

# Assignment 3, Part 1, Specification

SFWR ENG 2AA4

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This Module Interface Specification (MIS) document contains modules, types and methods for implementing the state of a game of Forty Thieves solitaire.

In applying the specification, there will be cases that involve undefinedness. We will interpret undefinedness following [1]:

If  $p : \alpha_1 \times \dots \times \alpha_n \rightarrow \mathbb{B}$  and any of  $a_1, \dots, a_n$  is undefined, then  $p(a_1, \dots, a_n)$  is False. For instance, if  $p(x) = 1/x < 1$ , then  $p(0) = \text{False}$ . In the language of our specification, if evaluating an expression generates an exception, then the value of the expression is undefined.

[The parts that you need to fill in are marked by comments, like this one. In several of the modules local functions are specified. You can use these local functions to complete the missing specifications. —SS]

[As you edit the tex source, please leave the `wss` comments in the file. Put your answer **before** the comment. This will make grading easier. —SS]

## References

- [1] William M. Farmer. Formalizing undefinedness arising in calculus. In David Basin and Michaël Rusinowitch, editors, *Automated Reasoning*, pages 475–489, Berlin, Heidelberg, 2004. Springer Berlin Heidelberg.

# Card Types Module

## Module

CardTypes

## Uses

N/A

## Syntax

### Exported Constants

TOTAL\_CARDS = 104

ACE = 1

JACK = 11

QUEEN = 12

KING = 13

### Exported Types

SuitT = {Heart, Diamond, Club, Spade}

RankT = [1..13]

CategoryT = {Tableau, Foundation, Deck, Waste}

CardT = tuple of (s: SuitT, r: RankT)

### Exported Access Programs

None

## Semantics

### State Variables

None

### State Invariant

None

## Generic Stack Module

### Generic Template Module

Stack(T)

### Uses

N/A

### Syntax

#### Exported Types

Stack(T) = ?

#### Exported Constants

None

#### Exported Access Programs

Routine name	In	Out	Exceptions
new Stack	seq of T	Stack	none
push	T	Stack	none
pop		Stack	out_of_range
top		T	out_of_range
size		N	
toSeq		seq of T	

### Semantics

#### State Variables

$S$ : seq of T

#### State Invariant

None

## Assumptions & Design Decisions

- The `Stack(T)` constructor is called for each object instance before any other access routine is called for that object. The constructor can only be called once.
- Though the `toSeq()` method violates the essential property of the stack object, since this could be achieved by calling `top` and `pop` many times, this method is provided as a convenience to the client. In fact, it increases the property of separation of concerns since this means that the client does not have to worry about details of building their own sequence from the sequence of pops.

## Access Routine Semantics

`new Stack(s)`:

- transition:  $S := s$
- output:  $out := self$
- exception: none

`push(e)`:

- output:  $out := new\ Stack(S \parallel \langle e \rangle)$
- exception: none

`pop()`:

- output:  $out := new\ Stack(S[0..|S| - 2])$
- exception:  $exc := (|S| = 0 \Rightarrow out\_of\_range)$

`top()`:

- output:  $out := S[|S| - 1]$
- exception:  $exc := (|S| = 0 \Rightarrow out\_of\_range)$

`size()`:

- output:  $out := |S|$
- exception: None

`toSeq()`:

- output:  $out := S$
- exception: None

## CardStack Module

### Template Module

CardStackT is Stack(CardT)

# Game Board ADT Module

## Template Module

BoardT

## Uses

CardTypes

CardStack

## Syntax

### Exported Access Programs

Routine name	In	Out	Exceptions
new BoardT	seq of CardT	BoardT	invalid_argument
is_valid_tab_mv	CategoryT, $\mathbb{N}$ , $\mathbb{N}$	$\mathbb{B}$	out_of_range
is_valid_waste_mv	CategoryT, $\mathbb{N}$	$\mathbb{B}$	invalid_argument, out_of_range
is_valid_deck_mv		$\mathbb{B}$	
tab_mv	CategoryT, $\mathbb{N}$ , $\mathbb{N}$		invalid_argument
waste_mv	CategoryT, $\mathbb{N}$		invalid_argument
deck_mv			invalid_argument
get_tab	$\mathbb{N}$	CardStackT	out_of_range
get_foundation	$\mathbb{N}$	CardStackT	out_of_range
get_deck		CardStackT	
get_waste		CardStackT	
valid_mv_exists		$\mathbb{B}$	
is_win_state		$\mathbb{B}$	

