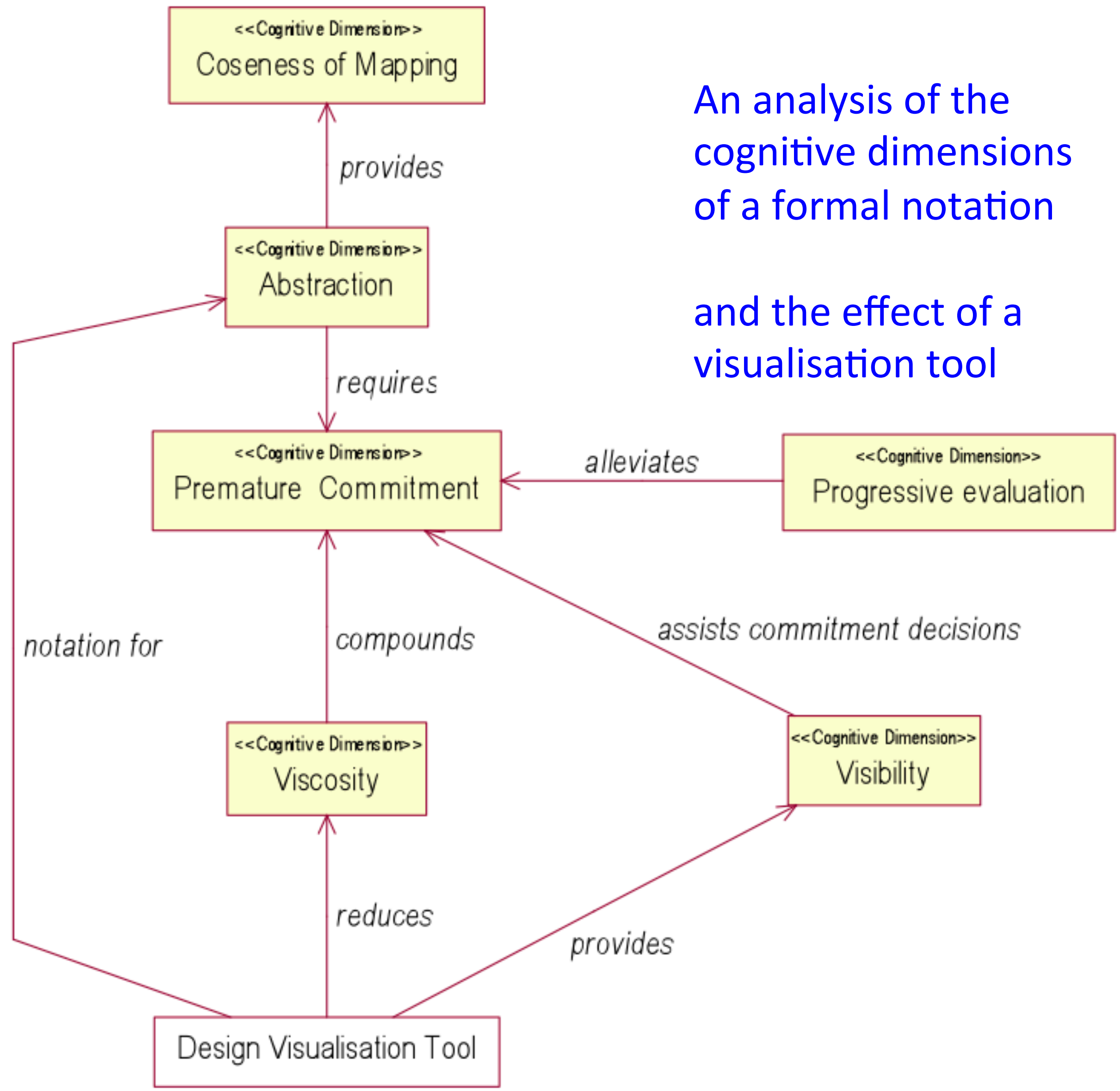
Introduction to UML-B, UML-B Class Diagrams, UML-B Context Diagrams

Cognitive Dimensions of Formal Notations

Cognitive Dimensions of Notations
(Thomas Green)

“provide a common vocabulary for discussing many factors in notation, UI or programming language design”



An analysis of the cognitive dimensions of a formal notation

and the effect of a visualisation tool

Motivation

Provide a more approachable interface for newcomers to Event-B

Provide diagrams to help visualise models

Provide extra features to Event-B

N.b. not trying to formalise UML

What is UML-B?

