SE 2AA4, CS 2ME3 (Introduction to Software Development)

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18 Maze Tracing Robot Example DRAFT

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- Administrative details
- Index set example
- Solar water heating tank example
- Dr. v. Mohrenschildt's maze tracing robot (see GitLab)
- MIS for maze_storage

Administrative Details

TBD

Index Set

Write a function `indexSet(x, B)` that takes a value `x` and a list of values `B` and returns a list of indices where `B[i] = x`.

As a first step, how would you say this mathematically?

Index Set

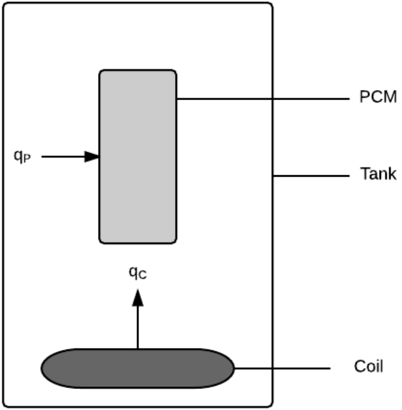
Write a function `indexSet(x, B)` that takes a value `x` and a list of values `B` and returns a list of indices where `B[i] = x`.

$$\text{indexSet}(x, B) \equiv \{i : \mathbb{N} | i \in [0..|B| - 1] \wedge B_i = x : i\}$$

How could you use `indexSet` to calculate `rank(x, A)`?

Solar Water Heating System Example

- https://github.com/smiths/swhs
- Solve ODEs for temperature of water and PCM
- Solve for energy in water and PCM
- Generate plots



Anticipated Changes

- The specific hardware on which the software is to run
- The format of the initial input data
- The format of the input parameters
- The constraints on the input parameters
- The format of the output data
- The constraints on the output results
- How the governing ODEs are defined using the input parameters
- How the energy equations are defined using the input parameters
- How the overall control of the calculations is orchestrated
- The implementation of the sequence data structure
- The algorithm used for the ODE solver
- The implementation of plotting data

Module Hierarchy by Secrets

Level 1	Level 2
Hardware-Hiding Module	
Behaviour-Hiding Module	Input Format Module Input Parameters Module Output Format Module Temperature ODEs Module Energy Equations Module Control Module
Software Decision Module	Sequence Data Structure Module ODE Solver Module Plotting Module

Table: Module Hierarchy

Example Modules from SWHS

Hardware Hiding Modules

Secrets: The data structure and algorithm used to implement the virtual hardware.

Services: Serves as a virtual hardware used by the rest of the system. This module provides the interface between the hardware and the software. So, the system can use it to display outputs or to accept inputs.

Implemented By: OS

Example Modules from SWHS

Input Verification Module

Secrets: The rules for the physical and software constraints.

Services: Verifies that the input parameters comply with physical and software constraints. Throws an exception if a parameter violates a physical constraint. Throws a warning if a parameter violates a software constraint.

Implemented By: SWHS

Example Modules from SWHS

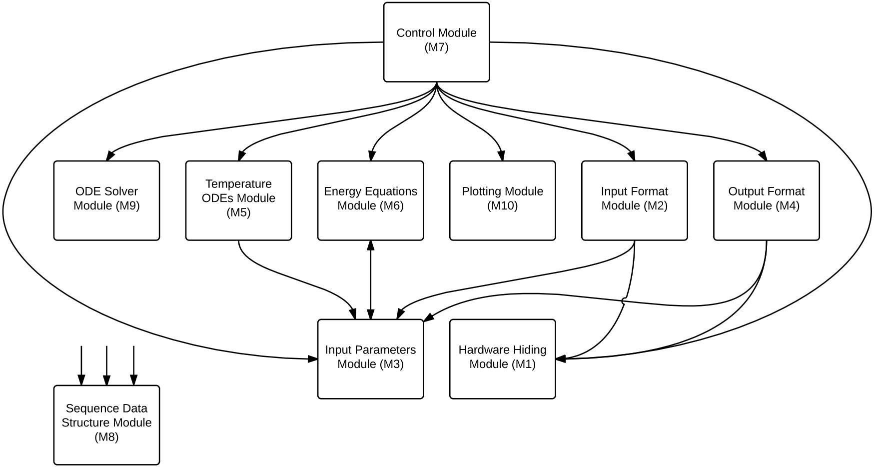
ODE Solver Module

Secrets: The algorithm to solve a system of first order ODEs.

