EECS 1010 01 Spring 2020
AntVengers!

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DA3-2

Ant-Man Image: MarvelHeroes.com

Maze: Shutterstock

Ant-Man!

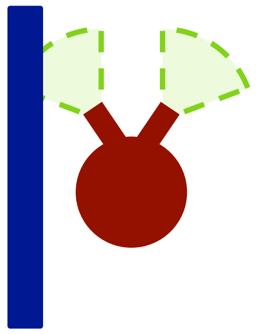
- You woke up and found yourself becoming an Ant-Man (or Ant-Person?!), being trapped in a dark Maze Universe!!
  - You lost the eyesight!
  - Instead, you got two antennas, left and right.
- You need to escape the Maze Universe (and save the world, of course)!
  - "With Great Power Comes Great Responsibility" you know
  - Using two antennas you can sense the Maze walls.

Image Source: MarvelHeroes.com

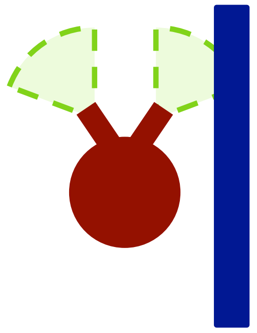
How The Antennas Work

2-bit Antenna Signal = `{ant_l, ant_r}` (or Simply {L, R}) as inputs

