MODULE *Assumes*

EXTENDS *Integers*, *Sequences*, *FiniteSets*, *Naturals*

You can run this as a model using "No behavior spec" mode

Single line comment

ASSUME
$\land$ TRUE $=$ TRUE
$\land$ $\neg$FALSE $=$ TRUE

$Jason \triangleq$ "jason"

ASSUME
$Jason =$ "jason"

$record \triangleq [name \mapsto$ "jason", $age \mapsto 2]$

ASSUME
$\land\ record.name =$ "jason"
$\land\ record.name \neq$ "foo"

ASSUME
$\forall F \in \{\text{TRUE}\} : F = F$

ASSUME
$\forall F \in \{\text{FALSE}\} : F = F$

ASSUME $\Rightarrow$ means "implies", as in $A \Rightarrow B$ is "(*not* A) OR B"
FALSE $\Rightarrow$ TRUE $=$ TRUE

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FALSE $\Rightarrow$ FALSE $=$ TRUE

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TRUE $\Rightarrow$ TRUE $=$ TRUE

ASSUME $\Rightarrow$ means "implies", as in $A \Rightarrow B$ is "(*not* A) OR B"
TRUE $\Rightarrow$ FALSE $=$ FALSE

ASSUME
TRUE $\equiv$ TRUE

ASSUME
FALSE $\equiv$ FALSE

ASSUME
$\forall F, G \in \{\text{TRUE}, \text{FALSE}\} : (F \Rightarrow G) \equiv \neg F \lor G$

Sets

ASSUME
$\{1, 2, 2, 2, 3\} = \{1, 2, 3\}$

ASSUME
$\{1, 2, 3, 3, 4, 4\} \setminus \{4\} = \{1, 2, 3\}$

ASSUME
$\{1, 2, 3\} \cup \{4, 5, 6\} = \{1, 2, 3, 4, 5, 6\}$

ASSUME
$\exists\, x \in \{3, 4, 5\} : x = 5$

ASSUME
$\{1, 3\} \subseteq \{3, 2, 1\}$

ASSUME
$(\forall\, i \in \{2, 4, 8\} : i\%2 = 0) = \text{TRUE}$

ASSUME
$(\{1, 2\} \in \text{SUBSET } \{1, 2, 3\}) = \text{TRUE}$

ASSUME
$(\{1, 2\} \in \text{SUBSET } (\{1, 3\} \cup \{4, 2\})) = \text{TRUE}$

ASSUME
$\land \{\text{“one”}, \text{“two”}\} \neq \{\}$
$\land \{\text{“one”}, \text{“two”}\} \neq \{\}$
$\land \{\text{“one”}, \text{“two”}\} \setminus \{\text{“one”}\} = \{\text{“two”}\}$

ASSUME
$\land \mathit{IsFiniteSet}(\{1, 2, 3\})$
$\land \neg \mathit{IsFiniteSet}(\mathit{Nat})$

ASSUME
$\land \mathit{Cardinality}(\{3, 4, 1\}) = 3$
$\land \mathit{Cardinality}(\{\}) = 0$

ASSUME
$\{x \in 1 \,..\, 8 : x\%2 = 1\} = \{1, 3, 5, 7\}$

ASSUME
$\{x \in 1 \,..\, 8 : x\%2 = 1 \land \neg(x\%5 = 0)\} = \{1, 3, 7\}$

ASSUME

$\{\langle x, y\rangle \in \{\langle 1, 2\rangle, \langle 4, 2\rangle\} : x > y\} = \{\langle 4, 2\rangle\}$

IF STATEMENTS

ASSUME

$\land\, (\textsc{if}\ 1 < 3\ \textsc{then}\ 1\ \textsc{else}\ \ 0) = 1$
$\land\, (\textsc{if}\ 1 < 3\ \textsc{then}\ \textsc{if}\ 2 > 1\ \textsc{then}\ 6\ \textsc{else}\ \ 4\ \textsc{else}\ \ 7) = 6$

LET STATEMENTS

ASSUME

$\land\ \textsc{let}\ x \triangleq 6\textsc{in}\quad x \in \{6, 7\}$

For all y in S such that y is not prime or y is less than or equal to x

$$IsPrime(x) \triangleq x > 1 \land \neg \exists\, d \in 2 \,..\, (x-1) : x \% d = 0$$

