COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

The Drone Language
A Stack-Based Imperative Language
Fall 2012
COMS 4115

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Content

Chapter 1: Introduction & Purpose

1.1 Purpose & Background

Drone War is a video game, which belongs to the “programming game” genre. As in all such games, the player has no direct influence on the course of the game. Instead, a player writes a program, which acts as an AI for the game characters and watch how those characters interact. The Drone War is based on a concept of a battle-royal between several drones (each with its own AI program). Drones are randomly dropped into the arena and fight with each other until only one is left or the time limit for the battle is exceeded.

Since the Drone War’s primary concept is a battle, the language for the AIs used in it should encourage writing fast, predictable, and efficient algorithms. On the other hand, the Drone War is essentially a game and its intended audience is as wide as possible, but not all potential players know the art of programming and have experience in playing with the programming game. So, in order to lower the threshold, the language for drones should be simple and it should have as few operators and concepts as possible.

To satisfy these requirements, the Drone Language was designed.

1.2 The Drone Language

Drone language is a stack-based imperative language. The stack accepts only integers, booleans, and flags. Integers can be used as arithmetic operands or parameters of the functions. Booleans are subject to stack manipulation operations and as parameter for conditional jump operators. Flags are subject to stack manipulation operations and special functions which check the flag is it of the expected kind and leave boolean true or false on the stack. Each word read from the source code is either a comment, integer, boolean, call to a user defined function, label, variable, or operator.

To make the Drone Language easier to use, we added conditional execution, endless loops and conditional loops. Those compound statements are considered to be “a syntactic sugar”. They are not executed directly, but translated into a set of labels and conditional jumps.

1.3 The Drone War Game

1.3.1 Game Overview

The battle in the Drone War game happens in fixed-size arena and with multiple drones acting individually, under control of AI programs written by players. Each AI file passed to the game from command line is considered to be individual drone (it is possible to run several drones against each other under the control of the same AI). Before the battle starts, drones can be separated into different teams and if drone's AI is smart enough, several drones of the same team can help each other.

Drones can move around the Arena, look around and shoot Bullets. Bullets are flying to a specified distance in the specified direction and once distance is reached or Bullet hits the wall of the Arena, Bullet explodes. The explosion of the Bullet damages all Drones which are close enough. Once Drone life reach 0, it considered "dead".

The concept of the "fighting machine" and simplicity of the Drone Language lead to the very strict unforgiveness of the errors in programming, any error in AI is considered to be a fatal one and if it happened, the drone instantly become "brain dead". There is no graceful error handling in the drones' AI. The drone which encounter such problem become frozen and while it is not technically dead yet, it does nothing for the remainder of the battle and become an easy prey for the opponents.

The flow of the battle is controlled by ticks. Each operation performed by the AI takes exactly one tick to complete. The moving of drones and bullets also happens under the same tick counter. That ensures that each drones are moving simultaneously and the AI which acts more efficiently has a better chance of winning against a not so efficient drones.

The battle continues until only one drone is left in play or battle for the predefined length of time.

1.3.2 Arena

Arena is a square of size 1000*1000 units enclosed by impenetrable walls. Drone which hits the wall receive some damage. Bullet which hits the wall immediately explodes.

1.3.3 Drone

In the arena, Drone is represented as a land vehicle with a freely turning cannon (meaning a drone can move in one direction while shooting in another). Each Drone has 100 health points at the start of the battle. Once drone's HP reaches 0, it cannot do anything and leaves its body in the arena.

At the start of the battle, drones are put on the Arena at random X and Y coordinates.

1.3.4 Bullet

Bullets are shot by drones. They are not controlled by players in any way. Bullet always flies until it reaches the specified distance or hit the wall of the arena.

Bullet's explosion has a radius of 50 points and damage received by the drone inside the blast radius is proportional to the distance from the center of explosion. If a drone was hit directly it receives 50 points of damage. If distance to the epicenter was 1 point, drone receives 49 points of damage. Distance of 50 points or more is completely safe. A drone can be damaged by its own projectile if it blows up close enough. Bullet's speed is 5 points per tick. A Bullet cannot travel for more than 500 points (half of the arena).

1.3.5 Drone Actions

1.3.5.1 Move

Drone can move around the arena by issuing command: *move* with one parameter *direction*. Once the command is issued, the drone starts moving in the desired direction until next *move* command changes it or the *stop* command cancel the movement. Drone does not have "mass" so there is no need to worry about inertia. If drone hits the wall of the arena it loses 10 HP as a result of the hit. The movement speed is set to 1 unit per step.

1.3.5.2 Look

Drone can see other drones and walls of the arena by issuing a command: *look* with one parameter *direction*. *Look* has an "angle of vision" with the side angle of 30 degrees. This means, the drone sees not just objects on the straight line but in the area of a triangle. The distance to the wall is calculated by the exact direction of the *look*.

The *look* command returns a list of tuples: [drone1 [drone2 ...]] wall

Where each tuple consists of a flag (what this tuple describes?), direction (exact direction the object), and distance (distance to the object). The 'type' flags can be one of FOE, ALLY, or WALL. The WALL tuple is always the last one in the list and acts as an indicator that there were no more drones seen in the given direction.

1.3.5.3 Shoot

Drone can shoot by issuing command: *shoot* with two parameters *direction* and *distance*, which mean where and how far the bullet will fly before exploding. Drone can issue a *shoot* command once every 10 ticks. This timeout represents “gun is reloading” or “cooling off period”. If drone attempts to shoot more often, the *shoot* will return FALSE. If shooting was successful – TRUE.

NB: this return code does not tell was the target hit or not.

1.4 GUI

The GUI of the Drone War Game shows the state of the battle tick by tick, as well as stats of each drone on the battlefield.

The GUI representation of the arena depends on the size of the window and arena does not always look like square but it shows the correct position of each object.

The detail information of drones is displayed to the right of the arena. “The total ticks” shows the total number of ticks since the battle started. And “AI ticks” of each drone will show its live time.

The drones are drawn as a triangle with a line coming from its center. The direction that the acute angle pointing at is the moving direction of drone and the direction of the line is the drone’s gun direction. Also, drones in different teams will be displayed in different color with their names and health near them. When a drone is dead, a red cross will be shown over it.

The bullet in GUI is a black solid circle and when bullet explodes, it will be a red solid five-pointed star that we can easily find out whether a drone is damaged by this bullet.

Chapter 2: Tutorial

2.1 Getting Started

The idea is to create a drone to beat others'. As to "write" a drone, you may need operations like: *dup*, *drop*, *dropall*, *swap*, *over*, or *rot* to manipulate the stack. Operations like *read* and *store* can help declare or use variables. Labels in conjunction with operations *Jump* and *jumpif* can help build a complex control flow (or you can choose the easier way: use *begin*, *while*, *again* to make loops and *if*, *else*, *endif* for branching; just like in any high-level programming language). Like in other languages *and*, *or*, and *not* are logic operators to deal with boolean. As stated, Drone language is a game language thus, there are several game oriented functions: *move*, *shoot*, *look*, *wait*, *getHealth*, *isFoe*, *isAlly*, *isWall*. By using these functions and operations above, a programmer can easily create a smart drone to fight with other drones.

Here is a simple example of a drone:

```
// This drone is a kind of wimp.
// It continues running from one wall to another until dead
begin                    // start of the main loop
     0 360 random        // randomly pick a direction
     direction store     // save the randomly picked value
     direction read move // move to the direction
     begin               // move to the wall stop before hitting
     direction read look // Look forward.
          begin
               iswall not while    // If object is not a wall,
               drop                // ignore direction
               drop                // and distance to it.
          again
          drop           // ignore direction to the wall
          20 > while     // If distance to the wall is more
     again               // than 20, then repeat the loop.
stop                // Stop moving once wall was reached.
again                    // Repeat the main loop forever
```

2.2 Compiling and running Drones

In the Drone War, each Drone file contains a complete AI for exactly one drone. The files with a text of the AI should have an extension **.dt**.

To add Drones to the game, player just passes files with AIs to the game engine in the command line.

It is almost meaningless to pass single drone to the game, since it would be the only one on the arena and the battle finish immediately with a “winner by default”. Usually, the game starts with passing several drone files to the game engine:

./DroneWar drone1.dt drone2.dt drone3.dt drone4.dt

Teams can be specified by adding **-t** key between drone files:

./DroneWar drone1.dt drone2.dt -t drone3.dt drone4.dt

Here, the first two drones will fight for themselves, but third and fourth will be a team mates.

Beside the **-t** key, the game engine recognizes two other useful keys: **-D** and **-q**.

The **-D** enables the debug mode for all drones passed after it. For example:

./DroneWar drone1.dt drone2.dt -D drone3.dt drone4.dt

The first two drones will fight as usual, but for the last two, at the start of the battle, the game engine will create a **.dt.decompiled** file which will contain the exact list of bytecodes which would control the drone’s behavior. All labels will disappear and all jumps to labels will be converted into absolute jumps to the operation.

After the battle started, each drone in debug mode will add a line to the **.dt.debug** file. In this file the player will find which exact operation the drone was supposed to perform at some tick and what was the contents of the stack before the operation.

This mode is useful for finding errors in the AI and detailed understanding what are the high-level compound statements actually are.

The **-q** flag disables GUI completely. This can be used to considerably speed up a battle. For example if player wants to gather statistics on how better or worse one drone actually is. The individual battle cannot answer this question with a good degree of certainty because drones appear at random position in the arena and some possible randomness in the drones’ behavior.

2.3 Variable types

Integer, Boolean, and Flags are fundamental types in the Drone language. Integer and Boolean are the standard types which can be found in any other language. Flags, on the other hand, are specific to the DroneWar game and can be one of Foe, Ally or Wall. Flags have only one purpose, they are used to indicate what the drone sees. The Drone language has several functions which use flags as input and return a boolean type value to tell if top of the stack contains a flag of the specified kind, it's, say did *look* function detected a foe or an ally.

Below are some examples about the usage of fundamental types:

```
// some arithmetic operations and compound statements
begin               // start of the loop
a read         // read contents of variable a
9 < while      // if it is less then 9, stay in the loop
b read         // read contents of variable b
2 +            // add 2 to it and leave result on stack
store b        // save top of the stack to variable b
a read 1 + a store  //  increment contents of a
again               // repeat the loop
// example of a flag operation
60 look        // fill the stack with tuples
isfoe          // does the top of the stack contain FOE flag?
if             // if yes
     shoot     // then shoot
else           // if not
     move      // then move
endif          // end of branching
```

2.4 Functions

Player can define functions by starting it with "sub" and ending with "endsub". Between "sub" and "endsub" is the function's body. All the names of functions are global. So, never try to define two functions using the same name. Also, one function cannot contain another. Functions can be called by simply using their names.

Below is an example of definition and call of a function:

```
sub increment           // define a function called "increment"
     1 +                // the function will put 1 on the stack
                        // and add it to whatever was on top of
endsub                  // the stack before the call

a read 1 +              // direct use of the 1 + operators
a read increment        // call to a function
```

2.5 Labels and Jumps

Instead of (or in conjunction with) using high-level compound statements as in examples above, the same algorithms can be created by using labels and jumps.

Labels are defined by adding colon to the word and a program can do unconditional and conditional jumps to these labels.

The simple unconditional loop is a just a:

```
labelA:                   // define a point in the code
     doSomething          // call a function
     labelA jump          // and repeat it indefinetely
```

The conditional branching is a little more difficult:

```
a read 9 <           // is contents of variable less than 9?
labelDone jumpif     // if yes, then goto the label
doSomething          // if not, do this
labelDone:                // just a label
doSomethingElse      // this will be done either immediately
                     // if a is less than 9, or after the
                          // the doSomething if variable a is
                          // equal or more than 9
```

Conditional loops are done by combining this two technics:

```
labelStart:               // the start of the loop
a read 9 <           // is contents of variable less than 9?
labelDone jumpif     // if yes, then jump out of the loop
doSomething          // if not, do this
labelStart jump      // and repeat
labelDone:                // once variable become less than 9,
                          // we exit the loop here
```

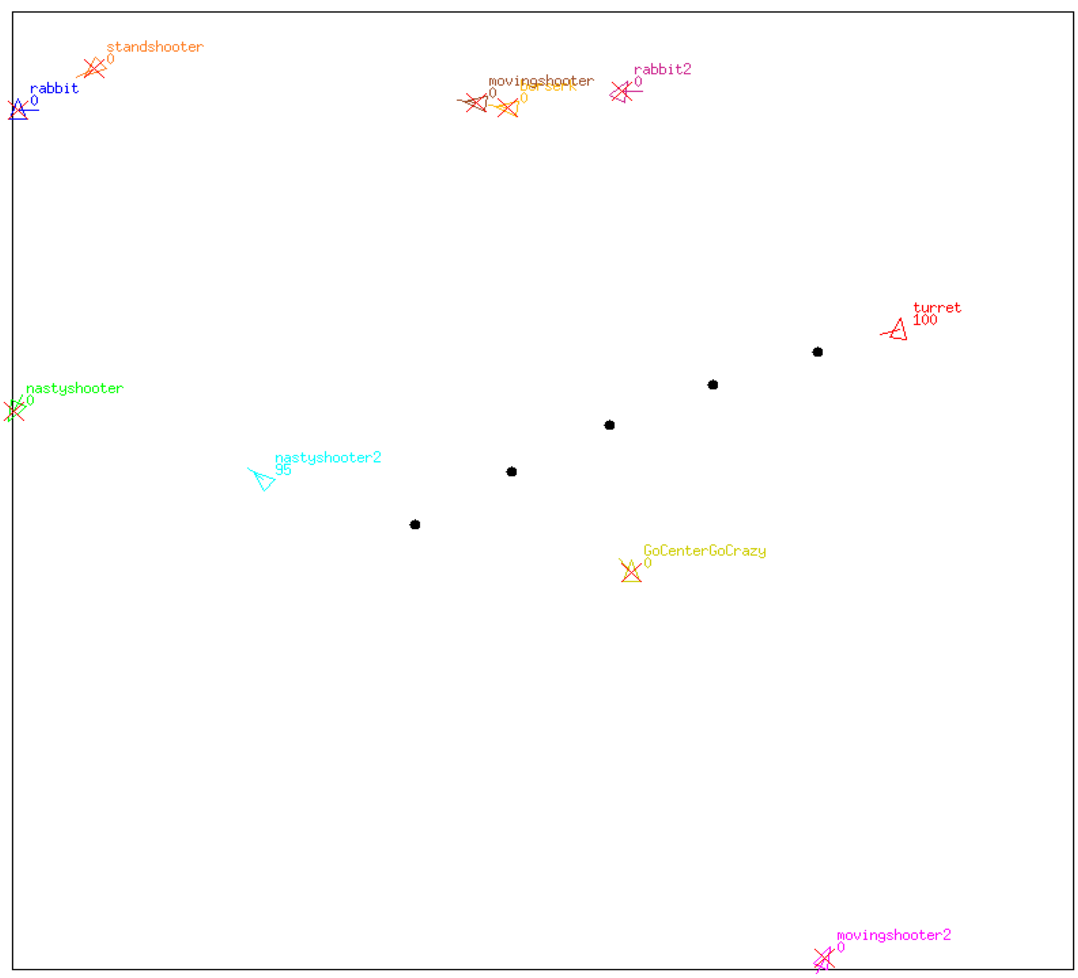
2.6 GUI Outputs

2.6.1 Text Status of Drones

The text part of the GUI shows total ticks each Drones runs as well as other information such as “Team ID”, “AI Ticks”, “Moving”, “Gun cooldown” and etc.

2.6.2 Arena GUI

Each Drone in the arena is displayed as a triangle with a “gun” on it, the direction of the “gun” shows in which direction the Drone is searching or shooting. And the direction of drone’s triangle shows where is it moving (or moved last if it is standing still right now). Bullets are displayed as black spots which moving faster than Drones. Once Bullet explodes, a “star” is displayed to show the range of damage. What’s more, on the top of each Drone, its name and health are displayed. Once Drones’ health becomes 0, there is a cross displayed over the Drone to show its death.



Chapter 3: Reference Manual

3.1. Language Syntax

3.1.1 Keywords

Keywords used by the language are case insensitive (i.e Dup is the same as DUP or dup). The list of known keywords is:

dup	drop	dropAll	swap	over	rot	read	store	jump	jumpIf
sub	endSub	move	stop	shoot	look	wait	getHealth	random	mod
isFoe	isAlly	isWall	and	or	not	if	else	endif	
begin	while	again							

3.1.2 Player defined names

Unlike keywords (which are case insensitive), names defined by the player are case sensitive. Those names are used as names for variables, labels, and user defined functions.

3.1.3 Comments

Single line comments, start with a word // and continue to the end of the line. E.g. each of the following lines contains a comment

```
// whole line can be a comment
2 2  + // or comment can start after some compilable words
// any word appeared after first // is still a comment
```

Multi line comments, start with a word /* and continue to the first */ word. The nested comments are not supported.

```
/* Inside here is
     a comment */
```

3.1.4 Functions

3.1.4.1 Structure of Function

User functions are marked with a word "Sub" followed by a function name, any number of commands and ends with "EndSub". It is not allowed to redefine any function or having a function inside a function.

```
Sub foo   // correctly defined function
     these words a body of a function
EndSub
Sub foo   // this is an error: function redefinition
     another words
EndSub

Sub foo 1 2    /* correctly defined function,
                  words 1 and 2 are body of the function */
     Sub bar        // error: sub functions are not allowed
          3 4
     EndSub
EndSub

Sub myAdd + EndSub  // correctly defined function
```

3.1.4.2 Call of Function

The call to the user defined function is just its name. E.g. assuming we defined the function ‘myAdd’ as in the previous chapter, then the next two lines will do exactly the same:

```
     2 2 +
     2 2 myAdd
```

3.1.5 Label

3.1.5.1 Structure of Label

Labels start with a letter followed by any number of letters, numbers, and '_' (underscore) symbols. Labels ended with a colon:

```
this_is_label:
this-is/not_a.label:
123456: // also not a label
```

Of course, the white-space character split sequences of characters into sequence of words and the next line will be understood as four words and a label with the name 'label':

```
this is not a label:
```

3.1.5.2 Unconditional and conditional jumps to the label

Operation "unconditional jump to the label" is marked by adding, "jump" to the name. The next line shows an unconditional jump to the labels defined in the previous example:

```
this_is_label jump
```

Conditional jump (marked jumpIf) checks the top of the stack first, if there was a true value, then the jump happens, if there was a false value, then jump does not happen and the execution is passed to the next operation after jumpif.

3.1.5.3 Local & Global Labels

Label visibility is restricted to the function. For example:

```
Sub foo
          2
lbl1:     2 +
          lbl1 Jump // ok
          lbl2 Jump // error
EndSub

lbl2:     lbl1 JumpIf    // error
```

Here, label *lbl1* is defined inside a function *foo* and jump to it is allowed. The label *lbl2* is defined in the main program and jump to it is allowed from anywhere from the main program, but not from the inside of user defined function. Conversely, the conditional jump to *lbl1* will fail since the label is defined inside of the function, but the jump is attempted from the main program.

3.2. Fundamental Types

3.2.1 Integer

Integer is word which consists solely from characters 0-9.

```
123       // one integer
1 2 3     // three integers
```

These words put the specified integer directly on the stack.

3.2.2 Boolean

Booleans are two words "true" and "false" which represent the logical values and are subject to logical operations and conditional jumps.

3.2.3 Flags

Flags are game specific type. They are produced by the function Look and explain what drone sees. There are four such flags: Foe, Ally, and Wall.

3.3. Variables

Variables are words started with a letter and any number of letters, digits and underscore symbols that directly followed by keywords "store" or "read". The first one takes the top of the stack and stores it into the variable (creating the variable in the process if necessary). The second one reads variable and puts its contents on the stack. E.g.

```
2 abc store
```

In this example, we assign 2 to a variable *abc* so that we can use it in the future.

```
abc read
```

Get the content of variable *abc* and push it into the stack. In this example, we push 2 to the stack because we assigned 2 to *abc* in the previous example.

Variables can contain any of the three fundamental types: integer, boolean or flag.

3.4. Operators

Operators are always taking some number of values from the stack and return some values back on the stack:

In the next examples, the top of the stack is considered to be on the left and the $ word symbolizes the end of stack

3.4.1 Arithmetic operators

```
+          b a $ -> (a + b) $
-          b a $ -> (a - b) $
*          b a $ -> (a * b) $
/          b a $ -> (a / b) $
mod        b a $ -> (a mod b) $
^          b a $ -> (a ^ b) $
```

3.4.2 Logic operators

```
and        b a $ -> (a and b) $
or         b a $ -> (a or b) $
not        a $   -> (not a) $
```

3.4.3 Logic constants

```
true       $ -> true $
false      $ -> false $
```

3.4.4 Conditions

```
=          b a $ -> (a = b) $
<          b a $ -> (a < b) $
>          b a $ -> (a > b) $
```

3.4.5 Variable manipulation

```
name store     a $ -> $
```

Store value into variable "name", create the variable if necessary. Always read the first on the stack and value it to “name”.

```
name read      $ -> a $
```

Read value from variable "name". Die if such variable does not exist.

3.4.6 Stack manipulation

```
drop      c b a $ -> b a $
dropall   c b a $ -> $
dup       c b a $ -> c c b a $
swap      c b a $ -> b c a $
over      c b a $ -> b c b a $
rot       c b a $ -> a c b $
```

3.5. Game specific functions

3.5.1 Move

```
move      direction $ -> $
```

Start moving in the specified direction

3.5.2 Stop

```
stop      $ -> $
```

Stop moving

3.5.3 Shoot

```
shoot     direction distance $ -> bool $
```

Shoot in the specified direction and distance. This function returns boolean value:

true -> shooting was successful and projectile is on its way

false -> cannon did not have enough time to cool-down

3.5.4 Look

```
look      direction $ -> flag1 dir1 dist1 ... WALL dir dist $
```

Look for other drones and walls in the specified direction. The function returns one or more triplets: type of the object, exact direction to it, and distance to the object. Type of the object is a flag from the set: FOE, ALLY, or WALL.

The WALL triplet is always the last one, so it can be used to detect an end of the look's output.

3.5.5 isFoe

`isFoe`	`flag $ -> bool $`

Checks is the top of the stack contains a flag FOE and returns corresponding boolean value.

3.5.6 isAlly

`isAlly`	`flag $ -> bool $`

Checks is the top of the stack contains a flag ALLY and returns corresponding boolean value.

3.5.7 isWall

`isWall`	`flag $ -> bool $`

Checks is the top of the stack contains a flag WALL and returns corresponding boolean value.

3.5.8 wait

`wait`	`ticks $  -> $`

Be idle (do nothing) for specified number of ticks

3.5.9 getHealth

`getHealth`	`$ -> health $`

Put current drone's health on the stack

3.5.10 random

`random`	`b a $ -> integer $`

Make a random integer in the range [a,b] (inclusive) and return it.

3.6. Pseudo-commands

All operators and game-specific commands described in sections 4 and 5 take exactly are executed directly by the game engine and take one tick to perform. The next set of commands added for convenience. They are compiled by the translator into several simple operators and can take any number of additional ticks to complete.