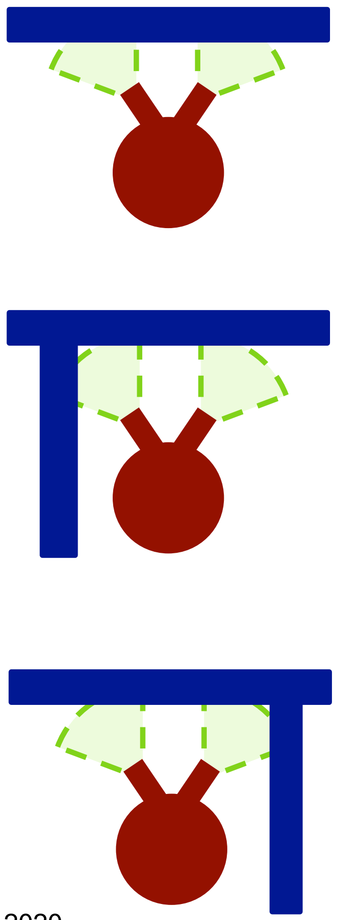
Case 1
Wall to the Left
LR = 10



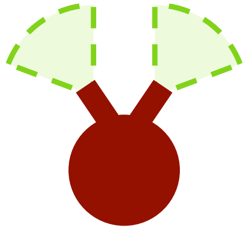
Case 2
Wall to The Right
LR = 01



Case 3
Wall Ahead
LR = 11

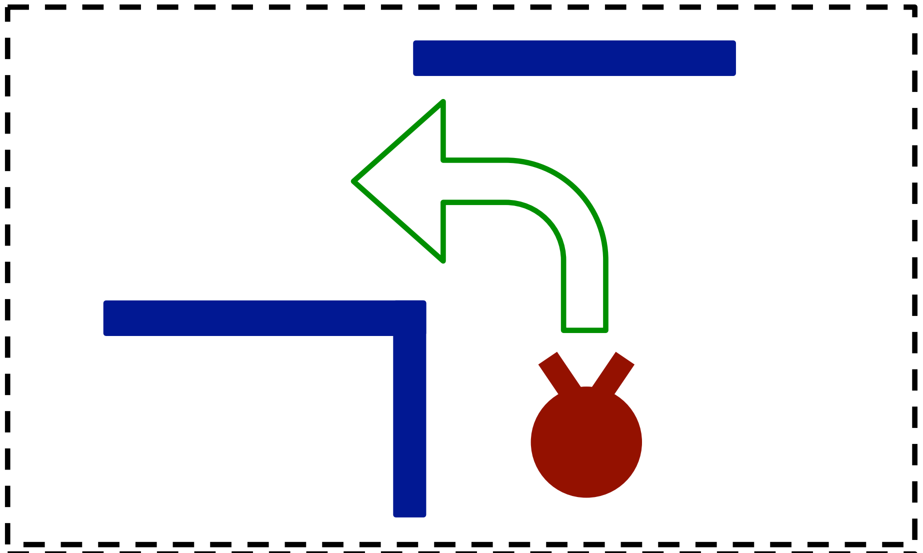


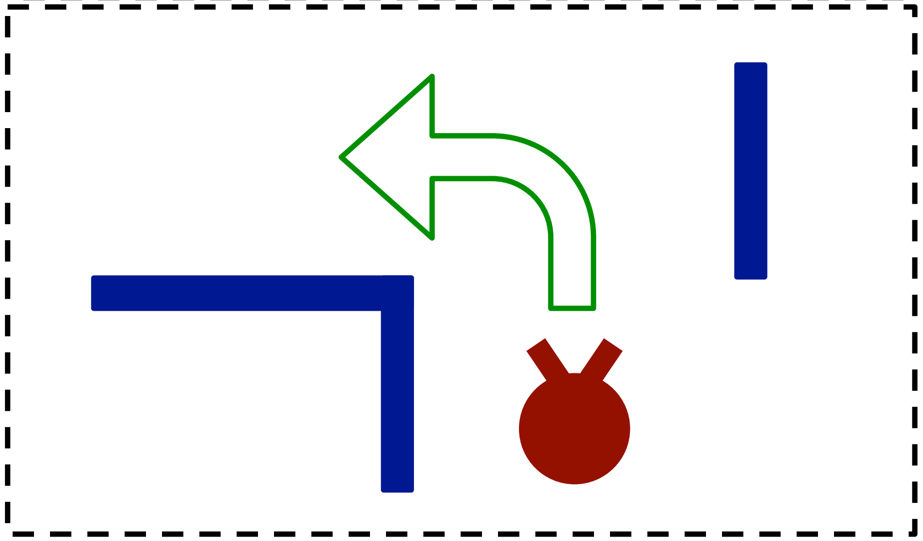
Case 4
Open Space
LR = 00



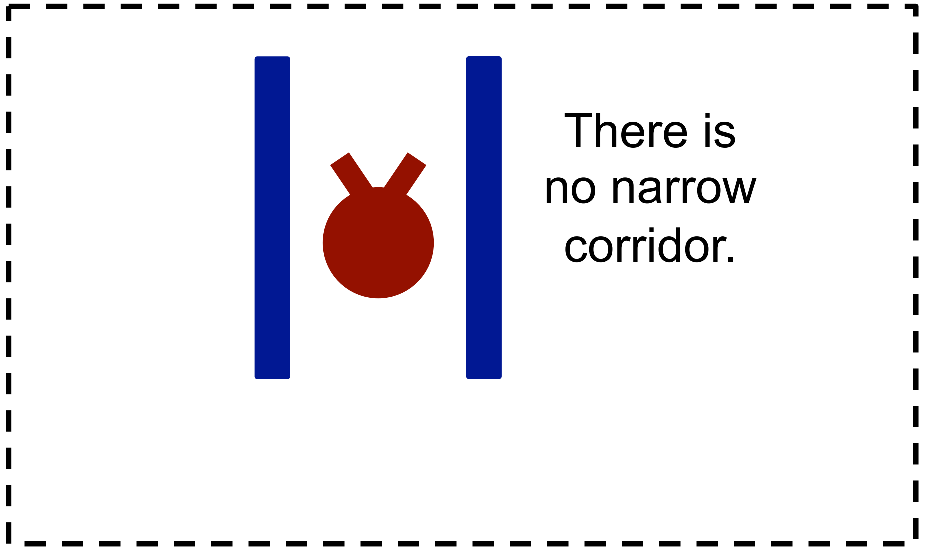
What Will Not Happen

No Narrow Corner





Wall at Both Sides



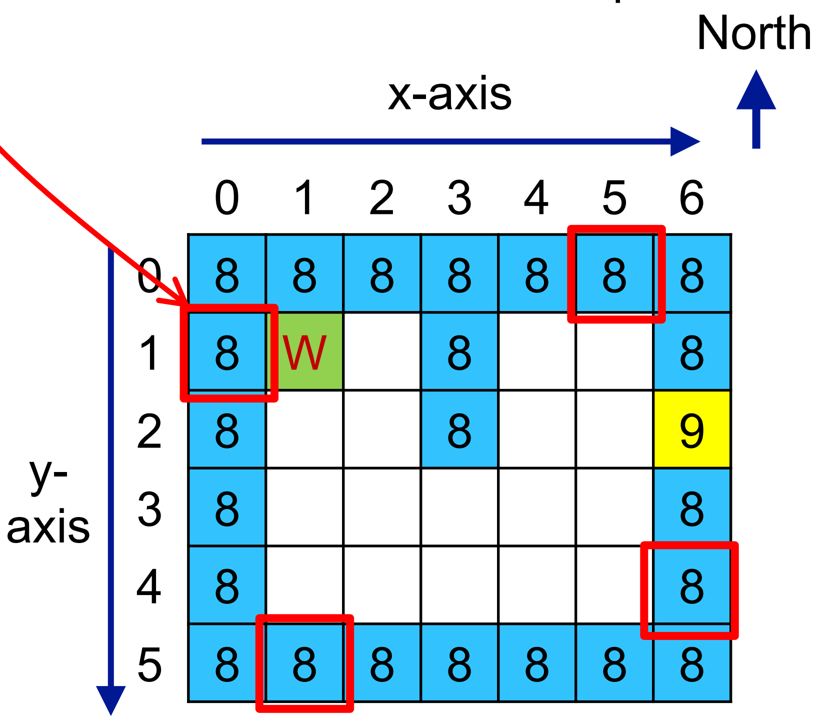
There is no narrow corridor.

Maze Universe

- Encoding
  - 8: Wall
  - 0: Empty space
  - 9: Exit
- You can be at any position inside the maze initially, except upon a wall
- You can face to any of four different directions: N (north), E (east), S (south), W (west)