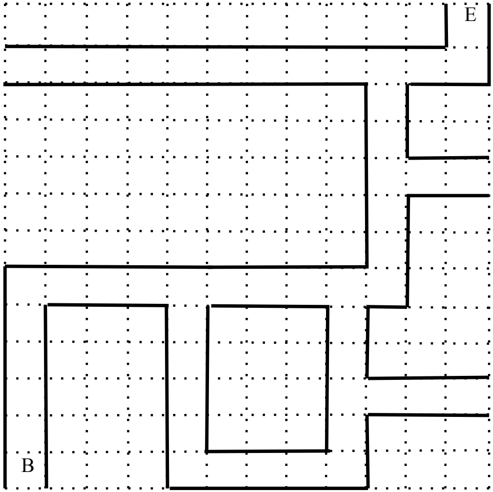
Services: Provides solvers that take the governing equation, initial conditions, and numerical parameters, and solve them.

Implemented By: Matlab

SWHS Uses Hierarchy



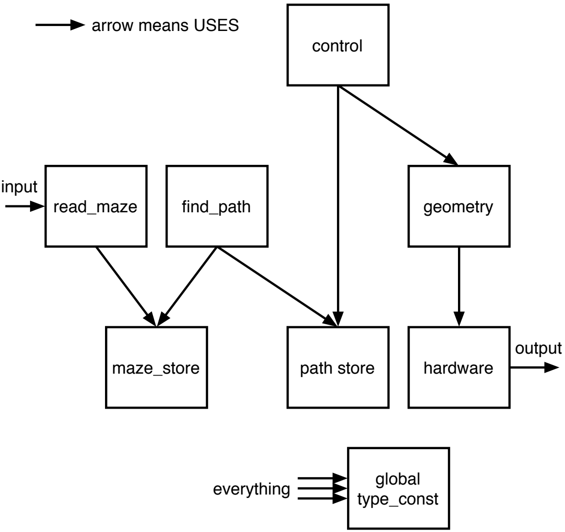
Dr. v. Mohrenschildt's Maze Tracing Robot Example



Maze Tracing Robot Expected Changes

- Changes to the geometry of the robot such that the mapping from a position to the robot inputs is different
- Changes to the interface to the robot
- Changes to the format of the maze
- Changes to any constant values

Maze Tracing Robot Uses Hierarchy



Maze Tracing Robot MG

- Module name: maze_storage
  - Secret: how the maze is stored
  - Service: stores the maze
  - Module prefix: ms_
- Module name: load_maze
  - Secret: where and how the maze file is read in
  - Service: loads the maze
  - Module prefix: lm_
- Module name: find_path
  - Secret: the algorithm for finding the shortest path
  - Service: finds the shortest path through the maze
  - Module prefix: fp_

Maze Tracing Robot MG Continued

- Module name: control
  - Secret: how the arm moves from position to position and how the buttons are checked
  - Service: controls the movement of the arm
  - Module prefix: cn_
- Module name: geometry
  - Secret: how the calculations from cell coords to robot coords are performed
  - Service: handles geometric positioning of the arm
  - Module prefix: gm_
- Module name: hardware
  - Secret: how it interfaces with the robot
  - Service: handles hardware aspects of arm (movement and button checking)
  - Module prefix: hw_

Maze Tracing Robot MG Continued

- Module name: types_constants
  - Secret: how the data structures are defined and constants defined
  - Service: provides standard variable types and constants to modules

maze_storage MIS

Module

maze_storage

Uses

types_constants #*provides NUM_X_CELLS, NUM_Y_CELLS*

Exported Access Programs

Routine name	**In**	**Out**	**Exceptions**
...	...	...	...

maze_storage Exported Access Programs

Routine name	In	Out	Exceptions
ms_init			
ms_set_maze_start	cell		ms_not_initialized, ms_cell_out_of_range
ms_set_maze_end	cell		ms_not_initialized, ms_cell_out_of_range
ms_get_maze_start		cell	ms_not_initialized
ms_get_maze_end		cell	ms_not_initialized
ms_set_wall	cell, cell		ms_not_initialized, ms_not_valid_wall
ms_is_connected	cell, cell	boolean	ms_not_initialized, ms_cell_out_of_range

cell = tuple of (x: integer, y: integer)

maze_storage Semantics

State Variables

State Invariant: none

Assumptions

ms_get_maze_start and ms_get_maze_end are not called until after the corresponding set routines have been called.

maze_storage Semantics

State Variables

maze: set of tuple of (cell, cell)
start : cell
end : cell
is_init : boolean := *false*

State Invariant: none

Assumptions

ms_get_maze_start and ms_get_maze_end are not called until after the corresponding set routines have been called.

