# EVENT-B REFINEMENT IN PRESENCE OF DATA MEASURES

EBRP-ANR meeting
IRIT-ENSEEIHT, Toulouse, 8-9 July 2024

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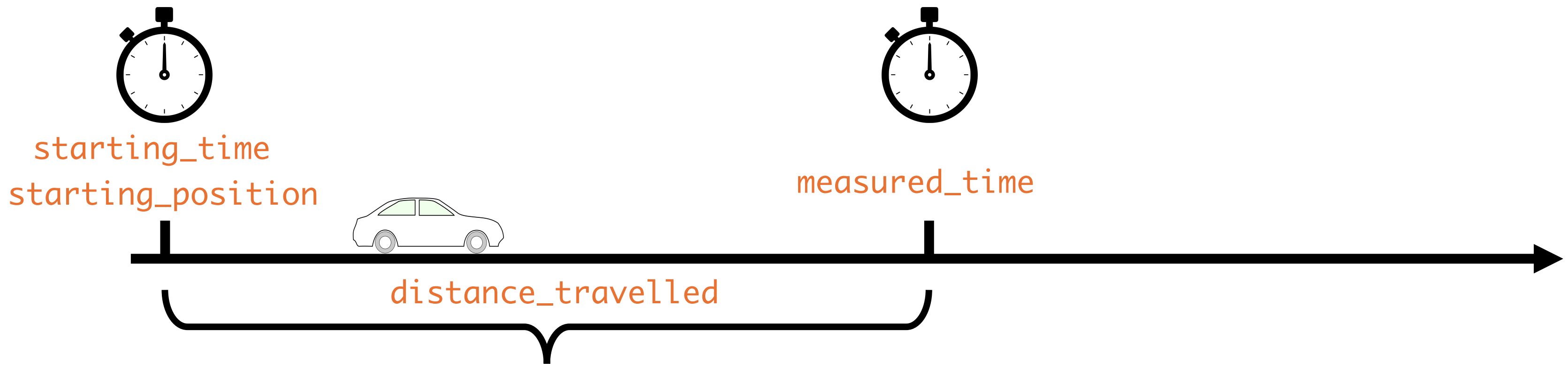
# A SIMPLE EXAMPLE

- System that continuously calculates **a moving object's speed**




- Analysing **two functional properties**:
  - **PROP-1** : **the speed of the moving object** is equal to the $distance\_travelled$ divided by the $measured\_time$ ($v = d/t$).
  - **PROP-2** : when the $distance\_travelled$ is strictly positive, the $speed$ of the moving object must also be strictly positive.
    - **the object moves** when its $speed$ is different from zero.

# THE FIRST APPROACH

- A simple example in a single **Event-B model/machine**.
- The obtained Event-B machine is built using **two Event-B theories**:
  1. Floating-point numbers **theory**
  2. International System of Units **theory**

# THE EVENT-B MODEL

```
MACHINE mch_car_speed
...
INVARIANTS
  @inv1: distance_travelled ∈ SI_MEASURE_Type(METRE_UNIT)
  @inv2: measured_time ∈ SI_MEASURE_Type(SECOND_UNIT)
  @inv3: speed ∈ SI_MEASURE_Type(METRE_PER_SECOND_UNIT)
  @inv4: starting_position ∈ SI_MEASURE_Type(METRE_UNIT)
  @inv5: starting_time ∈ SI_MEASURE_Type(SECOND_UNIT)
  @PROP-1: speed SI_EQ distance_travelled SI_DIV measured_time
  @PROP-2: distance_travelled SI_GT MEASURE(F0,METRE_UNIT) ⇒ speed SI_GT MEASURE(F0,METRE_PER_SECOND_UNIT)
EVENTS
  ...
  get_starting_point ≙
    any p t
    where
      @grd1: p ∈ SI_MEASURE_Type(KILO_METRE_UNIT)
      @grd2: t ∈ SI_MEASURE_Type(SECOND_UNIT)
    then
      @act1: starting_position := SI_CONVERT(METRE_UNIT, p)
      @act2: starting_time := t
    end
  ...
END
```