The exit will not appear at the corners (e.g., at (0,1), (5,0), (6,4), (1,5) in this case). Or it forms a narrow corner to prevent you from going out, probably.

A 7x6 Maze Example



	0	1	2	3	4	5	6
0	8	8	8	8	8	8	8
1	8	W		8			8
2	8			8			9
3	8						8
4	8						8
5	8	8	8	8	8	8	8

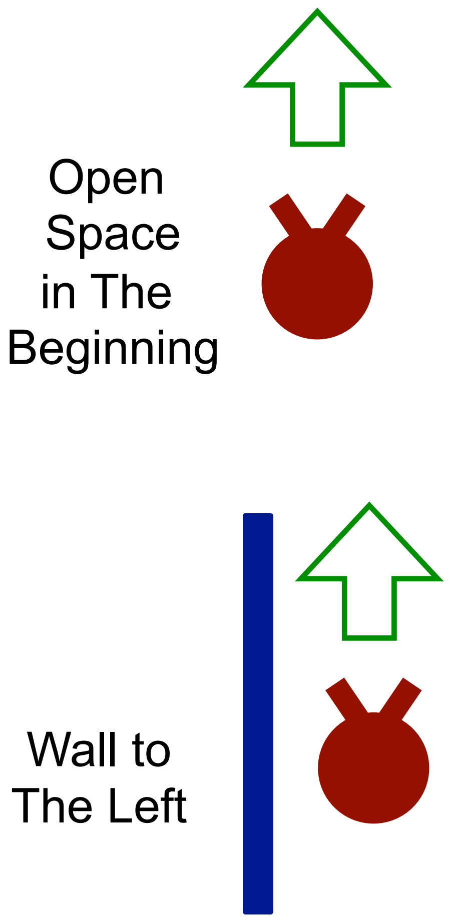
What Actions You Can Take

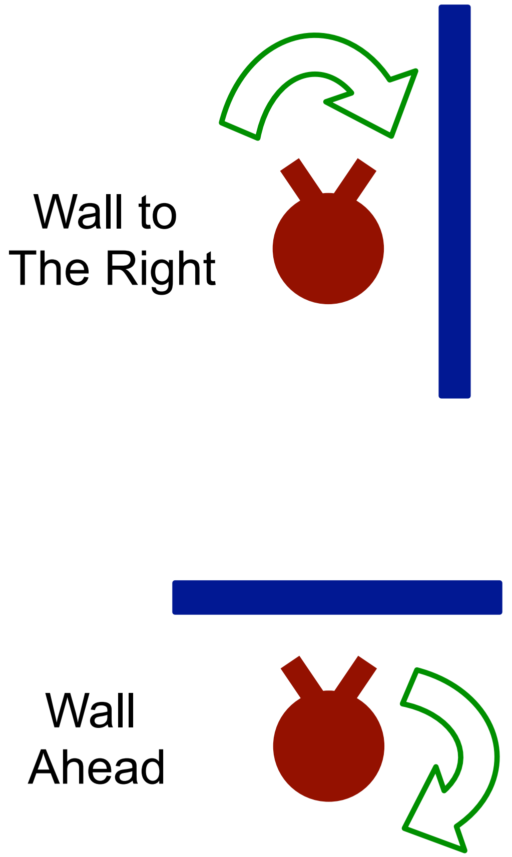
- You have four actions to take (2-bit `move` as the output)
  - Standing still (halt)
  - Move forward (for 1-unit distance)
  - Turn left (in place, 90 degree, counterclockwise)
  - Turn right (in place, 90 degree, clockwise)
- One at a clock cycle (synchronous to rising clock edges)