3.6.1 Conditions

Conditional branching is done by the means IF/ELSE/ENDIF. The stack should contain a Boolean value before the IF. If this value is true, then the set of command which follows the IF would be executed. If the value is false, then control jumps to the set of commands after the keyword ELSE, or to the command which follows ENDIF, if the ELSE keyword is omitted. Nested IF branching is allowed. For example, shoot if the top of the stack contains the description of the enemy drone

```
isFoe if shoot endif
```

This code will be transformed by compiler into:

```
isFoe not endif_label jumpIf shoot endif_label:
```

3.6.2 Loops

3.6.2.1 Endless loop

The endless loop is the most simple one, it is defined by keywords BEGIN and AGAIN:

```
begin 100 500 random 0 360 random shoot again
```

This will make the drone to shoot endlessly to a random distance in a random direction. This code is converted into a simple:

```
L1: 100 500 random 0 360 random shoot L1 jump
```

3.6.2.2 Conditional loop

Conditional loops are defined by the same BEGIN and AGAIN keywords. Addition of the WHILE keyword allows to leave the endless loop if top of the stack is false when execution reach the WHILE keyword. For example, the cleanup after the LOOK command can be like this:

```
begin isEnd while drop drop again
```

This is code will be compiled into

```
L1: isend L2 jumpif drop drop L1 jump L2:
```

The WHILE keyword can appear anywhere inside the BEGIN-AGAIN block, this allows to create loops with post-conditions or even with conditions in the middle of the block:

```
begin dup isfoe shoot endif isend while drop drop again
```

Both types of loops can be nested.

Chapter 4: Drone-Basic

The Drone-Basic language was designed as an afterthought for the Drone War project. The language itself is based in a Visual Basic and tweaked to allow special, game-related operations and concepts.

The Drone-Basic mostly follows the syntax of Visual Basic: One statement per line of source code, several statements can be grouped inside one compound statement, the language is completely case-insensitive, only single-line comments started with apostrophe, user procedures and functions.

4.1 The conditional branching

There are three types of conditional compound statements:

```
IF condition THEN statement
```

```
IF conditions THEN
     statements
END IF
```

```
IF conditions THEN
     statements
ELSE
     statements
END IF
```

4.2 The conditional loops

There are two ways to do a conditional loops, with pre-condition and post-condition. Both variants can use the keyword WHILE (continue the loop, while the condition is true) and UNTIL (continue the loop until the condition become true):

```
DO [WHILE | UNTIL] condition
     statements
LOOP
```

```
DO
     statements
LOOP [WHILE | UNTIL] condition
```

All types of the conditional loop accept the EXIT DO statement which ends the loop immediately without checking the loop condition.

4.3 The counted loop

Just a regular FOR loop:

```
FOR variable=a TO b [STEP c]
     statements
NEXT
```

The FOR loop also can be ended with EXIT FOR statement.

4.4 User procedures and functions

The user-defined procedures are following the Visual Basic's syntax:

```
SUB name(parameters)
     statements
END SUB
```

Calls to a procedures are done with a special keyword CALL:

```
CALL name(arguments)
```

Unlike Visual Basic, the keyword CALL and parenthesis after the procedure name are necessary.

The user-defined functions are also following the Visual Basic's syntax:

```
FUNCTION name(parameters)
     statements
     name = result
END FUNCTION
```

The function have to have at least one assignment statement where the function name acts as a variable.

Parameters of procedures and functions are local to the procedures they are defined in. But since those variables are still has global bindings - only tail recursion in user procedures or functions are allowed. The use of other types of recursion can result in unpredictable behavior.

4.5 Variables

Variables in Drone-Basic are integer only (with the exception for the records returned by STARTSCAN and NEXTSCAN function, see below).

4.6 The game-related functions

Most of Drone-Basic game-related features are following the syntax for calling user-defined procedures and functions:

The Drone-Basic has next set of procedures (which require a CALL to be called):

```
CALL SLEEP(ticks)
CALL MOVE(direction)
CALL STOP()
```

The SHOOT(direction, distance) operation can act as both function and procedure. In case of a function – it returns a boolean value and can be used inside any conditional expression (in the IF or WHILE/UNTIL loops). The true returned by the SHOOT means that the bullet was shot successfully, the false – gun is still reloading. If the SHOOT is called as procedure – we ignore the result of the SHOOT.

The GETHEALTH() and RANDOM(min, max) are regular functions which can be used in any arithmetic expression.

4.7 The search procedure

The search procedure in the Drone-Basic language is the farthest operation from the classical Visual Basic. It consists of two functions:

The search procedure is started by the call to a function STARTSCAN(direction). This returns an object of the scan-result type:

```
var = STARTSCAN(direction)
```

The var here is not a single variable, but a collection of variables which represent a closes object the drone saw in the given direction. The next object the drone saw can be accessed by calling a function:

```
var = NEXTSCAN()
```

The NEXTSCAN function can be called several times until the list of objects seen by the first STARTSCAN operation is exhausted. The extra calls to NEXTSCAN can result in a drone coma with “Nothing to store” explanation.

The object read by STARTSCAN and NEXTSCAN is actually a structure with several elements:

obj.DIRECTION Integer. The exact direction to the object

obj.DISTANCE Integer. The exact distance to the object.

obj.ISFOE Boolean. The object is a drone and belongs to one of the opposing teams

obj.ISALLY Boolean. The object is a drone and belongs to the same team as the drone itself.

obj.ISWALL Boolean. The object is a wall.

obj.ISEND Boolean. The last object in the list of objects. After receiving such object it is not allowed to call NEXTSCAN.

4.8 Comparison between the base Drone language and Drone-Basic

Both languages allow the full control over drones. The text of the program in Drone-Basic is a little easier to understand since it is a higher level language. But as a downside after compilation to the IR it produces a less efficient code. Also while using the Drone-Basic, programmer is unable to access some of convenient functions (like dropall) which result in a necessity to write an extra code.

Here is an example of the same algorithm written in both languages:

drones/drone.dt

```
0 direction store
main_loop:
     dropall
     direction read look
     isFoe
     shootIt jumpif
     direction read 10 + direction store
     main_loop jump
shootIt:
     dup direction store
     shoot
     10 wait
     main_loop jump
```

drones/drone.dbt

```
direction=0
start:
    drone = startScan(direction)
    if drone.isfoe then
        direction = drone.direction
        call shoot(drone.direction, drone.distance)
        call sleep(10)
    else
        direction = direction + 10
    end if
    do until drone.isWall
          drone = nextScan()
     loop
goto start
```

Chapter 5: Project Plan

5.1 Process

5.1.1 Planning

To make a decent design of the project, our team decided to start planning process earlier right after we learnt what need to be included as parts of a language, which we believed was the key to success. So as to make continuous progress and good communications within the team, we first set up a short meeting after each lecture, and could share the latest updates of the progress and discuss about what to do in the next few days. Besides, we set up Google Code with SVN so as to keep all source code in good shape and up to date for everybody in the team.

For the topic of the project, our team first agreed on the designing rules, which were “Interesting, Simple, and Efficient”.

5.1.2 Specification

An advantage of our team, was that we have an experienced leader who can always give advice, indicate what to do. After discussing about several ideas, we agreed on that a programming game would be attractive to most people and a stack-based language for it would fit our design rules best. Since a stack based language is easy to use and any user who knows nothing about programming would be able to make his or her own AI programs.

After handing in the proposal, we got help both from team leader and MICRO-C example of how to create a language starting from building Scanner, Parser and Ast. Based on the basic design of our language, we successfully agreed on and finished designing details for our game part.

5.1.3 Development

Mentioned before, our team used SVN version control tool during the development process to manage and keep every team member update up to date. So as to make sure each component of the project works correctly, our team applied a waterfall approach, in which each component was implemented and tested properly before we moved on to next step. First of all, our leader gave us an overview description of the language outline by creating Scanner and AST tree for us. Based on the language keywords and other basic information designed by our team leader, we discussed about the future work and made sure nothing was missing.

During when, Professor indicated that our language was somehow too hard to be understood and might need more high level “meat” such as conditional execution, endless loops as well as conditional loops.

After adding compound statements mentioned by professor into the language, our team continued to work on the compiler part of our project, which includes processing of all bytecodes, storing variables and subs. Some changes and corrections to the language design was implemented as a result of a more close work on the actual compiler and attempts to write a working drone AI. Tests also got implemented in this part.

After language part has been tested, our team then moved on to the game engine part of our project. Built in functions such as *move*, *look* and *shoot* were created according to the game description. Drone and Bullet were converted into object-oriented classes each containing local variables inside. However, applying our language to a real game was the most challenging part since multiple errors in different perspectives could happen.

When the game part was tested thoroughly, we created GUI part to make the game more interesting and completed all functionalities.

At this time, together with the initial development of GUI, the compiler from Drone-Basic was added. It was intended as a template for adding other languages of different styles and paradigms into the Drone War game. Unfortunately we did not have enough time to complete them to any degree of testing.

5.1.4 Testing

Since our team implemented a waterfall approach in the development process, every component was tested thoroughly before we moved on to next part. We developed and tested the project in order of Scanner, Parser, Ast, Engine, Arena and GUI. After unit testings, we implemented integration testing on the whole project by creating testing Drones, and which contained all possible syntax of our language. Based on the behaviours of Drones, our language could be tested in a large scale. However, multiple bugs and errors did happen during both unit testing and integration testing. Everyone in the team took part in the testing part and fixing the bugs.

5.2 Programming Style Guide

5.2.1 General Programming Principles

During the early meetings, our team made agreements on the designing and programming on the whole project, which were “Interesting”, “Simple” and “Efficient”. Later, after we learnt that stack-base language would be the best choice for us, we then decided to use a waterfall approach to make development of this project. So as to keep everyone in the team concentrate on the main ideas of, we made some extra programming principles to help us continuously make progress, which included “keep testing everything”, “keep communication”, “using version control tool”, “mutual code review”, and “code documentation”. Based on these rules, our team could better understand work as well as communicate with each other in a smooth way.

5.2.2 Keep Testing Everything

To development process in a waterfall approach, our team needed to make sure every functionality and every single method had been tested correctly before we move on to next step. Thus, our team designed and created several methods for unit testing for each component. After the game was finished, a number of testing Drones were created so as to implement integration testing. We all believed that testing everything from some time to time can always lead to better products in the future.

5.2.3 Keep Communications

Decided in the first meeting, our team scheduled a short meeting after each lecture, which could not only share ideas from the lecture, but also discuss about progress in the project. As usual, our team leader separated works into pieces and assigned to every team member according to our timeline, and this was also good timing to solve difficulties met during the development.

Beside meeting, our team kept emailing everyone about the latest progress had been made as well as TO-DO works for other. One could always send new ideas or possible improvements about the project.

5.2.4 Using Version Control Tool

Recommended by Professor Edwards, version control tool was always the best choice for a team work in programming. However, we strongly agreed with him since SVN made great help in our project. Each team member’s code could be merged and pushed to server any time and no one needed to worry about losing or ruining latest code.

5.2.5 Mutual Code Review

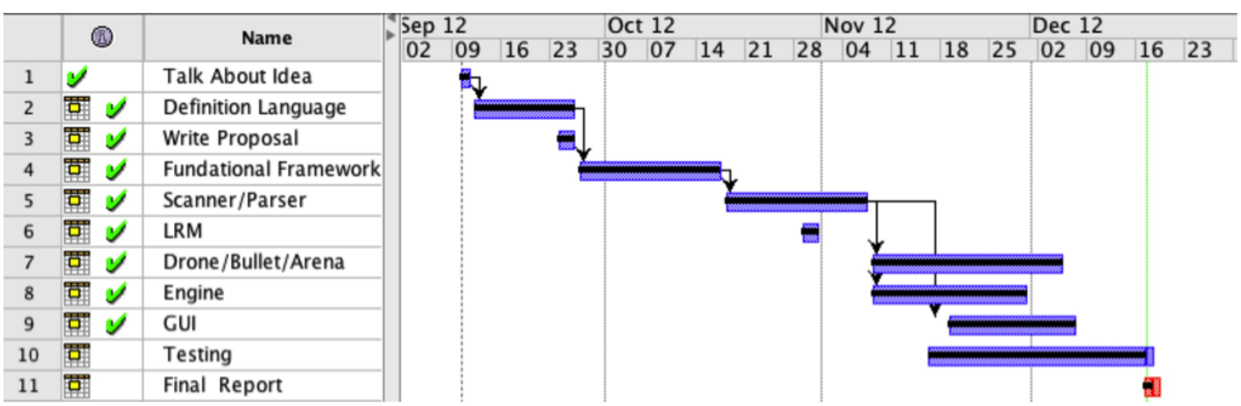
Another great principle of our team, once new progress was made, team leader as well as other team members would always do code review. Also, this was another way to reduce error and make improvement of the project.

5.2.6 Code Documentation & Comments

Because of the complexity of the functional language like OCaml it was always a problem to make other team member understand the code. And the fact that all team members were beginners to OCaml also hindered us a lot. As a solution mentioned by Professor Edwards, we always kept comments in the code up to date and wrote documentation for each new feature of the component. What's more, multiple warning symbols were designed to let others know the information such as "something need to be improved", "error might exists", "TO-DO", "not working" and etc.

5.3 Project Timeline

Major milestone and progress of the project is indicated as follow.



Date	Milestone/Progress
9/10/12	Talk About Idea Brainstorming
9/26/12	Language Definition

	Syntax Definition Game Definition
9/29/12	Language Proposal
10/17/12	Foundational Framework
11/7/12	Language Syntax & Semantic Analysis Scanner Parser Abstract Syntax Tree
11/15/12	Engine Part Done Drone Arena Bullet
12/05/12	GUI Part Started

5.4 Project Log

The project log of our team is attached as follow, and please refer to SVN log for more detail information.

Date	Milestone/Progress
9/10/12	Talk About Idea Brainstorming
9/12/12	Decided on project topic Of The Drone War
9/16/12	Agreed on a Stack-based language
9/24/12	Started Game design & Rules design
9/26/12	Language Definition

	Syntax Definition Game Definition
9/29/12	Language Proposal
10/03/12	First draft of Scanner, Parser Created by team leader
10/15/12	AST tree generated
10/17/12	Foundational Framework
10/22/12	Studied MICRO-C compiler New features to be considered Based on it
10/24/12	Scanner, Parser and AST are finished Start to work on Engine part
10/29/12	First draft of the Engine part byte code operations are finished; Variables & Subs' stacks and hash tables are created
11/5/12	Second draft of Engine is modified by team leader and multiple changes are implemented
11/7/12	Language Syntax & Semantic Analysis Scanner Parser Abstract Syntax Tree tested and finished
11/12/12	Start to work on game helper functions and other classes such Bullet and Utils are created
11/19/12	Game helper functions are generated and first draft of the game is done
11/21/12	Several testing Drones are created and first integration testing implemented
11/26/12	Second draft of engine part is done
12/5/12	Engine Part done

	Drone Arena Bullet
12/10/12	GUI Part Started
12/14/12	First draft of GUI-enabled game is done
12/16/12	GUI part is done and more testing drones are created to implement integration testing
12/17/12	Start to work on final report and final testing for the whole project

5.5 Team Responsibility

As we have an experienced team leader, the project was separated into different components and each team member made contribution to it. After the project was finished, everyone implemented reports about his component in the representation slides as well as the final report. Here comes the assigned responsibilities of each team member:

George	Team Leader Created Scanner, Parser, AST Engine parts' features and improvement in every class Code review and giving advice in every process of the project Testing and modification in all perspectives Unit testing & Integration testing Basic-like translator (Individual)
Xiaotong	Parser: compound loops, conditional loops Engine part: bytecode operations, variables & subs' stack and hash table Drones: objects variables, Drones operation functions Arena: objects variables, Arena operation functions Game: Bullet and Utils classes and other helper functions Testing Drones created

	Unit testing & Integration testing
Xiang	Parser: compound loops, conditional loops Engine part: bytecode operations, variables & subs' stack and hash table Drones: objects variables, Drones operation functions Arena: objects variables, Arena operation funcitons Game: Bullet and Utils classes and other helper functions Testing Drones created Unit testing & Integration testing
Shuo	Parser: compound loops Engine part: bytecode operations, debug Drones: objects variables, Drones operation functions Arena: objects variables, Arena operation funcitons GUI: objects variables, Arena operation funcitons Testing Drones created Integration testing

5.6 Development Environment

Operating systems: Mac OX, Windows XP, Windows 7, Linux Debian
Language: Objective Caml (OCaml)
Compiler: OCaml
Editors: Eclipse with OCaml Plugins, other various text editors
GUI: Ocaml Graphics Standard Library
Version Control: SVN, Google Code
Other tools: Google Docs, Emails,

Chapter 6: Architecture Design

6.1 Design Overview

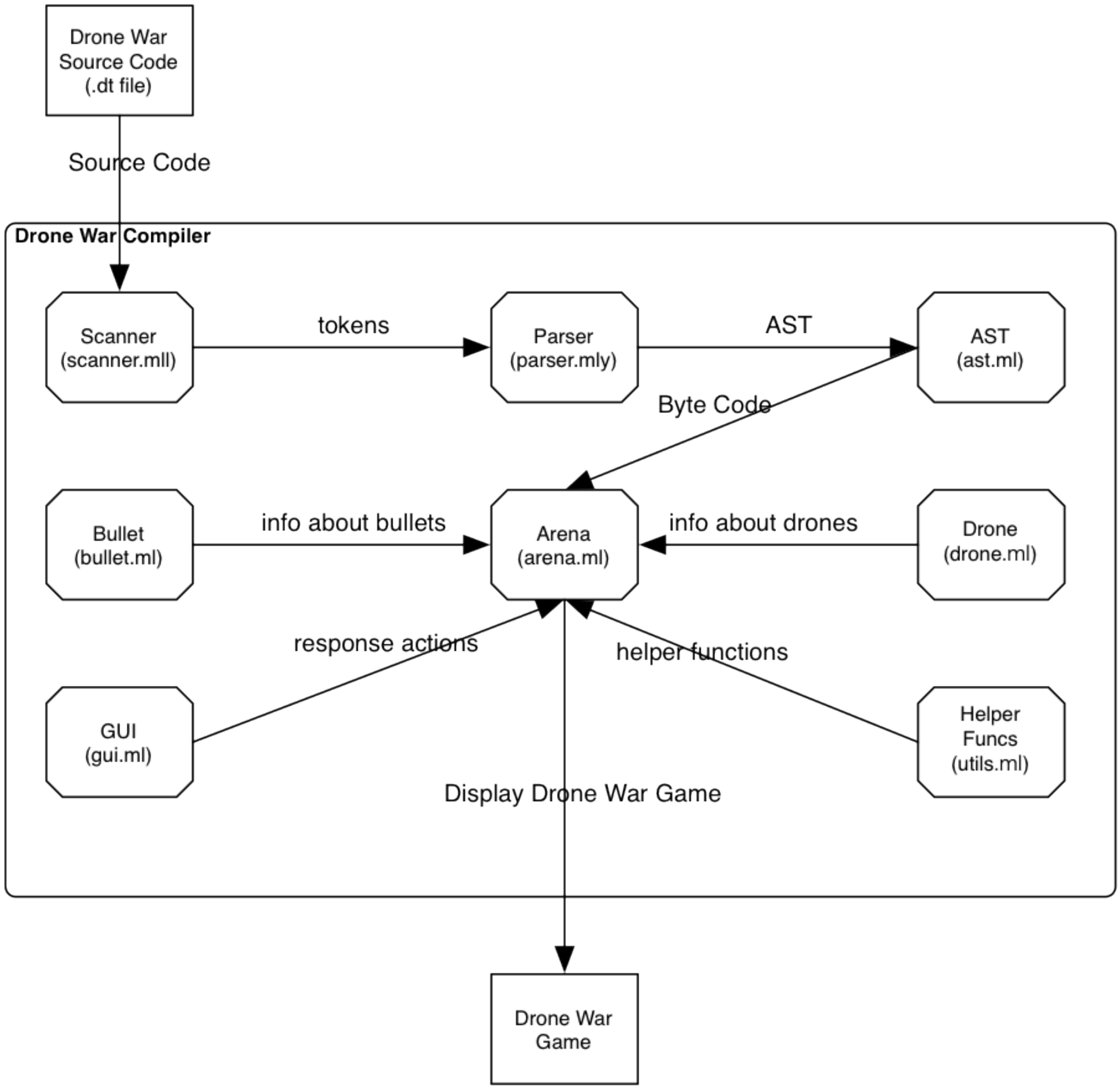
In our design, the Drone War project is composed of several components, which includes Syntax Analysis, Semantic Analysis, Compiler, Game Engine, GUI and other helper functions. When a qualified input file such as ***.dt*** or ***.dbt*** comes in, Compiler first links all needed files and sends it to Syntax Analysis part which contains the Scanner to get tokens. Secondly, tokens are passed to Semantics Analysis which contains Parser, so as to filter illegal tokens and store all necessary information like variables and subs. After that, arrays of bytecode are generated based on Abstract Syntax Tree and corresponding operations are to be implemented and stored in each Drone object's stack. Thus, the Drone Language has successfully finished its work.

Followed by the language part, our Game Engine is going to take charge of all Drones in the arena. As controlled by arena object, all Drones will do exactly one tick in a single round, and all corresponding operations popped from the stack such as "look", "move", "shoot" will be implemented. After all Drones make a single tick, all updated information is to be stored. In this part all the operations are controlled by the arena and Game Engine functions from Drone.ml, Arena.ml, Bullet.ml and Utils.ml are called from time to time.

Once all updates to Arena's objects (Drones or Bullets) are done, the Arena will call GUI part to visualize it on the graphic screen.

The last step in the main Arena's loop is to check are there more than one Drone left alive? If not, then Arena considers that last Drone to be a winner and game ends. Another reason for exit from the main Arena's loop is if total count of loops exceeds predefined constant. In that case, Arena presumes that the remaining live drones will not attack each other and the normal one-winner scenario is unachievable.

If Arena decided that the battle should continue, it again start requesting from the drones to execute one step of their AIs.


Drone War
Source Code
(.dt file)
Source Code
Drone War Compiler
Scanner
(scanner.mll)
tokens
Parser
(parser.mly)
AST
AST
(ast.ml)
Byte Code
Bullet
(bullet.ml)
info about bullets
Arena
(arena.ml)
info about drones
Drone
(drone.ml)
response actions
helper functions
GUI
(gui.ml)
Helper
Funcs
(utils.ml)
Display Drone War Game
Drone War
Game

(Figure 5.1)

6.2 Interfaces Between the Components

6.2.1 Scanner (scanner.mll -Author: George)

The role of the scanner is to define what tokens are acceptable in our language. The scanner will go through the **.dt** file, which is our input source code, and recognize the stream of input file as tokens in our language or not. This component will convert all the input source code to tokens defined by us, so that it can reject the code that is not in the syntax of our language.

6.2.2 Parser (parser.mly -Author: George, Xiaotong, Xiang)

The role of the parser is to catch the tokens generated by the scanner. Although, we are sure these tokens are defined in our language, we still need to make sure these tokens together are meaningful, that is they can construct the AST defined by us. If these tokens don't satisfy our grammar, parser will reject them。

6.2.3 AST (ast.ml -Author: George)

The role of AST is to define the structure of a program in our language. As stated above, during the execution of parser, it will check AST to see if the input tokens are valid or not. That is, the AST will be built during the parser. Also, from this component, we can get a list of bytecode defined in our language.

6.2.4 Arena (arena.ml -Author: George, Xiaotong, Xiang, Shuo)

Arena is the synchronizing piece of the game engine. It keeps track of all game objects (drones and bullets) and prompts them to do their assigned roles. The Drone object can request a creation of a Bullet object (shooting) and request the relative position of other drones (looking). These requests (as well as destruction of Bullets) are satisfied by the Arena.

