hardware :** the current value of the registers + the input bits

- transitions ("state change")
  - a switch from one colour to another
  - **software :** the execution of a program statement
  - **hardware :** the change of the registers and output bits for a new input

MODELLING WITH EVENT-B

MODELLING WITH EVENT-B

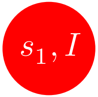
- An **Event-B** specification contains :

MODELLING WITH EVENT-B

- An **Event-B** specification contains :
  - a state (data, sets, relationships, ...)

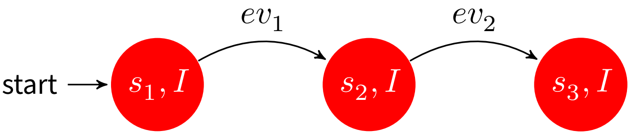
MODELLING WITH EVENT-B

- An **Event-B** specification contains :
  - a state (data, sets, relationships, ...)
  - invariant properties (first order predicates logic)



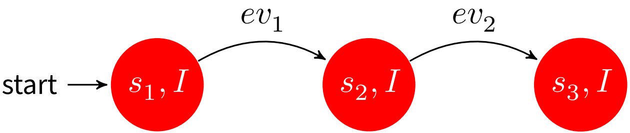
MODELLING WITH EVENT-B

- An **Event-B** specification contains :
  - a state (data, sets, relationships, ...)
  - invariant properties (first order predicates logic)
  - transitions (initialisation and events) to update the state (substitutions)



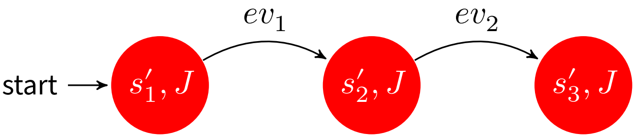
CentraleSupélec

THE REFINEMENT OF AN EVENT-B MODEL



THE REFINEMENT OF AN EVENT-B MODEL

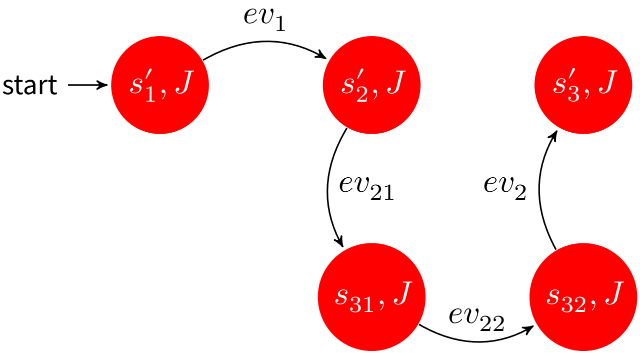
- Refining a specification consists of enriching it and reformulating it with another more concrete specification.



Data refinement (states)

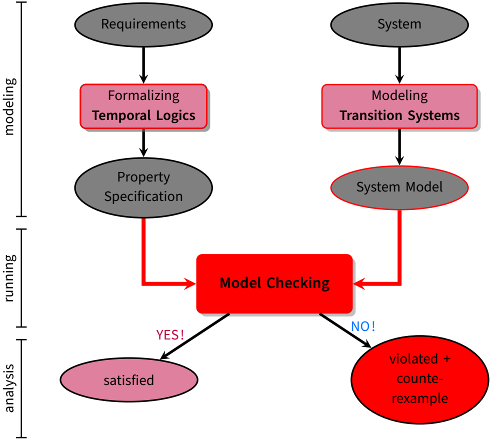
THE REFINEMENT OF AN EVENT-B MODEL

- Refining a specification consists of enriching it and reformulating it with another more concrete specification.



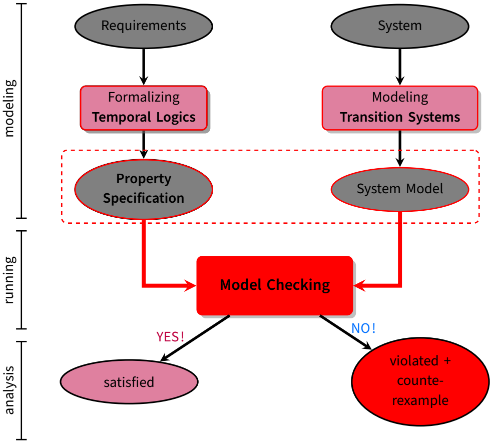
Behavior refinement (events)

PROPERTY SPECIFICATION



CentraleSupélec

PROPERTY SPECIFICATION



CentraleSupélec

INVARIANTS, SAFETY AND LIVENESS PROPERTIES

- **Safety properties** $\rightarrow$ “nothing bad should happen”
  - Typical safety property : mutual exclusion property
  - the bad thing (having > 1 process in the critical section) never occurs