Your Strategies

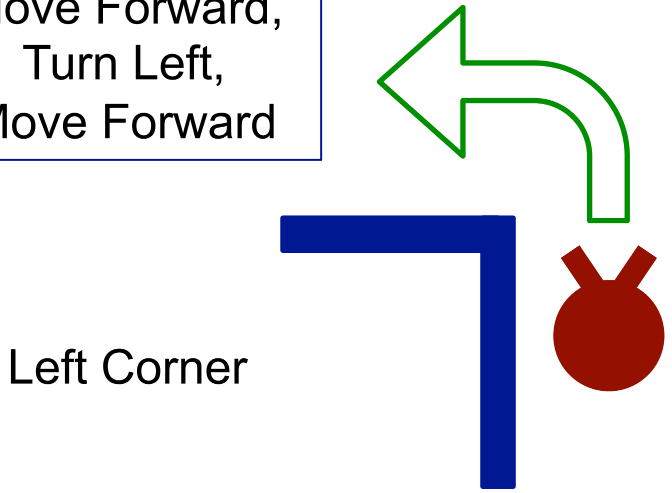
Move Forward

Turn Right





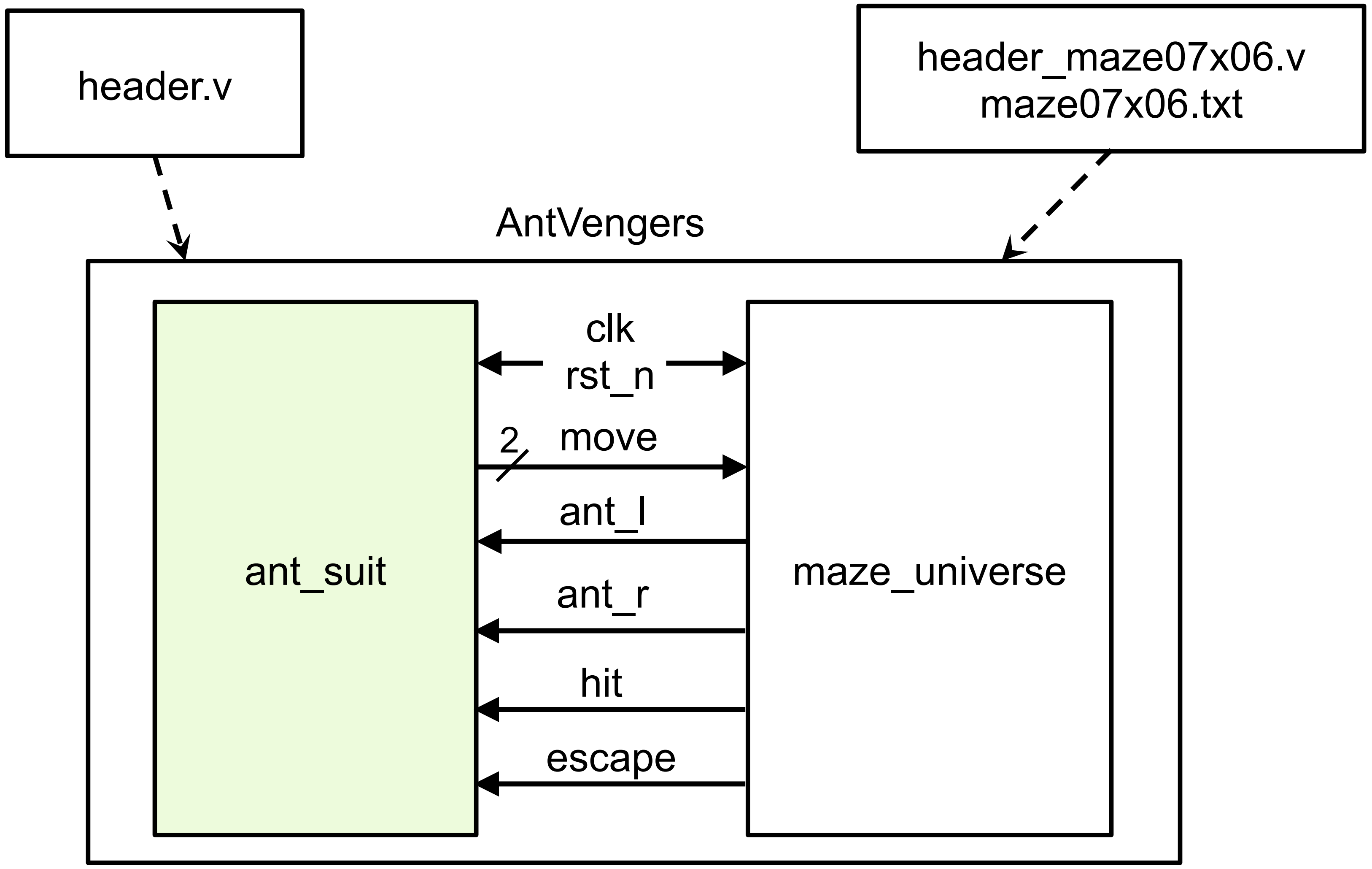
Move Forward,
Turn Left,
Move Forward



Assumptions

- There is no wall islands in the maze
  - All walls are connected to prevent loops
- Keep the wall to your left
- Corridors are always wider enough
  - Assume there is "wall ahead" if both antennas detect something
- You will know when you bump into the wall
  - 1-bit `hit` signal as a status input
  - Your position and direction remain the same
- You will know when you escape the Maze