A Graphical front-end for Event-B

- Plug-in for Rodin

Not UML …

- Has its own meta-model (abstract syntax)
- Semantics inherited from translation to Event-B

… but it has some similarities with UML

- Project Diagrams (something like package diagrams)
- Class Diagrams
- State Machine Diagrams

Translator generates Event-B automatically

What are the benefits?

Visualisation

- Helps understanding
- communication

Faster modelling (allows you to experiment)

- One drawing node = several lines of B
- Extra information inferred from position of elements
  (e.g. if contained in a class or statemachine)
- Experiment with different abstractions

Provides structuring constructs

finding useful abstractions is hard

- Class
  Event-B has no *lifting* mechanism
- Hierarchical state-machines
  Event-B has no *event sequencing* mechanism

Getting Started

Install UML-B using the Rodin update site

- Help – Install, select the main Rodin update site, wait for it to retrieve the categories, select UML-B Modelling Environment under Modelling Extensions.

UML-B Perspective

UML-B New Project Wizard

- Opens a project diagram for you
- Add machines and contexts
- Double click on a machine to open a class diagram
- or on a context to open a context diagram

Look for this icon

UML-B Menu

- Enable automatic translation on every save
- Disabled by default (Recommend leaving disabled for larger models)

UML-B toolbar button

- Save and translate

Class-oriented problems

In Event-B models, often find a pattern

- Set I (or could be constant or variable)
- Variables $v \in I \rightarrow T$
- Events
```
e (i,..) =
    when i ∈ I,  …
    then  v(i) := x
```

I is a set of instances of a class

v is a set of values, one for each instance (a class attribute)

e is a ‘family’ of identical events to assign values to v (a class event)

I.e. trying to represent class-oriented problems

An Event-B model of a class-oriented problem

VARIABLES

allocation , rooms

INVARIANTS

inv1 : $rooms \in \mathbb{P}(ROOMS)$ class

inv2 : $allocation \in rooms \mathrel{+\!\!\!\rightarrow} GUESTS$ attribute (or association)

EVENTS

Initialisation

begin

act1 : $rooms := \varnothing$

act2 : $allocation := \varnothing$

end

Event $Check\_in \mathrel{\widehat{=}}$ class event

any **g, r** **where**

grd1 : $g \in GUESTS$

grd2 : $r \in rooms \setminus dom(allocation)$

then

act1 : $allocation(r) := g$

end

constructor

Event $Add\_Room \mathrel{\widehat{=}}$

any **r** **where**

grd1 : $r \in ROOMS \setminus rooms$

then

act1 : $rooms := rooms \cup \{r\}$

end

destructor

Event $Remove\_Room \mathrel{\widehat{=}}$

any **r** **where**

grd1 : $r \in rooms \setminus dom(allocation)$

then

act1 : $rooms := rooms \setminus \{r\}$

end

Example - modelling with UML-B

In a university degree programme,

students are registered on degree courses.

Students must be enrolled to be registered in a course.

Courses can be removed from the degree programme.

There is no need to consider multiple degree programmes – just assume we are modelling a single degree programme.