INVARIANTS, SAFETY AND LIVENESS PROPERTIES

- **Safety properties** $\rightarrow$ “nothing bad should happen”
  - Typical safety property : mutual exclusion property
  - the bad thing (having > 1 process in the critical section) never occurs

- An **Invariant property** is a particular safety property
  - that is given by a condition ϕ over AP
  - requires that condition ϕ holds for all states (reachable ones)
  - e.g. for mutual exclusion property $\phi = \neg(crit_1 \wedge crit_2)$

CentraleSupélec

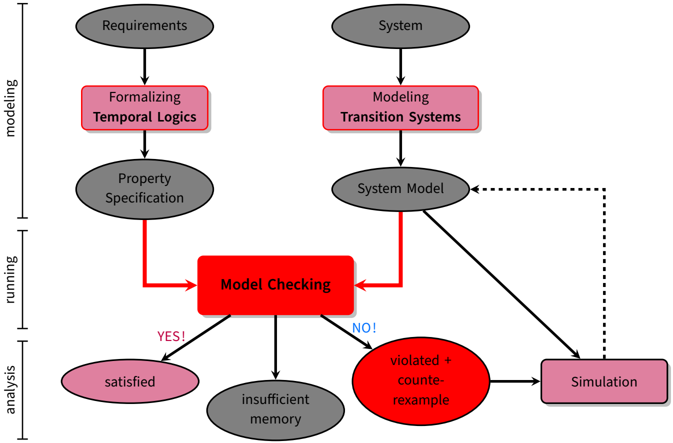
INVARIANTS, SAFETY AND LIVENESS PROPERTIES

- **Safety properties** $\rightarrow$ "nothing bad should happen"
  - Typical safety property : mutual exclusion property
  - the bad thing (having > 1 process in the critical section) never occurs

- An **Invariant property** is a particular safety property
  - that is given by a condition ϕ over AP
  - requires that condition ϕ holds for all states (reachable ones)
  - e.g. for mutual exclusion property $\phi = \neg(crit_1 \wedge crit_2)$

- Safety properties are complemented by **Liveness properties**
  - that require some progress
  - that assert : ”something good” will happen eventually
  - e.g. Eventually : $\Diamond\, crit_1 \wedge \Diamond\, crit_2$

MODEL CHECKING PROCESS



CentraleSupélec

MODEL CHECKING PROCESS

1. **Modeling phase**
   - Model the system under consideration into a formal representation
   - Formalize the property to check using a temporal logic

MODEL CHECKING PROCESS

1. **Modeling phase**
   - Model the system under consideration into a formal representation
   - Formalize the property to check using a temporal logic

2. **Running phase**
   - run automatically the model checker to check the validity of the property in the model

MODEL CHECKING PROCESS

1. **Modeling phase**
   - Model the system under consideration into a formal representation
   - Formalize the property to check using a temporal logic

2. **Running phase**
   - run automatically the model checker to check the validity of the property in the model

3. **Analysis phase** (3 cases)
   - property satisfied : check next property (if any)
   - property violated :
     - analyze generated counterexample by simulation
     - modify the model and repeat the entire procedure
   - out of memory : try to reduce the model (abstraction) and try again

CentraleSupélec

THE PROS OF MODEL CHECKING

THE PROS OF MODEL CHECKING

✔ widely applicable (hardware, software, protocol systems, ...)

THE PROS OF MODEL CHECKING

- ✔ widely applicable (hardware, software, protocol systems, ...)

- ✔ potential “push-button” technology (software-tools)

THE PROS OF MODEL CHECKING

- ✔ widely applicable (hardware, software, protocol systems, ...)
- ✔ potential “push-button” technology (software-tools)
- ✔ rapidly increasing industrial interest

THE PROS OF MODEL CHECKING

- ✔ widely applicable (hardware, software, protocol systems, ...)
- ✔ potential “push-button” technology (software-tools)
- ✔ rapidly increasing industrial interest
- ✔ in case of property violation, a counter-example is provided

THE PROS OF MODEL CHECKING

- ✔ widely applicable (hardware, software, protocol systems, ...)
- ✔ potential “push-button” technology (software-tools)
- ✔ rapidly increasing industrial interest
- ✔ in case of property violation, a counter-example is provided
- ✔ sound and interesting mathematical foundations

THE PROS OF MODEL CHECKING

- ✓ widely applicable (hardware, software, protocol systems, ...)
- ✓ potential “push-button” technology (software-tools)
- ✓ rapidly increasing industrial interest
- ✓ in case of property violation, a counter-example is provided
- ✓ sound and interesting mathematical foundations
- ✓ not biased to the most possible scenarios (such as testing)

THE CONS OF MODEL CHECKING

THE CONS OF MODEL CHECKING

- ✘ mainly focused on control-intensive systems
    - state explosion problem must be addressed to apply to data-oriented systems

THE CONS OF MODEL CHECKING

✘ mainly focused on control-intensive systems

- state explosion problem must be addressed to apply to data-oriented systems

✘ model checking is based on two error-prone activities :