Access Routine Semantics

ms_init():

- transition:
- exception:

ms_set_maze_start(c):

- transition:
- exception:

ms_set_maze_end(c):

- transition:
- exception:

Access Routine Semantics

ms_init():

- transition: $maze, is\_init := \{\}, true$
- exception: none

ms_set_maze_start(c):

- transition:
- exception:

ms_set_maze_end(c):

- transition:
- exception:

Access Routine Semantics

ms_init():

- transition: $maze, is\_init := \{\}, true$
- exception: none

ms_set_maze_start(c):

- transition: $start := c$
- exception:

ms_set_maze_end(c):

- transition: $end := c$
- exception:

Access Routine Semantics

ms_init():

- transition: $maze, is\_init := \{\}, true$
- exception: none

ms_set_maze_start(c):

- transition: $start := c$
- exception: $exc := (\neg is\_init \Rightarrow$ $\text{ms\_not\_initialized} \mid \neg \text{cell\_in\_range}(c) \Rightarrow$ $\text{ms\_cell\_out\_of\_range})$

ms_set_maze_end(c):

- transition: $end := c$
- exception: $exc := (\neg is\_init \Rightarrow$ $\text{ms\_not\_initialized} \mid \neg \text{cell\_in\_range}(c) \Rightarrow$ $\text{ms\_cell\_out\_of\_range})$

Access Routine Semantics Continued

ms_get_maze_start():

- output:
- exception:

ms_get_maze_end():

- output:
- exception:

Access Routine Semantics Continued

ms_get_maze_start():

- output: $out := start$
- exception:

ms_get_maze_end():

- output: $out := end$
- exception:

Access Routine Semantics Continued

ms_get_maze_start():

- output: $out := start$
- exception: $exc := (\neg is\_init \Rightarrow \text{ms\_not\_initialized})$

ms_get_maze_end():

- output: $out := end$
- exception: $exc := (\neg is\_init \Rightarrow \text{ms\_not\_initialized})$

Access Routine Semantics Continued

ms_set_wall(c1, c2):

- transition:
- exception:

Access Routine Semantics Continued

ms_set_wall(c1, c2):

- transition: $maze := maze \cup \{< c1, c2 >\}$
- exception:

Access Routine Semantics Continued

ms_set_wall(c1, c2):

- transition: $\mathit{maze} := \mathit{maze} \cup \{< c1, c2 >\}$
- exception: $\mathit{exc} := (\neg \mathit{is\_init} \Rightarrow$ $\text{ms\_not\_initialized} \mid \text{wall\_is\_point}(c1, c2) \vee$ $\text{wall\_is\_diagonal}(c1, c2) \vee \text{wall\_is\_out\_of\_range}(c1, c2) \Rightarrow$ $\text{ms\_not\_valid\_wall})$

Access Routine Semantics Continued

ms_is_connected(c1, c2):

- output:
- exception:

 # Assumes that all intermediate points are in the input. Could rephrase to be more intelligent about it.

Access Routine Semantics Continued

ms_is_connected(c1, c2):

- output:
  $out := \exists p : \text{sequence of cell} | p[0] = c1 \wedge p[|p| - 1] = c2 \wedge \forall(i : \mathbb{N} | 0 \leq i \leq |p| - 2 :< p[i], p[i+1] > \in maze)$
- exception:

 # Assumes that all intermediate points are in the input. Could rephrase to be more intelligent about it.

Access Routine Semantics Continued

ms_is_connected(c1, c2):

- output:
  $out := \exists p : \text{sequence of cell} | p[0] = c1 \wedge p[|p| - 1] = c2 \wedge \forall (i : \mathbb{N} | 0 \leq i \leq |p| - 2 : < p[i], p[i+1] > \in maze)$
- exception: $exc := (\neg is\_init \Rightarrow$ ms_not_initialized $|$ $\neg$cell_in_range$(c1) \Rightarrow$ ms_cell_out_of_range $|$ $\neg$cell_in_range$(c2) \Rightarrow$ ms_cell_out_of_range)

