1 Generated Z Specification

section *Model_Preamble* **parents** *ZOO_Toolkit*

$CLASS ::= CustomerCl \mid AccountCl$

$$subCl : CLASS \leftrightarrow CLASS$$
$$subCl = \{\}$$

$$\mathbb{O} : CLASS \to \mathbb{P}_1\ OBJ$$
$$\mathbb{O}x : CLASS \to \mathbb{P}_1\ OBJ$$
$$\text{disjoint } \mathbb{O}x$$
$$\forall\, cl : CLASS \bullet \mathbb{O}\ cl = \mathbb{O}x\ cl \cup \bigcup(\mathbb{O}x \ltimes (subCl^{+})^{\sim}(\{cl\}))$$
$$\forall\, cl, cl' : CLASS \mid cl \mapsto cl' \in subCl \bullet \mathbb{O}\ cl \subseteq \mathbb{O}\ cl'$$

section *Bank* **parents** *ZOO_Toolkit*, *Model_Preamble*

$[Name]$

$[Address]$

$CustType ::= corporate \mid personel$

$[AccID]$

$AccType ::= savings \mid current$

$[CustID]$

*Customer*0
$$name : Name$$
$$cType : CustType$$
$$address : Address$$
$$custNo : CustID$$

Customer

$Customer0$

SCustomer

$sCustomer : \mathbb{P}(\mathbb{O}\, CustomerCl)$

$stCustomer : \mathbb{O}\, CustomerCl \pfun Customer$

$\mathrm{dom}\ stCustomer = sCustomer$

*Account*0

$aType : AccType$

$balance : \mathbb{Z}$

$accNo : AccID$

AccountSavingsArePositive

$Account0$

$aType = savings \Rightarrow balance \geq 0$

Account

$Account0$

$AccountSavingsArePositive$

SAccount

$sAccount : \mathbb{P}(\mathbb{O}\, AccountCl)$

$stAccount : \mathbb{O}\, AccountCl \pfun Account$

$\mathrm{dom}\ stAccount = sAccount$

AHolds

$rHolds : \mathbb{O}\, CustomerCl \rel \mathbb{O}\, AccountCl$

AccountGetBalance

$Account$

$bal! : \mathbb{Z}$

$bal! = balance$

AccountDelete

$$Account$$

$$balance = 0$$

BankGblSt

$$SCustomer$$
$$SAccount$$
$$AHolds$$

BankCorporateHaveNoSavings

$$BankGblSt$$

$$(\{o : sCustomer \mid (stCustomer\ o).cType = corporate\} \lhd rHolds) \rhd \{o : sAccount \mid (stAccount\ o).aType = savings\} = \varnothing$$

BankCustsWithSavings

$$BankGblSt$$
$$custsSav : \mathbb{P}\ \mathbb{O}\ CustomerCl$$

$$custsSav = \mathrm{dom}\,(rHolds \rhd \{o : \mathbb{O}\ AccountCl \mid (stAccount\ o).aType = savings\})$$

BankCustsWithCurrent

$$BankGblSt$$
$$custsCurr : \mathbb{P}\ \mathbb{O}\ CustomerCl$$

$$custsCurr = \mathrm{dom}\,(rHolds \rhd \{o : \mathbb{O}\ AccountCl \mid (stAccount\ o).aType = current\})$$

*BankHasCurrentBefSavings*0

$$BankGblSt$$
$$BankCustsWithSavings$$
$$BankCustsWithCurrent$$

$$custsSav \subseteq custsCurr$$

$$BankHasCurrentBefSavings == \exists\ custsCurr : \mathbb{P}\ \mathbb{O}\ CustomerCl;\ \ custsSav : \mathbb{P}\ \mathbb{O}\ CustomerCl \bullet BankHasCurrentBefSavings0$$

*BankSavingsArePositive*2

$$BankGblSt$$

$$\{o : sAccount \mid (stAccount\ o).aType = savings \land (stAccount\ o).balance < 0\} = \varnothing$$

BankHoldsGCnt

$BankGblSt$

$mult\,(rHolds,\ sCustomer,\ sAccount, om, \{\}, \{\})$

BankGbl

$BankGblSt$

$BankHoldsGCnt$

$BankCorporateHaveNoSavings$

$BankHasCurrentBefSavings$

$BankSavingsArePositive2$

BankGetAccsInDebt

$BankGblSt$
$accs! : \mathbb{P}\ \mathbb{O}\ AccountCl$

$accs! = \{o : \mathbb{O}\ AccountCl \mid (stAccount\ o).balance < 0\}$

BankGetCustAccs

$BankGblSt$
$cNo? : CustID$
$accs! : \mathbb{P}\ \mathbb{O}\ AccountCl$

$accs! = \mathrm{ran}\,((\{o : \mathbb{O}\ CustomerCl \mid (stCustomer\ o).custNo = cNo?\} \lhd rHolds))$

BankGetAccountGivenAccNo

$BankGblSt$
$a! : \mathbb{O}\ AccountCl$
$aNo? : AccID$

$a! \in \{o : \mathbb{O}\ AccountCl \mid (stAccount\ o).accNo = aNo?\}$

SAccountOF

$SAccount$
$Account$
$o? : \mathbb{O}\ AccountCl$

$o? \in sAccount$

$\theta\ Account = stAccount\ o?$

$$SAccountGetBalance == \exists\ Account \bullet SAccountOF \land AccountGetBalance$$

$$\begin{array}{|l} BankAccGetBalance0 \\ \hline BankGblSt \\ aNo? : AccID \\ BankGetAccountGivenAccNo \\ SAccountGetBalance[a!/o?] \\ \hline \end{array}$$

$$BankAccGetBalance == \exists\ a! : \mathbb{O}\ AccountCl \bullet BankAccGetBalance0$$