Also Arena calls the GUI to show current state of the battle.

6.2.5 Drone (drone.ml -Author: George, Xiaotong, Xiang, Shuo)

As said in Arena, each drone is an "object". It has many attributes like position, health, team and so on. The most important part of drone is that it contains two hash tables: *vars* to store the variables and *subs* to store the functions including the "main" (arrays of bytecode). This component is one of the most important parts of the engine. It includes many basic actions as well as the actual "drone's CPU" which process the bytecodes.

6.2.6 Bullet (bullet.ml -Author: Xiaotong, Xiang)

Bullet is also a part of engine to represent the object of bullet. Compared with drone.ml, bullet.ml is very simple, it contains only the most basic information such as the position and the direction of a bullet.

6.2.7 GUI (gui.ml -Author: Shuo, George)

The role of GUI is to display the state of the game. This component is implemented by using the Graphics module in OCaml.

6.2.8 Helper Funcs (utils.ml -Author: Xiaotong, Xiang)

Utils.ml is a helper file for common functions. It contains several functions that can be called by arena and drone, such as the one help calculate the distance between two point, represented by (X,Y), common constants and such.

6.2.9 Drone-Basic (scanner_dbt.mll and parser_dbt.mly –Author: George)

Implementation of the Drone-Basic language.

Chapter 7: Test Plan

7.1 Unit Testing

Mentioned above as a testing functionality, while compiling the Drone language, we provide a debug mode, in which two extra debugging files are created. ***<filename>.dt.decompiled*** is the file shows what bytecode is generated based on input file, while ***<filename>.dt.debug*** shows everything in the stack for each step. The unit testing cases for each component goes as followed:

7.1.1 Integer

test case:
1 2 3 4 5 6

generated byte code:

```
  0: Int(1)
  1: Int(2)
  2: Int(3)
  3: Int(4)
  4: Int(5)
  5: Int(6)
```

stack:

```
  1        [  0]       Int(1)  | EOS
  2        [  1]       Int(2)  | 1 EOS
  3        [  2]       Int(3)  | 2 1 EOS
  4        [  3]       Int(4)  | 3 2 1 EOS
  5        [  4]       Int(5)  | 4 3 2 1 EOS
  6        [  5]       Int(6)  | 5 4 3 2 1 EOS
```

result: successfully recognized the input integer.

7.1.2 Comment

test case:

```
6 // This is a comment 7
8
/* this is also
  9  a comment */
10
```

generated byte code:

```
  0: Int(6)
  1: Int(8)
  2: Int(10)
```

stack:

```
  1        [  0]     Int(6)  | EOS
  2        [  1]     Int(8)  | 6 EOS
  3        [  2]    Int(10)  | 8  6 EOS
```

result: the comment parts have been ignored by the compiler.

7.1.3 Variables

test case:

```
36 var1 store
3 var1 read
```

generated byte code:

```
  0: Int(36)
  1: Store(var1)
  2: Int(3)
  3: Read(var1)
```

stack:

```
  1        [  0]    Int(36)      | EOS
  2        [  1]    Store(var1)  | 36 EOS
  3        [  2]    Int(3)       | EOS
  4        [  3]    Read(var1)   | 3 EOS
```

result: successfully set and get the value of a variable.

7.1.4 Arithmetic operators

test case:
1 2 + 1 - 1 * 2 / 2 mod 4 ^

generated byte code:

```
 0: Int(1)
 1: Int(2)
 2: Plus
 3: Int(1)
 4: Minus
 5: Int(1)
 6: Times
 7: Int(2)
 8: Divide
 9: Int(2)
10: Mod
11: Int(4)
12: Power
```

stack:

```
 1    [ 0]    Int(1)  | EOS
 2    [ 1]    Int(2)  | 1 EOS
 3    [ 2]    Plus    | 2 1 EOS
 4    [ 3]    Int(1)  | 3 EOS
 5    [ 4]    Minus   | 1 3 EOS
 6    [ 5]    Int(1)  | 2 EOS
 7    [ 6]    Times   | 1 2 EOS
 8    [ 7]    Int(2)  | 2 EOS
 9    [ 8]    Divide  | 2 2 EOS
10    [ 9]    Int(2)  | 1 EOS
11    [10]    Mod     | 2 1 EOS
12    [11]    Int(4)  | 1 EOS
13    [12]    Power   | 4 1 EOS
```

result: successfully calculate the result of arithmetic expression.

7.1.5 Logic constants

test case:
true
drop
false
drop

generated byte code:
0: Bool(true)
1: Drop
2: Bool(false)
3: Drop

stack:

1	[0]	Bool(true) | EOS
2	[1]	Drop | true EOS
3	[2]	Bool(false) | EOS
4	[3]	Drop | false EOS

result: successfully store or drop a bollean.

7.1.6 Logic operators

test case:
true true and
drop
true false and
drop
false false and
drop
true true or
drop
true false or
drop
false false or
drop
true not
drop

```
false not
drop

generated byte code:
  0: Bool(true)
  1: Bool(true)
  2: And
  3: Drop
  4: Bool(true)
  5: Bool(false)
  6: And
  7: Drop
  8: Bool(false)
  9: Bool(false)
 10: And
 11: Drop
 12: Bool(true)
 13: Bool(true)
 14: Or
 15: Drop
 16: Bool(true)
 17: Bool(false)
 18: Or
 19: Drop
 20: Bool(false)
 21: Bool(false)
 22: Or
 23: Drop
 24: Bool(true)
 25: Not
 26: Drop
 27: Bool(false)
 28: Not
 29: Drop

stack:
  1        [ 0]     Bool(true)  | EOS
  2        [ 1]     Bool(true)  | true EOS
```

3	[2]	And	| true true EOS
4	[3]	Drop	| true EOS
5	[4]	Bool(true)	| EOS
6	[5]	Bool(false)	| true EOS
7	[6]	And	| false true EOS
8	[7]	Drop	| false EOS
9	[8]	Bool(false)	| EOS
10	[9]	Bool(false)	| false EOS
11	[10]	And	| false false EOS
12	[11]	Drop	| false EOS
13	[12]	Bool(true)	| EOS
14	[13]	Bool(true)	| true EOS
15	[14]	Or	| true true EOS
16	[15]	Drop	| true EOS
17	[16]	Bool(true)	| EOS
18	[17]	Bool(false)	| true EOS
19	[18]	Or	| false true EOS
20	[19]	Drop	| true EOS
21	[20]	Bool(false)	| EOS
22	[21]	Bool(false)	| false EOS
23	[22]	Or	| false false EOS
24	[23]	Drop	| false EOS
25	[24]	Bool(true)	| EOS
26	[25]	Not	| true EOS
27	[26]	Drop	| false EOS
28	[27]	Bool(false)	| EOS
29	[28]	Not	| false EOS
30	[29]	Drop	| true EOS

result: successfully calculate the result of logic expression.

7.1.7 Stack manipulation

test case:
1 drop
1 2 3 dropall
1 dup
dropall
1 2 swap

```
dropall
1 2 3 over
dropall
1 2 3 rot
dropall
```

generated byte code:

```
 0: Int(1)
 1: Drop
 2: Int(1)
 3: Int(2)
 4: Int(3)
 5: Dropall
 6: Int(1)
 7: Dup
 8: Dropall
 9: Int(1)
10: Int(2)
11: Swap
12: Dropall
13: Int(1)
14: Int(2)
15: Int(3)
16: Over
17: Dropall
18: Int(1)
19: Int(2)
20: Int(3)
21: Rot
22: Dropall
```

stack:

```
1    [ 0]    Int(1)    | EOS
2    [ 1]    Drop      | 1 EOS
3    [ 2]    Int(1)    | EOS
4    [ 3]    Int(2)    | 1 EOS
5    [ 4]    Int(3)    | 2 1 EOS
6    [ 5]    Dropall   | 3 2 1 EOS
```

```
 7          [  6]      Int(1)    | EOS
 8          [  7]      Dup       | 1 EOS
 9          [  8]      Dropall   | 1 1 EOS
10          [  9]      Int(1)    | EOS
11          [ 10]      Int(2)    | 1 EOS
12          [ 11]      Swap      | 2 1 EOS
13          [ 12]      Dropall   | 1 2 EOS
14          [ 13]      Int(1)    | EOS
15          [ 14]      Int(2)    | 1 EOS
16          [ 15]      Int(3)    | 2 1 EOS
17          [ 16]      Over      | 3 2 1 EOS
18          [ 17]      Dropall   | 3 2 2 1 EOS
19          [ 18]      Int(1)    | EOS
20          [ 19]      Int(2)    | 1 EOS
21          [ 20]      Int(3)    | 2 1 EOS
22          [ 21]      Rot       | 3 2 1 EOS
23          [ 22]      Dropall   | 2 3 2 2 1 EOS
```

result: successfully manipulate the stack by variable operators.

7.1.8 Function

test case:

```
2 2 foo
sub foo
    2
    2
    +
endsub
```

generated byte code:

```
 0: Int(2)
 1: Int(2)
 2: Call(foo)
sub foo
 0: Int(2)
 1: Int(2)
 2: Plus
esub
```

stack:

1	[0]	Int(2)	| EOS
2	[1]	Int(2)	| 2 EOS
3	[2]	Call(foo)	| 2 2 EOS
4	foo[0]	Int(2)	| 2 2 EOS
5	foo[1]	Int(2)	| 2 2 2 EOS
6	foo[2]	Plus	| 2 2 2 2 EOS

result: successfully call the function.

7.1.9 Label

test case:
label:
main:
this_is_a_label:

generated byte code:
-- nothing

stack:
-- nothing

7.1.10 Move

test case:
45 move

generated byte code:
0: Int(45)
1: Move

stack:

1	[0]	Int(45)	| EOS
2	[1]	Move	| 45 EOS

result: successfully move to direction 45.

7.1.11 Stop

test case:
45 move
stop

generated byte code:
0: Int(45)
1: Move
2: Stop

stack:

1	[0]	Int(45)	| EOS
2	[1]	Move	| 45 EOS
3	[2]	Stop	| EOS

result: stop moving.

7.1.12 Shoot

test case:
45 100 shoot

generated byte code:
0: Int(45)
1: Int(100)
2: Shoot

stack:

1	[0]	Int(45)	| EOS
2	[1]	Int(100)	| 45 EOS
3	[2]	Shoot	| 100 45 EOS

result: shoot to the direction of 45 and distance of 100.

7.1.13 Look

test case:
180 look

generated byte code:
0: Int(180)
1: Look

stack:

1	[0]	Int(180)	| EOS
2	[1]	Look	| 180 EOS

result: successfully return a list of Flags.

7.1.14 isFoe

test case:
100 look
isFoe

generated byte code:
0: Int(100)
1: Look
2: IsFoe

stack:

1	[0]	Int(100)	| EOS
2	[1]	Look	| 100 EOS
3	[2]	IsFoe	| Foe 71 252 Foe 121 426 Wall 100 416 EOS

result: successfully identify the FOE.

7.1.15 isAlly

test case:
100 look
isAlly

generated byte code:
0: Int(100)
1: Look
2: IsAlly

stack:

1	[0]	Int(100) | EOS
2	[1]	Look | 100 EOS
3	[2]	IsAlly | Foe 71 252 Foe 121 426 Wall 100 416 EOS

result: successfully identify the Ally.

7.1.16 isWall

test case:
100 look
isWall

generated byte code:
0: Int(100)
1: Look
2: IsWall

stack:

1	[0]	Int(100) | EOS
2	[1]	Look | 100 EOS
3	[2]	IsWall | Wall 100 108 EOS

result: successfully identify the Wall.

7.1.17 Wait

test case:
10 wait

generated byte code:
0: Int(10)
1: Wait

stack:

1	[0]	Int(10) | EOS
2	[1]	Wait | 10 EOS

3 waiting for 10 ticks
4 waiting for 9 ticks

5 waiting for 8 ticks
6 waiting for 7 ticks
7 waiting for 6 ticks
8 waiting for 5 ticks
9 waiting for 4 ticks
10 waiting for 3 ticks
11 waiting for 2 ticks
12 waiting for 1 ticks
result: this drone will be hang up.

7.1.18 GetHealth

test case:
100 health store
health read getHealth =

generated byte code:
0: Int(100)
1: Store(health)
2: Read(health)
3: GetHealth
4: Equal

stack:

1	[0]	Int(100)	EOS
2	[1]	Store(health)	100 EOS
3	[2]	Read(health)	EOS
4	[3]	GetHealth	100 EOS
5	[4]	Equal	100 100 EOS

result: successfully get the health of the drone.

7.1.19 Random

test case:
1 100 random
generated byte code:
0: Int(1)

1: Int(100)
2: Random

stack:

```
 1        [ 0]      Int(1)  | EOS
 2        [ 1]    Int(100)  | 1 EOS
 3        [ 2]      Random  | 100 1 EOS
```

result: successfully generate a number between 1 and 100.

7.1.20 Endless Loop

test case:

```
begin
    100 100 shoot
again
```

generated byte code:

```
0: Int(100)
1: Int(100)
2: Shoot
3: AbsJump(0)
```

stack:

```
 1        [ 0]    Int(100)  | EOS
 2        [ 1]    Int(100)  | 100 EOS
 3        [ 2]       Shoot  | 100 100 EOS
 4        [ 3]  AbsJump(0)  | true EOS
 5        [ 0]    Int(100)  | true EOS
 6        [ 1]    Int(100)  | 100 true EOS
 7        [ 2]       Shoot  | 100 100 true EOS
 8        [ 3]  AbsJump(0)  | false true EOS
 9        [ 0]    Int(100)  | false true EOS
10        [ 1]    Int(100)  | 100 false true EOS
11        [ 2]       Shoot  | 100 100 false true EOS
12        [ 3]  AbsJump(0)  | false false true EOS
13        [ 0]    Int(100)  | false false true EOS
14        [ 1]    Int(100)  | 100 false false true EOS
15        [ 2]       Shoot  | 100 100 false false true EOS
```

```
16    [ 3]   AbsJump(0)  | true false false true EOS
17    [ 0]     Int(100)  | true false false true EOS
18    [ 1]     Int(100)  | 100 true false false true EOS
19    [ 2]        Shoot  | 100 100 true false false true EOS
20    [ 3]   AbsJump(0)  | false true false false true EOS
21    [ 0]     Int(100)  | false true false false true EOS
22    [ 1]     Int(100)  | 100 false true false false true EOS
23    [ 2]        Shoot  | 100 100 false true false false true EOS
24    [ 3]   AbsJump(0)  | false false true false false true EOS
25    [ 0]     Int(100)  | false false true false false true EOS
26    [ 1]     Int(100)  | 100 false false true false false true EOS
27    [ 2]        Shoot  | 100 100 false false true false false true EOS
28    [ 3]   AbsJump(0)  | true false false true false false true EOS
29    [ 0]     Int(100)  | true false false true false false true EOS
30    [ 1]     Int(100)  | 100 true false false true false false true EOS
31    [ 2]        Shoot  | 100 100 true false false true false false true EOS
32    [ 3]   AbsJump(0)  | false true false false true false false true EOS
33    [ 0]     Int(100)  | false true false false true false false true EOS
34    [ 1]     Int(100)  | 100 false true false false true false false true EOS
35    [ 2]        Shoot  | 100 100 false true false false true false false true EOS
36    [ 3]   AbsJump(0)  | false false true false false true false false true EOS
37    [ 0]     Int(100)  | false false true false false true false false true EOS
```

…

result: convert endless loop to jump and work correctly.

7.1.21 Conditional Loop

test case:

```
0 a store
begin
    a read 1 + a store
    a read 10 <
while
    100 100 shoot
again
```

generated byte code:

```
 0: Int(0)
```

```
 1: Store(a)
 2: Read(a)
 3: Int(1)
 4: Plus
 5: Store(a)
 6: Read(a)
 7: Int(10)
 8: Less
 9: Not
10: AbsJumpIf(15)
11: Int(100)
12: Int(100)
13: Shoot
14: AbsJump(2)
```

stack:

```
 1    [ 0]     Int(0)  | EOS
 2    [ 1]     Store(a)  | 0 EOS
 3    [ 2]     Read(a)  | EOS
 4    [ 3]     Int(1)  | 0 EOS
 5    [ 4]     Plus  | 1 0 EOS
 6    [ 5]     Store(a)  | 1 EOS
 7    [ 6]     Read(a)  | EOS
 8    [ 7]     Int(10)  | 1 EOS
 9    [ 8]     Less  | 10 1 EOS
10    [ 9]     Not  | true EOS
11    [ 10]    AbsJumpIf(15)  | false EOS
12    [ 11]    Int(100)  | EOS
13    [ 12]    Int(100)  | 100 EOS
14    [ 13]    Shoot  | 100 100 EOS
15    [ 14]    AbsJump(2)  | true EOS
16    [ 2]     Read(a)  | true EOS
17    [ 3]     Int(1)  | 1 true EOS
18    [ 4]     Plus  | 1 1 true EOS
19    [ 5]     Store(a)  | 2 true EOS
20    [ 6]     Read(a)  | true EOS
21    [ 7]     Int(10)  | 2 true EOS
22    [ 8]     Less  | 10 2 true EOS
```

```
23    [ 9]      Not  | true true EOS
24    [ 10]     AbsJumpIf(15)  | false true EOS
25    [ 11]     Int(100)  | true EOS
26    [ 12]     Int(100)  | 100 true EOS
27    [ 13]     Shoot  | 100 100 true EOS
28    [ 14]     AbsJump(2)  | true true EOS
29    [ 2]      Read(a)  | true true EOS
30    [ 3]      Int(1)  | 2 true true EOS
31    [ 4]      Plus  | 1 2 true true EOS
32    [ 5]      Store(a)  | 3 true true EOS
33    [ 6]      Read(a)  | true true EOS
34    [ 7]      Int(10)  | 3 true true EOS
35    [ 8]      Less  | 10 3 true true EOS
36    [ 9]      Not  | true true true EOS
37    [ 10]     AbsJumpIf(15)  | false true true EOS
38    [ 11]     Int(100)  | true true EOS
39    [ 12]     Int(100)  | 100 true true EOS
40    [ 13]     Shoot  | 100 100 true true EOS
41    [ 14]     AbsJump(2)  | true true true EOS
42    [ 2]      Read(a)  | true true true EOS
43    [ 3]      Int(1)  | 3 true true true EOS
44    [ 4]      Plus  | 1 3 true true true EOS
45    [ 5]      Store(a)  | 4 true true true EOS
46    [ 6]      Read(a)  | true true true EOS
47    [ 7]      Int(10)  | 4 true true true EOS
48    [ 8]      Less  | 10 4 true true true EOS
49    [ 9]      Not  | true true true true EOS
50    [ 10]     AbsJumpIf(15)  | false true true true EOS
51    [ 11]     Int(100)  | true true true EOS
52    [ 12]     Int(100)  | 100 true true true EOS
53    [ 13]     Shoot  | 100 100 true true true EOS
54    [ 14]     AbsJump(2)  | true true true true EOS
55    [ 2]      Read(a)  | true true true true EOS
56    [ 3]      Int(1)  | 4 true true true true EOS
57    [ 4]      Plus  | 1 4 true true true true EOS
58    [ 5]      Store(a)  | 5 true true true true EOS
59    [ 6]      Read(a)  | true true true true EOS
60    [ 7]      Int(10)  | 5 true true true true EOS
```

```
61        [ 8]         Less  | 10 5 true true true true EOS
62        [ 9]          Not  | true true true true true EOS
63        [ 10]  AbsJumpIf(15)  | false true true true true EOS
64        [ 11]     Int(100)  | true true true true EOS
65        [ 12]     Int(100)  | 100 true true true true EOS
66        [ 13]        Shoot  | 100 100 true true true true EOS
67        [ 14]    AbsJump(2)  | true true true true true EOS
68        [ 2]       Read(a)  | true true true true true EOS
69        [ 3]        Int(1)  | 5 true true true true true EOS
70        [ 4]         Plus  | 1 5 true true true true true EOS
71        [ 5]      Store(a)  | 6 true true true true true EOS
72        [ 6]       Read(a)  | true true true true true EOS
73        [ 7]       Int(10)  | 6 true true true true true EOS
74        [ 8]         Less  | 10 6 true true true true true EOS
75        [ 9]          Not  | true true true true true true EOS
```

result: convert conditional loop to jumpif and work correctly.

7.1.22 if

test case:

```
1 2 <
if
1
endif
```

generated byte code:

```
0: Int(1)
1: Int(2)
2: Less
3: Not
4: AbsJumpIf(6)
5: Int(1)
```

stack:

```
1      [ 0]      Int(1)  | EOS
2      [ 1]      Int(2)  | 1 EOS
3      [ 2]        Less  | 2 1 EOS
```

4	[3]	Not	| true EOS
5	[4]	AbsJumpIf(6)	| false EOS
6	[5]	Int(1)	| EOS

result: the if statement has been successfully convert to jumpif statement.

7.1.23 if-else

test case:

```
1 2 <
if
1
else
2
endif
```

generated byte code:

```
0: Int(1)
1: Int(2)
2: Less
3: Not
4: AbsJumpIf(7)
5: Int(1)
6: AbsJump(8)
7: Int(2)
```

stack:

1	[0]	Int(1)	| EOS
2	[1]	Int(2)	| 1 EOS
3	[2]	Less	| 2 1 EOS
4	[3]	Not	| true EOS
5	[4]	AbsJumpIf(7)	| false EOS
6	[5]	Int(1)	| EOS
7	[6]	AbsJump(8)	| 1 EOS

result: the if-else statement has been successfully convert to jumpif statement.

7.2 Integration Test: An Example Programs

To test the whole project thoroughly, we created a number of simple-minded Drones which can serve as examples for real players in creation of a really complicated AIs. In the example below, we show several drones written in the drone war language.