$LargestPrime(S) \triangleq \textsc{choose}\ x \in S :$
$\quad \land\, IsPrime(x)$
$\quad \land\, \forall\, y \in S :$
$\qquad IsPrime(y) \Rightarrow y \leq x$
$\quad$ or $y > x \Rightarrow \neg IsPrime(y)$

ASSUME

$LargestPrime(\{1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}) = 7$

$$IsEven(x) \triangleq x \% 2 = 0$$

$LargetEven(S) \triangleq \textsc{choose}\ x \in S :$
$\quad \land\, IsEven(x)$
$\quad \land\, \forall\, y \in S :$
$\qquad IsEven(y) \Rightarrow y \leq x$

ASSUME

$LargetEven(\{1, 2, 3, 4, 5, 5, 5\}) = 4$

ASSUME

$\forall\, x \in \{\} : \textsc{false}$

ASSUME

$\forall\, x \in \{\} : \textsc{true}$

ASSUME

$\forall x \in \{\} : 7$

ASSUME
$\forall x \in \{\text{FALSE}\} : \text{TRUE}$

ASSUME
$\forall x \in \{\text{TRUE}\} : \text{TRUE}$

ASSUME
$(\forall x \in \{\text{FALSE}\} : \text{FALSE}) = \text{FALSE}$

$$IsCommutative(Op(\_, \_), S) \triangleq \forall x \in S : \forall y \in S : Op(x, y) = Op(y, x)$$

$$Add(x, y) \triangleq x + y$$
$$Divide(x, y) \triangleq x \div y$$

ASSUME
$IsCommutative(Add, \{1, 2, 3\})$

ASSUME
$IsCommutative(Divide, \{1, 2, 3\}) = \text{FALSE}$

ASSUME
$IsCommutative(Divide, \{1, 2, 3\}) \Rightarrow \text{FALSE}$

ASSUME
$IsCommutative(Divide, \{1, 2, 3\}) \Rightarrow \text{TRUE}$

ASSUME
$\neg IsCommutative(Divide, \{1, 2, 3\})$

ASSUME
$\neg \exists x \in \{1, 3, 5\} : IsEven(x)$

$Pick(S) \triangleq$ CHOOSE $s \in S : \text{TRUE}$
RECURSIVE $SetReduce(\_, \_, \_)$
$SetReduce(Op(\_, \_), S, value) \triangleq$ IF $S = \{\}$ THEN $value$
ELSE LET $s \triangleq Pick(S)$
IN $SetReduce(Op, S \setminus \{s\}, Op(s, value))$

$Sum(S) \triangleq$ LET $\_op(a, b) \triangleq a + b$
IN $SetReduce(\_op, S, 0)$

ASSUME
$Sum(\{1, 2, 3\}) = 6$

$Min(S) \triangleq$ CHOOSE $x \in S : \forall y \in S : x \leq y$

ASSUME
$Min(\{5, 3, 7, 10, 2, 9\}) = 2$

$Max(S) \triangleq \text{CHOOSE } x \in S : \forall y \in S : x \geq y$

ASSUME
$Max(\{4, 6, 1, 2, 9, 3, 5\}) = 9$

SEQUENCES

$Seq(S)$ is the set of all finite sequences of set S.

ASSUME
$\land \langle\rangle \in Seq(\{1, 0\})$
$\land \langle 1 \rangle \in Seq(\{1, 0\})$
$\land \langle 0 \rangle \in Seq(\{1, 0\})$
$\land \langle 0, 0 \rangle \in Seq(\{1, 0\})$
$\land \langle 0, 1 \rangle \in Seq(\{1, 0\})$
$\land \langle 1, 0 \rangle \in Seq(\{1, 0\})$
$\land \langle 1, 1 \rangle \in Seq(\{1, 0\})$

ASSUME
$\land \{\langle 0 \rangle\} \subseteq Seq(\{0, 1\})$

ASSUME
$\langle 1, 2, 3 \rangle \in Seq(\{1, 2, 3\})$

ASSUME
$\langle 4 \rangle \notin Seq(\{1, 2, 3\})$

ASSUME
$\langle 1, 2, 3, 4 \rangle \notin Seq(\{1, 2, 3\})$

ASSUME
$\land \langle 1, 2 \rangle \circ \langle 3, 4 \rangle = \langle 1, 2, 3, 4 \rangle$