Example - modelling with UML-B

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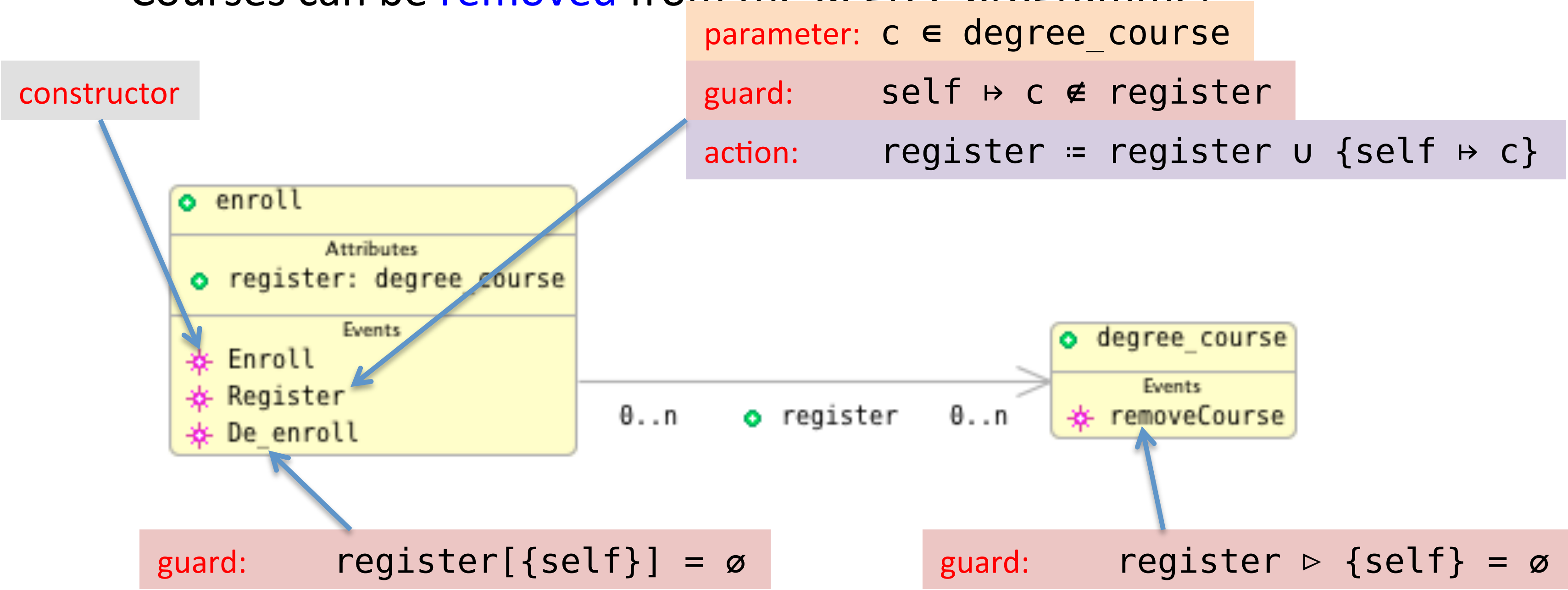
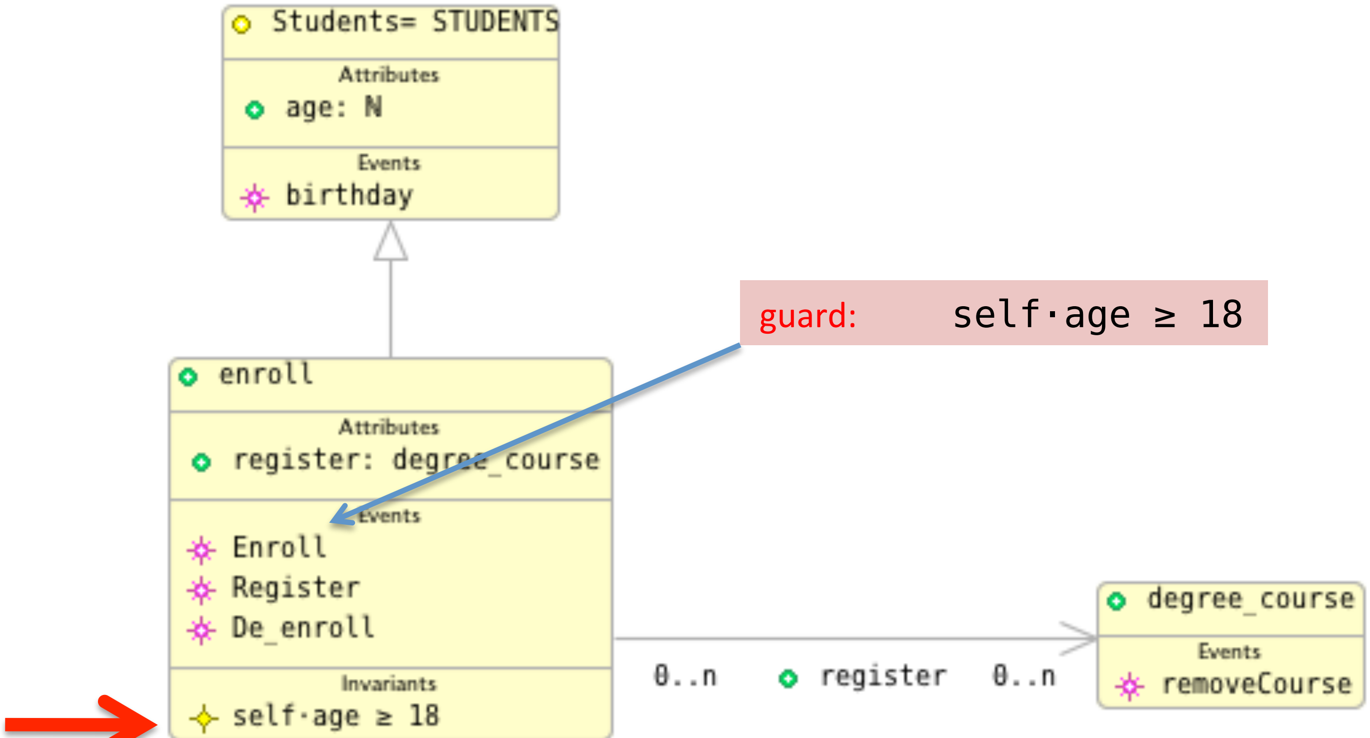