  - 1-bit `escape` signal as a status input

Building Blocks and IOs



Requirement

- Design an Ant-Person suit (`ant_suit` module) to get through the Maze Universe
  - Detail your design concept
- Create your own maze (>= 15x15)
- Read the source code
  - You may improve the Maze Universe (any bug inside?)
- Have fun!

Challenge?!

- What if there exists narrow corridors and/or narrow corners?
- What if you are not sure if there is any wall islands in the maze

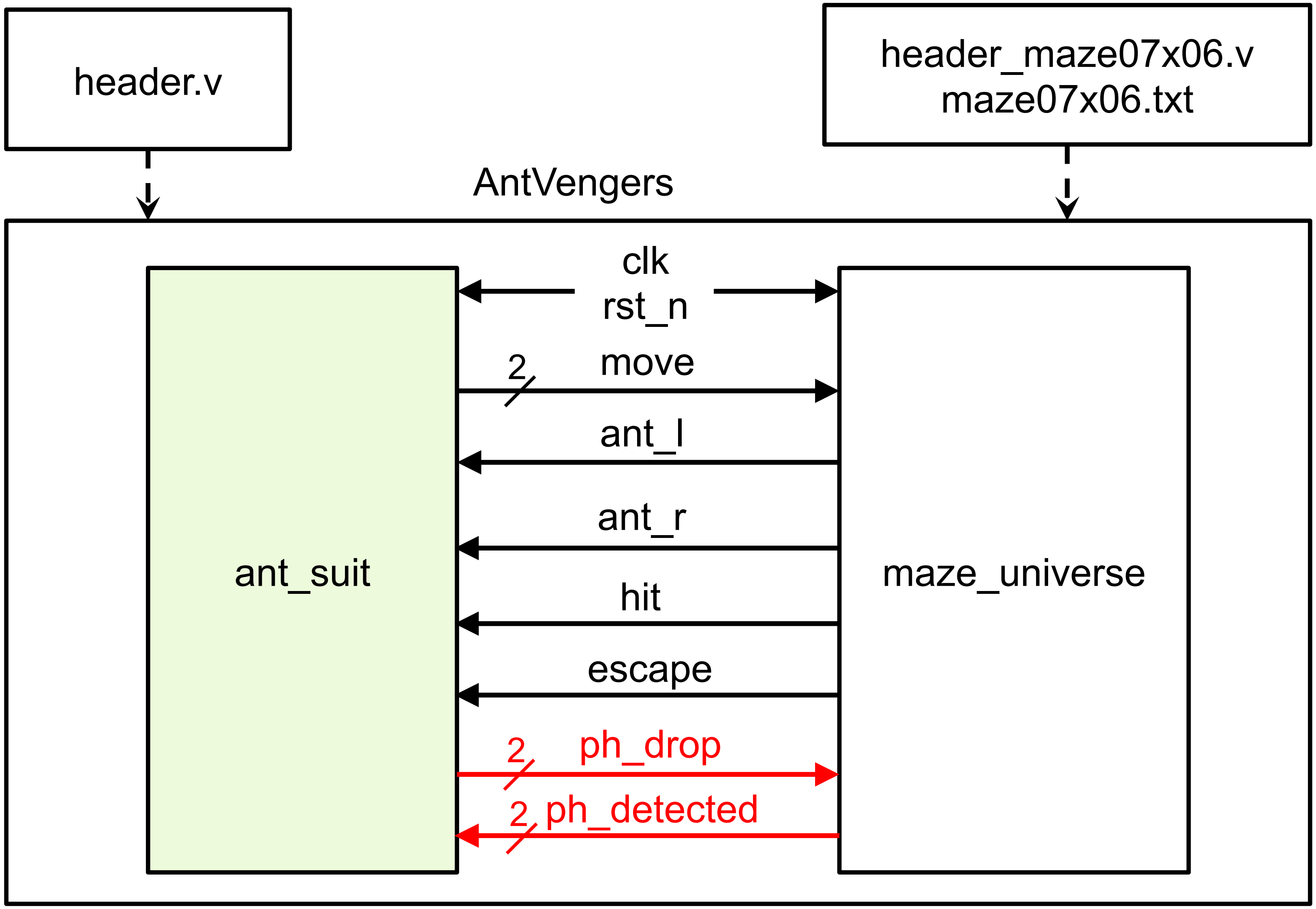
Challenge of Narrow Corridors and/or Narrow Corners