$LessThanThree(x) \triangleq x < 3$

ASSUME
$\land Head(\langle 2, 3, 4 \rangle) = 2$
$\land Tail(\langle 2, 3, 4 \rangle) = \langle 3, 4 \rangle$
$\land Append(\langle 1, 2 \rangle, 3) = \langle 1, 2, 3 \rangle$
$\land Len(\langle 5, 2, 1 \rangle) = 3$
$\land SubSeq(\langle 9, 3, 5, 6 \rangle, 1, 3) = \langle 9, 3, 5 \rangle$
$\land SelectSeq(\langle 5, 2, 9 \rangle, LessThanThree) = \langle 2 \rangle$

TUPLES

$chessboard\_squares \triangleq \{\text{"a"}, \text{"b"}, \text{"c"}, \text{"d"}, \text{"e"}, \text{"f"}, \text{"g"}, \text{"h"}\} \times (1 \, .. \, 8)$

ASSUME
$\land \langle \text{"a"}, 1 \rangle \in chessboard\_squares$
$\land \langle \text{"a"}, 2 \rangle \in chessboard\_squares$
$\land \langle \text{"a"}, 3 \rangle \in chessboard\_squares$
$\land \langle \text{"a"}, 4 \rangle \in chessboard\_squares$

$jason \triangleq (1 \, .. \, 2) \times \{\text{"Jason"}, \text{"DeBolt"}\}$

ASSUME
$\land \langle 1, \text{"Jason"} \rangle \in jason$
$\land \langle 2, \text{"Jason"} \rangle \in jason$
$\land \langle 1, \text{"DeBolt"} \rangle \in jason$
$\land \langle 2, \text{"DeBolt"} \rangle \in jason$

$digits \triangleq \{\text{"one"}, \text{"three"}\} \times \{\text{"two"}, \text{"four"}\}$

ASSUME
$\land \langle \text{"one"}, \text{"two"} \rangle \in digits$
$\land \langle \text{"three"}, \text{"four"} \rangle \in digits$

ASSUME
$\land \langle \text{"one"}, \text{"two"} \rangle \circ \langle \text{"three"} \rangle = \langle \text{"one"}, \text{"two"}, \text{"three"} \rangle$
$\land \langle \text{"one"}, \text{"two"} \rangle \circ \langle \text{"three"} \rangle = \langle \text{"one"}, \text{"two"}, \text{"three"} \rangle$

$A \triangleq \{1\}$
$B \triangleq \{2\}$
$C \triangleq \{3\}$

ASSUME
$\land \langle 1, 2, 3 \rangle \in A \times B \times C$
$\land \langle 1, \langle 2, 3 \rangle \rangle \in A \times (B \times C)$
$\land \langle \langle 1, 2 \rangle, 3 \rangle \in (A \times B) \times C$

Structures.

Structures are hashes. They have keys and values. You specify them as [key $\mapsto$ *value*] and query them with either ["key"] or *.key*. Both are legal and valid.

$SomeHash \triangleq [x \mapsto 1, \; y \mapsto \{2, 3\}]$

ASSUME
$\land SomeHash.x = 1$

$\land \ SomeHash[\text{"x"}] = 1$
$\land \ SomeHash.y = \{2, 3\}$
$\land \ SomeHash[\text{"y"}] = \{2, 3\}$
$\land \ \textsc{domain} \ SomeHash = \{\text{"x"}, \text{"y"}\}$

$SomeHash2 \triangleq [x \mapsto 1, \ y \mapsto \{2, 3\}]$
$SomeHash3 \triangleq [SomeHash2 \ \textsc{except} \ ![\text{"x"}] = 6]$

ASSUME
$\land \ SomeHash3.x = 6$

Aside from that, there's one extra trick structures have. Instead of key $\mapsto$ *value*, you can do key : set. In that case, instead of a structure you get the set of all structures which have, for each given key, a value in the set.