7.2.1 Drone Berserk

drones/berserk.dt

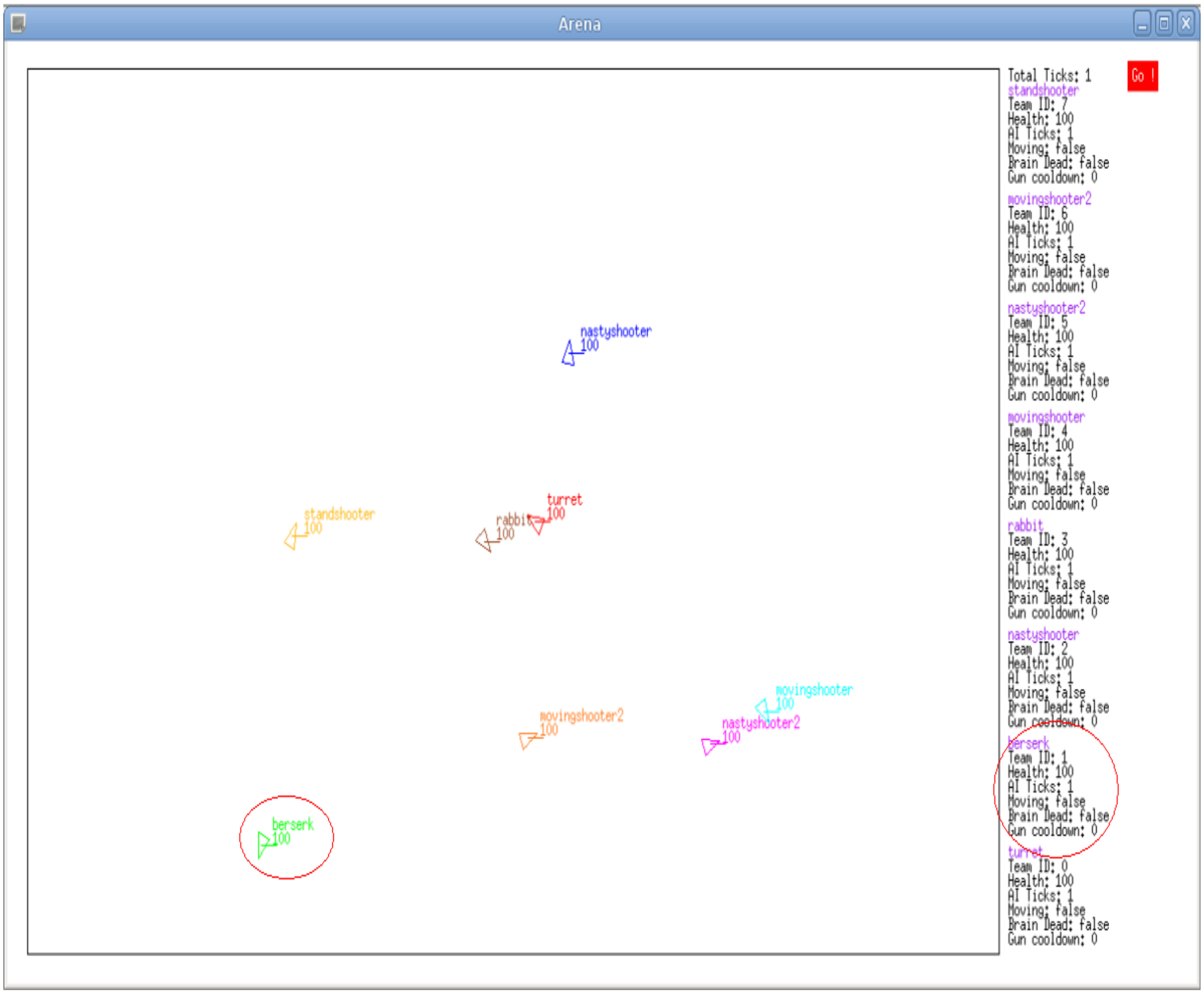
```
// This drone is very aggressive. It looks for any other drone,
// regardless of is it friend or foe, runs toward it and shoot.
0 direction store
main_loop:
     direction read look
     // if drones sees a wall, that means it does not see
     // any drone
     isWall not sees_a_drone jumpif
     stop      // do not move if drone does not have a target
     drop2     // if we sees a wall, then drop the distance
               // to it (stack should be empty now)
     0 360 random        // get a random direction value
     direction store     // and the drone will look for the next
                         // target in this random direction
     main_loop jump

sees_a_drone:
     dup direction store   // store the direction to the drone
     dup move              // start moving toward the target
     shoot                 // and shoot in the same direction
     drop                  // ignore the result of shooting
     // after charged to the nearest drone, we still
     // have to cleanup data for other objects seen by look.
look_cleanup:
     swap drop                // drop direction and
     swap drop                // distance to the next target
     isWall main_loop jumpif  // if the last target was a wall
     look_cleanup jump        // else repeat clean up process

// user function
// drop two values from the stack
sub drop2 drop drop endsub
```

This file will be complied into:

```
 0: Int(0)
 1: Store(direction)
 2: Read(direction)
 3: Look
 4: IsWall
 5: Not
 6: AbsJumpIf(14)
 7: Stop
 8: Call(drop2)
 9: Int(0)
10: Int(360)
11: Random
12: Store(direction)
13: AbsJump(2)
14: Dup
15: Store(direction)
16: Dup
17: Move
18: Shoot
19: Drop
20: Swap
21: Drop
22: Swap
23: Drop
24: IsWall
25: AbsJumpIf(2)
26: AbsJump(20)

sub drop2
 0: Drop
 1: Drop
esub
```

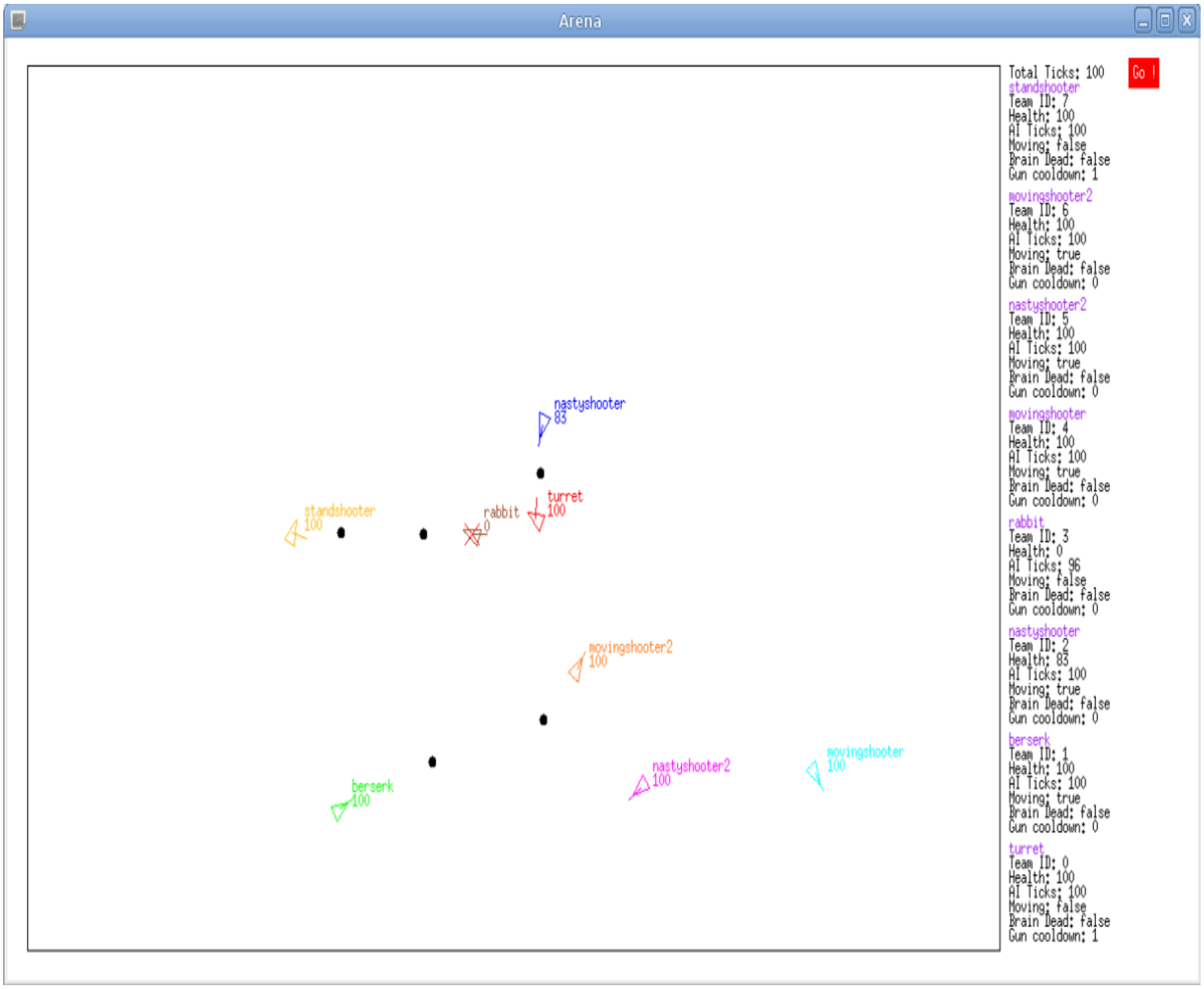
The running state of a game:

1. when it get started:



The stack:

1	[0]	Int(0) | EOS



The stack:

1 [0] Int(0) | EOS

2 [1] Store(direction) | 0 EOS

3 [2] Read(direction) | EOS //set and get the original direction 0

4 [3] Look | 0 EOS //use look function to see the objects in direction

5 [4] IsWall | Foe 23 300 Foe 14 477 Foe 16 540 … //look result

6 [5] Not | false 23 300 Foe 14 477 Foe 16 540 … //find a drone

7 [6] AbsJumpIf(14) | true 23 300 Foe 14 477 Foe 16 540 … //jump

8 [14] Dup | 23 300 Foe 14 477 Foe 16 540 Wall … //duplicate

9 [15] Store(direction) | 23 23 300 Foe 14 477 Foe 16 540 … //store direction

10 [16] Dup | 23 300 Foe 14 477 Foe 16 540 Wall … //duplicate

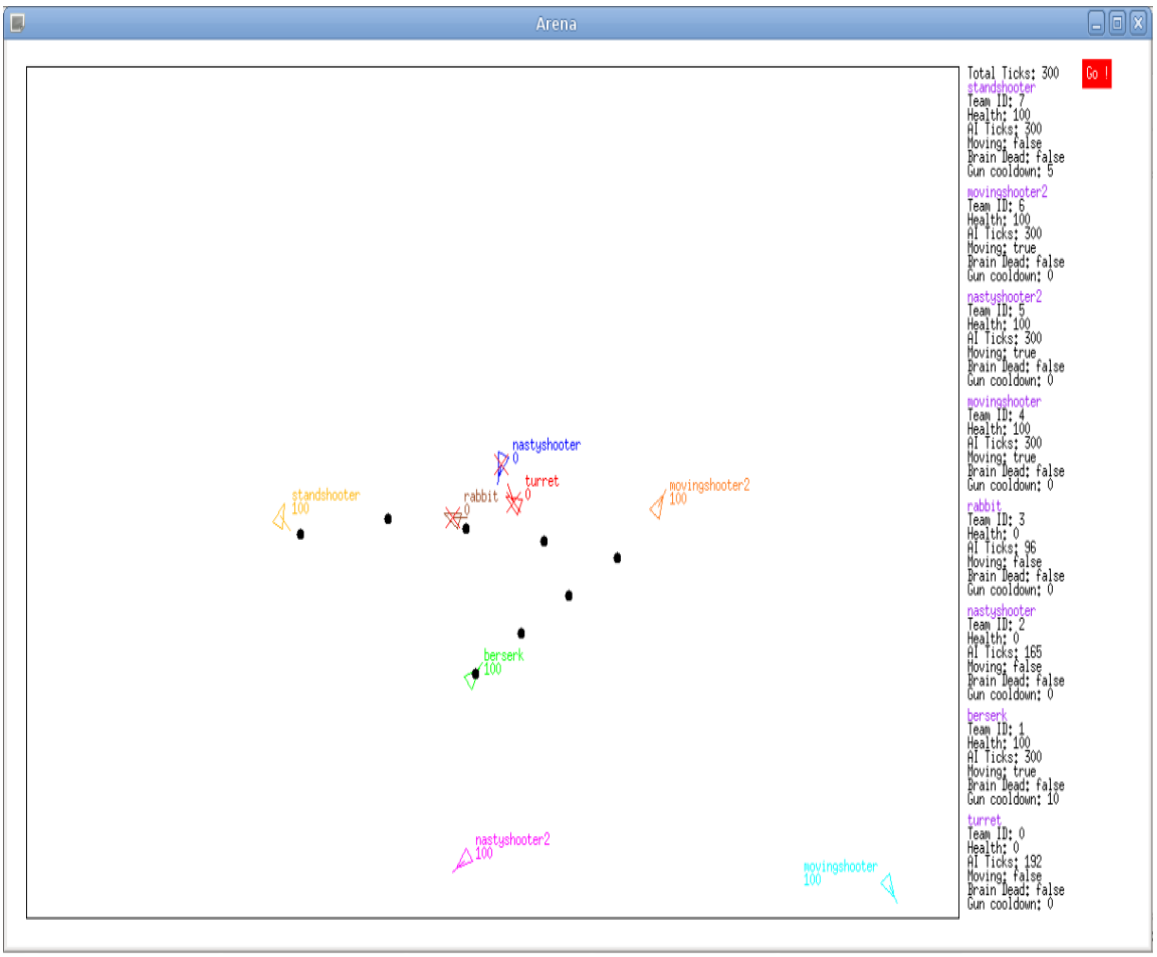
11 [17] Move | 23 23 300 Foe 14 477 Foe 16 540 …//move in direction

12 [18] Shoot | 23 300 Foe 14 477 Foe 16 540 Wall …//shoot in directio

13 [19] Drop | true Foe 14 477 Foe 16 540 Wall 0 …//not care shoot result
14 [20] Swap | Foe 14 477 Foe 16 540 Wall 0 758 EOS
15 [21] Drop | 14 Foe 477 Foe 16 540 Wall 0 758 EOS
16 [22] Swap | Foe 477 Foe 16 540 Wall 0 758 EOS
17 [23] Drop | 477 Foe Foe 16 540 Wall 0 758 EOS
18 [24] IsWall | Foe Foe 16 540 Wall 0 758 EOS
19 [25] AbsJumpIf(2) | false Foe 16 540 Wall 0 758 EOS
20 [26] AbsJump(20) | Foe 16 540 Wall 0 758 EOS
21 [20] Swap | Foe 16 540 Wall 0 758 EOS
22 [21] Drop | 16 Foe 540 Wall 0 758 EOS
23 [22] Swap | Foe 540 Wall 0 758 EOS
24 [23] Drop | 540 Foe Wall 0 758 EOS
25 [24] IsWall | Foe Wall 0 758 EOS
26 [25] AbsJumpIf(2) | false Wall 0 758 EOS
27 [26] AbsJump(20) | Wall 0 758 EOS
28 [20] Swap | Wall 0 758 EOS
29 [21] Drop | 0 Wall 758 EOS
30 [22] Swap | Wall 758 EOS
31 [23] Drop | 758 Wall EOS
32 [24] IsWall | Wall EOS
33 [25] AbsJumpIf(2) | true EOS //check if we have drop all the look result
34 [2] Read(direction) | EOS //get the stored direction
35 [3] Look | 23 EOS //look at this direction
36 [4] IsWall | Foe 26 297 Foe 12 431 Foe 13 524 ...//find a drone
37 [5] Not | false 26 297 Foe 12 431 Foe 13 524 ...
38 [6] AbsJumpIf(14) | true 26 297 Foe 12 431 Foe 13 524 ...
39 [14] Dup | 26 297 Foe 12 431 Foe 13 524 Wall ...
40 [15]Store(direction) | 26 26 297 Foe 12 431 Foe 13 524 ...//store the new direction
41 [16] Dup | 26 297 Foe 12 431 Foe 13 524 Wall ...
42 [17] Move | 26 26 297 Foe 12 431 Foe 13 524 ...
43 [18] Shoot | 26 297 Foe 12 431 Foe 13 524 Wall ...
44 [19] Drop | true Foe 12 431 Foe 13 524 Wall 23 ...
45 [20] Swap | Foe 12 431 Foe 13 524 Wall 23 799 EOS
46 [21] Drop | 12 Foe 431 Foe 13 524 Wall 23 799 EOS
47 [22] Swap | Foe 431 Foe 13 524 Wall 23 799 EOS
48 [23] Drop | 431 Foe Foe 13 524 Wall 23 799 EOS

```
49    [ 24]    IsWall  | Foe Foe 13 524 Wall 23 799 EOS
50    [ 25]    AbsJumpIf(2)  | false Foe 13 524 Wall 23 799 EOS
51    [ 26]    AbsJump(20)  | Foe 13 524 Wall 23 799 EOS
52    [ 20]    Swap  | Foe 13 524 Wall 23 799 EOS
53    [ 21]    Drop  | 13 Foe 524 Wall 23 799 EOS
54    [ 22]    Swap  | Foe 524 Wall 23 799 EOS
55    [ 23]    Drop  | 524 Foe Wall 23 799 EOS
56    [ 24]    IsWall  | Foe Wall 23 799 EOS
57    [ 25]    AbsJumpIf(2)  | false Wall 23 799 EOS
58    [ 26]    AbsJump(20)  | Wall 23 799 EOS
59    [ 20]    Swap  | Wall 23 799 EOS
60    [ 21]    Drop  | 23 Wall 799 EOS
61    [ 22]    Swap  | Wall 799 EOS
62    [ 23]    Drop  | 799 Wall EOS
63    [ 24]    IsWall  | Wall EOS
64    [ 25]    AbsJumpIf(2)  | true EOS //check if we have drop all the look result
65    [  2]    Read(direction)  | EOS//get the stored direction
66    [  3]    Look  | 26 EOS    //use look to see objects in direction
67    [  4]    IsWall  | Foe 29 293 Foe 9 373 Foe 9 506 ...//look result
68    [  5]    Not  | false 29 293 Foe 9 373 Foe 9 506 ...//find a drone
69    [  6]    AbsJumpIf(14)  | true 29 293 Foe 9 373 Foe 9 506 ...//jump
70    [ 14]    Dup  | 29 293 Foe 9 373 Foe 9 506 Wall ...//duplicate
71    [ 15]    Store(direction)  | 29 29 293 Foe 9 373 Foe 9 506 ...//store direction
72    [ 16]    Dup  | 29 293 Foe 9 373 Foe 9 506 Wall ...//duplicate
73    [ 17]    Move  | 29 29 293 Foe 9 373 Foe 9 506 ...//move in direction
74    [ 18]    Shoot  | 29 293 Foe 9 373 Foe 9 506 Wall ...//shoot in directio
75    [ 19]    Drop  | true Foe 9 373 Foe 9 506 Wall 26 ...
76    [ 20]    Swap  | Foe 9 373 Foe 9 506 Wall 26 787 EOS
77    [ 21]    Drop  | 9 Foe 373 Foe 9 506 Wall 26 787 EOS
78    [ 22]    Swap  | Foe 373 Foe 9 506 Wall 26 787 EOS
79    [ 23]    Drop  | 373 Foe Foe 9 506 Wall 26 787 EOS
80    [ 24]    IsWall  | Foe Foe 9 506 Wall 26 787 EOS
81    [ 25]    AbsJumpIf(2)  | false Foe 9 506 Wall 26 787 EOS
82    [ 26]    AbsJump(20)  | Foe 9 506 Wall 26 787 EOS
83    [ 20]    Swap  | Foe 9 506 Wall 26 787 EOS
84    [ 21]    Drop  | 9 Foe 506 Wall 26 787 EOS
85    [ 22]    Swap  | Foe 506 Wall 26 787 EOS
86    [ 23]    Drop  | 506 Foe Wall 26 787 EOS
```

87	[24]	IsWall | Foe Wall 26 787 EOS
88	[25]	AbsJumpIf(2) | false Wall 26 787 EOS
89	[26]	AbsJump(20) | Wall 26 787 EOS
90	[20]	Swap | Wall 26 787 EOS
91	[21]	Drop | 26 Wall 787 EOS
92	[22]	Swap | Wall 787 EOS
93	[23]	Drop | 787 Wall EOS
94	[24]	IsWall | Wall EOS
95	[25]	AbsJumpIf(2) | true EOS//check if we have drop all the look result
96	[2]	Read(direction) | EOS//get the stored direction
97	[3]	Look | 29 EOS
98	[4]	IsWall | Foe 32 290 Foe 5 317 Foe 58 388 ...
99	[5]	Not | false 32 290 Foe 5 317 Foe 58 388 ...
100	[6]	AbsJumpIf(14) | true 32 290 Foe 5 317 Foe 58 388 ...



101	[14]	Dup | 32 290 Foe 5 317 Foe 58 388 Foe ...
102	[15]	Store(direction) | 32 32 290 Foe 5 317 Foe 58 388 ...
103	[16]	Dup | 32 290 Foe 5 317 Foe 58 388 Foe ...

104	[17]	Move	| 32 32 290 Foe 5 317 Foe 58 388 ...
105	[18]	Shoot	| 32 290 Foe 5 317 Foe 58 388 Foe ...
106	[19]	Drop	| true Foe 5 317 Foe 58 388 Foe 5 ...
107	[20]	Swap	| Foe 5 317 Foe 58 388 Foe 5 492 ...
108	[21]	Drop	| 5 Foe 317 Foe 58 388 Foe 5 492 ...
109	[22]	Swap	| Foe 317 Foe 58 388 Foe 5 492 Wall ...
110	[23]	Drop	| 317 Foe Foe 58 388 Foe 5 492 Wall ...
111	[24]	IsWall	| Foe Foe 58 388 Foe 5 492 Wall 29 ...
112	[25]	AbsJumpIf(2)	| false Foe 58 388 Foe 5 492 Wall 29 ...
113	[26]	AbsJump(20)	| Foe 58 388 Foe 5 492 Wall 29 778 EOS
114	[20]	Swap	| Foe 58 388 Foe 5 492 Wall 29 778 EOS
115	[21]	Drop	| 58 Foe 388 Foe 5 492 Wall 29 778 EOS
116	[22]	Swap	| Foe 388 Foe 5 492 Wall 29 778 EOS
117	[23]	Drop	| 388 Foe Foe 5 492 Wall 29 778 EOS
118	[24]	IsWall	| Foe Foe 5 492 Wall 29 778 EOS
119	[25]	AbsJumpIf(2)	| false Foe 5 492 Wall 29 778 EOS
120	[26]	AbsJump(20)	| Foe 5 492 Wall 29 778 EOS
121	[20]	Swap	| Foe 5 492 Wall 29 778 EOS
122	[21]	Drop	| 5 Foe 492 Wall 29 778 EOS
123	[22]	Swap	| Foe 492 Wall 29 778 EOS
124	[23]	Drop	| 492 Foe Wall 29 778 EOS
125	[24]	IsWall	| Foe Wall 29 778 EOS
126	[25]	AbsJumpIf(2)	| false Wall 29 778 EOS
127	[26]	AbsJump(20)	| Wall 29 778 EOS
128	[20]	Swap	| Wall 29 778 EOS
129	[21]	Drop	| 29 Wall 778 EOS
130	[22]	Swap	| Wall 778 EOS
131	[23]	Drop	| 778 Wall EOS
132	[24]	IsWall	| Wall EOS
133	[25]	AbsJumpIf(2)	| true EOS
134	[2]	Read(direction)	| EOS
135	[3]	Look	| 32 EOS
136	[4]	IsWall	| Foe 35 287 Foe 60 354 Wall 32 764 EOS
137	[5]	Not	| false 35 287 Foe 60 354 Wall 32 764 EOS
138	[6]	AbsJumpIf(14)	| true 35 287 Foe 60 354 Wall 32 764 EOS
139	[14]	Dup	| 35 287 Foe 60 354 Wall 32 764 EOS
140	[15]	Store(direction)	| 35 35 287 Foe 60 354 Wall 32 764 EOS
141	[16]	Dup	| 35 287 Foe 60 354 Wall 32 764 EOS

```
142   [ 17]   Move  | 35 35 287 Foe 60 354 Wall 32 764 EOS
143   [ 18]   Shoot  | 35 287 Foe 60 354 Wall 32 764 EOS
144   [ 19]   Drop  | true Foe 60 354 Wall 32 764 EOS
145   [ 20]   Swap  | Foe 60 354 Wall 32 764 EOS
146   [ 21]   Drop  | 60 Foe 354 Wall 32 764 EOS
147   [ 22]   Swap  | Foe 354 Wall 32 764 EOS
148   [ 23]   Drop  | 354 Foe Wall 32 764 EOS
149   [ 24]   IsWall  | Foe Wall 32 764 EOS
150   [ 25]   AbsJumpIf(2)  | false Wall 32 764 EOS
151   [ 26]   AbsJump(20)  | Wall 32 764 EOS
152   [ 20]   Swap  | Wall 32 764 EOS
153   [ 21]   Drop  | 32 Wall 764 EOS
154   [ 22]   Swap  | Wall 764 EOS
155   [ 23]   Drop  | 764 Wall EOS
156   [ 24]   IsWall  | Wall EOS
157   [ 25]   AbsJumpIf(2)  | true EOS
158   [  2]   Read(direction)  | EOS
159   [  3]   Look  | 35 EOS
160   [  4]   IsWall  | Foe 37 286 Foe 62 333 Wall 35 767 EOS
161   [  5]   Not  | false 37 286 Foe 62 333 Wall 35 767 EOS
162   [  6]   AbsJumpIf(14)  | true 37 286 Foe 62 333 Wall 35 767 EOS
163   [ 14]   Dup  | 37 286 Foe 62 333 Wall 35 767 EOS
164   [ 15]   Store(direction)  | 37 37 286 Foe 62 333 Wall 35 767 EOS
165   [ 16]   Dup  | 37 286 Foe 62 333 Wall 35 767 EOS
166   [ 17]   Move  | 37 37 286 Foe 62 333 Wall 35 767 EOS
167   [ 18]   Shoot  | 37 286 Foe 62 333 Wall 35 767 EOS
168   [ 19]   Drop  | true Foe 62 333 Wall 35 767 EOS
169   [ 20]   Swap  | Foe 62 333 Wall 35 767 EOS
170   [ 21]   Drop  | 62 Foe 333 Wall 35 767 EOS
171   [ 22]   Swap  | Foe 333 Wall 35 767 EOS
172   [ 23]   Drop  | 333 Foe Wall 35 767 EOS
173   [ 24]   IsWall  | Foe Wall 35 767 EOS
174   [ 25]   AbsJumpIf(2)  | false Wall 35 767 EOS
175   [ 26]   AbsJump(20)  | Wall 35 767 EOS
176   [ 20]   Swap  | Wall 35 767 EOS
177   [ 21]   Drop  | 35 Wall 767 EOS
178   [ 22]   Swap  | Wall 767 EOS
179   [ 23]   Drop  | 767 Wall EOS
```