## Semantics

### State Variables

$T$ : SeqCrdStckT # *Tableau*

$F$ : SeqCrdStckT # *Foundation*

$D$ : CardStackT # *Deck*

$W$ : CardStackT # *Waste*

## State Invariant

$$|T| = 10$$

$$|F| = 8$$

$$\text{cnt\_cards}(T, F, D, W, \lambda c : \text{True}) = \text{TOTAL\_CARDS}$$

$$\text{two\_decks}(T, F, D, W) \# \text{ each card appears twice in the combined deck}$$

## Assumptions & Design Decisions

- The BoardT constructor is called before any other access routine is called on that instance. Once a BoardT has been created, the constructor will not be called on it again.
- The Foundation stacks must start with an ace, but any Foundation stack can start with any suit. Once an Ace of that suit is placed there, this Foundation stack becomes that type of stack and only those type of cards can be placed there.
- Once a card has been moved to a Foundation stack, it cannot be moved again.
- For better scalability, this module is specified as an Abstract Data Type (ADT) instead of an Abstract Object. This would allow multiple games to be created and tracked at once by a client.
- The getter function is provided, though violating the property of being essential, to give a would-be view function easy access to the state of the game. This ensures that the model is able to be easily integrated with a game system in the future. Although outside of the scope of this assignment, the view function could be part of a Model View Controller design pattern implementation (<https://blog.codinghorror.com/understanding-model-view-controller/>)
- A function will be available to create a double deck of cards that consists of a random permutation of two regular decks of cards (TOTAL\_CARDS cards total). This double deck of cards can be used to build the game board.

## Access Routine Semantics

BoardT(*deck*):

- transition:  
$$T, F, D, W := \text{tab\_deck}(\text{deck}[0..39]), \text{init\_seq}(8), \text{CardStackT}(\text{deck}[40..103]), \text{CardStackT}(\langle \rangle)$$
- exception:  $\text{exc} := (\neg \text{two\_decks}(\text{init\_seq}(10), \text{init\_seq}(8), \text{CardStackT}(\text{deck}), \text{CardStackT}(\langle \rangle))) \Rightarrow \text{invalid\_argument}$

is\_valid\_tab\_mv( $c, n_0, n_1$ ):

- output:

	$out :=$
$c = \text{Tableau}$	$\text{valid\_tab\_tab}(n_0, n_1)$
$c = \text{Foundation}$	$\text{valid\_tab\_foundation}(n_0, n_1)$
$c = \text{Deck}$	False
$c = \text{Waste}$	False

- exception:

	$exc :=$
$c = \text{Tableau} \wedge \neg(\text{is\_valid\_pos}(\text{Tableau}, n_0) \wedge \text{is\_valid\_pos}(\text{Tableau}, n_1))$	out_of_range
$c = \text{Foundation} \wedge \neg(\text{is\_valid\_pos}(\text{Tableau}, n_0) \wedge \text{is\_valid\_pos}(\text{Foundation}, n_1))$	out_of_range

is\_valid\_waste\_mv( $c, n$ ):

- output:

	$out :=$
$c = \text{Tableau}$	$\text{valid\_waste\_tab}(n)$
$c = \text{Foundation}$	$\text{valid\_waste\_foundation}(n)$
$c = \text{Deck}$	False
$c = \text{Waste}$	False

- exception:

	$exc :=$
$W.\text{size}() = 0$	invalid_argument
$c = \text{Tableau} \wedge \neg \text{is\_valid\_pos}(\text{Tableau}, n)$	out_of_range
$c = \text{Foundation} \wedge \neg \text{is\_valid\_pos}(\text{Foundation}, n)$	out_of_range

is\_valid\_deck\_mv():

