

# 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.

[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]

# 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 = ? [\[What should be written here —SS\]](#)

#### 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

$S$ : sequence of T [\[What is the type of the state variable? —SS\]](#)

#### 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:  $new\ Stack(S[0..|S| - 2])$  [What should go here? —SS]
- exception:  $|S| = 0 \implies out\_of\_range$  [What should go here? —SS]

`top()`:

- output:  $out := S[|S| - 1]$
- exception:  $|S| = 0 \implies out\_of\_range$  [What should go here? —SS]

`size()`:

- output:  $out := |S|$  [What should go here? —SS]
- exception: None

`toSeq()`:

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

## CardStack Module

### Template Module

CardStackT is a Stack(CardT) [\[What should go here? —SS\]](#)

# 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

$|T| = 10$ [What goes here? — — — *SS*]

$|F| = 8$ [What goes here? — — — *SS*]

$\text{cnt\_cards}(T, F, D, W, f \text{ [What goes here? —SS]}) = \text{TOTAL\_CARDS}$

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

## 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

GameBoard(*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:

	$out :=$
$c = \text{Tableau}$	valid_tab_tab( $n_0, n_1$ )
$c = \text{Foundation}$	valid_tab_foundation( $n_0, n_1$ )
$c = \text{Deck}$	false [What goes here? —SS]
$c = \text{Waste}$	false [What goes here? —SS]

- 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:

	$out :=$
$c = \text{Tableau}$	valid_waste_tab( $n$ )
$c = \text{Foundation}$	valid_waste_foundation( $n$ )
$c = \text{Deck}$	false [What goes here? —SS]
$c = \text{Waste}$	false [What goes here? —SS]

- 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:  $|D| > 0$  [What goes here? The deck moves involves moving a card from the deck stack to the waste stack. —SS]
- exception: None

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

- transition:

$c = \text{Tableau}$	$T[n_0], T[n_1] := T[n_0].\text{pop}(), T[n_1].\text{push}(T[n_0].\text{top}())$ [What goes here? —SS]
$c = \text{Foundation}$	$T[n_0], F[n_1] := T[n_0].\text{pop}(), F[n_1].\text{push}(F[n_0].\text{top}())$ [What goes here? —SS]



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

waste\_mv( $c, n$ ):

- transition:

$c = \text{Tableau}$	$W, T[n] := W.\text{pop}(), T[n].\text{push}(W.\text{top}())$ <a href="#">[What goes here? —SS]</a>
$c = \text{Foundation}$	$W, F[n] := W.\text{pop}(), F[n].\text{push}(W.\text{top}())$ <a href="#">[What goes here? —SS]</a>

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

deck\_mv():

- transition:  $D, W := D.\text{pop}(), W.\text{push}(D.\text{top}())$  [\[What goes here? —SS\]](#)
- 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

$\text{valid\_tab\_mv} \equiv (\exists c : \text{CategoryT}, n_0 : \mathbb{N}, n_1 : \mathbb{N} | n_0 = 0..|c| - 1 \wedge n_1 = 0..|c| - 1$   
 $\text{[What goes here? — SS]} : \text{is\_valid\_tab\_mv}(c, n_0, n_1))$

$\text{valid\_waste\_mv} \equiv (\exists c : \text{CategoryT}, n : \mathbb{N} | n = 0..|c| \text{[What goes here? — SS]} :$   
 $\text{is\_valid\_waste\_mv}(c, n))$

- exception: None

$\text{is\_win\_state}()$ :

- output:  $\text{cnt\_cards\_seq}(T, \lambda t \rightarrow \text{True}) = 104$   $\text{[What goes here? — SS]}$
- exception: None

## Local Types

$\text{SeqCrdsStckT} = \text{seq of CardStackT}$

## Local Functions

$\text{two\_decks} : \text{SeqCrdsStckT} \times \text{SeqCrdsStckT} \times \text{CardStackT} \times \text{CardStackT} \rightarrow \mathbb{N}$