\# *Assumes that all intermediate points are in the input. Could rephrase to be more intelligent about it.*

Local Functions

cell_in_range : cell $\rightarrow$ boolean

wall_is_point: cell $\times$ cell $\rightarrow$ boolean

wall_is_diagonal: cell $\times$ cell $\rightarrow$ boolean

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cell_in_range : cell $\rightarrow$ boolean

- cell_in_range (c) $\equiv (0 \leq c.x <$ NUM_X_CELLS$) \wedge (0 \leq c.y <$ NUM_Y_CELLS$)$

wall_is_point: cell $\times$ cell $\rightarrow$ boolean

wall_is_diagonal: cell $\times$ cell $\rightarrow$ boolean

Local Functions

cell_in_range : cell $\rightarrow$ boolean

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wall_is_point: cell $\times$ cell $\rightarrow$ boolean

- wall_is_point (c1, c2) $\equiv c1 = c2$

wall_is_diagonal: cell $\times$ cell $\rightarrow$ boolean

Local Functions

cell_in_range : cell $\rightarrow$ boolean

- cell_in_range (c) $\equiv (0 \leq c.x < \text{NUM\_X\_CELLS}) \wedge (0 \leq c.y < \text{NUM\_Y\_CELLS})$

wall_is_point: cell $\times$ cell $\rightarrow$ boolean

- wall_is_point (c1, c2) $\equiv c1 = c2$

wall_is_diagonal: cell $\times$ cell $\rightarrow$ boolean

- wall_is_diagonal (c1, c2)
  $\equiv \neg((c1.x = c2.x) \vee (c1.y = c2.y))$

Additional Specifications for Determining the Path

pathT = sequence of cell
validPath : pathT $\rightarrow$ boolean

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pathT = sequence of cell
validPath : pathT → boolean

- validPath (p)
  $\equiv (p[0] = \text{ms\_get\_maze\_start}() \wedge p[|p| - 1] = \text{ms\_get\_maze\_end}() \wedge \forall (i : \mathbb{N} | 0 \leq i \leq |p| - 2 : \text{ms\_is\_connected}(p[i], p[i+1]))$

Additional Specifications for Determining the Path

pathT = sequence of cell

validPath : pathT → boolean

- validPath (p)
  $\equiv (p[0] = \text{ms\_get\_maze\_start}() \wedge p[|p|-1] = \text{ms\_get\_maze\_end}() \wedge \forall(i : \mathbb{N} | 0 \leq i \leq |p|-2 : \text{ms\_is\_connected}(p[i], p[i+1]))$

How would you specify the length of a wall?

Additional Specifications for Determining the Path

pathT = sequence of cell
validPath : pathT $\rightarrow$ boolean

- validPath (p)
  $\equiv (p[0] = \text{ms\_get\_maze\_start}() \wedge p[|p|-1] = \text{ms\_get\_maze\_end}() \wedge \forall(i : \mathbb{N} | 0 \leq i \leq |p|-2 : \text{ms\_is\_connected}(p[i], p[i+1]))$

How would you specify the length of a wall?
lenWall: tuple of cell $\rightarrow$ integer

$$\text{lenWall}(< c1, c2 >) \equiv (c1.x = c2.x \Rightarrow |c1.y - c2.y|$$

$$|c1.y = c2.y \Rightarrow |c1.x - c2.x|)$$

Shortest Path

How would you specify the length of a path?

How would you specify whether a path is the shortest path?

Shortest Path

How would you specify the length of a path?

lenPath: pathT $\rightarrow$ integer

$$\text{lenPath}(p) \equiv +(i : \mathbb{N} | 0 \leq i < (|p|-1) : \text{lenWall}(< p_i, p_{i+1} >))+1$$

How would you specify whether a path is the shortest path?

Shortest Path

How would you specify the length of a path?
lenPath: pathT $\rightarrow$ integer

$$\text{lenPath}(p) \equiv +(i : \mathbb{N} | 0 \leq i < (|p| - 1) : \text{lenWall}(< p_i, p_{i+1} >)) + 1$$

How would you specify whether a path is the shortest path?
isShortest: pathT $\rightarrow$ boolean

$$\text{isShortest}(p) \equiv \forall(q : \text{pathT}$$

$$|\text{validPath}(q) : \text{validPath}(p) \wedge \text{lenPath}(p) \leq \text{lenPath}(q))$$