- output:  $out := D.\text{size}() > 0$
- exception: None

tab\_mv( $c, n_0, n_1$ ):

- transition:

$c = \text{Tableau}$	$T[n_0], T[n_1] := T[n_0].\text{pop}(), T[n_1].\text{push}(T[n_0].\text{top}())$
$c = \text{Foundation}$	$T[n_0], F[n_1] := T[n_0].\text{pop}(), F[n_1].\text{push}(T[n_0].\text{top}())$

- exception:  $exc := (\neg \text{is\_valid\_tab\_mv}(c, n_0, n_1) \Rightarrow \text{invalid\_argument})$



waste\_mv( $c, n$ ):

- transition:

$c = \text{Tableau}$	$W, T[n] := W.\text{pop}(), T[n].\text{push}(W.\text{top}())$
$c = \text{Foundation}$	$W, F[n] := W.\text{pop}(), F[n].\text{push}(W.\text{top}())$

- exception:  $exc := (\neg \text{is\_valid\_waste\_mv}(c, n) \Rightarrow \text{invalid\_argument})$

deck\_mv():

- transition:  $D, W := D.\text{pop}(), W.\text{push}(D.\text{top}())$
- exception:  $exc := (\neg \text{is\_valid\_deck\_mv}() \Rightarrow \text{invalid\_argument})$

get\_tab( $i$ ):

- output:  $out := T[i]$
- exception:  $exc : (\neg \text{is\_valid\_pos}(\text{Tableau}, i) \Rightarrow \text{out\_of\_range})$

get\_foundation( $i$ ):

- output:  $out := F[i]$
- exception:  $exc : (\neg \text{is\_valid\_pos}(\text{Foundation}, i) \Rightarrow \text{out\_of\_range})$

get\_deck():

- output:  $out := D$
- exception: None

get\_waste():

- output:  $out := W$
- exception: None

valid\_mv\_exists():

- output:  $out := \text{valid\_tab\_mv} \vee \text{valid\_waste\_mv} \vee \text{is\_valid\_deck\_mv}()$  where

$\text{valid\_tab\_mv} \equiv (\exists c : \text{CategoryT}, n_0 : \mathbb{N}, n_1 : \mathbb{N} | c \in \{\text{Tableau}, \text{Foundation}\} \wedge \text{is\_valid\_pos}(\text{Tableau}, n_0) \wedge \text{is\_valid\_pos}(c, n_1) : \text{is\_valid\_tab\_mv}(c, n_0, n_1))$

$\text{valid\_waste\_mv} \equiv (\exists c : \text{CategoryT}, n : \mathbb{N} | c \in \{\text{Tableau}, \text{Foundation}\} \wedge \text{is\_valid\_pos}(c, n) : \text{is\_valid\_waste\_mv}(c, n))$

- exception: None

is\_win\_state():

- output:  $out := (\forall i : \mathbb{N} | i \in [0..7] : F[i].size() > 0 \wedge F[i].top().r = \text{KING})$
- exception: None

## Local Types

SeqCrdStckT = seq of CardStackT

## Local Functions

two\_decks : SeqCrdStckT  $\times$  SeqCrdStckT  $\times$  CardStackT  $\times$  CardStackT  $\rightarrow \mathbb{B}$

two\_decks( $T, F, D, W$ )  $\equiv$

$(\forall st : \text{SuitT}, rk : \text{RankT} | st \in \text{SuitT} \wedge rk \in \text{RankT} : \text{cnt\_cards}(T, F, D, W, \lambda c : c.s = st \wedge c.r = rk) = 2)$

cnt\_cards\_seq : SeqCrdStckT  $\times$  (CardT  $\rightarrow \mathbb{B}$ )  $\rightarrow \mathbb{N}$

cnt\_cards\_seq( $S, f$ )  $\equiv (+s : \text{CardStackT} | s \in S : \text{cnt\_cards\_stack}(s, f))$

cnt\_cards\_stack : CardStackT  $\times$  (CardT  $\rightarrow \mathbb{B}$ )  $\rightarrow \mathbb{N}$