180	[24]	IsWall	Wall EOS
181	[25]	AbsJumpIf(2)	true EOS
182	[2]	Read(direction)	EOS
183	[3]	Look	37 EOS
184	[4]	IsWall	Foe 39 285 Foe 64 312 Wall 37 762 EOS
185	[5]	Not	false 39 285 Foe 64 312 Wall 37 762 EOS
186	[6]	AbsJumpIf(14)	true 39 285 Foe 64 312 Wall 37 762 EOS
187	[14]	Dup	39 285 Foe 64 312 Wall 37 762 EOS
188	[15]	Store(direction)	39 39 285 Foe 64 312 Wall 37 762 EOS
189	[16]	Dup	39 285 Foe 64 312 Wall 37 762 EOS
190	[17]	Move	39 39 285 Foe 64 312 Wall 37 762 EOS
191	[18]	Shoot	39 285 Foe 64 312 Wall 37 762 EOS
192	[19]	Drop	true Foe 64 312 Wall 37 762 EOS
193	[20]	Swap	Foe 64 312 Wall 37 762 EOS
194	[21]	Drop	64 Foe 312 Wall 37 762 EOS
195	[22]	Swap	Foe 312 Wall 37 762 EOS
196	[23]	Drop	312 Foe Wall 37 762 EOS
197	[24]	IsWall	Foe Wall 37 762 EOS
198	[25]	AbsJumpIf(2)	false Wall 37 762 EOS
199	[26]	AbsJump(20)	Wall 37 762 EOS
200	[20]	Swap	Wall 37 762 EOS
201	[21]	Drop	37 Wall 762 EOS
202	[22]	Swap	Wall 762 EOS
203	[23]	Drop	762 Wall EOS
204	[24]	IsWall	Wall EOS
205	[25]	AbsJumpIf(2)	true EOS
206	[2]	Read(direction)	EOS
207	[3]	Look	39 EOS
208	[4]	IsWall	Foe 40 284 Wall 39 759 EOS
209	[5]	Not	false 40 284 Wall 39 759 EOS
210	[6]	AbsJumpIf(14)	true 40 284 Wall 39 759 EOS
211	[14]	Dup	40 284 Wall 39 759 EOS
212	[15]	Store(direction)	40 40 284 Wall 39 759 EOS
213	[16]	Dup	40 284 Wall 39 759 EOS
214	[17]	Move	40 40 284 Wall 39 759 EOS
215	[18]	Shoot	40 284 Wall 39 759 EOS
216	[19]	Drop	true Wall 39 759 EOS
217	[20]	Swap	Wall 39 759 EOS

218	[21]	Drop	| 39 Wall 759 EOS
219	[22]	Swap	| Wall 759 EOS
220	[23]	Drop	| 759 Wall EOS
221	[24]	IsWall	| Wall EOS
222	[25]	AbsJumpIf(2)	| true EOS
223	[2]	Read(direction)	| EOS
224	[3]	Look	| 40 EOS
225	[4]	IsWall	| Foe 41 283 Wall 40 753 EOS
226	[5]	Not	| false 41 283 Wall 40 753 EOS
227	[6]	AbsJumpIf(14)	| true 41 283 Wall 40 753 EOS
228	[14]	Dup	| 41 283 Wall 40 753 EOS
229	[15]	Store(direction)	| 41 41 283 Wall 40 753 EOS
230	[16]	Dup	| 41 283 Wall 40 753 EOS
231	[17]	Move	| 41 41 283 Wall 40 753 EOS
232	[18]	Shoot	| 41 283 Wall 40 753 EOS
233	[19]	Drop	| true Wall 40 753 EOS
234	[20]	Swap	| Wall 40 753 EOS
235	[21]	Drop	| 40 Wall 753 EOS
236	[22]	Swap	| Wall 753 EOS
237	[23]	Drop	| 753 Wall EOS
238	[24]	IsWall	| Wall EOS
239	[25]	AbsJumpIf(2)	| true EOS
240	[2]	Read(direction)	| EOS
241	[3]	Look	| 41 EOS
242	[4]	IsWall	| Foe 42 283 Wall 41 747 EOS
243	[5]	Not	| false 42 283 Wall 41 747 EOS
244	[6]	AbsJumpIf(14)	| true 42 283 Wall 41 747 EOS
245	[14]	Dup	| 42 283 Wall 41 747 EOS
246	[15]	Store(direction)	| 42 42 283 Wall 41 747 EOS
247	[16]	Dup	| 42 283 Wall 41 747 EOS
248	[17]	Move	| 42 42 283 Wall 41 747 EOS
249	[18]	Shoot	| 42 283 Wall 41 747 EOS
250	[19]	Drop	| true Wall 41 747 EOS
251	[20]	Swap	| Wall 41 747 EOS
252	[21]	Drop	| 41 Wall 747 EOS
253	[22]	Swap	| Wall 747 EOS
254	[23]	Drop	| 747 Wall EOS
255	[24]	IsWall	| Wall EOS

256	[25]	AbsJumpIf(2) | true EOS
257	[2]	Read(direction) | EOS
258	[3]	Look | 42 EOS
259	[4]	IsWall | Foe 43 282 Wall 42 742 EOS
260	[5]	Not | false 43 282 Wall 42 742 EOS
261	[6]	AbsJumpIf(14) | true 43 282 Wall 42 742 EOS
262	[14]	Dup | 43 282 Wall 42 742 EOS
263	[15]	Store(direction) | 43 43 282 Wall 42 742 EOS
264	[16]	Dup | 43 282 Wall 42 742 EOS
265	[17]	Move | 43 43 282 Wall 42 742 EOS
266	[18]	Shoot | 43 282 Wall 42 742 EOS
267	[19]	Drop | true Wall 42 742 EOS
268	[20]	Swap | Wall 42 742 EOS
269	[21]	Drop | 42 Wall 742 EOS
270	[22]	Swap | Wall 742 EOS
271	[23]	Drop | 742 Wall EOS
272	[24]	IsWall | Wall EOS
273	[25]	AbsJumpIf(2) | true EOS
274	[2]	Read(direction) | EOS
275	[3]	Look | 43 EOS
276	[4]	IsWall | Foe 44 282 Wall 43 737 EOS
277	[5]	Not | false 44 282 Wall 43 737 EOS
278	[6]	AbsJumpIf(14) | true 44 282 Wall 43 737 EOS
279	[14]	Dup | 44 282 Wall 43 737 EOS
280	[15]	Store(direction) | 44 44 282 Wall 43 737 EOS
281	[16]	Dup | 44 282 Wall 43 737 EOS
282	[17]	Move | 44 44 282 Wall 43 737 EOS
283	[18]	Shoot | 44 282 Wall 43 737 EOS
284	[19]	Drop | true Wall 43 737 EOS
285	[20]	Swap | Wall 43 737 EOS
286	[21]	Drop | 43 Wall 737 EOS
287	[22]	Swap | Wall 737 EOS
288	[23]	Drop | 737 Wall EOS
289	[24]	IsWall | Wall EOS
290	[25]	AbsJumpIf(2) | true EOS
291	[2]	Read(direction) | EOS
292	[3]	Look | 44 EOS
293	[4]	IsWall | Foe 44 282 Wall 44 732 EOS

294	[5]	Not | false 44 282 Wall 44 732 EOS
295	[6]	AbsJumpIf(14) | true 44 282 Wall 44 732 EOS
296	[14]	Dup | 44 282 Wall 44 732 EOS
297	[15]	Store(direction) | 44 44 282 Wall 44 732 EOS
298	[16]	Dup | 44 282 Wall 44 732 EOS
299	[17]	Move | 44 44 282 Wall 44 732 EOS
300	[18]	Shoot | 44 282 Wall 44 732 EOS

7.2.2 Drone Rabbit

drones/berserk.dt

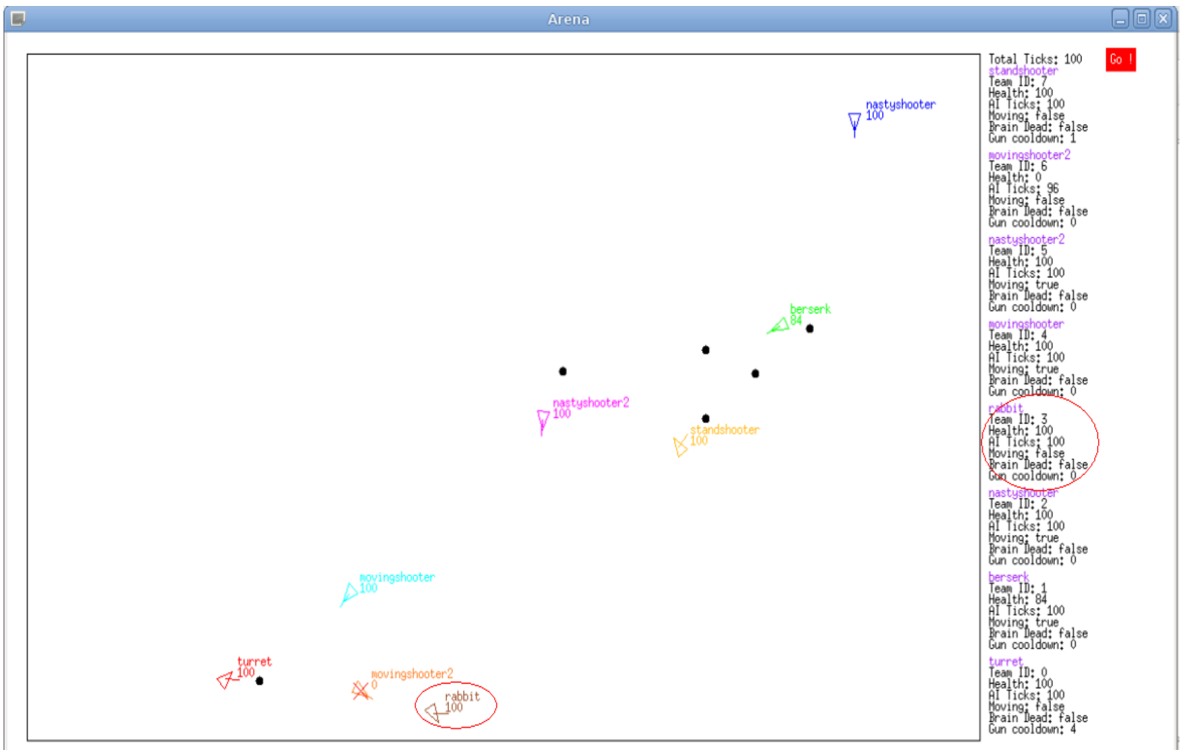
```
// The extremly harmless drone.
// It sits on one place and checks its health
// If damage detected - run somewhere for 0.1 seconds in hope to
// leave the the zone of danger. Then stop and wait until
// it again recieve some damage.
100 health store     // set initial health to 100

main_loop:
     10 wait         // wait for 10 ticks
     health read getHealth =
     // repeat indefinetely if no one harmed the drone
     main_loop jumpif
     // what to do if drone recieved some damage
     0 359 random    // get a random value in the range 1-360
     move            // move in the random direction
     10 wait         // wait for 10 ticks
     stop            // stop
     main_loop jump      // and go back to the beginning
```

This file will be compiled into:

0: Int(100)
1: Store(health)
2: Int(10)
3: Wait
4: Read(health)
5: GetHealth
6: Equal
7: AbsJumpIf(2)
8: Int(0)
9: Int(359)
10: Random
11: Move
12: Int(10)
13: Wait
14: Stop
15: AbsJump(2)

The state of the game:

1 [0] Int(100) | EOS
1 [0] Int(100) | EOS
2 [1] Store(health) | 100 EOS // store 100 in variable health
3 [2] Int(10) | EOS
4 [3] Wait | 10 EOS //wait ten ticks
5 waiting for 10 ticks
6 waiting for 9 ticks

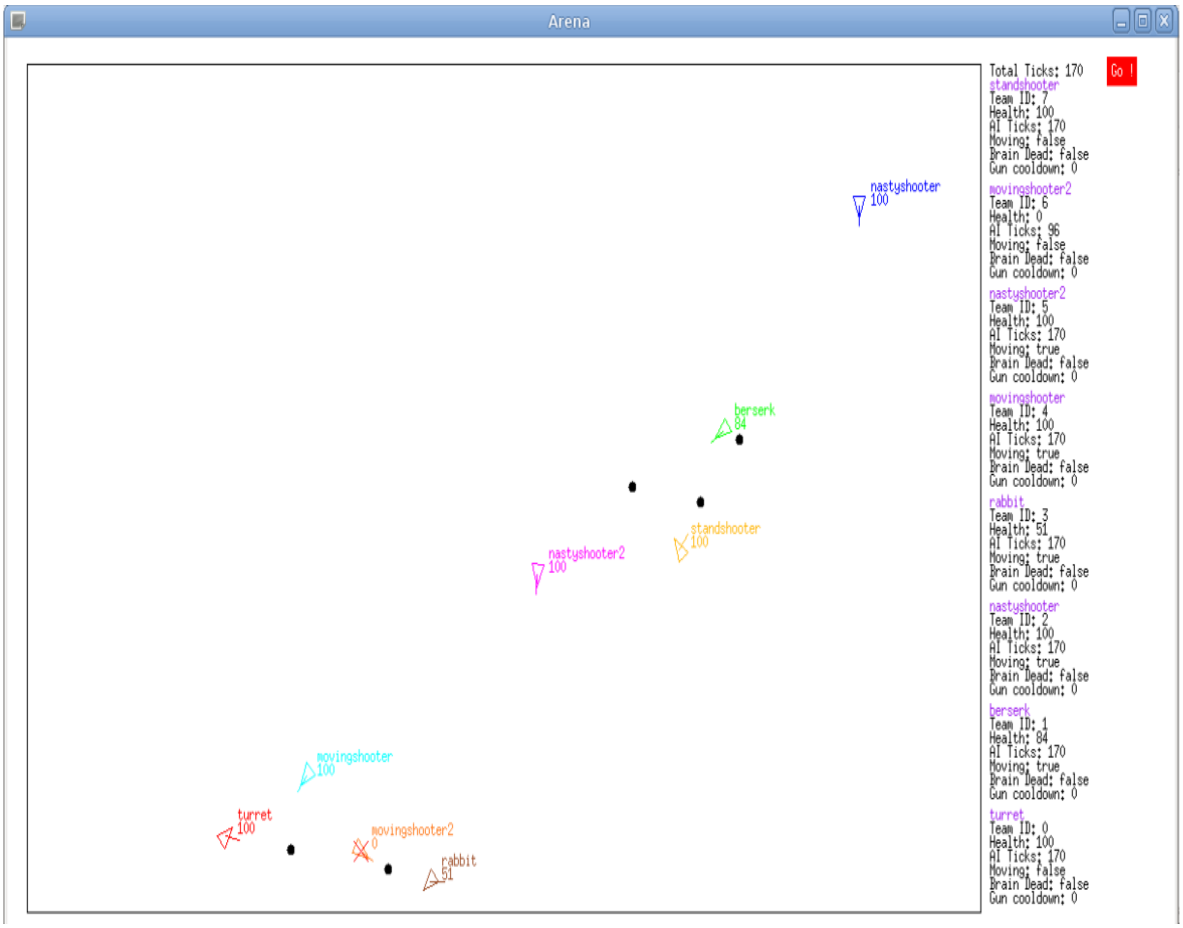


7 waiting for 8 ticks
8 waiting for 7 ticks
9 waiting for 6 ticks
10 waiting for 5 ticks
11 waiting for 4 ticks
12 waiting for 3 ticks
13 waiting for 2 ticks
14 waiting for 1 ticks
15 [4] Read(health) | EOS //get the stored health
16 [5] GetHealth | 100 EOS //get current health
17 [6] Equal | 100 100 EOS //check if it is damaged

```
18              [ 7]      AbsJumpIf(2)  | true EOS   //no damaged
19              [ 2]         Int(10)  | EOS
20              [ 3]           Wait  | 10 EOS    //wait ten ticks
21  waiting for 10 ticks
22  waiting for 9 ticks
23  waiting for 8 ticks
24  waiting for 7 ticks
25  waiting for 6 ticks
26  waiting for 5 ticks
27  waiting for 4 ticks
28  waiting for 3 ticks
29  waiting for 2 ticks
30  waiting for 1 ticks
31              [ 4]      Read(health)  | EOS//get the stored health
32              [ 5]        GetHealth  | 100 EOS//get current health
33              [ 6]          Equal  | 100 100 EOS//check if it is damaged
34              [ 7]      AbsJumpIf(2)  | true EOS//no damaged
35              [ 2]         Int(10)  | EOS//wait ten ticks
36              [ 3]           Wait  | 10 EOS
37  waiting for 10 ticks
38  waiting for 9 ticks
39  waiting for 8 ticks
40  waiting for 7 ticks
41  waiting for 6 ticks
42  waiting for 5 ticks
43  waiting for 4 ticks
44  waiting for 3 ticks
45  waiting for 2 ticks
46  waiting for 1 ticks
47              [ 4]      Read(health)  | EOS//get the stored health
48              [ 5]        GetHealth  | 100 EOS//get current health
49              [ 6]          Equal  | 100 100 EOS//check if it is damaged
50              [ 7]      AbsJumpIf(2)  | true EOS//no damaged
51              [ 2]         Int(10)  | EOS
52              [ 3]           Wait  | 10 EOS//wait ten ticks
53  waiting for 10 ticks
54  waiting for 9 ticks
55  waiting for 8 ticks
```

```
56  waiting for 7 ticks
57  waiting for 6 ticks
58  waiting for 5 ticks
59  waiting for 4 ticks
60  waiting for 3 ticks
61  waiting for 2 ticks
62  waiting for 1 ticks
63              [  4]      Read(health)  | EOS
64              [  5]        GetHealth  | 100 EOS
65              [  6]            Equal  | 100 100 EOS
66              [  7]      AbsJumpIf(2)  | true EOS
67              [  2]          Int(10)  | EOS
68              [  3]             Wait  | 10 EOS
69  waiting for 10 ticks
70  waiting for 9 ticks
71  waiting for 8 ticks
72  waiting for 7 ticks
73  waiting for 6 ticks
74  waiting for 5 ticks
75  waiting for 4 ticks
76  waiting for 3 ticks
77  waiting for 2 ticks
78  waiting for 1 ticks
79              [  4]      Read(health)  | EOS
80              [  5]        GetHealth  | 100 EOS
81              [  6]            Equal  | 100 100 EOS
82              [  7]      AbsJumpIf(2)  | true EOS
83              [  2]          Int(10)  | EOS
84              [  3]             Wait  | 10 EOS
85  waiting for 10 ticks
86  waiting for 9 ticks
87  waiting for 8 ticks
88  waiting for 7 ticks
89  waiting for 6 ticks
90  waiting for 5 ticks
91  waiting for 4 ticks
92  waiting for 3 ticks
93  waiting for 2 ticks
```

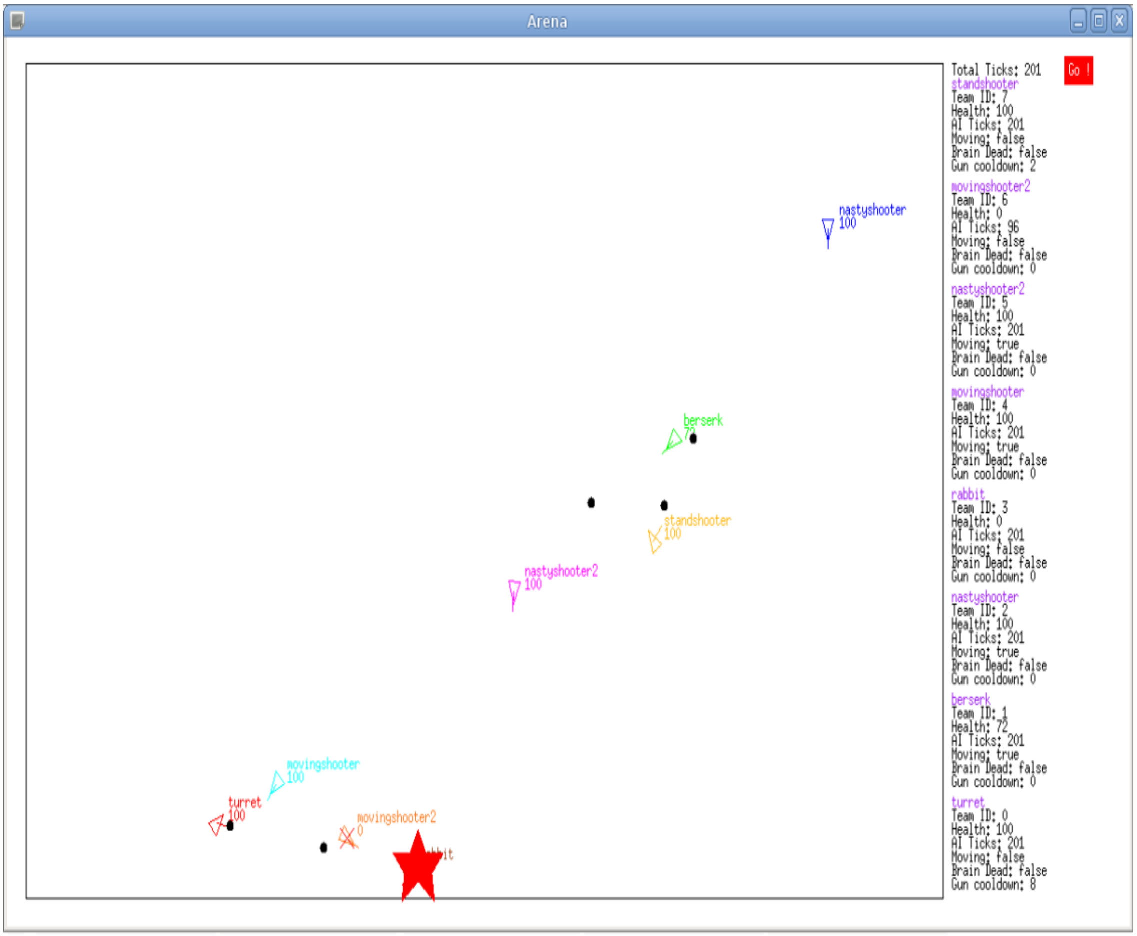
94 waiting for 1 ticks
95 [4] Read(health) | EOS
96 [5] GetHealth | 100 EOS
97 [6] Equal | 100 100 EOS
98 [7] AbsJumpIf(2) | true EOS
99 [2] Int(10) | EOS
100 [3] Wait | 10 EOS