- Assume that it is possible to have narrow corridors and/or narrow corners in the maze
- How do you conquer them? Is it possible to solve the challenge with the present I/O signals?
- Note: disable the wall checking by using NOCHECK mode when dealing with the challenge

Challenge of Wall Islands

- Assume that it is possible to have wall island(s) in the maze
- How do you conquer the wall island? Possibly to learn from ant:
  - Deploy (drop) pheromone along the path
  - We implement 2-bit pheromone but only use 2'b00 (no pheromone) and 2'b01 (pheromone detected)
- You can even use different kinds of pheromone (with 2'b10 and 2'b11)
  - Use your imagination to extend the problem;
  - Then solve the problem as best as you can
- Note: turn on CHALLENGE mode

Possible Solution: Modified IOs



Completeness of Challenge

- Propose your solution
  - Is it complete?
  - Discuss your assumptions
- Design the upgraded Ant-Person suit
  - You can turn on the challenge mode by including `challenge.v` for Verilog simulation or adding `+define+CHALLENGE` when invoking `ncverilog`
    E.g.,
    ```
    $ ncverilog +define+CHALLENGE ...
    ```
- Design your own maze
  - To test your Ant-Person suit (and beat others', if possible)
- Improve the specification?
  - You may modify and improve the maze universe for a better problem scenario (or solution)

00_README.txt

```
00_README.txt        : This README file.
ant.sh               : Shell script to simulate the maze example.
ant_fsdb.sh          : Shell script to simulate the maze example
                     : with fsdb output.
ant_challenge.sh     : Shell script to turn on the challenge
                     : mode.
ant_nocheck.sh       : Shell script to disable the wall checking.
header.v             : Header file for AntVengers!
AntVengers.v         : AntVengers! test stimulus.
maze_universe.v      : Maze Universe that reacts to your
                     : Ant-Person suit.
ant_suit.v           : Ant-Person suit that you are going to
                     : design and replace with.
header_maze*.v       : Header files for maze examples.
maze*.txt            : Maze examples.
```

ant.sh

```
#!/bin/sh
ncverilog \
  header.v \
  header_maze07x06.v \
  AntVengers.v maze_universe.v ant_suit.v \
  +debug=1 \
  +access+r
```

You may execute the shell script by

```
$ sh ./ant.sh
```

maze_universe.v

```
module maze_universe (
...
)
...
  initial begin
    if ($value$plusargs("debug=%d", debug)) begin
      $display(">>> Debug level = %d", debug);
    end else begin
      debug = 0;
    end
    if ($value$plusargs("fsdbfile=%s", fsdbfile)) begin
      if (debug >= 1)
        $display(">>> Dumping the wafeform to [%s]", fsdbfile);
      $fsdbDumpfile(fsdbfile);
      $fsdbDumpvars;
    end
```

