EventB Assignment 2

Ken Robinson

30th March 2012

Name of assignment	**ass2**	
Due date	RailTicketR1	**1st April 2012**
	RailTicketR2	**3rd April 2012**
Assessment	**15** marks	

Submission: use either the web-based give:
`https://cgi.cse.unsw.edu.au/~give/Student/give.php?session=12s1`
or the cse command
give cs2111 ass2 RailTicket.zip
Please *do not* submit the assignment as an email attachment.

1 Purpose of this assignment

This assignment is concerned with:

- use of context invariants machine and SEES;
- consolidation of the understanding of invariant;
- consolidation of the understanding of guard;
- expansion of general knowledge of and experience with Event-B;
- specifying events;
- experience with *refinement*, including *data refinement*.
- using proof obligations to find problems in developments.
- using the animator to check the understanding and capture of requirements;

2 TicketMachine: A Simple Rail Ticket dispensing machine

This assignment is concerned with the modelling of a simple rail ticket dispensing machine. The modelling is to be done in three stages:

atomic the first stage in which the purchase of tickets is an indivisible event.

refinement the second stage in which the purchase of tickets is distributed across a number of events with actions that are typical of what is commonly seen on a real ticket machine. In this refinement payment is made using coins.

Event	**Parameters**	**Purpose**
InitPrice	station, price	set initial *price* of a ticket to *station*
ChangePrice	station, price	change the *price* of a ticket to *station*
AddTickets	station, count	provide for restocking of *count* tickets to destination *station*
BuyTickets	station, count, payment	buy *count* tickets to *station*. The *payment* must be the exact cost of the tickets. This machine does not give change.

3 TicketMachineR1: Refinement of TicketMachine

The objective of the refinement is to distribute the single atomic event *BuyTicket* across a sequence of the following events events that might represent the buttons you have to press on a ticket machine to get a number of tickets.

Event	**Parameters**	**Purpose**
Choose	station,number	a customer chooses a *station* and the *number* of tickets required
Pay	coin	pay with a single *coin* towards the cost of the tickets. This event can be run a number of times until the customer has paid at least the cost of the tickets.
GiveChange		give change if the customer has given more than the cost of the tickets
Cancel		the transaction is cancelled by either the customer or the machine. The requested tickets are not delivered and the amount of money inserted is returned. "Returning money" should be an adjustment of the state of the machine; there is no mechanism for "delivering" money.
BuyTickets		finally, the refinement of *BuyTickets* —now with no explicit parameters— delivers the tickets when they have been completely paid for.

While payment is by coin, the moneybox and change are still expressed as numeric values. The moneybox may not necessarily record the current state of the transaction, but should be correct at least by the end of each transaction.

4 TicketMachineR2: Data Refinement of TicketMachineR1

The objective of this refinement is to replace the *moneybox*, which only records values, to *coinbox* that should be a box of (bag) of *coins*. This introduces a complication for giving change, as that now involves the choice of a bag of coins whose value is the required change, compared with simply subtracting the value of the change.

4.1 Initiating RailTicket2B

Follow the following process for RailTicket2B

1. Using the Event-B Explorer to create a refinement of RailTicket2A named RailTicket2B.
2. Add the context *CoinBag*.
3. Delete *moneybox* from the variables and invariant.
4. Add the variable *coinbox*.
5. Add an invariant for *coinbox*.
6. Add an invariant relating *coinbox* to *moneybox*. This is known as the refinement relation; it describes how *coinbox* models *moneybox*.

Essentially, the rest of *TicketMachine2B* consists of replacing occurences of *moneybox* in *TicketMachine2A* with *coinbox*. Of course, it's not as direct or simple as that might sound.

Importantly the only references to *moneybox* should occur in the invariants.

4.2 Contexts and Machines provided

The archive provides:

RailTicket a context defining a STATION, an opaque set of stations, that could be replaced by an enumerated set of stations.

Coin a context defining COIN, a finite set of coins, and CoinValue, a total injective function that maps coins to their value. The set COIN is presented as an opaque set, but could be enumerated. COIN could be replaced by an enumerated set of coins.

TicketMachine a skeletal machine that SEES RailTicket.

CoinBag a context defining the concept of a *bag* of coins and the functions required to manipulate such a bag.

4.3 Importing Just the CoinBag context

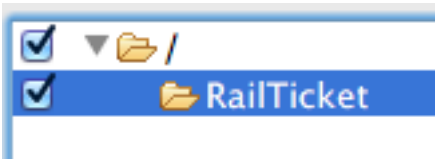
If you have already developed the RailTicket machine then you won't want to overwrite that with *TicketMachine* from the archive. The following instructions explain how you can selectively import from an archive, in this case just the *CoinBag* component of the archive.