# THE EVENT-B MODEL

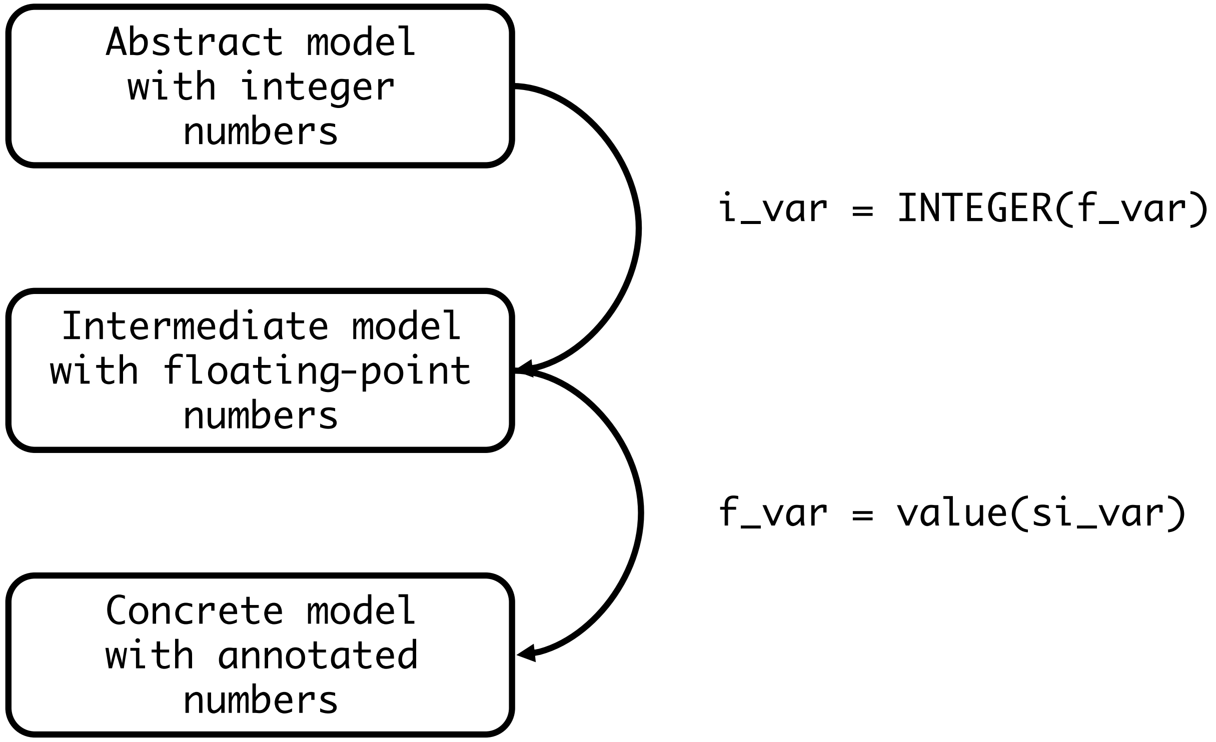
```
MACHINE mch_car_speed
...
INVARIANTS
  @inv1: distance_travelled ∈ SI_MEASURE_Type(METRE_UNIT)
  @inv2: measured_time ∈ SI_MEASURE_Type(SECOND_UNIT)
  @inv3: speed ∈ SI_MEASURE_Type(METRE_PER_SECOND_UNIT)
  @inv4: starting_position ∈ SI_MEASURE_Type(METRE_UNIT)
  @inv5: starting_time ∈ SI_MEASURE_Type(SECOND_UNIT)
  @PROP-1: speed SI_EQ distance_travelled SI_DIV measured_time
  @PROP-2: distance_travelled SI_GT MEASURE(F0,METRE_UNIT) ⇒ speed SI_GT MEASURE(F0,METRE_PER_SECOND_UNIT)
EVENTS
  ...
  get_speed ≙
    any p t
    where
      @grd1: p ∈ SI_MEASURE_Type(METRE_UNIT) ∧ p SI_GT starting_position
      @grd2: t ∈ SI_MEASURE_Type(SECOND_UNIT) ∧ t SI_GT starting_time
    then
      @act1: distance_travelled := p SI_MINUS starting_position
      @act2: measured_time := t SI_MINUS starting_time
      @act3: speed := (p SI_MINUS starting_position) SI_DIV (t SI_MINUS starting_time)
    end
END
```