cnt\_cards\_stack( $s, f$ )  $\equiv (+c : \text{CardT} | c \in s.\text{toSeq}() \wedge f(c) : 1)$

cnt\_cards : SeqCrdStckT  $\times$  SeqCrdStckT  $\times$  CardStackT  $\times$  CardStackT  $\times$  (CardT  $\rightarrow \mathbb{B}$ )  $\rightarrow \mathbb{N}$

cnt\_cards( $T, F, D, W, f$ )  $\equiv \text{cnt\_cards\_seq}(T, f) + \text{cnt\_cards\_seq}(F, f) + \text{cnt\_cards\_stack}(D, f) + \text{cnt\_cards\_stack}(W, f)$

init\_seq :  $\mathbb{N} \rightarrow \text{SeqCrdStckT}$

init\_seq( $n$ )  $\equiv s$  such that  $(|s| = n \wedge (\forall i \in [0..n-1] : s[i] = \text{CardStackT}(\langle \rangle)))$

tab\_deck : (seq of CardT)  $\rightarrow \text{SeqCrdStckT}$

tab\_deck( $deck$ )  $\equiv T$  such that  $(\forall i : \mathbb{N} | i \in [0..9] : T[i].\text{toSeq}() = \text{deck}[4i..4(i+1)-1])$

is\_valid\_pos: CategoryT  $\times \mathbb{N} \rightarrow \mathbb{B}$

is\_valid\_pos( $c, n$ )  $\equiv (c = \text{Tableau} \Rightarrow n \in [0..9] | c = \text{Foundation} \Rightarrow n \in [0..7] | \text{True} \Rightarrow \text{True})$

valid\_tab\_tab:  $\mathbb{N} \times \mathbb{N} \rightarrow \mathbb{B}$

valid\_tab\_tab( $n_0, n_1$ )  $\equiv$

$T[n_0].size() > 0$	$T[n_1].size() > 0$	$\text{tab\_placeable}(T[n_0].top(), T[n_1].top())$
	$T[n_1].size() = 0$	True
$T[n_0].size() = 0$	$T[n_1].size() > 0$	False
	$T[n_1].size() = 0$	False

$\text{valid\_tab\_foundation}: \mathbb{N} \times \mathbb{N} \rightarrow \mathbb{B}$

$\text{valid\_tab\_foundation}(n_0, n_1) \equiv$

$T[n_0].size() > 0$	$F[n_1].size() > 0$	$\text{foundation\_placeable}(T[n_0].top(), F[n_1].top())$
	$F[n_1].size() = 0$	$T[n_0].top().r = \text{ACE}$
$T[n_0].size() = 0$	$F[n_1].size() > 0$	False
	$F[n_1].size() = 0$	False

$\text{valid\_waste\_tab}: \mathbb{N} \rightarrow \mathbb{B}$

$\text{valid\_waste\_tab}(n) \equiv$

$T[n].size() > 0$	$\text{tab\_placeable}(W.top(), T[n].top())$
$T[n].size() = 0$	True

$\text{valid\_waste\_foundation}: \mathbb{N} \rightarrow \mathbb{B}$

$\text{valid\_waste\_foundation}(n) \equiv$

$F[n].size() > 0$	$\text{foundation\_placeable}(W.top(), F[n].top())$
$F[n].size() = 0$	$W.top().r = \text{ACE}$

$\text{tab\_placeable}: \text{CardT} \times \text{CardT} \rightarrow \mathbb{B}$

$\text{tab\_placeable}(c, d) \equiv c.s = d.s \wedge c.r = d.r - 1$

$\text{foundation\_placeable}: \text{CardT} \times \text{CardT} \rightarrow \mathbb{B}$

$\text{foundation\_placeable}(c, d) \equiv c.s = d.s \wedge c.r = d.r + 1$

## Critique of Design

[Write a critique of the interface for the modules in this project. Is there anything missing? Is there anything you would consider changing? Why? —SS]

Potential discussion points:

- The stack module provides a toSeq module that violates essentiality. To address this, another module could be built to provide the toSeq service through a function that takes a stack as input and return a sequence.