Adding an Invariant

Enrolled students must be 18.



Translation: $\forall self \cdot ((self \in enroll) \Rightarrow (age(self) \geq 18))$

UML-B Class Diagrams – Translation rules (part)

UML-B	Event-B

Class (variable instances)
Class (fixed instances)
Class (variable inst and has super class)
Class (fixed inst and has super class)
	`Variable ⊆ Set`
	`Set`
	`Variable ⊆ SuperClass`
	`Constant ⊆ SuperClass`

Attribute (card 0..n - 1..1)
Attribute (card 0..n - 0..1)
Attribute (card 0..n - 0..n)
Etc. (try other cardinalities in UML-B)
	`Variable ∈ Class → Type`
	`Variable ∈ Class ⇸ Type`
	`Variable ∈ Class ↔ Type`
	Etc.

Associations	As Attribute but Type is another class
Class Event	`Event(self) WHEN self ∈ Class …`
Class Constructor	`Event(self) WHEN self ∈ SET\Class …`
Class Invariant	`∀self·((self∈Class)⇒ Class invariant`

Example – Event-B produced by UML-B

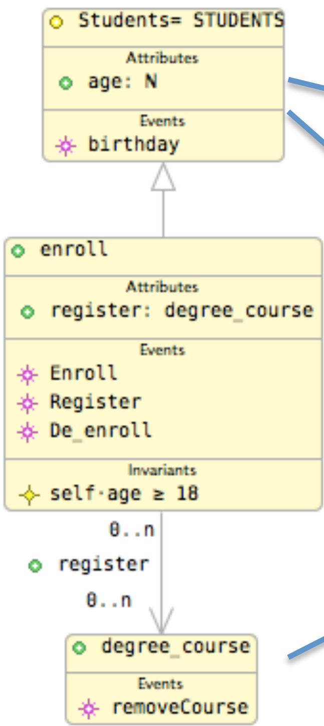
```
machine m sees m_implicitContext

variables enroll // class instances
          degree_course // class instances
          register // attribute of enroll
          age // attribute of Students


invariants
  @type enroll ∈ ℙ (Students)
  @type degree_course ∈ ℙ (degree_course_SET)
  @type register ∈ enroll ↔ degree_course
  @type age ∈ Students → ℕ
  @Invariant1 ∀self·((self∈enroll)⇒(age(self) ≥ 18))

events
  event INITIALISATION
    then
      @init enroll ≔ ∅
      @init degree_course ≔ ∅
      @init register ≔ ∅
      @init age ≔ Students × {0}
  end
```

```
event Enroll
  any self // constructed instance of class enroll

  where
    @type self ∈ Students \ enroll
    @Guard1 age(self) ≥ 18
  then
    @enroll_constructor enroll ≔ enroll ∪ {self}
end

event Register
  any self // contextual instance of class enroll
      c
  where
    @type c ∈ degree_course
    @type self ∈ enroll
    @Guard1 self ↦ c ∉ register
  then
    @Action1 register ≔ register ∪ {self ↦ c}
end
```