101 waiting for 10 ticks
102 waiting for 9 ticks
103 waiting for 8 ticks
104 waiting for 7 ticks
105 waiting for 6 ticks
106 waiting for 5 ticks
107 waiting for 4 ticks
108 waiting for 3 ticks
109 waiting for 2 ticks
110 waiting for 1 ticks
111 [4] Read(health) | EOS

```
112             [  5]       GetHealth  | 100 EOS
113             [  6]           Equal  | 100 100 EOS
114             [  7]    AbsJumpIf(2)  | true EOS
115             [  2]         Int(10)  | EOS
116             [  3]            Wait  | 10 EOS
117  waiting for 10 ticks
118  waiting for 9 ticks
119  waiting for 8 ticks
120  waiting for 7 ticks
121  waiting for 6 ticks
122  waiting for 5 ticks
123  waiting for 4 ticks
124  waiting for 3 ticks
125  waiting for 2 ticks
126  waiting for 1 ticks
127             [  4]    Read(health)  | EOS
128             [  5]       GetHealth  | 100 EOS
129             [  6]           Equal  | 100 100 EOS
130             [  7]    AbsJumpIf(2)  | true EOS
131             [  2]         Int(10)  | EOS
132             [  3]            Wait  | 10 EOS
133  waiting for 10 ticks
134  waiting for 9 ticks
135  waiting for 8 ticks
136  waiting for 7 ticks
137  waiting for 6 ticks
138  waiting for 5 ticks
139  waiting for 4 ticks
140  waiting for 3 ticks
141  waiting for 2 ticks
142  waiting for 1 ticks
143             [  4]    Read(health)  | EOS
144             [  5]       GetHealth  | 100 EOS
145             [  6]           Equal  | 100 100 EOS
146             [  7]    AbsJumpIf(2)  | true EOS
147             [  2]         Int(10)  | EOS
148             [  3]            Wait  | 10 EOS
149  waiting for 10 ticks
```

```
150  waiting for 9 ticks
151  waiting for 8 ticks
152  waiting for 7 ticks
153  waiting for 6 ticks
154  waiting for 5 ticks
155  waiting for 4 ticks
156  waiting for 3 ticks
157  waiting for 2 ticks
158  waiting for 1 ticks
159                 [  4]        Read(health)  | EOS//get the stored health
160                 [  5]          GetHealth  | 100 EOS//get current health
161                 [  6]              Equal  | 51 100 EOS//check if it is damaged
162                 [  7]        AbsJumpIf(2)  | false EOS//is damaged
163                 [  8]             Int(0)  | EOS
164                 [  9]           Int(359)  | 0 EOS
165                 [ 10]             Random  | 359 0 EOS//get a random direction
166                 [ 11]               Move  | 223 EOS//move towards this direction
167                 [ 12]            Int(10)  | EOS
168                 [ 13]               Wait  | 10 EOS//wait ten ticks
```



169 waiting for 10 ticks
170 waiting for 9 ticks
171 waiting for 8 ticks
172 waiting for 7 ticks
173 waiting for 6 ticks
174 waiting for 5 ticks
175 waiting for 4 ticks
176 waiting for 3 ticks
177 waiting for 2 ticks
178 waiting for 1 ticks
179 [14] Stop | EOS
180 [15] AbsJump(2) | EOS
181 [2] Int(10) | EOS
182 [3] Wait | 10 EOS
183 waiting for 10 ticks
184 waiting for 9 ticks

```
185  waiting for 8 ticks
186  waiting for 7 ticks
187  waiting for 6 ticks
188  waiting for 5 ticks
189  waiting for 4 ticks
190  waiting for 3 ticks
191  waiting for 2 ticks
192  waiting for 1 ticks
193              [  4]      Read(health)  | EOS//get the stored health
194              [  5]        GetHealth  | 100 EOS//get current health
195              [  6]           Equal  | 15 100 EOS//check if it is damaged
196              [  7]      AbsJumpIf(2)  | false EOS//is damaged
197              [  8]          Int(0)  | EOS
198              [  9]        Int(359)  | 0 EOS
199              [ 10]          Random  | 359 0 EOS//get a random direction
200              [ 11]            Move  | 288 EOS//move towards this direction
201              [ 12]         Int(10)  | EOS
```

At last, I tested the game for 25 times and get the following table:

	Champion	Runner-up	Third Place	Last One	Score
berserk	9	3	2	3	50
qsLampard	11	3	2	1	64
nastyshooter	0	4	5	0	17
rabbit	3	1	4	5	12
movingshooter	0	5	3	3	12
movingshooter2	0	3	4	3	7
turret	2	1	3	5	6
standshooter	2	3	2	5	11

The score is 5*Champion+3*Runner-up+1*Third Place-2*Last One.

So if you can develop a good AI for your drone, you can make a difference and beat other drones!

Chapter 8: Lessons Learned

8.1 George Brink

My previous understanding of programming languages was pure practical one. I knew how to write program, how to choose correct feature of the language depending on the task, how to choose the language for the task. The lectures taught me the correct names for many of those features and more theoretical understanding of the language translation process.

The OCaml requirement of the class proved to me that I have more imperative style of thinking than functional. For example, the procedures like recursion and list reversion are fairly complex and heavy processes in most imperative languages, and as a result it pained me to use them during writing the code in OCaml.

Another problem I encountered while working with OCaml is a too liberal use of currying. The OCaml does not actually check did it encounter a function or not a function which result in a very strange style of code. For example, if we need a function which should do something with two integer values we can write such function in a very simple manner:

let add x y = x+y;;

But the call to such function will be “add 1 2;;” which by the currying rule should be a “add(1(2))”. I doubt that any sane human being can realize that “1(2)” actually means “1 and 2”.

As a result, I am sure that after this class I will not use OCaml anymore.

8.2 Shuo Qiu

Stay in contact with your team throughout the semester, to make sure you are always up to speed.

Make sure you thoroughly understand the OCaml examples from class and try to search for other OCaml code for better understanding. Learning the basic OCaml language is hard, but class and object is much easier to use, just like Java or C.

Using OCaml in Linux is much easier in Window. Do not need complicated configuration compared with windows, Linux just needs you type in a command and everything is done.

Better understanding of lexing, scanner, parser and ast. I learned how a compiler works by participating in building them for our own language.

SVN really helps. Although I have troubles in submitting the files, I can always get the latest version of the project and find what has been changed.

8.3 Xiang Yao

In this class, I learnt the definition of a language as well as how to create and design a language on my own. During the development of the project, I learnt how a compiler was generated from beginning. First in the language part, I learnt what syntax analysis and semantic analysis were, and building Scanner, Parser as well as AST provided me more opportunities to widen my view from the inside of a compiler. After the language part, the Game Engine part gave me chance to apply a new designed language to real life, and it was in this way that I learnt how important the design was since using a language was sometimes even harder than creating one.

Besides the topic about Drone War, this class also helped me to learn and get familiar a new language of Ocaml, which was really complicated and hard to understand at beginning, however, we finally understood how powerful it was when applied to developing compilers. As a functional language, Ocaml helped to reduce a number of useless work when compared to other high level languages such as Java and C++.

Finally, I also learnt a lot from team leader as well as other team members during cooperations and brainstorming. I learnt that good management of time and human resource always resulted in better progress in any kind of project.

8.4 Xiaotong Chen

Firstly, because of this course, I can touch ocaml as the development language, which I never know before. The new language I learnt can be one of the most important parts in this class. As a functional language, its strictly requirement of “type” is the most impressed feature. To my surprise, all the statements have to “return” the same type. In additional, the “return” strategy is also a kind of strange: all the operation will return some type of value. For a simple example, after print, it will return -unit(), which basically indicates nothing to return. So we must take care of the return type when coding. By doing this, I gained my patience.

Secondly, it’s also about this language. At the very beginning, we have no idea about how to execute multiple lines of codes just like in Java or C. After carefully study the document of Ocaml, we finally know how to execute multiple lines of code: use begin and end. By doing this we can build a block of code that can be seen as an entire action.

What’s more, we design a game oriented language at the very beginning. We think like a designer instead of a programmer. This is the first time I have that kind of feel, that’s amazing. We design the game rules and operations of the drones. Then we construct the related scanner to analyze the source code. By doing this, we convert the source code to tokens. Next step is to analyze the tokens to check if these tokens are satisfied our grammar. Both parser and ast together can help us finish this step. With the definition of the “program” ast and parser can construct an AST after the grammar analysis. When finish these steps, which are general compiling processes, we convert source code to byte code. Then we implement the engine part that response the byte code. Finishing above steps will generate a game.

Appendix

Source Code Listing

1. Scanner.mll

```
{
open Parser;;
open Lexing;;

let debug=1;;

let incr_lineno lexbuf =
     let pos = lexbuf.lex_curr_p in
     lexbuf.lex_curr_p <- { pos with
          pos_lnum = pos.pos_lnum + 1;
          pos_bol = pos.pos_cnum;
     }
;;
exception Unknown_token of string * int * int;;

let create_hashtable size init =
     let tbl = Hashtbl.create size in
     List.iter (fun (key, data) -> Hashtbl.add tbl key data) init;
     tbl

let keyword_table =
     create_hashtable 8 [
          ( "dup", DUP );
          ( "drop", DROP );
          ( "dropall", DROPALL );
          ( "swap", SWAP );
          ( "over", OVER );
          ( "rot", ROT );
          ( "read", READ );
          ( "store", STORE );
          ( "jump", JUMP );
          ( "jumpif", JUMPIF );
          ( "sub", SUB );
          ( "endsub", END_SUB );
          ( "if", IF );
          ( "else", ELSE );
          ( "endif", END_IF );
          ( "begin", BEGIN );
          ( "while", WHILE );
          ( "again", AGAIN );
          ( "move", MOVE );
          ( "stop", STOP );
          ( "shoot", SHOOT );
          ( "look", LOOK );
          ( "wait", WAIT );
          ( "gethealth", GETHEALTH );
```

```
          ( "random", RANDOM );
          ( "isfoe", ISFOE );
          ( "isally", ISALLY );
          ( "iswall", ISWALL );
          ( "mod", MOD );
          ( "and", AND );
          ( "or",  OR );
          ( "not", NOT );
     ];;
}

let digit      = ['0'-'9']
let space      = [' ' '\t']
let whitespace = [' ' '\t' '\r']
let notspace   = [^ ' ' '\t' '\r' '\n']
let name       = ['a'-'z' 'A'-'Z'] ['a'-'z' 'A'-'Z' '0'-'9' '_']*

rule token = parse
     | '\n'                    { incr_lineno lexbuf; token lexbuf }
     | digit+ as str           { INTEGER (int_of_string str) }
     | '+'                      { PLUS }
     | '-'                     { MINUS }
     | '*'                     { TIMES }
     | '/'                     { DIVIDE }
     | '^'                     { POWER }
     | "true"|"false" as str { BOOL(bool_of_string str) }
     | '='                     { EQUAL }
     | '<'                     { LESS }
     | '>'                     { GREATER }

     | ['a'-'z' 'A'-'Z']+ as str  {try
                                  let token = Hashtbl.find keyword_table
(String.lowercase str) in
                                  token
                                with Not_found -> NAME (str) }
     | name ':' as str         { LABEL (String.sub str 0 ((String.length str)-
1) ) }
     | name as str             { NAME (str) }

     | whitespace              { token lexbuf }
     | "//"                    { sinlge_line_comment lexbuf }
     | "/*"                    { multi_line_comment lexbuf }
     | notspace * as str       { raise (Unknown_token (str,
lexbuf.lex_curr_p.pos_lnum, lexbuf.lex_start_p.pos_cnum-
lexbuf.lex_start_p.pos_bol +1)  ) }
     | eof                     { EOF }

and sinlge_line_comment = parse
     | '\n'            { Lexing.new_line lexbuf; token lexbuf }
     | _               { sinlge_line_comment lexbuf }

and multi_line_comment = parse
     | "*/"            { token lexbuf }
     | '\n'            { Lexing.new_line lexbuf; multi_line_comment lexbuf }
     | _               { multi_line_comment lexbuf }
```

2. Parser.ply

```
%{

open Ast;;
open Printf;;
open Lexing;;
open Utils;;

let auto_label_counter = ref 0;;

let make_label() =
     incr auto_label_counter;
     ("-" ^ string_of_int(!auto_label_counter))
     ;;

%}

%token SUB END_SUB
%token IF ELSE END_IF
%token BEGIN WHILE AGAIN
%token READ STORE
%token COLON
%token JUMP JUMPIF
%token <string> LABEL
%token <string> NAME
%token <int> INTEGER
%token PLUS MINUS TIMES DIVIDE MOD POWER
%token AND OR NOT
%token <bool> BOOL
%token EQUAL LESS GREATER
%token DROP DROPALL DUP SWAP OVER ROT
%token MOVE STOP SHOOT LOOK ISFOE ISALLY ISWALL WAIT GETHEALTH RANDOM
%token EOF

%start drone
%type <Ast.sub list> drone

%%

drone:
  program { let main_sub = { name="--"; body = List.rev (fst $1); } in
              main_sub :: snd $1 }

program:
     { [], [] }                                       /* two lists for main
body  of the program and for functions defined by users */
     | program operation { ($2 :: fst $1), snd $1 }  /* add operations to the
body of the main program */
     | program sub { fst $1, ($2 :: snd $1) }         /* add user function to
the list of subs */
     | program compaund_statment { ($2 @ fst $1), snd $1 }

sub:
     SUB NAME operations END_SUB      { { name = $2; body = List.rev $3; } }
/* store the function name and function operations between "sub" and "esub"
*/
```

```
operations:
     { [] }
     | operations operation    { if $2=Nop then $1 else $2 :: $1 }
     | operations compaund_statment     { $2 @ $1 }
     | operations error        { let pos = Parsing.rhs_start_pos 2 in
                                 raise (Parse_failure ("Unrecognized tokens
starting from line %d position %d\n", pos.pos_lnum, (pos.pos_cnum -
pos.pos_bol +1)));
                               }


compaund_statment:
     IF operations END_IF      {  let lbl = make_label() in
                                       ( Label(lbl):: $2 ) @ [ JumpIf(lbl) ;
Not ]
                                  }
      | IF operations ELSE operations END_IF    { let lbl1 = make_label() and
lbl2= make_label() in
                                        ( Label(lbl2):: $4) @
( Label(lbl1)::(Jump(lbl2):: $2 )) @ [ JumpIf(lbl1) ; Not ]
                                  }
      | BEGIN operations AGAIN { let lbl=make_label() in
                                       (Jump(lbl)::$2) @ [Label(lbl)]
                                }
      | BEGIN operations WHILE operations AGAIN {let lbl1 =make_label() and
lbl2 = make_label() in
                                       [Label(lbl1); Jump(lbl2)] @ $4 @
[ JumpIf(lbl1) ; Not ] @ $2 @ [Label(lbl2)]
                                }

operation:
        INTEGER        { Int($1) }
      | PLUS           { Plus }
      | MINUS          { Minus }
      | TIMES          { Times }
      | DIVIDE         { Divide }
      | MOD            { Mod }
      | POWER          { Power }
      | AND            { And }
      | OR             { Or }
      | NOT            { Not }
      | BOOL           { Bool($1) }
      | EQUAL          { Equal }
      | LESS           { Less }
      | GREATER        { Greater }
      | NAME READ      { Read($1) }
      | NAME STORE     { Store($1) }
      | DROP           { Drop }
      | DROPALL        { Dropall }
      | DUP            { Dup }
      | SWAP           { Swap }
      | OVER           { Over }
      | ROT            { Rot }
      | LABEL          { Label($1) }
      | NAME JUMP      { Jump($1) }
      | NAME JUMPIF    { JumpIf($1) }
      | NAME           { Call($1) }
```

```
| MOVE          { Move }
| STOP          { Stop }
| SHOOT         { Shoot }
| LOOK          { Look }
| ISFOE         { IsFoe }
| ISALLY        { IsAlly }
| ISWALL        { IsWall }
| WAIT          { Wait }
| GETHEALTH     { GetHealth }
| RANDOM        { Random }
```

3. AST.ml

```
module StringMap = Map.Make(String);;

type bytecode =
        Nop
      | Int of int
      | Plus
      | Minus
      | Times
      | Divide
      | Mod
      | Power
      | And
      | Or
      | Not
      | Bool of bool
      | Equal
      | Less
      | Greater
      | Colon
      | Store of string
      | Read of string
      | Label of string
      | Drop
      | Dropall
      | Dup
      | Swap
      | Over
      | Rot
      | Jump of string
      | JumpIf of string
      | AbsJump of int
      | AbsJumpIf of int
      | Call of string
      | Move
      | Stop
      | Shoot
      | Look
      | IsFoe
      | IsAlly
      | IsWall
      | Wait
      | GetHealth
      | Random
;;

let string_of_bytecode code =
     match code with
       Nop              -> ""
     (* *)
     | Int(x)           -> "Int(" ^ (string_of_int x) ^ ")"              (* 5,
integer*)
     | Plus             -> "Plus"
     (* 1 2 +, addition of integers *)
     | Minus            -> "Minus"
     (* 1 2 -, subtraction of integers *)
```

```
      | Times              -> "Times"
      (* 1 2 *, mutip of integers *)
      | Divide             -> "Divide"
      (* 1 2 /, division of integers *)
      | Mod                -> "Mod"
      (* 1 2 mod, take mod of 1 by 2 *)
      | Power              -> "Power"
      (* 1 2 ^, take the power of 1 by 2  *)
      | And                -> "And"                                    (* bool1
bool2 and, return bool1 && bool2 *)
      | Or                 -> "Or"                                     (* bool1
bool2 or, return bool1 || bool2 *)
      | Not                -> "Not"                                    (* bool1
not, return negation of bool1  *)
      | Bool(b)            -> "Bool(" ^ (string_of_bool b) ^ ")"       (* true,
boolean type true or false *)
      | Equal              -> "Equal"                                  (* 2 2 =,
equal *)
      | Less               -> "Less"                                   (* 1 2 <,
smaller *)
      | Greater            -> "Greater"                                (* 2 1 >,
greater *)
      | Colon              -> "Colon"                                  (* : ,
colon *)
      | Store(var)         -> "Store(" ^var ^ ")"                      (* 2
store , store the value of 2 *)
      | Read(var)          -> "Read(" ^var ^ ")"                       (* 2
read , read the value of 2 *)
      | Label(name)        -> "Label(" ^ name ^ ")"                    (*
label1: , take the label of name label1 *)
      | Drop               -> "Drop"                                   (* a b c
-> a b, drop the first element in the stack *)
      | Dropall            -> "Dropall"                                (* a b c
->, drop all elements in the stack *)
      | Dup                -> "Dup"                                    (* a b c
-> a b c c, duplicate first element in the stack *)
      | Swap               -> "Swap"                                   (* a b c
-> a c b, swap the elements in the stack *)
      | Over               -> "Over"                                   (* a b c
-> a b c b *)
      | Rot                -> "Rot"                                    (* a b c
-> b c a *)
      | Jump(name)         -> "Jump(" ^ name ^ ")"                     (* label1
jump, jump the label names label1 *)
      | JumpIf(name)       -> "JumpIf(" ^ name ^ ")"                   (* label1
jumpif, condition jump*)
      | AbsJump(addr)      -> "AbsJump(" ^ (string_of_int addr) ^ ")"
      | AbsJumpIf(addr) -> "AbsJumpIf(" ^ (string_of_int addr) ^ ")"
      | Call(name)         -> "Call(" ^ name ^ ")"                        (*
call the function by the name *)
      | Move               -> "Move"
      | Stop               -> "Stop"
      | Shoot              -> "Shoot"
      | Look               -> "Look"
      | IsFoe              -> "IsFoe"
      | IsAlly             -> "IsAlly"
      | IsWall             -> "IsWall"
      | Wait               -> "Wait"
```

```
        | GetHealth        -> "GetHealth"
        | Random           -> "Random"
;;

type look_flags =
          Foe
        (* enemy type *)
        | Ally                                                              (* friend
type*)
        | Wall                                                              (*
boundary of arena *)

type operands =
          Undefined
        | Integer of int
        | Boolean of bool
        | Flag of look_flags

let string_of_operand op =
      match op with
          Undefined  -> "undef"
        | Integer(x) -> string_of_int x
        | Boolean(b) -> string_of_bool b
        | Flag(f)    -> match f with
                            Foe  -> "Foe"
                          | Ally -> "Ally"
                          | Wall -> "Wall"


type sub = {                                                               (*
function defined by user *)
    name    : string;                                                      (*
function name *)
    body    : bytecode list;                                               (*
function body *)
  }

type program = bytecode list * sub list                               (* compiled,
but not-linked program defintion returned from the parser *)
```