On the import menu choose:

General
Archive
Next

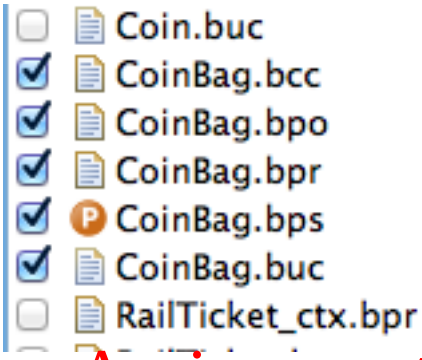
From the archive file: *choose the archive*

then select the options as follows:



Now choose *Deselect all*

and then select the components of the CoinBag context:



Next select the RailTicket project folder

followed by Finish.

This should install only the CoinBag components into your RailTicket project.

4.4 Costs and Coins

TicketMachine: payment is by value, not coin;

TicketMachineR1: payment is by coin, but change and total payment is by value.

TicketMachineR2: a refinement of *TicketMachineR1* that uses coins to model the contents of the *coinbox*, payment and change.

5 Discharge of Proof Obligations

- As usual your invariants and guards should be strong enough to ensure no exceptional behaviour.
- The proof obligations should give a reasonably good indication of the correctness of your model. You should be able to get your POs automatically discharged.

The following table gives the PO statistics for a solution that satisfies the above.

Statistics

Element Name	Total	Auto	Manual	Reviewed	Undischarged
Total	**140**	**110**	**28**	**1**	**1**
Coin	0	0	0	0	0
CoinBag	25	9	15	1	0
RailTicket	0	0	0	0	0
RailTicketR	0	0	0	0	0
TicketMachine	15	14	1	0	0
TicketMachineR1	41	41	0	0	0
TicketMachineR2	59	46	12	0	1

5.1 Other requirements

The machine should not dispense tickets that do no have a known price. The implication of that is the machine should not contain tickets for sale that do not have *real* price.

Payment is represented by a value; you do not model coins.

5.2 What you have to do

1. Import the provided archive. To do that:

   Open Rodin on an existing or new workspace.

   Select Import on the file menu;

   Select General and then "Existing Projects into Workspace"

   Select Next

   Check *Copy projects into workspace*. Very important: ensures the project is in this workspace, not shared with some other workspace.

   Choose Select *archive file* and browse to where you have placed the archive. This should list the projects in the archive, in this case *RailTicket*

   Select *choose project* and *Finish*.

   The archive should be installed and you can view the project using the *Event-B Explorer*

   Important: the archive is offered as a skeleton and apart from adding to that skeleton it may be necessary to make changes.

2. **TicketMachineR**

   You will notice that the archive does not contain *TicketMachineR*. This is because the easiest and best way to obtain this machine is to generate it from within the Event-B Explorer by right-clicking on *TicketMachine* and choosing Refine. This will produce a refinement that is automatically consistent with your version of *RailTicket*, so is best done when you have filled out that machine.

3. You should monitor the proof obligations very carefully. Attempt to discharge them if possible, but at the very least check them for indications that there is something inconsistent in your model.

4. Remember that the objective is not to reduce the number of POs; the stronger the invariant the more POs you can expect, in general. POs are very useful.
5. Animate your model using AnimB.
6. When you are finished, archive your project and submit as shown at the top of this specification.

CONTEXT RailTicket

SETS

`STATION` Finite set of stations

AXIOMS

`axm1 :` $finite(STATION)$

END

MACHINE TicketMachine

SEES Stations

VARIABLES

`stations` Stations known to this machine

`ticketprice` Price of tickets

`tickets` Number of available tickets

`moneybox` amount of all money paid (value not coins)

EVENTS

Initialisation

begin

`skip`

end

Event *InitPrice* $\widehat{=}$

Set initial price for tickets to station

any

station

price

where

`skip`

end

Event *ChangePrice* $\widehat{=}$

Change price for tickets to station

any

station

price

where

`skip`

end

Event *AddTickets* $\widehat{=}$

Add count tickets to station

any

station

count

where

`skip`

end

Event *BuyTickets* $\widehat{=}$
Request and pay for count tickets to station

any

station
count
payment

where

`skip`

end

END

CONTEXT Coin

SETS

`COIN`

CONSTANTS

`CoinValue`

AXIOMS

`axm1` : $finite(COIN)$

`axm2` : $CoinValue \in COIN \rightarrowtail \mathbb{N}_1$

END

CONTEXT CoinBag

EXTENDS Coin

CONSTANTS

`COINBAG`

`bagvalue`

`emptybag`

`bagunion`

`subbag`

`bagdiff`

`addcoin`

`removecoin`

AXIOMS

axm1 : $COINBAG = COIN \to \mathbb{N}$

axm3 : $bagvalue \in COINBAG \to \mathbb{N}$

axm4 : $\forall b, c \cdot b \in COINBAG \land c \in dom(b)$
$\Rightarrow bagvalue(b) = b(c) * CoinValue(c) + bagvalue(b \lhd\!\!\!- \{c \mapsto 0\})$