$\text{two\_decks}(T, F, D, W) \equiv \text{[This function returns True if there is two of each card in the game — SS]}$

$(\forall st : \text{SuitT}, rk : \text{RankT} | st \in \text{SuitT} \wedge rk \in \text{RankT} : \text{cnt\_cards}(T, F, D, W, \lambda t \rightarrow t[0] = st \wedge t[1] = rk) = 2)$

$\text{[What goes here? — SS]}$

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

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

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

$\text{cnt\_cards\_stack}(S, f) \equiv (+t : \text{CardT} | t \in S : f(t))$   $\text{[What goes here? — SS]}$

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

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

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

tab\_deck( $deck$ )  $\equiv T$  such that ( $\forall i : \mathbb{N} | i \in [0..9] : T[i].\text{toSeq}() = \text{deck}[4*i+3[\text{What goes here?} \text{---SS}]]$ )

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

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 ( $n_0, n_1$ )  $\equiv$

$T[n_0].\text{size}() > 0$	$T[n_1].\text{size}() > 0$	$\text{tab\_placeable}(n_0, n_1)$ [What goes here? —SS]
	$T[n_1].\text{size}() = 0$	True [What goes here? —SS]
$T[n_0].\text{size}() = 0$	$T[n_1].\text{size}() > 0$	False [What goes here? —SS]
	$T[n_1].\text{size}() = 0$	False [What goes here? —SS]

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

valid\_tab\_foundation( $n_0, n_1$ )  $\equiv$  [What goes here? You may need a table? —SS]

$T[n_0].\text{size}() > 0$	$F[n_1].\text{size}() > 0$	$\text{foundation\_placeable}(n_0, n_1)$ [What goes here? —SS]
	$F[n_1].\text{size}() = 0$	True [What goes here? —SS]
$T[n_0].\text{size}() = 0$	$F[n_1].\text{size}() > 0$	False [What goes here? —SS]
	$F[n_1].\text{size}() = 0$	False [What goes here? —SS]

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

valid\_waste\_tab ( $n$ )  $\equiv$

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

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

valid\_waste\_foundation ( $n$ )  $\equiv$

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

tab\_placeable:  $\mathbb{N} \times \mathbb{N} \rightarrow \mathbb{B}$  [Complete this specification —SS]

tab\_placeable ( $n_0, n_1$ )  $\equiv$

$\begin{array}{l} T[n_0].top()[0] \\ T[n_1].top()[0] \end{array}$	=	$\begin{array}{l} T[n_0].top()[1] \\ T[n_1].top()[1] \end{array}$	<	True, T[n <sub>0</sub> ].pop(), T[n <sub>1</sub> ].push(T[n <sub>0</sub> ].pop())
		$\begin{array}{l} T[n_0].top()[1] \\ T[n_1].top()[1] \end{array}$		False
$\begin{array}{l} T[n_0].top()[0] \\ T[n_1].top()[0] \end{array}$	≠			False
				False

foundation\_placeable:  $\mathbb{N} \times \mathbb{N} \rightarrow \mathbb{B}$  [\[Complete this specification —SS\]](#)

$\begin{array}{l} T[n_0].top()[0] \\ F[n_1].top()[0] \end{array}$	=	$\begin{array}{l} T[n_0].top()[1] \\ F[n_1].top()[1] \end{array}$	>	True, T[n <sub>0</sub> ].pop(), F[n <sub>1</sub> ].push(T[n <sub>0</sub> ].pop())
		$\begin{array}{l} T[n_0].top()[1] \\ F[n_1].top()[1] \end{array}$		False
$\begin{array}{l} T[n_0].top()[0] \\ F[n_1].top()[0] \end{array}$	≠			False
				False

## 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]

I think that the two decks function is unnecessary because if the creation of the deck is done properly, there is no need to check again if it was created properly. It seems redundant and not necessary.

Other than that, I think the modules are laid out well and they implement information hiding. They also flow together well and the understandability of it is not too bad.