A ZOO Toolkit

section *ZOO_Toolkit* **parents** *standard_toolkit*

$[OBJ]$

relation$(opt\ \_)$

$$
\begin{array}{|l}
[X] \\
\hline
opt\ \_ : \mathbb{P}(\mathbb{P}\ X) \\
the : \mathbb{P}\ X \pfun X \\
\hline
\forall\ S : \mathbb{P}\ X \bullet opt\ S \Leftrightarrow (\exists\ x : X \bullet S = \{x\}) \lor S = \{\} \\
\forall\ x : X \bullet the\ \{x\} = x \\
\hline
\end{array}
$$

$$
\begin{array}{|l}
[L] \\
\hline
\Sigma : (L \pfun \mathbb{Z}) \to \mathbb{Z} \\
\hline
\Sigma\ \{\} = 0 \\
\forall\ l : L;\ n : \mathbb{Z} \bullet \Sigma\ \{(l, n)\} = n \\
\forall\ l : L;\ n : \mathbb{Z};\ S : L \pfun \mathbb{Z} \mid \neg\ l \in \mathrm{dom}\ S \bullet \Sigma\ (\{(l, n)\} \cup S) = n + \Sigma\ S \\
\hline
\end{array}
$$

$MultTy ::= mm \mid mo \mid om \mid mzo \mid zom \mid mlo \mid lom \mid lolo \mid loo \mid olo \mid lozo \mid zolo \mid oo \mid zozo \mid zoo \mid ozo \mid ms \mid sm \mid ss \mid so \mid os \mid szo \mid zos$

relation$(mult\ \_)$

$[X, Y]$

$mult\_ : \mathbb{P}((X \leftrightarrow Y) \times \mathbb{P}\, X \times \mathbb{P}\, Y \times MultTy \times \mathbb{F}\, \mathbb{N} \times \mathbb{F}\, \mathbb{N})$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, mm, s_1, s_2)) \Leftrightarrow r \in sx \leftrightarrow sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, mo, s_1, s_2)) \Leftrightarrow r \in sx \to sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, om, s_1, s_2)) \Leftrightarrow r^{\sim} \in sy \to sx$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, mzo, s_1, s_2)) \Leftrightarrow r \in sx \pfun sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, zom, s_1, s_2)) \Leftrightarrow r^{\sim} \in sy \pfun sx$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, mlo, s_1, s_2)) \Leftrightarrow r \in sx \leftrightarrow sy \land \mathrm{dom}\ r = sx$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, lom, s_1, s_2)) \Leftrightarrow r \in sx \leftrightarrow sy \land \mathrm{ran}\ r = sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, lolo, s_1, s_2)) \Leftrightarrow r \in sx \leftrightarrow sy \land \mathrm{dom}\ r = sx \land \mathrm{ran}\ r = sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, loo, s_1, s_2)) \Leftrightarrow r \in sx \pfunsur sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, olo, s_1, s_2)) \Leftrightarrow r^{\sim} \in sy \pfunsur sx$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, lozo, s_1, s_2)) \Leftrightarrow r \in sx \pfunsur sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, zolo, s_1, s_2)) \Leftrightarrow r^{\sim} \in sy \pfunsur sx$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, oo, s_1, s_2)) \Leftrightarrow r \in sx \rightarrowtail sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, zozo, s_1, s_2)) \Leftrightarrow r \in sx \pinj sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, zoo, s_1, s_2)) \Leftrightarrow r \in sx \rightarrowtail sy$

$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$
$(mult(r, sx, sy, ozo, s_1, s_2)) \Leftrightarrow r^{\sim} \in sy \rightarrowtail sx$

$$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$$
$$(mult(r, sx, sy, ms, s_1, s_2)) \Leftrightarrow (mult(r, sx, sy, mm, s_1, s_2))$$
$$\land\ (\forall\, x : \mathrm{dom}\, r \bullet \#(\{x\} \lhd r) \in s_1)$$

$$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$$
$$(mult(r, sx, sy, sm, s_1, s_2)) \Leftrightarrow (mult(r, sx, sy, mm, s_1, s_2))$$
$$\land\ (\forall\, y : \mathrm{ran}\, r \bullet \#(r \rhd \{y\}) \in s_1)$$

$$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$$
$$(mult(r, sx, sy, ss, s_1, s_2)) \Leftrightarrow (mult(r, sx, sy, ms, s_1, \{\}))$$
$$\land\ (mult(r, sx, sy, sm, s_2, \{\}))$$

$$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$$
$$(mult(r, sx, sy, so, s_1, s_2)) \Leftrightarrow (mult(r, sx, sy, mo, s_1, s_2))$$
$$\land\ (mult(r, sx, sy, sm, s_1, s_2))$$

$$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$$
$$(mult(r, sx, sy, os, s_1, s_2)) \Leftrightarrow (mult(r, sx, sy, om, \{\}, \{\}))$$
$$\land\ (mult(r, sx, sy, ms, s_1, \{\}))$$

$$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$$
$$(mult(r, sx, sy, szo, s_1, s_2)) \Leftrightarrow (mult(r, sx, sy, mzo, \{\}, \{\}))$$
$$\land\ (mult(r, sx, sy, sm, s_1, \{\}))$$

$$\forall\, r : X \leftrightarrow Y;\ sx : \mathbb{P}\, X;\ sy : \mathbb{P}\, Y;\ s_1, s_2 : \mathbb{F}\, \mathbb{N} \bullet$$
$$(mult(r, sx, sy, zos, s_1, s_2)) \Leftrightarrow (mult(r, sx, sy, zom, \{\}, \{\}))$$
$$\land\ (mult(r, sx, sy, ms, s_1, \{\}))$$