$SetOfStructures \triangleq [x : \{1\}, \ y : \{2, 3, 4\}]$

If you use : syntax and any of the values are not sets, then the entire construct is invalid. In other words, while [a: {1}, *b*: {2, 3}] is the above set, [a: 1, *b*: {2, 3}] will throw an error if you try to use it.

ASSUME
$\land \ [x \mapsto 1, \ y \mapsto 2] \in SetOfStructures$
$\land \ [x \mapsto 1, \ y \mapsto 3] \in SetOfStructures$
$\land \ [x \mapsto 1, \ y \mapsto 4] \in SetOfStructures$

Functions

ASSUME
$\land \ [\{1, 2, 3\} \rightarrow \{\text{"done"}\}] = \{\langle \text{"done"}, \text{"done"}, \text{"done"} \rangle\}$ Turns a function into a set of tuples
$\land \ [\{\text{"a"}, \text{"b"}\} \rightarrow \{\text{"done"}\}] = \{[a \mapsto \text{"done"}, \ b \mapsto \text{"done"}]\}$ Turns a function into a set of structs
$\land \ [\{\text{"a"}, \text{"b"}\} \rightarrow \{\text{"done"}, \text{"pc"}\}] = \{[a \mapsto \text{"done"}, \ b \mapsto \text{"done"}],$ Turns a function into a set of structs
$[a \mapsto \text{"done"}, \ b \mapsto \text{"pc"}],$
$[a \mapsto \text{"pc"}, \ b \mapsto \text{"done"}],$
$[a \mapsto \text{"pc"}, \ b \mapsto \text{"pc"}]\}$
$\land \ [\{\text{"p1"}, \text{"p2"}\} \rightarrow \{\text{"a"}, \text{"b"}, \text{"c"}, \text{"done"}\}] = \{[p1 \mapsto \text{"a"}, \ p2 \mapsto \text{"a"}],$
$[p1 \mapsto \text{"a"}, \ p2 \mapsto \text{"b"}],$
$[p1 \mapsto \text{"a"}, \ p2 \mapsto \text{"c"}],$
$[p1 \mapsto \text{"a"}, \ p2 \mapsto \text{"done"}],$
$[p1 \mapsto \text{"b"}, \ p2 \mapsto \text{"a"}],$
$[p1 \mapsto \text{"b"}, \ p2 \mapsto \text{"b"}],$
$[p1 \mapsto \text{"b"}, \ p2 \mapsto \text{"c"}],$
$[p1 \mapsto \text{"b"}, \ p2 \mapsto \text{"done"}],$
$[p1 \mapsto \text{"c"}, \ p2 \mapsto \text{"a"}],$
$[p1 \mapsto \text{"c"}, \ p2 \mapsto \text{"b"}],$
$[p1 \mapsto \text{"c"}, \ p2 \mapsto \text{"c"}],$
$[p1 \mapsto \text{"c"}, \ p2 \mapsto \text{"done"}],$

$$[p1 \mapsto \text{“done”},\ p2 \mapsto \text{“a”}],$$
$$[p1 \mapsto \text{“done”},\ p2 \mapsto \text{“b”}],$$
$$[p1 \mapsto \text{“done”},\ p2 \mapsto \text{“c”}],$$
$$[p1 \mapsto \text{“done”},\ p2 \mapsto \text{“done”}]\}$$