You can select the debug mode by

```
$ ncverilog +debug=1
```

You can assign the file name by

```
$ ncverilog +fsdbfile=whatever.fsdb
```

ant_fsdb.sh

```
#!/bin/sh
ncverilog \
  header.v \
  header_maze10x11.v \
  AntVengers.v \
  maze_universe.v \
  ant_suit.v \
  +fsdbfile=maze10x11.fsdb \
  +debug=1 \
  +access+r
```

ant_challenge.sh

```
#!/bin/sh
ncverilog \
  header.v \
  header_maze15x15-2.v \
  AntVengers.v maze_universe.v ant_suit.v \
  +debug=2 \
  +define+CHALLENGE \
  +access+r
```

challenge.v

```
// turn on the challenge mode
`define CHALLENGE 1
```

maze_universe.v

```
module maze_universe (
  input wire clk,
  input wire rst_n,
  input wire [1:0] move,
// challenge mode
`ifdef CHALLENGE
  input wire [`PH_WIDTH - 1:0] ph_drop,
  output wire [`PH_WIDTH - 1:0] ph_detected,
`endif
  output reg ant_r = 0,
  output reg ant_l = 0,
  output reg hit = 0,
  output reg escape = 0
);
```

header_maze07x06.v

```
`define MAZE_WIDTH 7
`define MAZE_HEIGHT 6
`define INIT_X 1
`define INIT_Y 1
`define INIT_DIR `WEST
`define DEFAULT_MAZE "maze07x06.txt"
```

maze07x06.txt

```
8 8 8 8 8 8 8
8 ● 0 8 0 0 8
8 0 0 8 0 0 9
8 0 0 0 0 0 8
8 0 0 0 0 0 8
8 8 8 8 8 8 8
```

header.v

```
`timescale 1ns/100ps
`define POS_WIDTH 8
`define MAZE_ELE_WIDTH 5
`define DIR_WIDTH 4
`define CYC      10
`define DELAY    1
`define ABORT    500
`define STRING   32
`define NORTH    4'b1000
`define EAST     4'b0100
`define SOUTH    4'b0010
`define WEST     4'b0001
```

```
`define HALT    2'b00
`define RIGHT   2'b01
`define LEFT    2'b10
`define FORWARD 2'b11
`define WALL    4'd8
`define EXIT    4'd9

`define PH_WIDTH  2
```

Simulation will abort after **500** cycles by default. Remember to adjust it when necessary!

maze_universe.v

```
maze_description = `DEFAULT_MAZE;
fd = $fopen(maze_description, "r");
for (j = 0; j < `MAZE_HEIGHT; j = j + 1) begin
  for (i = 0; i < `MAZE_WIDTH; i = i + 1) begin
    status = $fscanf(fd, "%1d", maze[i][j]);
    if (maze[i][j] == `EXIT) begin
      exit_x = i;
      exit_y = j;
    end
  end
end
if (debug >= 1) begin
  display_maze_initial;
  display_maze;
end
if (debug == 3) display_maze_elements;
$fclose(fd);
```

ant_suit.v

```
module ant_suit (
  input wire clk,
  input wire rst_n,
  input wire ant_r,
  input wire ant_l,
  input wire hit,
  input wire escape,
// challenge mode
`ifdef CHALLENGE
  output reg [`PH_WIDTH - 1:0] ph_drop,
  input wire [`PH_WIDTH - 1:0] ph_detected,
`endif
  output reg [1:0] move
);
  // parameters: action
  parameter [1:0] halt       = `HALT;
  parameter [1:0] turn_right = `RIGHT;
  parameter [1:0] turn_left  = `LEFT;
  parameter [1:0] forward    = `FORWARD;
  parameter cyc = `CYC;
  parameter delay = `DELAY;
  // replace the initial block with
  // YOUR DESIGN
  initial begin
    #cyc;
    #cyc;
    @(posedge rst_n);
```

```
    standing_still;
    standing_still;
    moving_forward;
    turning_right;
    ...
  end
// challenge mode: deploy pheromone
`ifdef CHALLENGE
  always @* begin
    if (ph_detected == 0)
      ph_drop = 2'b1;
    else
      ph_drop = 0;
  end
`endif
  task moving_forward;
    begin
      @(posedge clk) move = forward;
    end
  endtask
  task turning_left;
    begin
      @(posedge clk) move = turn_left;
    end
  endtask
  ...
endmodule
```