4. Drone.ml

```
open Ast;;
open Parser;;
open Parser_dbt;;
open Printf;;
open Utils;;

exception Error_in_AI of string * string * int;;

type drone_action =
       No_Action
     | Do_Shoot of int * int
     | Do_Look of int


class drone =
    object (self)

        (* init the containers*)
        val mutable subs = Hashtbl.create 16
        val mutable vars : (string, Ast.operands) Hashtbl.t = Hashtbl.create
16
        val mutable current_sub = "--"
        val mutable instruction_pointer = 0
        val mutable call_stack: (string * int) Stack.t = Stack.create ()
        val mutable stack : (Ast.operands) Stack.t = Stack.create ()

        (* variables to enable debug functionality *)
        val mutable debug_mode = false
        val mutable debug_out_file = stderr (* channel for debug output *)
        val mutable tick_counter = 0         (* life-time ticks counter, used
in debug output function *)

        (* various members *)
        val mutable drone_name = ""   (* name of the drone for GUI *)
        val mutable team_id    = 0    (* id of the team this drone belongs to
*)

        (* variuables to describe current drone state *)
        val mutable health = 100
        val mutable direction_of_the_body = 0 (* used by GUI to draw where
the drone is moving if drone's image is not a circle *)
        val mutable direction_of_the_gun = 0  (* used by GUI to draw where
the drone's gun is pointing (direction of the last SHOOT command *)
        val mutable ticks_to_wait = 0         (* if non-zero, the AI will
skip a step *)
        val mutable moving = false            (* does the drone moving or
not? *)
        val mutable brain_dead = false        (* will become true if at some
step the drone caught an exception *)
        val mutable reason_for_coma = ""      (* explanation why AI died *)

        val mutable x_position = 0.    (* used by other drones to determine
the position in the arena can set maximum in Arena as Radius of the circle*)
        val mutable y_position = 0.    (* used by other drones to determine
the position in the arena 0-360*)
```

```
        (* maxmium bullet load is 5 can be displayed in the GUI *)
        val mutable bullet_capacity = 5
        val mutable has_bullet = true
        (* set to 10 each time drone shoots. drone cannot shoot until
gun_cooldown returns to zero *)
        val mutable gun_cooldown = 0

        method get_moving_direction = direction_of_the_body

        method set_moving_direction dire = direction_of_the_body <- dire

        method get_x_position = x_position

        method set_x_position x = x_position <- x

        method get_y_position = y_position

        method set_y_position y = y_position <- y

        method get_current_sub = current_sub;

        method get_direction_of_the_gun = direction_of_the_gun;

        method get_drone_name = drone_name

        method is_brain_dead = brain_dead

        method is_alive = (health > 0)

        method get_ai_ticks = tick_counter

        method get_health = health

        method belongs_to_team id = team_id <- id

        method get_team_id = team_id

        method get_moving_status = moving

        method set_health h =
             health <- max h 0;
             moving <- moving && health>0

        method get_reason_for_coma = reason_for_coma

        method get_gun_cooldown = gun_cooldown


        (* this method is called, by the engine's LOOK procedure *)
        method found_target dist dire flag=
             Stack.push (Integer (dist)) stack;
             Stack.push (Integer (dire)) stack;
             Stack.push (Flag (flag)) stack


        method move speed =
             if moving then
             begin
```

```
                    y_position <- y_position +. (float_of_int(speed) *. (sin
(float_of_int(direction_of_the_body) *. pi /. 180.)));
                    x_position <- x_position +. (float_of_int(speed) *. (cos
(float_of_int(direction_of_the_body) *. pi /. 180.)));

                    (* check did we hit a wall? *)
                    if x_position > 1000. || x_position < 0. || y_position >
1000. || y_position < 0. then
                    begin
                         self#set_health (health - 10);
                         if x_position > 1000. then x_position <- 1000.;
                         if x_position < 0. then x_position <- 0.;
                         if y_position > 1000. then y_position <- 1000.;
                         if y_position < 0. then y_position <- 0.;
                         (* this is still debated, what to do after hiting the
wall, stop or bounce from it? *)
                         (* direction_of_the_body <- ((direction_of_the_body +
180) mod 360; (* bouncing adds more chaos to the battle *) *)
                         moving <- false;    (* stopping is more easy to predict
and explain *)
                         if health=0 then moving <- false (* if drone died
after hitting the wall, it definetely will not move anymore *)
                    end
               end


          method set_debug_output out_file =
               debug_out_file <- out_file;
               debug_mode <- true

          (* print out all operations in the container *)
          method dump_code body_as_array out_file =
               let command_counter = ref 0 in
               Array.iter (fun x ->
                                   fprintf out_file "%3d: %s\n" !command_counter
(string_of_bytecode x);
                                   command_counter := !command_counter +1
                              ) body_as_array

          (* decompile the program into compilable text *)
          method decompile out_file =
               let body = (Hashtbl.find subs "--") in self#dump_code body
out_file;
               Hashtbl.iter (fun name body ->
                              if not (name="--") then begin
                                   fprintf out_file "\nsub %s\n" name;
                                   self#dump_code body out_file;
                                   fprintf out_file "esub\n"
                              end
                             ) subs

          (* takes a raw list of operators including a Label(name) operator,
             Remove all label, put them into temporary hash table
             Using this hash table satisfy all jump(name) and convert them to
jump(address) *)
          method link_jumps body_as_list =
               let lbls = Hashtbl.create 16 in
               let no_label = List.fold_left (fun acc x ->
```

```
                                          match x with
                                            Label(name) ->
                                               if Hashtbl.mem lbls name then
raise (Failure ("Label "^name^" defined twice"))
                                               else Hashtbl.add lbls name
(List.length acc);
                                               acc
                                          | _ -> x::acc
                                         ) [] body_as_list in
              let abs_jumps = List.map(fun x -> match x with
                                           Jump(name) ->
                                               if not (Hashtbl.mem lbls name)
then raise (Failure ("Label "^name^" is not defined"));
                                              AbsJump( Hashtbl.find lbls name )
                                         | JumpIf(name) ->
                                               if not (Hashtbl.mem lbls name)
then raise (Failure ("Label "^name^" is not defined"));
                                               AbsJumpIf( Hashtbl.find lbls
name )
                                         | _ -> x ) no_label in
              Array.of_list (List.rev abs_jumps)

         (* check existance of a called sub, complain if it is not defined *)
         method check_sub_existance body =
              Array.iter (fun x -> match x with
                           Call(name) -> if not (Hashtbl.mem subs name) then
raise (Failure ("Sub "^name^" is not defined"))
                           | _ -> ()
                         ) body


         (* Read the drone *)
         method load file_name =
              drone_name <- Filename.chop_extension (Filename.basename
file_name);
              let chan_in = Pervasives.open_in file_name in
              let lexbuf = Lexing.from_channel chan_in in
              let program =
                   (if (Filename.check_suffix file_name ".dt" ) then
Parser.drone Scanner.token lexbuf
                    else if (Filename.check_suffix file_name ".dbt" ) then
Parser_dbt.drone Scanner_dbt.drone_basic lexbuf
                    else ([])
                   ) in
              (* First convert all jumps to the label into absolute jumps *)
              List.iter (fun sub -> Hashtbl.add subs sub.name
(self#link_jumps sub.body)) program;
              (* Next step, check the existance of all called user funcitons
*)
              Hashtbl.iter (fun name body -> (self#check_sub_existance body))
subs;
              (* Last step, set starting position for the drone *)
              self#set_x_position (Random.float 1000.);
              self#set_y_position (Random.float 1000.);
              self#set_moving_direction (Random.int 360)
              (* self#print_current_pos; *)
```

```
        (* helping pop function which converts operand to integer *)
        method pop_int=
            if Stack.is_empty stack then self#freeze "Empty stack";
            match (Stack.pop stack) with
            Integer op-> op

            | _ -> self#freeze "Type mismatch"; 0

        (* helping pop function which converts operand to bool *)
        method pop_bool=
            if Stack.is_empty stack then self#freeze "Empty stack";
            match (Stack.pop stack) with
            Boolean op -> op
            | _ -> self#freeze "Type mismatch"; false

        (* helping pop function which converts operand to look_flag *)
        method pop_flag=
            if Stack.is_empty stack then self#freeze "Empty stack";
            match (Stack.pop stack) with
            Flag op -> op
            | _ -> self#freeze "Type mismatch"; Wall



        method step =
            tick_counter <- tick_counter+1;
            if gun_cooldown>0 then gun_cooldown <- gun_cooldown-1;
        if ticks_to_wait > 0 then begin
                if debug_mode then begin
                    fprintf debug_out_file "%4d  waiting for %d ticks\n"
tick_counter ticks_to_wait;
                end;
                ticks_to_wait <- ticks_to_wait-1;
                No_Action
            end else begin
                let body = (Hashtbl.find subs current_sub) in
                if (Array.length body) = instruction_pointer then begin
                    if Stack.is_empty call_stack then self#freeze "Main
program terminated";
                    let return_address = (Stack.pop call_stack) in begin
                        current_sub <- fst return_address;
                        instruction_pointer <- snd return_address;
                    end;
                    No_Action
                end else begin
                    if debug_mode then self#print_current_state;
                let action = match Array.get body instruction_pointer with
                        (* primitive types *)
                          Int (x) -> Stack.push (Integer x) stack;
No_Action
                        | Bool(x) -> Stack.push (Boolean x) stack;
No_Action

                        (* simple arithmetics *)
                        | Plus   -> let op2=self#pop_int and
op1=self#pop_int in Stack.push (Integer (op1 + op2)) stack; No_Action
                        | Minus  -> let op2=self#pop_int and
op1=self#pop_int in Stack.push (Integer (op1 - op2)) stack; No_Action
```

```
                             | Times  -> let op2=self#pop_int and op1=self#pop_int
in Stack.push (Integer (op1 * op2)) stack; No_Action
                                 | Divide -> let op2=self#pop_int and
op1=self#pop_int in Stack.push (Integer (op1 / op2)) stack; No_Action
                                 | Mod    -> let op2=self#pop_int and
op1=self#pop_int in Stack.push (Integer (op1 mod op2)) stack; No_Action
                                 | Power  -> let op2=self#pop_int and
op1=self#pop_int in Stack.push (Integer (int_of_float((float_of_int(op1)) **
(float_of_int(op2))))) stack; No_Action

                             (* boolean arithmetics *)
                                 | And -> let op2=self#pop_bool and
op1=self#pop_bool in Stack.push (Boolean (op1 && op2)) stack; No_Action
                                 | Or  -> let op2=self#pop_bool and
op1=self#pop_bool in Stack.push (Boolean (op1 || op2)) stack; No_Action
                                 | Not -> let op=self#pop_bool in Stack.push
(Boolean (not op)) stack; No_Action

                             (* conditions *)
                                 | Less    -> let op2=self#pop_int and
op1=self#pop_int in Stack.push (Boolean (op1 < op2)) stack; No_Action
                                 | Greater -> let op2=self#pop_int and
op1=self#pop_int in Stack.push (Boolean (op1 > op2)) stack; No_Action
                                 | Equal   -> let op2=self#pop_int and
op1=self#pop_int in Stack.push (Boolean (op1 = op2)) stack; No_Action

                                 (* call anothe sub*)
                                 | Call(name) -> begin
                                                  Stack.push (current_sub,
(instruction_pointer+1)) call_stack;
                                                  current_sub <- name;
                                                  instruction_pointer <- -1
                                                  end;
                                               No_Action
                             (* variables *)
                                 | Store(varName) -> if Stack.is_empty stack then
self#freeze "Nothing to store";
                                                      let op = Stack.pop stack
in Hashtbl.replace vars varName op;
                                                  No_Action

                                 | Read(varName)  -> if not (Hashtbl.mem vars
varName) then self#freeze "Variable not defined";
                                                      let op = Hashtbl.find vars
varName in
                                                      Stack.push op stack;
                                                      No_Action

                                 (* stack manipulation *)
                                 | Drop    -> ignore(Stack.pop stack); No_Action
                                 | Dropall -> Stack.clear stack; No_Action
                             | Dup     -> let op=Stack.top stack in Stack.push op
stack; No_Action
                                 | Swap    -> let op2=Stack.pop stack and
op1=Stack.pop stack in begin Stack.push op2 stack; Stack.push op1 stack end;
No_Action
```

```
                            | Over     -> let op2=Stack.pop stack and
op1=Stack.top stack in begin Stack.push op1 stack; Stack.push op2 stack end;
No_Action
                            | Rot      -> let op3=Stack.pop stack and
op2=Stack.top stack and op1=Stack.top stack in begin Stack.push op2 stack;
Stack.push op3 stack; Stack.push op1 stack end; No_Action

                            (* game specific operations *)
                            | Move       -> let direction=self#pop_int in
direction_of_the_body <- direction; moving <- true; No_Action
                            | Stop       -> moving <- false; No_Action
                            | Shoot      -> let direction=self#pop_int and
distance=self#pop_int in
                                            direction_of_the_gun <-
direction;
                                            Stack.push (Boolean
(gun_cooldown=0)) stack;
                                            if gun_cooldown>0
                                                then No_Action
                                                else (gun_cooldown<-10;
Do_Shoot(direction, distance))

                            | Look       -> let direction=self#pop_int in
                                            direction_of_the_gun <-
direction mod 360;
                                            if direction_of_the_gun > 180
then direction_of_the_gun <- direction_of_the_gun-360;
                                            Do_Look(direction_of_the_gun)
                            | IsFoe      -> let flag=self#pop_flag in
Stack.push (Boolean (flag=Foe)) stack; No_Action
                            | IsAlly     -> let flag=self#pop_flag in
Stack.push (Boolean (flag=Ally)) stack; No_Action
                            | IsWall     -> let flag=self#pop_flag in
Stack.push (Boolean (flag=Wall)) stack; No_Action
                           | GetHealth -> Stack.push (Integer(health)) stack;
No_Action
                            | Wait       -> ticks_to_wait <- self#pop_int;
No_Action

                            (* TO DO! get random int between min and max *)
                            | Random     -> let max=self#pop_int and
min=self#pop_int in Stack.push (Integer(Random.int (max - min + 1) + min))
stack; No_Action

                            (* jumps *)
                            | AbsJump(x)    -> instruction_pointer <- x-1;
No_Action
                            | AbsJumpIf(x) -> if self#pop_bool then
instruction_pointer <- x-1; No_Action
                            | _ -> No_Action
                        in
                        instruction_pointer <- instruction_pointer+1;
                        action
                    end
                end

            method print_current_pos =
                begin
```

```
                    print_endline drone_name;
                    print_float x_position;
                    print_endline "";
                    print_float y_position;
                    print_endline "";
                    print_endline "Direction: ";
                    print_int direction_of_the_body;
                    print_endline "";
                    print_endline "Gun Direction: ";
                    print_int direction_of_the_gun;
                    print_endline "";
                    print_endline "Health: ";
                    print_int health;
                                   print_endline "";
                    print_endline "team_id: ";
                    print_int team_id;
                    print_endline "";
                    print_endline "";
               end


          method freeze explanation =
               brain_dead <- true;
               reason_for_coma <- explanation;
               raise (Error_in_AI (explanation, current_sub,
instruction_pointer));


          method print_current_state =
               let sub_name = (if current_sub="--" then "" else current_sub)
in
               let body = (Hashtbl.find subs current_sub) in
               let bc = Array.get body instruction_pointer in
               fprintf debug_out_file "%4d %20s[%3d] %20s  |" tick_counter
sub_name instruction_pointer (string_of_bytecode bc);
               let stack_copy = Stack.copy stack in
               let cnt = ref 1 in
               while (!cnt < 10) && (not (Stack.is_empty stack_copy)) do
                    let op = Stack.pop stack_copy in
                    fprintf debug_out_file " %s" (string_of_operand op);
                    cnt := !cnt +1
               done;
               if (Stack.is_empty stack_copy) then
                    fprintf debug_out_file " EOS\n"
               else
                    fprintf debug_out_file " ...\n";
               flush debug_out_file


          (* for each shoot update bullet capacity and push boolean on the
stack *)
          method update_bullet_load =
               begin
               (* shoot *)
               if bullet_capacity > 0
               then
                    begin
```

```
                    bullet_capacity <- bullet_capacity - 1;
                    has_bullet <- true;
                end
            (* no bullet *)
            else
                has_bullet <- false;
            end;
            has_bullet

end;;
```

5. Arena.ml

```
open Drone;;
open Printf;;
open Bullet;;
open Ast;;
open Utils;;
open Gui;;

class arena =
object (self)
     val mutable drones : drone list = []
     val mutable bullets : bullet list = []
    val mutable arena_gui = new gui
     val mutable gui_enabled = true
     val mutable debug_mode = false

     val mutable look_range = 30          (* +30 and -30 on the given degree
*)
     val mutable bullet_speed = 5
     val mutable drone_speed = 1

     val mutable area_map_x = 1000
     val mutable area_map_y = 1000

     val mutable team_counter = 0
     val mutable gathering_team = false

     method disable_gui = gui_enabled<-false

     method set_debug_mode mode = debug_mode <- mode

     method load file_name =
          let d = new drone in begin
               d#load file_name;
               d#belongs_to_team team_counter;
               if not gathering_team then team_counter <- team_counter+1;
               if debug_mode then begin
                    let decompiled_file = open_out (file_name ^ ".decompiled")
in
                    d#decompile decompiled_file;
                    close_out decompiled_file;
                    d#set_debug_output (open_out (file_name ^ ".debug"))
               end;
               drones <- d :: drones
          end

     method get_drone_count = List.length drones;


     method add_bullet dist dire shoot_d =
          let b = new bullet in
          b#init shoot_d#get_x_position shoot_d#get_y_position dire dist;
          bullets <- b :: bullets


     method run =
          if gui_enabled then arena_gui#drawArena;
```

```
        let steps = ref 1 in
        while (self#step > 1) && (!steps < 2000) do
             incr steps
        done;
        printf "Results:\n";
        List.iter (fun d ->
             printf "%s: %s\n" d#get_drone_name
                  (if d#is_brain_dead then
                       ("brain dead after " ^ (string_of_int d#get_ai_ticks)
^ " ticks with explanation: " ^ d#get_reason_for_coma)
                   else if not d#is_alive then
                       ("died after " ^ (string_of_int d#get_ai_ticks) ^ "
ticks")
                   else
                       ("still alive with " ^ (string_of_int d#get_health) ^
"% of health ")
                  )
        ) drones


    (* get a distance to the wall in the exact direction of the drone's look
*)
     method look_wall dire d_look=
        let x=d_look#get_x_position and y=d_look#get_y_position in
        let md = dire mod 360 in
        let rd = radian_of_degree md in
        let dh = max (int_of_float ((0. -. x) /. (cos rd))) (int_of_float
((1000. -. x) /. (cos rd))) in
        let dv = max (int_of_float ((0. -. y) /. (sin rd))) (int_of_float
((1000. -. y) /. (sin rd))) in
        let dist = if md=0 || md=180 then dh
                   else if md=90 || md=270 then dv
                   else min dh dv in
       d_look#found_target dist dire Wall



    method explosion b d =
        let d_x=d#get_x_position and d_y=d#get_y_position and
exp_x=b#get_pos_x and exp_y=b#get_pos_y in
        let dist = distance (d_x, d_y, exp_x, exp_y) in
        if dist < 50 then d#set_health (d#get_health - 50 + dist)



    method step =
        let live_drones = ref 0 in       (* to check how many drones are
still alive and kicking *)
        List.iter (fun active_drone ->
             if (active_drone#is_alive) && (not active_drone#is_brain_dead)
then begin
                  incr live_drones;
                  try (
                       let action = active_drone#step in
                       match action with
                         No_Action                      -> ()
```

```
                        | Do_Shoot(direction, distance) -> self#add_bullet
distance direction active_drone
                        | Do_Look(direction)           ->   begin

     self#look_wall direction active_drone; (* the wall is always visible, and
it is always the farthest object from the active drone *)
                                                                  let
found_drones = List.filter (fun d ->
                                                                        if
d==active_drone then false     (* the drone cannot see itself *)
                                                                        else
if not d#is_alive then false (* ignore dead drones *)
                                                                        else
begin  (* check if the drone is in the look range *)

     let angle_to_drone = degree_of_radian (atan2 (d#get_y_position -.
active_drone#get_y_position)  (d#get_x_position -.
active_drone#get_x_position) ) in

     abs (direction - angle_to_drone)  < look_range
                                                                        end
                                                                  ) drones in
                                                                  (* sort all
drones in the look range by the distance from the active drone *)
                                                                  let
sorted_found_drones = List.rev(self#sort_by_dist active_drone found_drones)
in
                                                                  (* add all
found drones into the active drone's stack *)
                                                                  List.iter
(fun d -> active_drone#found_target (distance(active_drone#get_x_position,
active_drone#get_y_position, d#get_x_position, d#get_y_position))

                                        (degree_of_radian (atan2
(d#get_y_position -. active_drone#get_y_position)  (d#get_x_position -.
active_drone#get_x_position) ))

                                        (if
active_drone#get_team_id=d#get_team_id then Ally else Foe)

       ) sorted_found_drones
                                                                  end
                    )
                    with Error_in_AI (reason, sub, position) -> printf
"Drone %s died at %s:%d with explanation: %s\n" active_drone#get_drone_name
sub position reason
                end
          ) drones;
          (* update position for all drones and bullets *)
          List.iter (fun d -> d#move drone_speed ) drones;
          List.iter (fun b -> b#move bullet_speed; if b#is_exploded then
List.iter(fun d -> self#explosion b d) drones) bullets;

          (*  List.iter (fun d -> d#print_current_pos ) drones; *)
          if gui_enabled then begin
                 arena_gui#clear;
                 List.iter (fun d -> arena_gui#drawDroneDetail (int_of_float
d#get_x_position) (int_of_float d#get_y_position) (radian_of_degree
```

```
d#get_moving_direction) (radian_of_degree d#get_direction_of_the_gun)
d#get_drone_name d#get_health d#get_team_id d#get_ai_ticks
d#get_moving_status d#get_reason_for_coma d#get_gun_cooldown) drones;
                List.iter (fun b -> if(b#is_exploded) then
arena_gui#drawExplode (int_of_float b#get_pos_x) (int_of_float b#get_pos_y)
else arena_gui#drawBullet (int_of_float b#get_pos_x) (int_of_float
b#get_pos_y)) bullets;
                arena_gui#wait;
         end;
         (* remove all exploded bullets from the arena *)
         bullets <- List.filter (fun b -> not b#is_exploded) bullets;
         !live_drones


    method ins d drone d_list =
         let rec insert d e elements =
              match elements with
                [] -> [e]
              | head :: tail -> if distance (d#get_x_position,
d#get_y_position, e#get_x_position, e#get_y_position) <=
                                      distance (head#get_x_position,
head#get_y_position, d#get_x_position, d#get_y_position)
                                 then e :: elements
                                 else head :: insert d e tail
              in
         insert d drone d_list

    method sort_by_dist d d_list=
         let rec sort d elements =
              match elements with
                [] -> []
              | head :: tail -> self#ins d head (sort d tail)
         in
         sort d d_list


    method start_a_team =
         team_counter <- team_counter+1;
         gathering_team <- true

end;;
```

6. main.ml

```
open Arena;;
open Printf;;
open Utils;;


let main =
	print_string "The Drone War\nThe class project for COMS W4115 Programming Languages and
Translators\nColumbia University, Fall 2012\n\
					Professor:\tStephen A. Edwards\n\
					Students:\tGeorge Brink (gb2280)\n\
					\t\tXiang Yao (xy2191)\n\
					\t\tXiaotong Chen (xc2230)\n\
					\t\tShuo Qiu (sq2144)\n\n\
					";
	Random.self_init();
	let cage = new arena in
	Array.iter (fun parameter ->
		if parameter.[0]='-' then
		begin
			match parameter.[1] with
			 'D' -> cage#set_debug_mode true
			| 't' -> cage#start_a_team
			| 'q' -> cage#disable_gui
			|  _  -> print_endline ("Unknown option " ^parameter);
		end
		else
		if (Filename.check_suffix parameter ".dt" ) || (Filename.check_suffix parameter ".dbt" )
then
		begin
			print_string "Loading ";
			print_string parameter;
			try
				cage#load parameter;
				printf " - ok\n"
			with
			 Failure t          -> printf " - failed\n%s\n" t
	| Parse_failure(t,l,c) -> printf " - failed\n%s at %d:%d\n" t l c
			| Sys_error t        -> printf " - file error\n%s\n" t
		end
	) Sys.argv;
	Random.self_init();
	print_string ("Loaded " ^ (string_of_int cage#get_drone_count) ^ " drones\n");
	cage#run;
	exit 0;;
```