- system modeling
- property specification

CentraleSupélec

THE CONS OF MODEL CHECKING

✗ mainly focused on control-intensive systems

- state explosion problem must be addressed to apply to data-oriented systems

✗ model checking is based on two error-prone activities :

- system modeling
- property specification

doing things right $\not\Rightarrow$ doing the right thing

OUTLINE

- Introduction
- Model-checking
- **Model-checking with ProB plugin**
- Conclusion about ProB plugin

Back to the begin - Back to the outline

CentraleSupélec

THE PROB
ANIMATOR AND MODEL CHECKER

ProB Main Page 🌐

THE PROB
ANIMATOR AND MODEL CHECKER

- **ProB** is an animator, constraint solver and model checker for the **Event-B Method**.

ProB Main Page 🌍

THE PROB
ANIMATOR AND MODEL CHECKER

- **ProB** is an animator, constraint solver and model checker for the **Event-B Method**.
- **ProB**’s animation features allow developers to control and validate the behavior of their specifications.

ProB Main Page 🌐

THE PROB ANIMATOR AND MODEL CHECKER

- **ProB** is an animator, constraint solver and model checker for the **Event-B Method**.
- **ProB**'s animation features allow developers to control and validate the behavior of their specifications.
- Animation features are useful for infinite state machines, not for verification, but for debugging and testing.

ProB Main Page

CentraleSupélec

MODEL CHECKING WITH PROB

MODEL CHECKING WITH PROB

- The **ProB plugin** allows automatic verification of the consistency of **Event-B** machines through animation and model checking.

MODEL CHECKING WITH PROB

- The **ProB plugin** allows automatic verification of the consistency of **Event-B** machines through animation and model checking.
- For exhaustive model verification, the given sets must be limited to finite sets.

MODEL CHECKING WITH PROB

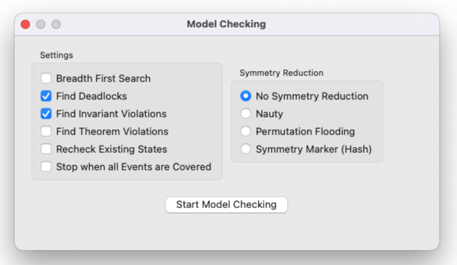
- The **ProB plugin** allows automatic verification of the consistency of **Event-B** machines through animation and model checking.
- For exhaustive model verification, the given sets must be limited to finite sets.
  - ➠ allows ProB to browse through the reachable states of the machine.

CentraleSupélec

MODEL CHECKING WITH PROB

- The **ProB plugin** allows automatic verification of the consistency of **Event-B** machines through animation and model checking.
- For exhaustive model verification, the given sets must be limited to finite sets.
  - ➠ allows ProB to browse through the reachable states of the machine.
- The **ProB plugin** graphically displays a counterexample when it discovers a property violation.

THE PROB PLUGIN



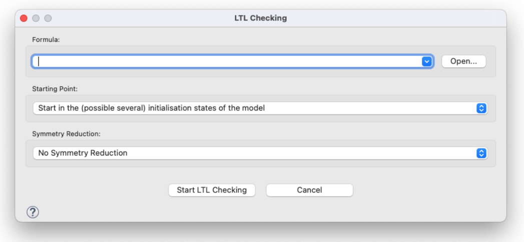
Model Checking

Settings

- ☐ Breadth First Search
- ☑ Find Deadlocks
- ☑ Find Invariant Violations
- ☐ Find Theorem Violations
- ☐ Recheck Existing States
- ☐ Stop when all Events are Covered

Symmetry Reduction

- ● No Symmetry Reduction
- ○ Nauty
- ○ Permutation Flooding
- ○ Symmetry Marker (Hash)



LTL Checking

Formula:

Starting Point: Start in the (possible several) initialisation states of the model

Symmetry Reduction: No Symmetry Reduction

- Tutorial Rodin First Step
- Tutorial First Model Checking
- LTL Model Checking

OUTLINE

- Introduction
- Model-checking
- Model-checking with ProB plugin
- **Conclusion about ProB plugin**

Back to the begin - Back to the outline

CONCLUSION ABOUT PROB

CONCLUSION ABOUT PROB

- The **ProB plugin** is useful in addition to the proof tools.

CONCLUSION ABOUT PROB

- The **ProB plugin** is useful in addition to the proof tools.
- As the interactive proof process can be quite long, the **ProB plugin** can be used as a complement to the interactive proof.

CONCLUSION ABOUT PROB

- The **ProB plugin** is useful in addition to the proof tools.
- As the interactive proof process can be quite long, the **ProB plugin** can be used as a complement to the interactive proof.
- Some errors will be discovered sooner and designers will waste less effort proving incorrect POs.

THANK YOU

Back to the begin - Back to the outline