$$\begin{aligned}
\wedge\, [\{\text{“p1”},\ \text{“p2”},\ \text{“p3”}\} \rightarrow \{\text{“a”},\ \text{“b”},\ \text{“c”}\}] = \ \{&[p1 \mapsto \text{“a”},\ p2 \mapsto \text{“a”},\ p3 \mapsto \text{“a”}],\\
&[p1 \mapsto \text{“a”},\ p2 \mapsto \text{“a”},\ p3 \mapsto \text{“b”}],\\
&[p1 \mapsto \text{“a”},\ p2 \mapsto \text{“a”},\ p3 \mapsto \text{“c”}],\\
&[p1 \mapsto \text{“a”},\ p2 \mapsto \text{“b”},\ p3 \mapsto \text{“a”}],\\
&[p1 \mapsto \text{“a”},\ p2 \mapsto \text{“b”},\ p3 \mapsto \text{“b”}],\\
&[p1 \mapsto \text{“a”},\ p2 \mapsto \text{“b”},\ p3 \mapsto \text{“c”}],\\
&[p1 \mapsto \text{“a”},\ p2 \mapsto \text{“c”},\ p3 \mapsto \text{“a”}],\\
&[p1 \mapsto \text{“a”},\ p2 \mapsto \text{“c”},\ p3 \mapsto \text{“b”}],\\
&[p1 \mapsto \text{“a”},\ p2 \mapsto \text{“c”},\ p3 \mapsto \text{“c”}],\\
&[p1 \mapsto \text{“b”},\ p2 \mapsto \text{“a”},\ p3 \mapsto \text{“a”}],\\
&[p1 \mapsto \text{“b”},\ p2 \mapsto \text{“a”},\ p3 \mapsto \text{“b”}],\\
&[p1 \mapsto \text{“b”},\ p2 \mapsto \text{“a”},\ p3 \mapsto \text{“c”}],\\
&[p1 \mapsto \text{“b”},\ p2 \mapsto \text{“b”},\ p3 \mapsto \text{“a”}],\\
&[p1 \mapsto \text{“b”},\ p2 \mapsto \text{“b”},\ p3 \mapsto \text{“b”}],\\
&[p1 \mapsto \text{“b”},\ p2 \mapsto \text{“b”},\ p3 \mapsto \text{“c”}],\\
&[p1 \mapsto \text{“b”},\ p2 \mapsto \text{“c”},\ p3 \mapsto \text{“a”}],\\
&[p1 \mapsto \text{“b”},\ p2 \mapsto \text{“c”},\ p3 \mapsto \text{“b”}],\\
&[p1 \mapsto \text{“b”},\ p2 \mapsto \text{“c”},\ p3 \mapsto \text{“c”}],\\
&[p1 \mapsto \text{“c”},\ p2 \mapsto \text{“a”},\ p3 \mapsto \text{“a”}],\\
&[p1 \mapsto \text{“c”},\ p2 \mapsto \text{“a”},\ p3 \mapsto \text{“b”}],\\
&[p1 \mapsto \text{“c”},\ p2 \mapsto \text{“a”},\ p3 \mapsto \text{“c”}],\\
&[p1 \mapsto \text{“c”},\ p2 \mapsto \text{“b”},\ p3 \mapsto \text{“a”}],\\
&[p1 \mapsto \text{“c”},\ p2 \mapsto \text{“b”},\ p3 \mapsto \text{“b”}],\\
&[p1 \mapsto \text{“c”},\ p2 \mapsto \text{“b”},\ p3 \mapsto \text{“c”}],\\
&[p1 \mapsto \text{“c”},\ p2 \mapsto \text{“c”},\ p3 \mapsto \text{“a”}],\\
&[p1 \mapsto \text{“c”},\ p2 \mapsto \text{“c”},\ p3 \mapsto \text{“b”}],\\
&[p1 \mapsto \text{“c”},\ p2 \mapsto \text{“c”},\ p3 \mapsto \text{“c”}]\}
\end{aligned}$$

Type Composition

Any type can be squeezed inside any other type.

$$crazy \triangleq [a \mapsto \{\langle\rangle,\ \langle 1,\ 2,\ 3\rangle,\ \langle 3,\ 2,\ 1\rangle\},\ b \mapsto \langle [a \mapsto 0]\rangle]$$

A function of keys mapping to sets of tuples or of keys mapping to tuples of functions.

ASSUME

$crazy.b[1].a = 0$ Remember that tuples are 1 indexed.

$$blah \triangleq [name \mapsto \text{“jason”},\ hobbies \mapsto [outdoor \mapsto \langle \text{“cycling”},\ \text{“hiking”}\rangle,\ indoor \mapsto \langle \text{“reading”},\ \text{“watching tv”}\rangle]]$$

ASSUME

$\land\ blah.name = \text{"jason"}$
$\land\ blah.hobbies.outdoor[1] = \text{"cycling"}$

$sing \triangleq \langle\langle 4, 5, 6\rangle, \langle\rangle, \langle\rangle\rangle$

ASSUME
DOMAIN $sing = \{1, 2, 3\}$

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