7. gui.ml

```
open Unix;;

class gui =
object (self)
  val mutable info_x = 0
  val mutable info_y = 0
  val mutable size_x = 0
  val mutable size_y = 0
  val mutable max_x = 0
  val mutable max_y = 0
  val mutable temp_x = 0
  val mutable temp_y = 0
  val mutable counter = 0




  method drawArena=
              Graphics.open_graph "";
              Graphics.set_window_title "Arena";
              Graphics.display_mode false;
              Graphics.remember_mode true;
              self#clear

  method translate x y=
    temp_x <- (20 + x * size_x / 1000);
    temp_y <- (20 + y * size_y / 1000);



  method drawDrone x y z=
      Graphics.set_color (Graphics.blue);
      self#translate x y;
        Graphics.draw_circle temp_x temp_y 6;
        Graphics.moveto temp_x temp_y;
        Graphics.lineto ( int_of_float(cos (z)*.12.) +size_x) (int_of_float(sin (z)*.12.)+temp_y);


  method drawCircleDroneDetail x y z name health=
      Graphics.set_color (Graphics.blue);
      self#translate x y;
        Graphics.draw_circle temp_x temp_y 6;
        Graphics.moveto temp_x temp_y;
        Graphics.lineto ( int_of_float(cos (z)*.12.) +temp_x) (int_of_float(sin (z)*.12.)+temp_y);
    if (x+String.length(name))>1000 then if (y+30)>1000 then self#translate (x-50) (y-13) else self#translate (x-50)
(y+13)
            else if (y+30)>1000 then self#translate (x+13) (y-13) else self#translate (x+13) (y+13);
    Graphics.moveto temp_x temp_y;
    Graphics.draw_string name;
```

```
    (*self#drawDroneHealth name health;*)
    if health=0 then (self#drawDroneDead x y);

  method drawDroneDetail x y body_direc gun_direc name health team_id ai_ticks moving_status
reason_for_coma gun_cooldown=
    self#drawDroneColor team_id;
    self#translate x y;
    self#drawDroneBody x y body_direc;          (*draw the body of the drone *)
      Graphics.moveto temp_x temp_y;
      Graphics.lineto ( int_of_float(cos (gun_direc)*.15.) +temp_x) (int_of_float(sin (gun_direc)*.15.)+temp_y);
(*draw the gun of the drone *)
    if (x+7*String.length(name))>1000 then if (y+30)>1000 then self#translate (x-7*String.length(name)) (y-23)
else self#translate (x-7*String.length(name)) (y+16)
          else if (y+30)>1000 then self#translate (x+13) (y-23) else self#translate (x+13) (y+16);
    Graphics.moveto temp_x temp_y;
    Graphics.draw_string name;      (*draw the name of the drone *)
    Graphics.moveto temp_x (temp_y-10);
    Graphics.draw_string (string_of_int health);       (*draw the name of the drone *)
    self#drawDroneInfo name health team_id ai_ticks moving_status reason_for_coma gun_cooldown;   (*draw
the information of the drone *)
    if health=0 then (self#drawDroneDead x y);     (*draw the deadbody of the drone *)

  method drawDroneBody x y body_direc=
    self#translate x y;
    let pi = 4. *. atan 1. in
    let x1=int_of_float(cos (body_direc)*.10.) +temp_x in
    let y1=int_of_float(sin (body_direc)*.10.) +temp_y in
    let x2=int_of_float(cos (body_direc +. (140.*. pi /.180.))*.10.) +temp_x in
    let y2=int_of_float(sin (body_direc +. (140.*. pi /.180.))*.10.) +temp_y in
    let x3=int_of_float(cos (body_direc +. (220.*. pi /.180.))*.10.) +temp_x in
    let y3=int_of_float(sin (body_direc +. (220.*. pi /.180.))*.10.) +temp_y in
    Graphics.draw_poly [|(x1,y1);(x2,y2);(x3,y3)|];

  method drawDroneInfo name health team_id ai_ticks moving_status reason_for_coma gun_cooldown=
    Graphics.set_color (10494192);
    info_y <- (info_y-15);
    Graphics.moveto info_x info_y;
    Graphics.draw_string name;
    Graphics.set_color (Graphics.black);
    info_y <- (info_y-10);
    Graphics.moveto info_x info_y;
    Graphics.draw_string "Team ID: ";
    Graphics.draw_string (string_of_int team_id);
    info_y <- (info_y-10);
    Graphics.moveto info_x info_y;
    Graphics.draw_string "Health: ";
    Graphics.draw_string (string_of_int health);
    info_y <- (info_y-10);
    Graphics.moveto info_x info_y;
    Graphics.draw_string "AI Ticks: ";
    Graphics.draw_string (string_of_int ai_ticks);
    info_y <- (info_y-10);
    Graphics.moveto info_x info_y;
```

```
    Graphics.draw_string "Moving: ";
    Graphics.draw_string (string_of_bool moving_status);
    info_y <- (info_y-10);
    Graphics.moveto info_x info_y;
    Graphics.draw_string "Reason for coma: ";
    if reason_for_coma="" then Graphics.draw_string "Not coma yet" else Graphics.draw_string
reason_for_coma;
    info_y <- (info_y-10);
    Graphics.moveto info_x info_y;
    Graphics.draw_string "Gun cooldown: ";
    Graphics.draw_string (string_of_int gun_cooldown);

  method drawDroneDead x y=
    Graphics.set_color (Graphics.red);
    self#translate x y;
    Graphics.moveto (temp_x-7) (temp_y+7);
    Graphics.lineto (temp_x+7) (temp_y-7);
    Graphics.moveto (temp_x-7) (temp_y-7);
    Graphics.lineto (temp_x+7) (temp_y+7);

  method drawDroneColor x=
    match x with
        0 ->  Graphics.set_color (Graphics.red)
      |  1 -> Graphics.set_color (Graphics.green)
      |  2 -> Graphics.set_color (Graphics.blue)
      |  3 -> Graphics.set_color (10506797)
      |  4 -> Graphics.set_color (Graphics.cyan)
      |  5 -> Graphics.set_color (Graphics.magenta)
      |  6 -> Graphics.set_color (16744228)
      |  7 -> Graphics.set_color (16759055)
      |  8 -> Graphics.set_color (13487360)
      |  9 -> Graphics.set_color (13445520)
      | 10 -> Graphics.set_color (12092939)
      | 11 -> Graphics.set_color (9005261)
      | 12 -> Graphics.set_color (9132544)
      | 13 -> Graphics.set_color (5577355)
      | 14 -> Graphics.set_color (128)
      | _ -> Graphics.set_color (Graphics.black)

  method drawBullet x y=
    Graphics.set_color (Graphics.black);
    self#translate x y;
    Graphics.fill_circle temp_x temp_y 4;

  method drawExplode x y=
    self#translate x y;
    Graphics.set_color (14423100);
   Graphics.draw_circle temp_x temp_y 10;
    Graphics.set_color (15597568);
   Graphics.draw_circle temp_x temp_y 20;
    Graphics.set_color (15608876);
   Graphics.draw_circle temp_x temp_y 30;
    Graphics.set_color (15613952);
```

```
   Graphics.draw_circle temp_x temp_y 40;
    Graphics.set_color (15627776);
   Graphics.draw_circle temp_x temp_y 50;


  method clear=
    Graphics.clear_graph ();
    Graphics.set_color (Graphics.black);
    max_x <- Graphics.size_x();
    max_y <- Graphics.size_y();
    info_x <-(max_x-190);
    info_y <-(max_y-25);
    size_x <-(max_x-220);
    size_y <-(max_y-40);
    counter <- (counter+1);
    Graphics.draw_rect 20 20 size_x size_y;
    Graphics.moveto info_x (max_y-30);
    Graphics.draw_string "Total Ticks: ";
    Graphics.draw_string (string_of_int counter);

  method wait=
                Graphics.synchronize();
    (*let s = Graphics.wait_next_event [Graphics.Button_down;Graphics.Key_pressed] in if s.Graphics.button
     then Graphics.set_color (Graphics.red); *)
                let tt = Unix.gettimeofday() in
                while Unix.gettimeofday() < tt +. 0.05 do () done
```

8. bullet.ml

```
open Utils;;

class bullet =
        object (self)

        val mutable direction = 0
        val mutable x_position = 0.
        val mutable y_position = 0.
        val mutable distance_to_fly = 0
        val mutable distance_traveled = 0

        val mutable start_x_position = 0.
        val mutable start_y_position = 0.
        val mutable exploded = false

        method get_pos_x = x_position

        method get_pos_y = y_position

        method get_direction = direction
```

```
        method is_exploded = exploded

        method init x y dir dist =
                start_x_position <- x;
                x_position <- x;
                start_y_position <- y;
                y_position <- y;
                direction <- dir;
                distance_to_fly <- min dist 1000


        method move speed =
                y_position <- y_position +. (float_of_int(speed) *. (sin (float_of_int(direction) *. pi /. 180.)));
                x_position <- x_position +. (float_of_int(speed) *. (cos (float_of_int(direction) *. pi /. 180.)));
                distance_traveled <- distance(x_position, y_position, start_x_position, start_y_position);
                exploded <- (x_position > 1000.) || (x_position < 0.) || (y_position > 1000.) || (y_position < 0.);
                if exploded
                        then self#update_position_if_flew_out_of_arena
                        else exploded <- distance_traveled >= distance_to_fly


        method update_position_if_flew_out_of_arena =
                begin
                        if x_position > 1000. then x_position <- 1000.;
                        if x_position < 0. then x_position <- 0.;
                        if y_position > 1000. then y_position <- 1000.;
                        if y_position < 0. then y_position <- 0.;
                end

end;;
```

9. utils.ml

```
exception Parse_failure of string * int * int;;

let pi = 4. *. atan 1.;;

let distance(x1, y1, x2, y2) =
        int_of_float(sqrt((x1 -. x2)*.(x1 -. x2) +. (y1 -. y2)*.(y1 -. y2)));;

let radian_of_degree angle =
        float_of_int(angle) *. pi /. 180.;;

let degree_of_radian angle =
        int_of_float( angle *. 180. /. pi );;
```

10. scanner_dbt.mll (George Brink's individual contribution)

```
open Parser_dbt;;
open String;;
open Lexing;;

let create_hashtable size init =
        let tbl = Hashtbl.create size in
        List.iter (fun (key, data) -> Hashtbl.add tbl key data) init;
        tbl

let keyword_table =
        create_hashtable 8 [
                ("if",       IF);
                ("then",     THEN);
                ("else",     ELSE);
                ("do",       DO);
                ("loop",     LOOP);
                ("while",    WHILE);
                ("until",    UNTIL);
                ("exit",     EXIT);
                ("sub",      SUB);
                ("function", FUNCTION);
                ("call",     CALL);
                ("end",      END);
                ("for",      FOR);
                ("to",       TO);
                ("step",     STEP);
                ("next",     NEXT);
                ("goto",     GOTO);
                ("true",     BOOL(true));
```

```
            ("false",     BOOL(false));
            ("and",       AND);
            ("or",        OR);
            ("not",       NOT);

            ("sleep",     SLEEP);
            ("move",      MOVE);
            ("stop",      STOP);
            ("shoot",     SHOOT);
            ("rnd",       RANDOM);
            ("health",    HEALTH);

            ("startscan", STARTSCAN);
            ("nextscan",  NEXTSCAN);
            (".iswall",   ISWALL);
            (".isfoe",    ISFOE);
            (".isally",   ISALLY);
            (".distance", DISTANCE);
            (".direction", DIRECTION);
        ]

exception Unknown_token of string * int * int;;

let incr_lineno lexbuf =
        let pos = lexbuf.lex_curr_p in
        lexbuf.lex_curr_p <- { pos with
            pos_lnum = pos.pos_lnum + 1;
            pos_bol = pos.pos_cnum;
        }
}

let digit = ['0' - '9']
let id = ['a'-'z' 'A'-'Z']['a'-'z' 'A'-'Z' '0'-'9']* | '.' ['a'-'z' 'A'-'Z']+
let space = [' ' '\t' '\r']
let not_space = [^ ' ' '\t' '\r']

rule drone_basic = parse
  | digit+ as inum  { let num = int_of_string inum in INT num }
  | id as word  { try
            let token = Hashtbl.find keyword_table (String.lowercase word) in
            token
           with Not_found -> ID (String.lowercase word)
          }
  | '('     { LPAREN }
  | ')'     { RPAREN }
  | ':'     { COLON }
  | ','     { COMMA }
  | '+'     { PLUS }
  | '-'     { MINUS }
  | '*'     { TIMES }
  | '/'     { DIVIDE }
  | '='     { EQUAL }
  | "<>"    { NOT_EQUAL }
```

```
  | '<'     { LESS }
  | "<="    { LESS_EQUAL }
  | ">"     { GREATER }
  | ">="    { GREATER_EQUAL }

  | '\'' [^ '\n']*      (* eat up one-line comments *)
  | space         (* eat up whitespace *)
              { drone_basic lexbuf }

  | '\n'         { incr_lineno lexbuf; CR }

(*  | not_space * as str { raise (Unknown_token (str, lexbuf.lex_curr_p.pos_lnum, lexbuf.lex_start_p.pos_cnum-
lexbuf.lex_start_p.pos_bol +1)  ) } *)

  | eof          { EOF }
```

11. parser_dbt.mly (George Brink's individual contribution)

```
%{

open Ast;;
open Printf;;
open Lexing;;
open Utils;;

let auto_label_counter = ref 0;;

let make_label() =
		incr auto_label_counter;
		("-" ^ string_of_int(!auto_label_counter))
		;;


let report_error error_starts_at message =
  raise (Parse_failure (message, error_starts_at.pos_lnum, (error_starts_at.pos_cnum-
error_starts_at.pos_bol+1)))
		;;

%}

%token CR
%token IF THEN ELSE
%token DO LOOP WHILE UNTIL EXIT
%token SUB FUNCTION CALL
%token END
%token FOR TO STEP NEXT
%token GOTO
%token <bool> BOOL
%token <string> ID
%token <int> INT
%token LPAREN RPAREN COLON COMMA
%token PLUS MINUS TIMES DIVIDE
%token EQUAL NOT_EQUAL
%token LESS GREATER LESS_EQUAL GREATER_EQUAL
%token AND OR NOT
%token SLEEP MOVE STOP SHOOT RANDOM HEALTH
%token STARTSCAN NEXTSCAN
%token ISWALL ISFOE ISALLY DISTANCE DIRECTION
%token EOF

%left AND OR NOT
%left EQUAL NOT_EQUAL
%left LESS GREATER LESS_EQUAL GREATER_EQUAL
%left PLUS MINUS
%left TIMES DIVIDE
```

```
%start drone
%type <Ast.sub list> drone

%%

drone:
  program { let main_sub = { name="--"; body = List.rev (fst $1); } in
                                          main_sub :: snd $1 }


program: {[],[]} /* at the begining we have nothing */
   | program CR               { $1 }
   | program statement          { ($2 @ fst $1), snd $1 }
   | program compaund_statement  { ($2 @ fst $1), snd $1 }
   | program sub               { fst $1, ($2 :: snd $1) }      /* add user function to the list of subs */


statements:
                /* nothing */               { [] }
               | statements CR               { $1 }
               | statements statement         { $2 @ $1 }
               | statements compaund_statement  { $2 @ $1 }


statement:
    ID EQUAL math_expr CR                          { Store($1) :: $3 }
   | EXIT DO CR                              { [ Jump("--ExitDo") ] }
   | EXIT FOR CR                              { [ Jump("--ExitFor") ] }
   | GOTO ID CR                               { [ Jump($2) ] }
   | ID COLON                                { [ Label($1) ] }
   | CALL ID LPAREN parameters RPAREN CR               { Call($2) :: $4 }
   | CALL SLEEP LPAREN math_expr RPAREN CR             { Wait :: $4 }
   | CALL MOVE LPAREN math_expr RPAREN CR              { Move :: $4 }
   | CALL STOP LPAREN RPAREN CR                  { [ Stop ] }
   | CALL SHOOT LPAREN math_expr COMMA math_expr RPAREN CR { Drop :: Shoot :: ($4 @ $6) }
   | ID EQUAL STARTSCAN LPAREN math_expr RPAREN CR       { [ Store($1^".distance"); Store($1^".direction");
Store($1^".flag"); Look ] @ $5 }
   | ID EQUAL NEXTSCAN LPAREN RPAREN CR               { [ Store($1^".distance"); Store($1^".direction");
Store($1^".flag"); ] }
   | error CR                              { report_error (Parsing.rhs_start_pos 1) "Syntax error" }


compaund_statement:
    IF condition THEN statement
                          { let lbl = make_label() in
                            Label(lbl) :: ( $4 @ ( [ JumpIf(lbl) ; Not ]  @ $2 ) )
                          }
   | IF condition THEN CR statements END IF
                          { let lbl = make_label() in
                            Label(lbl) :: ( $5 @ ( [ JumpIf(lbl) ; Not ]  @ $2 ) )
                          }
   | IF condition THEN CR statements ELSE CR statements END IF
                          { let lblTrue = make_label() in
```

```
                        let lblEndIf = make_label() in
                        Label(lblEndIf) :: ( $5 @ (Label(lblTrue) :: Jump(lblEndIf) :: ( $8 @ ( JumpIf(lblTrue) :: $2) ) ) )
                      }
  | DO WHILE condition CR statements LOOP
                      { let lblStart = make_label() and lblCheckCondition = make_label() and lblDone = make_label() in
                        let block = List.map (fun x -> match x with Jump("--ExitDo") -> Jump(lblDone) | _ -> x) $5 in
                        Label(lblDone) :: JumpIf(lblStart) :: ($3 @ (Label(lblCheckCondition) :: (block @ [Label(lblStart);
Jump(lblCheckCondition) ])))
                      }
  | DO statements LOOP WHILE condition
                      { let lblStart = make_label() and lblDone = make_label() in
                        let block = List.map (fun x -> match x with Jump("--ExitDo") -> Jump(lblDone) | _ -> x) $2 in
                        Label(lblDone) :: JumpIf(lblStart) :: ($5 @ (block @ [Label(lblStart)]))
                      }
  | DO UNTIL condition CR statements LOOP
                      { let lblCheckCondition = make_label() and lblDone = make_label() in
                        let block = List.map (fun x -> match x with Jump("--ExitDo") -> Jump(lblDone) | _ -> x) $5 in
                        Label(lblDone) :: Jump(lblCheckCondition) :: (block @ ( JumpIf(lblDone) :: ($3 @
[Label(lblCheckCondition)])))
                      }
  | DO statements LOOP UNTIL condition
                      { let lblStart = make_label() and lblDone = make_label() in
                        let block = List.map (fun x -> match x with Jump("--ExitDo") -> Jump(lblDone) | _ -> x) $2 in
                        Label(lblDone) :: JumpIf(lblStart) :: Not :: ($5 @ (block @ [Label(lblStart)]))
                      }
  | FOR ID EQUAL math_expr TO math_expr CR statements NEXT
                      { let lblAgain = make_label() and lblDone = make_label() in
                        let block = List.map (fun x -> match x with Jump("--ExitFor") -> Jump(lblDone) | _ -> x) $8 in
                        [Label(lblDone); JumpIf(lblAgain); Less] @ $6 @ [ Store($2); Dup; Plus; Int(1); Read($2)] @
block @ [Label(lblAgain); Store($2)] @ $4
                      }
  | FOR ID EQUAL math_expr TO math_expr STEP math_expr CR statements NEXT
                      { let lblAgain = make_label() and lblDone = make_label() in
                        let block = List.map (fun x -> match x with Jump("--ExitFor") -> Jump(lblDone) | _ -> x) $10 in
                        [Label(lblDone); JumpIf(lblAgain); Less] @ $6 @ [ Store($2); Dup; Plus] @ $8 @ [Read($2)] @
block @ [Label(lblAgain); Store($2)] @ $4
                      }

sub:
   SUB ID LPAREN args RPAREN CR statements END SUB CR
                      { let read_arguments = List.map (fun arg -> Store(arg)) $4 in
                        let sub_body = List.map(fun x -> match x with
                                      Read(name) -> if List.exists (fun arg -> arg=name) $4 then Read($2^"-"^name)
else Read(name)
                                    | Store(name) -> if List.exists (fun arg -> arg=name) $4 then Store($2^"-"^name)
else Store(name)
                                    | _ -> x) ($7 @ read_arguments) in
                        { name = $2; body = List.rev sub_body; }
                      }
  | FUNCTION ID LPAREN args RPAREN CR statements END FUNCTION CR
                      { let read_arguments = List.map (fun arg -> Store(arg)) $4 in
                        let sub_body = List.map(fun x -> match x with
                                      Read(name) -> if List.exists (fun arg -> arg=name) $4 then Read($2^"-"^name)
```

```
else Read(name)
                                        | Store(name) -> if List.exists (fun arg -> arg=name) $4 then Store($2^"-"^name)
else if name=$2 then Store($2^"-") else Store(name)
                                        | _ -> x) ($7 @ read_arguments) in
                          { name = $2; body = List.rev (Read($2^"-") :: sub_body); }
                         }

args: { [] }
  | ID          { [ $1 ] }
  | args COMMA ID { $3 :: $1 }


parameters: { [] }
  | math_expr { $1 }
  | parameters COMMA math_expr { $3 @ $1 }

condition:
   logic_expr                 { $1 }
  | logic_expr AND logic_expr      { And :: ($3 @ $1) }
  | logic_expr OR logic_expr      { Or :: ($3 @ $1) }
  | NOT logic_expr              { Not :: $2 }
  | error                    { report_error (Parsing.rhs_start_pos 1) "Malformed logical expression" }


logic_expr:
   BOOL                                 { [ Bool($1) ] }
  | LPAREN logic_expr RPAREN                    { $2 }
  | math_expr math_relation math_expr           { $2 @ ( $3 @ $1) }
  | SHOOT LPAREN math_expr COMMA math_expr RPAREN  { Shoot :: ($3 @ $5) }
  | ID ISFOE                             { [ IsFoe; Read($1^".flag") ] }
  | ID ISALLY                            { [ IsAlly; Read($1^".flag") ] }
  | ID ISWALL                             { [ IsWall; Read($1^".flag") ] }


math_relation:
   EQUAL       { [ Equal ] }
  | NOT_EQUAL     { [ Equal ; Not ] }
  | LESS        { [ Less ] }
  | GREATER      { [ Greater ] }
  | LESS_EQUAL    { [ Greater ; Not ] }
  | GREATER_EQUAL { [ Less ; Not ] }


math_expr:
   INT                   { [ Int($1) ] }
  | ID LPAREN parameters RPAREN  { Call($1) :: $3 }
  | ID                   { [ Read($1) ] }
  | math_expr PLUS math_expr    { Plus :: ( $3 @ $1) }
  | math_expr MINUS math_expr    { Minus :: ( $3 @ $1) }
  | math_expr TIMES math_expr    { Times :: ( $3 @ $1) }
  | math_expr DIVIDE math_expr   { Divide :: ( $3 @ $1) }
  | LPAREN math_expr RPAREN      { $2 }
  | RANDOM LPAREN math_expr COMMA math_expr RPAREN { Random :: ($5 @ $3) }
```

```
| HEALTH LPAREN RPAREN        { [ GetHealth ] }
| ID DISTANCE              { [ Read($1^".distance") ] }
| ID DIRECTION             { [ Read($1^".direction") ] }
| error                 { report_error (Parsing.rhs_start_pos 1) "Malformed math expression" }
```