# GENERATED AND PROVEN POS

- All POs are green but :
  - we get a lot of proof obligations
  - the proof of each of them was interactive
  - each proof needs several steps
- At the same time, we treat :
  - the system properties
  - the data measurement annotations

**Refinement** is an excellent solution to decompose a complex proof.

# THE REFINEMENT BASED APPROACH



# THE ABSTRACT MODEL

```
MACHINE mch_1
...
INVARIANTS
  @inv1: i_distance_travelled ∈ ℕ
  @inv2: i_measured_time ∈ ℕ1
  @inv3: i_speed ∈ ℕ
  @inv4: i_starting_position ∈ ℕ
  @inv5: i_starting_time ∈ ℕ
  @PROP-1: i_speed = i_distance_travelled ÷ i_measured_time
EVENTS
...
get_speed ≙
  any i_p i_t
  where
    @grd1: i_p ∈ ℕ ∧ i_p > i_starting_position
    @grd2: i_t ∈ ℕ ∧ i_t > i_starting_time
  then
    @act1: i_distance_travelled := i_p − i_starting_position
    @act2: i_measured_time := i_t − i_starting_time
    @act3: i_speed := (i_p − i_starting_position) ÷ (i_t − i_starting_time)
  end
END
```

# THE REFINEMENT MODEL

```
MACHINE mch_2 REFINES mch_1
...
INVARIANTS
  @inv1: f_distance_travelled ∈ PFLOAT_Type
  @inv2: f_measured_time ∈ PFLOAT1_Type
  @inv3: f_speed ∈ PFLOAT_Type
  @inv4: f_starting_position ∈ PFLOAT_Type
  @inv5: f_starting_time ∈ PFLOAT_Type
  @PROP-2: f_distance_travelled gt F0 ⇒ f_speed gt F0
  @glueing-1: INTEGER(f_distance_travelled) = i_distance_travelled
  ...
EVENTS
...
get_speed ≙
  any f_p f_t
  where
    @grd1: f_p ∈ PFLOAT_Type ∧ INTEGER(f_p) > INTEGER(f_starting_position)
    @grd2: f_t ∈ PFLOAT_Type ∧ INTEGER(f_t) > INTEGER(f_starting_time)
  with
    INTEGER(f_p) = i_p ∧ INTEGER(f_t) = i_t
  then
    @act1: f_distance_travelled := f_p minus f_starting_position
    @act2: f_measured_time := f_t minus f_starting_time
    @act3: f_speed := (f_p minus f_starting_position) div (f_t minus f_starting_time)
  end
END
```

# THE ANNOTATED MODEL

```
MACHINE mch_3 REFINES mch_2
...
INVARIANTS
  @inv1: si_distance_travelled ∈ SI_MEASURE_Type(METRE_UNIT)
  @inv2: si_measured_time ∈ SI_MEASURE_Type(SECOND_UNIT)
  @inv3: si_speed ∈ SI_MEASURE_Type(METRE_PER_SECOND_UNIT)
  @inv4: si_starting_position ∈ SI_MEASURE_Type(METRE_UNIT)
  @inv5: si_starting_time ∈ SI_MEASURE_Type(SECOND_UNIT)
  @glueing-1: value(si_distance_travelled) = f_distance_travelled
  ...
EVENTS
...
get_speed ≙
  any si_p si_t
  where
    @grd1: si_p ∈ SI_MEASURE_Type(METRE_UNIT) ∧ INTEGER(value(si_p)) > INTEGER(value(si_starting_position))
    @grd2: si_t ∈ SI_MEASURE_Type(SECOND_UNIT) ∧ INTEGER(value(si_t)) > INTEGER(value(si_starting_time))
  with
    value(si_p) = f_p ∧ value(si_t) = f_t
  then
    @act1: si_distance_travelled := si_p SI_MINUS si_starting_position
    @act2: si_measured_time := si_t SI_MINUS si_starting_time
    @act3: si_speed := (si_p SI_MINUS si_starting_position) SI_DIV (si_t SI_MINUS si_starting_time)
  end
END
```

# GENERATED AND PROVEN POS

- All POs are green with :
  - a lot of proof obligations
  - some proofs were done automatically
  - and some were interactives
  - **each interactive proof needs less steps than the first approach**

# THANK YOU

Back to the begin - Back to the outline