axm5 : $\forall b \cdot b \in COINBAG \land (b \neq \varnothing \Rightarrow ran(b) = \{0\})$
$\Leftrightarrow bagvalue(b) = 0$

axm6 : $emptybag = COIN \times \{0\}$

axm7 : $bagvalue(emptybag) = 0$

axm8 : $bagunion \in COINBAG \times COINBAG \to COINBAG$

axm9 : $\forall b1, b2 \cdot b1 \in COINBAG \land b2 \in COINBAG$
$\Rightarrow bagunion(b1 \mapsto b2) = \{c \cdot c \in COIN | c \mapsto b1(c) + b2(c)\}$

axm10 : $\forall b1, b2 \cdot b1 \in COINBAG \land b2 \in COINBAG$
$\Rightarrow bagunion(b1 \mapsto b2) = bagunion(b2 \mapsto b1)$

axm11 : $\forall b \cdot b \in COINBAG$
$\Rightarrow bagunion(emptybag \mapsto b) = b$

axm12 : $\forall b \cdot b \in COINBAG \Rightarrow bagvalue(emptybag \lhd\!\!\!- b) = bagvalue(b)$

axm13 : $subbag \in COINBAG \times COINBAG \to BOOL$

axm14 : $\forall b1, b2 \cdot b1 \in COINBAG \land b2 \in COINBAG$
$\land ((\forall c \cdot c \in COIN \land b1(c) \leq b2(c)) \Leftrightarrow subbag(b1 \mapsto b2) = TRUE)$

axm15 : $\forall b \cdot b \in COINBAG \Rightarrow subbag(emptybag \mapsto b) = TRUE$

axm16 : $bagdiff \in COINBAG \times COINBAG \nrightarrow COINBAG$

axm17 : $\forall b1, b2 \cdot b1 \in COINBAG \land b2 \in COINBAG$
$\Rightarrow (b1 \mapsto b2 \in dom(bagdiff) \Leftrightarrow subbag(b2 \mapsto b1) = TRUE)$

axm18 : $\forall b1, b2 \cdot b1 \in COINBAG \land b2 \in COINBAG \land subbag(b2 \mapsto b1) = TRUE$
$\Rightarrow bagdiff(b1 \mapsto b2) = \{c \cdot c \in COIN | c \mapsto b1(c) - b2(c)\}$

axm19 : $\forall b1, b2 \cdot b1 \in COINBAG \land b2 \in COINBAG \land subbag(b2 \mapsto b1) = TRUE$
$\Rightarrow bagvalue(bagdiff(b1 \mapsto b2)) = bagvalue(b1) - bagvalue(b2)$

axm20 : $\forall b1, b2 \cdot b1 \in COINBAG \land b2 \in COINBAG \land subbag(b1 \mapsto b2) = TRUE$
$\Rightarrow bagvalue(b1) \leq bagvalue(b2)$

axm21 : $\forall b1, b2 \cdot b1 \in COINBAG \land b2 \in COINBAG$
$\Rightarrow bagvalue(bagunion(b1 \mapsto b2)) = bagvalue(b1) + bagvalue(b2)$

axm22 : $addcoin \in COIN \times COINBAG \rightarrow COINBAG$

axm23 : $\forall c, b \cdot c \in COIN \land b \in COINBAG$
$\Rightarrow addcoin(c \mapsto b) = b \lhd\!\!\!\!- \{c \mapsto b(c) + 1\}$

axm24 : $removecoin \in (COIN \times COINBAG) \nrightarrow COINBAG$

axm25 : $\forall c, b \cdot c \in COIN \land b \in COINBAG \land b(c) \neq 0$
$\Rightarrow c \mapsto b \in dom(removecoin)$

axm26 : $\forall c, b \cdot c \in COIN \land b \in COINBAG \land b(c) \neq 0$
$\Rightarrow removecoin(c \mapsto b) = b \lhd\!\!\!\!- \{c \mapsto b(c) - 1\}$

axm27 : $\forall b \cdot b \in COINBAG$
$\Rightarrow b = \{c \cdot \top | c \mapsto b(c)\}$

END