

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

State Invariant

None

Assumptions & Design Decisions

- The $\text{Stack}(T)$ 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 $\text{toSeq}()$ 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

$\text{new Stack}(s)$:

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

$\text{push}(e)$:

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

$\text{pop}()$:

- $out : \text{Stack}(S[0], \dots, S[|S| - 2])$ [What should go here? —SS]
- exception: $(\text{Stack} = \epsilon) \implies out_of_range$ [What should go here? —SS]

$\text{top}()$:

- output: $out := S[|S| - 1]$
- exception: $(S = \epsilon) \implies out_of_range$ [What should go here? —SS]

$\text{size}()$:

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

$\text{toSeq}()$:

- 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]

$\text{cnt_cards}(T, F, D, W, f)$ [What goes here? — SS] = TOTAL_CARDS

$\text{two_decks}(T, F, D, W) \#$ *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

$\text{GameBoard}(\text{deck})$:

- 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: ($0 \leq |Deck| \leq 64$) [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:

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

- exception: $exc := (\neg \text{is_valid_tab_mv}(c, n_0, n_1) \Rightarrow \text{invalid_argument})$

waste_mv(c, n):

- transition:

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

- exception: $exc := (\neg \text{is_valid_waste_mv}(c, n) \Rightarrow \text{invalid_argument})$

deck_mv():

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

$\text{valid_tab_mv} \equiv (\exists c : \text{CategoryT}, n_0 : \mathbb{N}, n_1 : \mathbb{N} | (c : T \wedge (n_0 \in [0..9]) \wedge (n_1 \in [0..9])) \vee (c : F \wedge (n_0 \in [0..9]) \wedge (n_1 \in [0..7]))) [\text{What goes here?} - - - SS] : \text{is_valid_tab_mv}(c, n_0, n_1))$

$\text{valid_waste_mv} \equiv (\exists c : \text{CategoryT}, n : \mathbb{N} | (c : T \wedge (n \in [0..63])) \vee (c : F \wedge (n \in [0..63]))) [\text{What goes here?} - - - SS] : \text{is_valid_waste_mv}(c, n))$

- exception: None

$\text{is_win_state}()$:

- output: $(\forall f \in F : |f| = 13) [\text{What goes here?} - SS]$
- exception: None

Local Types

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

Local Functions

$\text{two_decks} : \text{SeqCrdsTckT} \times \text{SeqCrdsTckT} \times \text{CardStackT} \times \text{CardStackT} \rightarrow \mathbb{B}$

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

$(\forall st : \text{SuitT}, rk : \text{RankT} | st \in \text{SuitT} \wedge rk \in \text{RankT} :$

$(\exists (a, b : \text{CardT}) : (a.st = b.st) \wedge (a.rk = b.rk)) [\text{What goes here?} - - - SS])$

$\text{cnt_cards_seq} : \text{SeqCrdsTckT} \times (\text{CardT} \rightarrow \mathbb{B}) \rightarrow \mathbb{N}$

$\text{cnt_cards_seq}(S, f) \equiv (+s : \text{CardStackT} | s \in S : \text{cnt_cards_stack}(s, f))$

$\text{cnt_cards_stack} : \text{CardStackT} \times (\text{CardT} \rightarrow \mathbb{B}) \rightarrow \mathbb{N}$

$\text{cnt_cards_stack}(S, f) \equiv (+s : \text{CardT} | s \in S : 1)$

$[\text{What goes here?} - SS]$

$\text{cnt_cards} : \text{SeqCrdsTckT} \times \text{SeqCrdsTckT} \times \text{CardStackT} \times \text{CardStackT} \times (\text{CardT} \rightarrow \mathbb{B}) \rightarrow \mathbb{N}$

$\text{cnt_cards}(T, F, D, W, f) \equiv \text{cnt_cards_seq}(T, f) + \text{cnt_cards_seq}(F, f) + \text{cnt_cards_stack}(D, f) + \text{cnt_cards_stack}(W, f)$

$\text{init_seq} : \mathbb{N} \rightarrow \text{SeqCrdsTckT}$

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

tab_deck : (seq of CardT) \rightarrow SeqCrStckT

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

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

$T[n_0].\text{size}() > 0$	$T[n_1].\text{size}() > 0$	True [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

$T[n_0].\text{size}() > 0$	$F[n_1].\text{size}() > 0$	True [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]

[\[What goes here? You may need a table? ---SS\]](#)

valid_waste_tab: $\mathbb{N} \rightarrow \mathbb{B}$

valid_waste_tab(n) \equiv

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

valid_waste_foundation: $\mathbb{N} \rightarrow \mathbb{B}$

valid_waste_foundation(n) \equiv

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

tab_placeable: $\forall n_0, n_1 : \text{CardT} \cdot (((n_0).s = (n_1).s) \wedge (n_0.r + 1 = n_1.r))$ [\[Complete this specification ---SS\]](#)

foundation_placeable: $\forall n_0, n_1 : \text{CardT} \cdot (((n_0).s = (n_1).s) \wedge (n_0.r = n_1.r + 1))$ [\[Complete this specification ---SS\]](#)

Critique of Design

Here is my list of critiques for the given specification:

1. The purpose of some of the local functions were not automatically clear upon reading them. For example the `tab_decks(deck)` function. I would have never imagined it to be the function that sorts the tableau stacks from the complete deck of 104 cards as every other reference of deck means the game's stock pile.
2. I would consider using abstract objects for
 - Stacks that are each type of card suit. This ensures we'd always have the right amount and type of cards.
 - Each type of tableau as they differ in terms of the stack functions that can be performed upon them (E.g pop cannot be done on foundation stacks).
3. I would also consider adding a undo function to the game board module to make it more complete.

[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]