The ‘Implicit’ Context

Each class diagram creates an *implicit* context

- Contains the ‘basis’ of things on the class diagram
- e.g. a carrier set for the type of class instances




```
context m_implicitContext extends c

constants Students // class instances

sets degree_course_SET // Class

axioms
  @value Students = STUDENTS
end
```

Context Diagrams

How can we model constants that belong to a class?

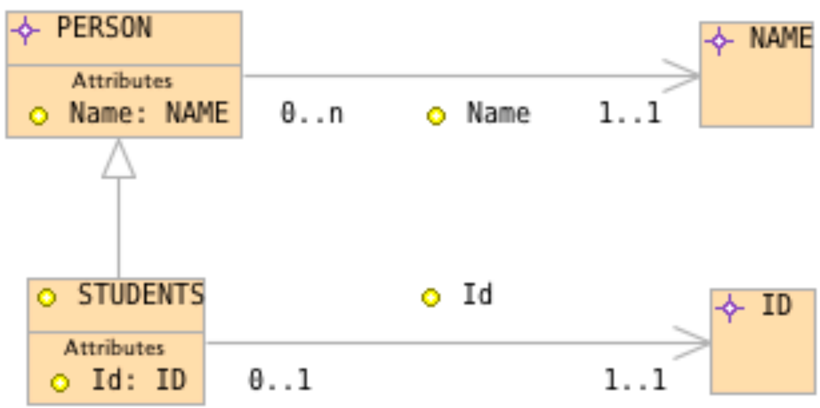
in Event-B our machine would see a Context

with sets, constants, axioms

UML-B takes a similar approach

- Class Diagram (Machine) sees Context Diagram
- Similar to a Class Diagram but translates to sets, constants and axioms
- ClassType instead of Class
- Constant Attributes/Associations represent constants
- Axioms instead of Invariants
- No Events

A Context Diagram and its translation



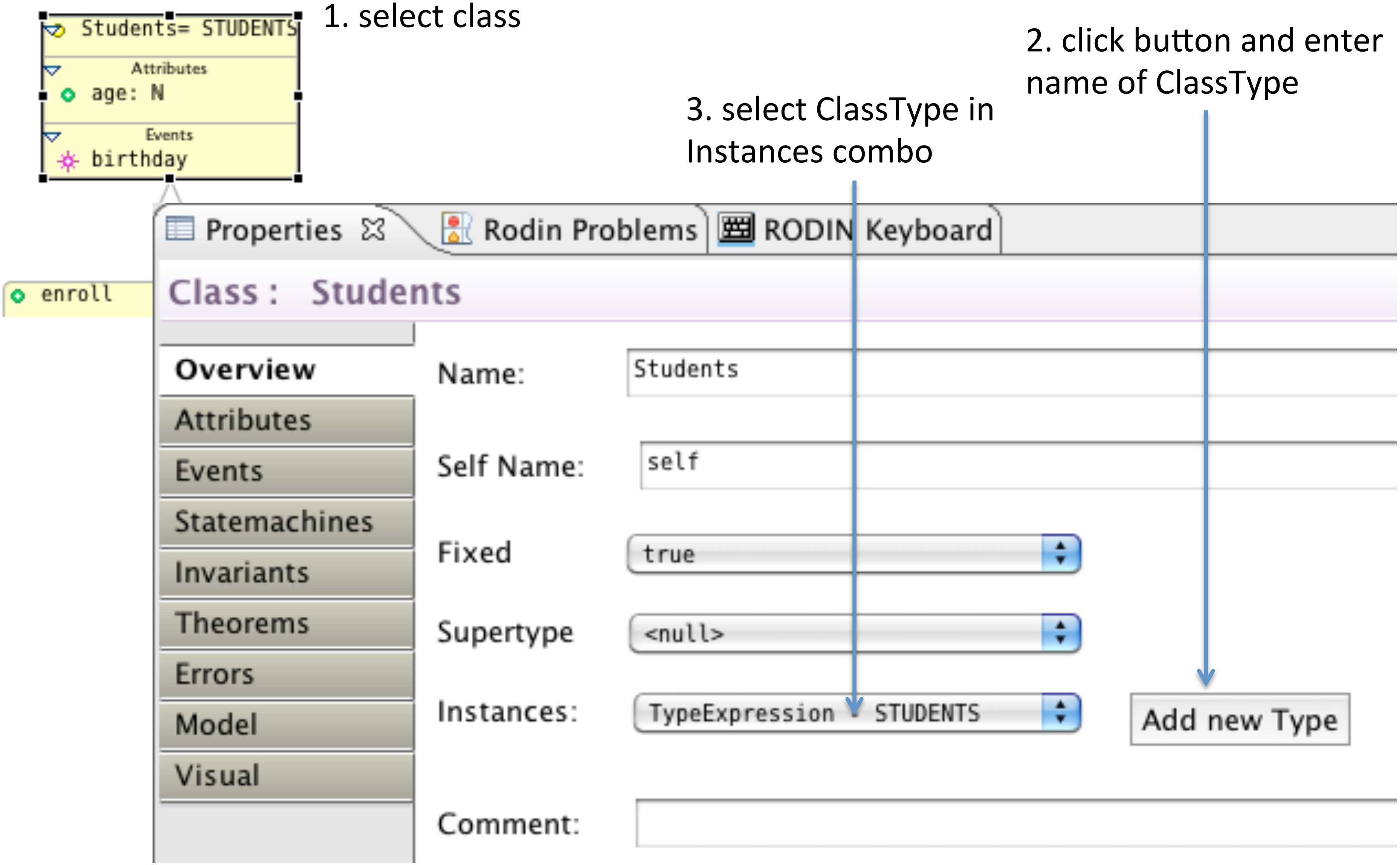

```
context c

constants STUDENTS // classType instances
          Id // attribute of STUDENTS
          Name // attribute of PERSON

sets ID // ClassType
     PERSON // ClassType
     NAME // ClassType

axioms
  @type STUDENTS ∈ ℙ (PERSON)
  @type Id ∈ STUDENTS ↣ ID
  @type Name ∈ PERSON → NAME
end
```

Linking a Class to a ClassType

1. select class

2. click button and enter name of ClassType

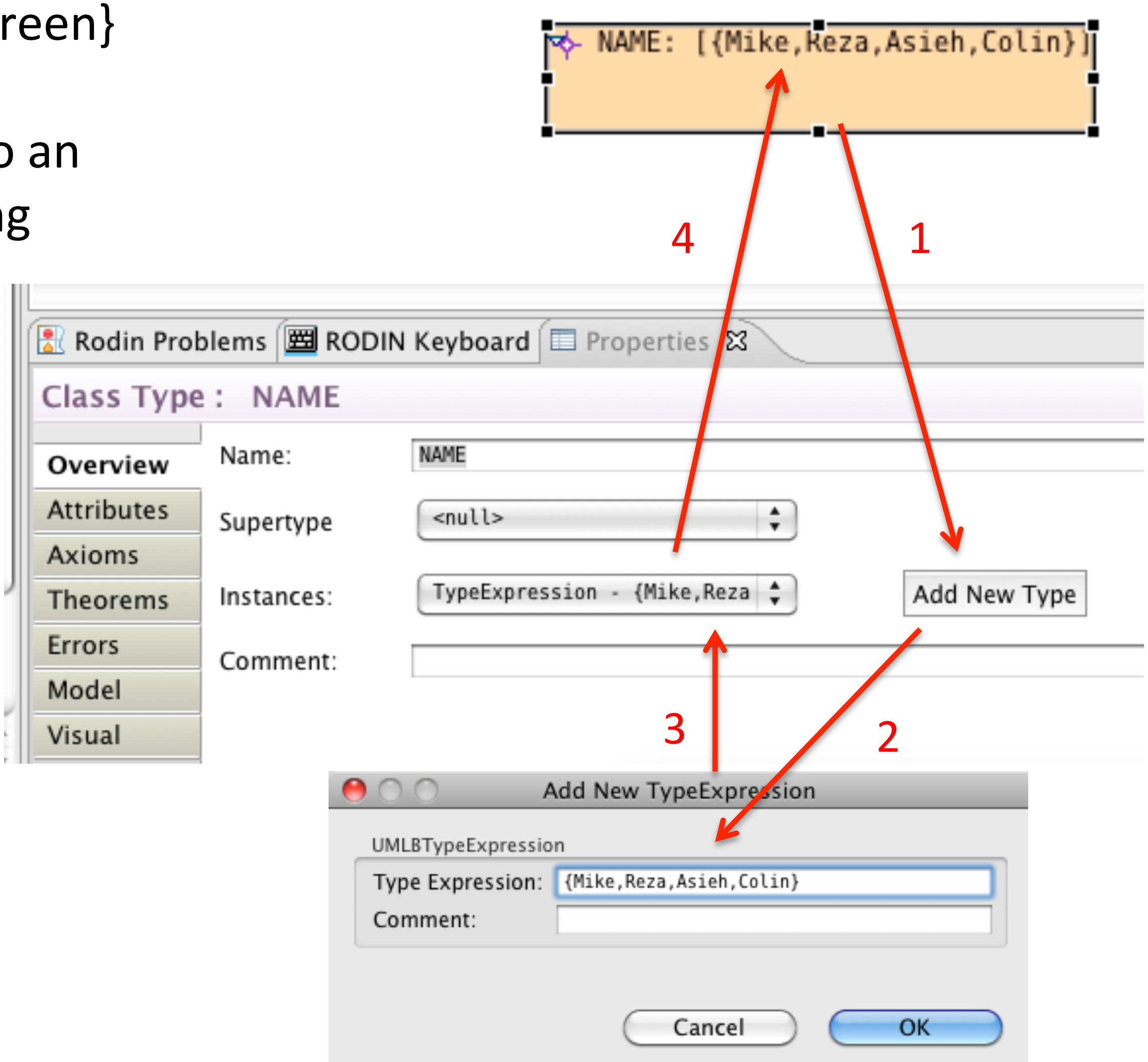
3. select ClassType in Instances combo



Enumerated Types

For real enumerated types e.g.
signal = {red, amber, green}

also, for restricting types to an example for model checking



Enumerated Types

```
CONTEXT
  Context1
SETS
  NAME      //   ClassType
CONSTANTS
  Mike      //   enumeration constant
  Reza      //   enumeration constant
  Asieh      //   enumeration constant
  Colin      //   enumeration constant
AXIOMS
  Mike.type   :   Mike ∈ NAME
  Reza.type   :   Reza ∈ NAME
  Asieh.type   :   Asieh ∈ NAME
  Colin.type   :   Colin ∈ NAME
  enumerationOf_NAME   :   partition(NAME,{Mike},{Reza},{Asieh},{Colin})
END
```

Summary

Project (package) diagrams show the machines and contexts and their relationships

Class diagrams for class-oriented modelling

- automatically generates class structures in Event-B

Attribute and association cardinalities

Options for class instances

- variable (constructors and destructors)
- fixed

Automatically generates an ‘implicit context’

Context diagrams for class oriented modelling of sets, constants and enumerated types